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A COMPARATIVE ANALYSIS OF STRUCTURAL CONCRETE QUALITY ASSURANCE PRACTICES ON NINE NUCLEAR POWER PLANT CONSTRUCTION PROJECTS

Final Report

J. H. Willenbrock, H. R. Thomas, Jr.

and J. L. Burati, Jr.

The Pennsylvania State University

University Park, PA 16802

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ABSTRACT

The basic objective of this research effort was to perform a comparative analysis of the Quality Assurance practices related to the structural concrete phase on nine nuclear power plant projects which are (or have been) under construction in the United States in the past ten years. This analysis identified the response of each Quality Assurance program to the applicable criteria of 10 CFR Part 50, Appendix B as well as to the pertinent regulatory requirements and industry standards. The major emphasis was placed on the construction aspects of the structural concrete phase of each project. The engineering and design aspects were examined whenever they interfaced with the construction aspects. For those aspects of the Quality Assurance system which can be considered managerial in nature (i.e., organizational relationships, types of Quality Assurance programs, corrective action procedures, etc.) an attempt has been made to present the alternative approaches that were identified. For those aspects of the Quality Assurance system which are technical in nature (i.e., the frequency of testing for slump, compressive strength, etc.) an attempt has been made to present a comparative analysis between projects and in relation to the recommended or mandated practices presented in the appropriate industry codes and standards.

FOREWORD

The basic objective of this research effort was to perform a comparative analysis of the Quality Assurance practices related to the structural concrete phase on nine nuclear power plant projects which are (or have been) under construction in the United States in the past ten years. This analysis identified the response of each Quality Assurance program to the applicable criteria of 10 CFR Part 50, Appendix B as well as to the pertinent regulatory requirements and industry standards (both concrete and Quality Assurance related). The major emphasis was placed on the construction aspects of the structural concrete phase of each project. The engineering and design aspects were examined whenever they interfaced with the construction aspects (i.e., development of project specifications, design change procedures, etc.). For those aspects of the Quality Assurance system which can be considered managerial in nature (i.e., organizational relationships, types of Quality Assurance programs, corrective action procedures, etc.) an attempt has been made to present the alternative approaches that were identified. Examples of the approaches which appear to be most cost and time effective without influencing the final quality of the concrete have been cited whenever possible.

For those aspects of the Quality Assurance system which are technical in nature (i.e., the frequency of testing for the slump, air, or compressive strength properties of concrete, the curing practices observed, etc.) an attempt has been made to present a comparative analysis (often in tabular format) between projects and in relation to the recommended or mandated practices presented in the appropriate industry codes and standards. In some instances it is possible to point out practices which are "Over and Above" what appears to be the "Average" practice and hence may be considered as unusually costly or time-consuming while resulting in only a marginal increase in quality.

It was not possible, within the time and budgetary constraints of this research project, to recommend what might be termed a "Reasonable" or "Average" Quality Assurance system for the entire structural concrete phase of a nuclear power plant project. It is felt, however, that Utilities, Engineers and Constructors will be able to determine how well their practices compare with other projects for specific areas within the total Quality Assurance system. Specific recommendations, (based on the data which was analyzed) are made in certain areas where it is felt that the industry must either modify its procedures or perform future analysis if the cost and time factors related to the Quality Assurance aspects of structural concrete are to be improved.

The writers would like to express their appreciation to: (1) the people within the Nuclear Power Plant Construction industry who either guided this research effort during the developmental stages or assisted during the data collection stage, and (2) the graduate students (R. Fron, P. Wilson, J. Rouland and A. Zilich) who assisted the writers in their efforts. These personnel and the firms within the industry which they represent are not cited directly in this preface or in the report in order to protect the identity of the projects that were included in the research study. The research effort could not have been completed however without the excellent cooperation which they provided.

The "Comparative Analysis" which is found in this report, represents, to a large degree, an interpretation by the writers of data which was collected as a result of countless hours of personal interviews and analysis of project documents. The majority of this effort took place from April, 1977, to December, 1977, and in general does not reflect all of the revisions to the practices observed which have been made since that time period. When

a research effort of such a magnitude is undertaken there will certainly be instances when the impressions which were obtained might have been partially inaccurate. Such a situation is unavoidable. Taken as a whole, however, it is felt that the results of the research study present a fairly reasonable interpretation of the topic which was studied. It is hoped that the report will be a valuable contribution to the Quality Assurance literature of the Nuclear Power Plant Construction industry.

The interested reader is also referred to a related report entitled "A Comparative Analysis of Structural Concrete Quality Assurance Practices on Three Fossil Fuel Power Plant Construction Projects" [Reference (7) in Chapter 1] which was also prepared by the writers as a part of the research project. A direct comparison between the two reports is not made in either report, it is left to the reader to draw his own conclusions after both reports have been examined in detail.

Jack H. Willenbrock

H. Randolph Thomas, Jr.

James L. Burati, Jr.

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Chapter 1

INTRODUCTION

The Shippingport Atomic Power Station, a 90 Mwe Pressurized Water Reactor owned by the Duquesne Light Company, became the first operational nuclear power plant in the United States when it began electric generation in December 1957. From its inception, because of the fuel source which is used to generate steam, the nuclear power industry has depended on effective Quality Assurance practices during the design and construction phases in order to achieve safe operating facilities. One of the early documents used to define the areas in which planned and systematic Quality Assurance actions were required appears to have been the Department of Defense document entitled MIL-Q-9858A--"Military Specification--Quality Program Requirements"(1)[1], dated December 16, 1963. According to Marash (2, pg 131) a number of companies in the nuclear power industry who were seeking to define specific Quality Assurance requirements during the 1960's apparently incorporated this specification as a part of their contractual arrangements with suppliers and manufacturers.

Quality Assurance Developmental Efforts

In the late 1960's, as more and more Utilities began to build nuclear power plants, the Atomic Energy Commission (i.e. A. E. C.) recognized that many of the parties involved were unaware of the difficulties, complexities, rapid development, uncertainties and economic risks that such a direction entailed. This set into motion in 1969 (at a time when there were 16 operable nuclear plants in the United States and 48 others under construction) the following series of events which eventually led to the development of a

---

[1] See List of References at the end of Chapter 1.

standardized Quality Assurance framework specifically designed for commercial nuclear power plants.

1. In 1967 the A. E. C. had released for comment a General Criteria for Light Water Cooled Nuclear Power Plants as Appendix A to Title 10, Part 50, Code of Federal Regulations (3) (i.e. 10CFR Part 50, Appendix A). Appendix A included a Criterion I--"Quality Standards and Records" which among other things required the establishment of a Quality Assurance program. Since this document left too much room for interpretation, the A. E. C. on April 17, 1969 published Appendix B to 10CFR Part 50 entitled "Quality Assurance Criteria for Nuclear Power Plants"(4). This appendix, which was officially issued on June 27, 1970 (i.e. in the Federal Register, Vol. 35, No. 125) consisted of 18 Criteria which were henceforth to be followed by the industry as the basic framework for nuclear Quality Assurance requirements. These requirements of 10CFR Part 50 applied directly to and placed responsibility on the Utility (who was the applicant for the power plant construction permit) for the establishment and execution of the total Quality Assurance program. The Quality Assurance requirements of Appendix B, specifically applied to the design, construction and operation of those structures, systems and components from which satisfactory performance is required to prevent or mitigate the consequences of postulated accidents that could cause undue risk to the health and safety of the public.

2. In May, 1969, a subcommittee on nuclear power of the ASME Boiler and Pressure Vessel Committee expanded its scope of activities to include in greater detail the major components of the nuclear power system of a plant. Out of this activity came an updated section III of the Boiler and Pressure Vessel Code (5) which was prepared and published in the 1971 edition of the code. The Quality Assurance provisions of that code apply directly to owners, manufacturers and

installers of nuclear power system components and include provisions for the establishment and execution of a Quality Assurance program on work covered by that Code.

3. In May 1969, the American National Standards Institutes (i.e. ANSI) Committee N45 (entitled "Reactor Plants and Their Maintenance") established what eventually became the ANSI N45.2 Nuclear Quality Assurance Subcommittee. In 1971 this subcommittee issued ANSI N45.2-1971: Quality Assurance Program Requirements for Nuclear Power Plants (6). As noted (6, pg iii):

> The purpose of this (sub) committee was to prepare a standard for general industry use that would among other things, satisfy the intent and amplify the requirements of the AEC quality assurance regulations and provide a basis for the development of detailed quality assurance practices and procedures. The Ad Hoc Committee was composed of representatives of the AEC and key segments of the nuclear industry, including utilities, reactor suppliers, plant engineers, and constructors...
>
> Whereas the AEC requirements apply directly to the applicant, (plant owner), the standard presented herein is intended to apply to any individual organization participating in the nuclear plant quality assurance program, such as the nuclear reactor system designer and supplier; the plant designer; the plant constructor; and equipment suppliers as well as the plant owner. Hence, in addition to furnishing guidance to the plant owner for carrying out his responsibilities, it may also serve as a standard suitable for incorporation, all or in part, in documents for procurement of items and services essential to the safe, reliable operation of the plant.

This standard was designed to be compatible with the previously mentioned Appendix B and ASME efforts. As will be noted later it was followed by a number of ANSI N45.2 "daughter" standards which attempted to further define the Quality Assurance requirements. As noted earlier, MIL-Q-9858A did not specifically apply to commercial nuclear power plants. It can therefore be seen that in the Spring of 1969 three new documents began to emerge which would have a tremendous influence on shaping the Quality Assurance systems on all nuclear power plants which were designed and constructed during the 1970's.

DESCRIPTION OF RESEARCH EFFORT

In 1969 the stage had been set for a maturing process with regard to Quality Assurance which would last through the 1970's. This period witnessed a rapid growth within the nuclear power plant industry, both in terms of the number of Construction Permits and Operating Licenses that were issued as well as in terms of the number of regulatory requirements and industry standards related to Quality Assurance that were developed.

Need for Research

It may be assumed that on each of the nuclear power plant projects that were in the process of construction in the last 10 years the parties involved (i.e. the Utility, the Engineer and the Constructor, etc.) implemented Quality Assurance programs which were largely based on their own interpretation of what the regulations required. Under the environment of changing requirements it might be expected that the degree and complexity of these Quality Assurance programs differed from project to project. Some Utilities, Engineers and Constructors, when interpreting the rules and regulations, may have implemented unnecessarily severe Quality Assurance programs. Others may have been able to meet the same goal of quality with more efficient and simpler programs. These different levels of reaction to perceived requirements undoubtedly influenced the cost and duration of the nuclear power plant projects being built.

One of the areas of power plant construction that has a tremendous impact on the project in terms of both cost and duration is structural concrete. Approximately one-third to one-half of the field controllable manhours and

about three to five years of construction time are consumed in this phase of work on a typical project. It is also one of the areas that is most directly influenced by field related Quality Assurance practices since concrete is essentially produced and placed by combining raw materials at the project site. Structural concrete that is used in the construction of the safety related (i.e. Category I, Q listed, etc.) structures of the power plant must be of very high quality. The achievement of this level of quality has proven to be more costly to the Utility than comparable concrete produced for conventional construction. Some of the high cost is probably related to the Quality Assurance practices which are required to insure this necessary quality.

It appears therefore that a research effort which examines the structural concrete phase of nuclear power plant projects, particularly in light of the Quality Assurance practices related to this phase that were developed during a period of changing regulatory requirements, would be very beneficial to the entire industry. Such an effort would undoubtedly surface problem areas which have repeatedly occurred on a number of projects (and should therefore be collectively considered by the industry). It would also allow Utilities to examine their own Quality Assurance practices in relation to those on other projects since the practices in the concrete area probably also reflect the practices in other areas on a project.

Objective of Research

The basic objective of this research effort was to perform a comparative analysis of the Quality Assurance practices related to the structural concrete phase on nine nuclear power plant projects which are (or have been) under construction in the United States in the last ten years. This analysis identified the response of each Quality Assurance program to the applicable criteria of

10 CFR Part 50, Appendix B as well as to the pertinent regulatory requirements and industry standards (both concrete and Quality Assurance related). The major emphasis was placed on the construction aspects of the structural concrete phase of each project. The engineering and design aspects were examined whenever they interfaced with the construction aspects (i.e., development of project specifications, design change procedures, etc.). For those aspects of the Quality Assurance system which can be considered managerial in nature (i.e., organizational relationships, types of Quality Assurance programs, corrective action procedures, etc.) an attempt has been made to present the alternative approaches that were identified. Examples of the approaches which appear to be most cost and time effective without influencing the final quality of the concrete have been cited whenever possible.

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It was not possible, within the time and budgetary constraints of this research project, to recommend what might be termed a "reasonable" or "average" Quality Assurance system for the entire structural concrete phase of a nuclear power plant project. It is felt, however, that Utilities, Engineers and Constructors will be able to determine how well their practices compare with other projects for specific areas within the total Quality Assurance

system. Specific recommendations, (based on the data which was analyzed) are made in certain areas where it is felt that the industry must either modify its procedures or perform future analysis if the cost and time factors related to the Quality Assurance aspects of structural concrete are to be improved.

Research Procedure

The research effort consisted of the following phases:

1. Literature review.

The literature review was divided into three parts:

a. Quality Assurance literature which commented on the practices which were being implemented on power plant projects in the last ten years as well as the regulatory environment under which they were being built. The background provided by that review is presented in Chapter 2 of this report.

b. The pertinent Quality Assurance requirements, codes, standards, and guides. These included Appendix B, the appropriate NRC Regulatory Guides, the ANSI standards, the ASME Boiler and Pressure Vessel Code, etc.

c. Concrete and concrete-component related literature such as the ACI Codes and Recommended Practices, ASTM Standards, the ASME Boiler and Vessel Code, etc.

2. Identification of Nuclear Projects

An attempt was made to select the nine nuclear power plant projects using the following criteria: a) The Construction Permit dates should be reasonably spread over the entire ten-year time frame from 1968 to 1978, b) They were constructed under the jurisdiction of several different NRC regional offices and c) They were constructed using different types of organizational relationships; (1) Construction Management, (i.e., C. M.),

(2) Engineering, Procurement and Construction (i.e. E.P.C.) and (3) Owner Design and Construction, etc. The projects that were chosen are described in Table 1.1. It will be noted that the projects are identified in an alphabetic fashion in order to protect their identity.

Table 1.1--Nuclear Projects In Research Study

Project	A	B	C	D	E	F	G	H	I
Description[a]	2 UNIT PWR	UNIT 2 PWR	2 UNIT BWR	2 UNIT BWR	2 UNIT PWR	UNIT 2 PWR	2 UNIT BWR	2 UNIT BWR	1 UNIT PWR
Type of Management	C.M.	C.M.	E.P.C.	E.P.C.	Owner Design Construct	C.M.	E.P.C.	C.M.	E.P.C.

[a]Description refers to Unit for which data was collected.
2 Unit--project consisted of 2 Units
Unit 2--data only collected on second unit of 2-unit facility.

3. Identification of Fossil Projects

In addition to the nine nuclear projects mentioned above it was decided that data should be collected for the Quality Assurance practices on three fossil fueled plants. It was felt that the practices on these projects would clearly reflect the current "state of the art" of structural concrete on non-nuclear type construction and could therefore provide an appropriate frame of reference. The data related to these fossil plants was analyzed and is presented in a separate report entitled "A Comparative Analysis of Structural Concrete Quality Assurance Practices on Three Fossil Fuel Power Plant Construction Projects (7).

It should be noted that a direct comparison between this nuclear based report and the one related to Fossil Fuel Power Plant Construction Projects (7) is not made in either report. It is left to the reader to draw his own conclusions after both reports have been examined in detail.

4. Data Collection.

The first step in the data collection phase involved the acquisition of as many of the project-related Quality Assurance documents (i.e., PSAR, concrete specifications, QA programs and procedures, QC programs, inspection plans, construction procedures, etc.) which each project would make available. An analysis of these documents resulted in a questionnaire which was sent to each project in order to obtain additional information.

Each project was visited at least once and an effort was made whenever possible to interview representatives of each of the parties involved with the project, often at both the home office and the project site. Three of the nuclear projects (i.e., Projects C, D and I) received more extensive coverage than the others because graduate students were assigned to work on these projects during the summer of 1977. Each was employed in a quality related position and thus was able to gain first-hand Quality Assurance experience. The net result of the data collection phase was the preparation of interim research documents which presented the Structural Concrete Assurance practices on each of the nine nuclear and three fossil projects. The level of detailed coverage was not uniform across all projects, however, because of the different levels of data that were acquired.

5. Comparative Analysis.

The final phase of the research effort with regard to the nuclear projects involved a comparative analysis of the nine interim research documents mentioned above. The information which resulted from this comparative analysis is presented in this report as follows:

Chapters 3 and 4 --Organization and Management of Quality Assurance Programs

Chapters 5 and 6 --Concrete Component Procurement, Storage, Batching and Testing

Chapters 7, 8 and 9--Concrete Preplacement, Placement and Post Placement

Appendix A --Nine Individual Project Case Studies

It should be noted that the above chapters are preceeded in the report by Chapter 2 which is entitled "Overview of the Nuclear Regulatory and Quality Assurance Environment".

Research Benefits

This report, by presenting a comparative analysis of the Quality Assurance practices related to the structural concrete phase, will surface the acceptable alternative approaches which are being implemented and indicate the generic type of problems which have occurred for the sample of projects which were studied. It will also reveal some of the inconsistencies that exist between project specifications, procedures and even the codes and standards which govern this phase of construction. Practices of Auditing, Surveillance, Inspection and Construction Supervision which appear to represent a duplication of effort on various projects will be noted whenever possible.

This information should be useful to those Utilities that will be involved with future nuclear power plant projects as well as those that are currently in the design or construction stages.

OBSERVATIONS AND RECOMMENDATIONS

The results which were obtained from the research study, as noted above, are presented in Chapters 2 to 9 and Appendix A to the report. Although a summary appears at the end of each chapter of the report, it is felt to be important to highlight some of the observations and recommendations which the writers of the report feel are of particular significance.

I. Organization and Management of Quality Assurance Programs. (Chapters 2, 3 and 4)

1. The ten year period which began with the issuance of Appendix A of 10 CFR Part 50 was one of rapid growth, both in terms of the number of nuclear power plants under construction as well as the number of regulatory requirements and industry standards that were developed related to Quality Assurance. The efforts of the AEC (and later the NRC), ANSI, ASME and ACI which are traced in Chapter 2 attest to this fact.

2. The Quality Assurance practices related to structural concrete which are implemented on each nuclear power plant construction project were influenced by a number of factors, both external and internal to the project. Some of the major factors of influence appear to be: (a) Development of Standards, (b) Difficulties of Interpretation of Requirements, (c) The Role of the NRC, (d) Documentation Requirements, (3) Cost of Quality Assurance, and (f) Additional Benefits of Quality Assurance. These factors are examined in Chapter 2 of the report.

3. The direct involvement of the Utility with regard to the Quality Assurance and Quality Control aspects of the construction phase varies widely on the nine projects in the research study. Relative to the other modes of management which were observed, it appears that the four Utilities involved with projects being constructed under the EPC mode have the least direct influence since they are primarily involved in the Third Level Quality Assurance activity.

The four projects being constructed under the CM Mode, each to varying degrees, provide examples of Utilities that are also directly involved in Second Level Surveillance and First Level Inspection activities. On one of the projects in this group the Utility, without utilizing many permanent Utility employees, has assumed direct management control for all Quality Assurance/

Quality Control responsibilities at the project site. The maximum involvement of a Utility was observed on Project E which is being constructed under the Owner Mode.

It does not appear possible to recommend one of the above approaches over the others since the choice of management mode is largely a function of the particular circumstances of each Utility. It is however recommended that both Chapter 3 and the Appendix of the report (which contains the nine individual Project Case Studies) be examined in detail by those parties interested in the alternative approaches which are available.

4. There appear to be a number of organizational alternatives to the "Independence" requirement for Quality Assurance and Quality Control personnel which is cited in Criteria I, X and XVIII of 10 CFR Part 50 Appendix B. All Utilities and Constructors have established a separate Quality Assurance group within their organizations. With regard to the Quality Control group, in some cases it is directly associated with the Quality Assurance group while in others it is organizationally related to the Construction group. There appear to be advantages and disadvantages to both approaches in terms of the level of documentation required, the overall coordination of quality related activities, etc. It is recommended that the industry support further study in this area to determine how the "Independance" criterion can most effectively be met by the firms within the industry.

5. There appears to be some duplication of effort with regard to the following quality related activities on some of the projects in the research study.

a. Auditing

With regard to Auditing for instance the projects under the EPC Mode placed this responsibility with both the Utility's QA group as well as the EPC Firm's QA group. In some cases, particularly when the NRC Audits are also

considered, it appeared that an overlap situation existed without any apparent increase in final concrete quality. There appeared to be less overlap in the Auditing area on the CM Mode and Owner Mode projects since the Utilities appeared to assume the primary responsibility for the preplanned Audit activity. It would seem reasonable to assume that a "working relationship" could be developed on a project between the separate QA organizations involved with the Auditing activity to minimize the overlap areas.

b. Surveillance

It appears that the Second Level Surveillance activity is in need of further definition by the industry since it is often assumed by not only the Utility's Q.A. group, the EPC Firm's Q.A. group but also by the EPC or CM Firm Q.C. group. Criterion X of 10 CFR Part 50 Appendix B indicates that either inspection or process monitoring (i.e. Surveillance) or both are viable verification activities which may be used. If it is determined that Surveillance is necessary for a particular activity which is a part of the concrete phase, then it would appear reasonable to assign it to only one group in order to avoid duplication of effort.

c. Quality Control and Construction Responsibility

There also appears to be an overlap area between the Quality Control and the Construction groups with respect to the responsibility for quality on some of the projects in the research study. There appears to be a need to develop a clearer definition of the interface between these two groups by the industry in order to avoid the situation where the Construction group abdicates its traditional responsibility for the quality of the final product to the Quality Control group.

It is recommended that during the preplanning stages of a project the Utility and the other parties involved mutually develop a quality system which

considers, among other things, the above areas of potential overlap and duplication. The savings which result over the life of a project, both in terms of human and financial resources as well as documentation efficiency, will probably justify the effort.

6. The role of documentation as a key part of the Q.A. program on nuclear power plant construction projects is identified in Criterion V of 10 CFR Part 50. A simplified model which indicates an idealized relationship between the quality related documents is presented in Chapter 3 of the report. The practices which were observed with regard to this relationship are also presented in Chapter 3 as well as the Appendix of this report (i.e. in the Individual Project Case Studies). Examples of the level of documentation which is required for the structural concrete phase are presented throughout Chapters 5 to 9 of the report.

It is recommended that the documentation system which is developed for a project should insure that, as much as possible, the Construction Specifications and the Quality Assurance/Quality Control Procedures are properly meshed to eliminate unnecessary duplication and redundancy.

With regard to the above point, the case of Project H which is being constructed under the CM Mode, using a "Work Package" approach, should be noted. It is felt that whenever the structural concrete phase (or any other construction phase) is divided among a number of independent contractors it would be to the Utility's benefit to develop a standardized set of construction procedures, instructions etc. which would apply to all of these contractors. The task of reviewing a vast number of procedures, etc. and tracking the changes to them can lead to problems which are avoidable if a Utility in such a situation adopts a standardization approach at the beginning of the project. The legal and economic ramifications of such an approach would of course have to be thoroughly examined.

7. It is noted in Chapter 4 of the report that an industry wide assessment of the current situation in the structural concrete area may be needed to determine if the "General Construction" codes and standards which are being used should be revised to more closely reflect the "Nuclear Construction" situation. It is felt that these codes and standards were perhaps never intended for the "literal" interpretation stance which occurs on nuclear construction projects.

In the nuclear situation, it was noted that the Engineering Firm must assume an active "interpretive" role when the requirements for a project are being developed. If the Engineer does not assume this role then it will be assumed by the QA, QC and Construction personnel by default, often without the extent of information which is at the disposal of the Engineer.

8. An area of concern on many of the projects in the research study dealt with the extent of the Engineering Changes which occurred. Some of the possible reasons for these changes are: (a) The development of specifications with unrealistic requirements, (b) The lack of a feedback loop between the Construction and Engineering groups which could be used to make the Engineering documents more responsive to the construction situation and (c) The reuse of an Engineering Firm "Standard Specification" at the beginning of each new project.

One of the impacts of Engineering Changes is the need to revise a number of supportive Construction and QA/QC Procedures whenever a specification is revised. A second impact arises because of the need for strict compatibility between the PSAR and the Engineering documents. Examples of these impacts are presented in Chapter 4 of the report.

An in-depth analysis of the entire area of Design and Document Control, in light of the great impact that an Engineering Change has on the project cost and schedule, appears to be justified in order to perhaps establish a system which is more effective than the practices currently being implemented.

9. An extensive coverage of the practices which were observed on the projects in the research study related to Nonconformance Control is presented

in Chapter 4 of the report. Some of the observations and recommendations should be highlighted since it appears that the Nonconformance Control system which is adopted on a project has a great deal of impact on the "smooth progress towards construction completion" which is achieved.

a. It appears that the flow path of a Nonconformance document should be closely examined on a project because on some of the projects in the research study it had to travel through a number of organizations (sometimes more than once) before a Nonconformance event was finally "closed" and construction progress could be reestablished. A number of actions, such as site located "Deviation Review" Boards, site located Engineering Firm representatives, the establishment of various levels of severity for Nonconformance (so that some of them can be addressed in a quicker, less formal, manner), etc. all appear to offer some possibilities for improvement of the existing practices.

b. Consideration should also be given to the amount of information which appears on a Nonconformance Report and the other documentation which is generated as a result of it. Some of the information might in fact be unnecessary while other information (such as the requirement that the affected party indicate the corrective action that will be taken to prevent the reoccurrence of the nonconformity) may not even appear on the Nonconformance Report.

c. From the limited amount of data which was made available on the projects in the research study, it appears that a large percentage of the Nonconformance Reports related to structural concrete on most projects are dispositioned "Use As Is". In light of the cost of a typical Nonconformance Report in terms of both manpower and project time, it seems that an industry wide study should be initiated in order to identify a number of general areas related to structural concrete which are consistently dispositioned "Use As Is". This might lead to a reassessment of the necessity for all of the requirements which currently exist in the concrete specifications, industry codes and standards, etc

10. The practices related to Corrective Action and Audits which were observed on the projects in the research study are also discussed in Chapter 4 of the report. Several examples are presented.

II. Concrete Component Procurement, Storage, Batching and Testing (Chapters 5 and 6)

1. There was very little indication of the use of statistical concepts for considering the natural variability of materials on the projects in the study. It is recommended that statistical techniques, similar to those which have been employed for years in highway construction, be incorporated into the specification requirements on nuclear projects. Techniques such as random sampling and multiple sampling, which are currently not being employed on the projects, could help to give a better representation of the properties of the materials which are being tested. These techniques could possibly help to reduce some of the high testing frequencies which are currently employed on nuclear projects, while, at the same time, maintaining the level of quality of the concrete.

2. It is recommended that the acceptance practices which are currently being used for concrete be reevaluated. The practice of using in-process tests of concrete ingredients as partial acceptance criteria results in the generation of many nonconformance reports which are ultimately dispositioned "Use As Is" because compressive strength test results are acceptable. Since ultimate acceptance is based on compressive strength, it is recommended that the in-process tests be conducted as process control tests, with the final acceptance criteria being concrete compressive strength. This would result in elimination of many nonconformance reports which will ultimately be dispositioned "Use As Is".

3. It is recommended that the maximum limit on cement delivery temperatures be re-evaluated. Cement temperature has less effect on concrete temperature

than does either water or aggregate temperature. The approach employed on one project which requires that successful results of 7-day mortar cube strength tests be obtained before cement can be delivered to the project is preferable to an absolute limit on delivery temperature. The approach allows the cement time to cool before delivery, but does not place an arbitrary maximum limit on delivery temperature.

4. It is recommended that the codes provide more specific guidance in the area of quality requirements for mixing water. Current statements in the codes concerning mixing water quality tend to be qualitative rather than establishing quantitative requirements. These qualitative statements have led to a very wide range in the water testing requirements and acceptance limits which are used on the projects studied.

5. It is recommended that the use of high levels of air entrainment in all concrete be avoided, and the high levels of air entrainment only be used for concrete which will be exposed to severe weathering conditions where high concrete durability is necessary. Guidance in the use of air entrainment in various exposure conditions should be taken from the graded table which was recommended by ACI Committee 211. This table is included in Chapter 5 of this report.

6. It is recommended that superplasticizing admixtures be considered for use in concrete which is placed in highly congested rebar areas. These admixtures have been used for a number of years in Japan and Germany. Their use allows the production of very high slump concrete at the low water-cement ratios necessary for high strengths.

7. It was noted that on some of the projects the batch plant inspector has so much responsibility that he is, in essence, the operator of the batch plant. It is suggested here that the role of Quality Control should be the inspection of construction activities rather than their actual performance or direction.

8. It is recommended that the design mix water-cement ratio not be used to establish an upper limit on the amount of mixing water which may be used. This is referred to as the "locked water meter" approach. It is recommended that water requirements in the field be controlled by controlling slump rather than water-cement ratio. This will help to account for batch to batch variation in moisture content of the aggregate. In this way the average moisture content of the aggregates and the average additional water requirements at the mixer can be used to determine whether the average mix conforms to the specifications regarding water-cement ratio.

9. It is recommended that design strengths of concrete be reduced, where possible, particularly for concrete used in massive placements. On the projects in the study it was extremely rare for a cylinder test to fail. In numerous instances the average compressive strengths far exceeded the required strengths. The high cement contents necessary to achieve these high strengths can add to potential heat of hydration problems. It is recommended that mix designs be adjusted in accordance with guidance provided in the codes when compressive strengths results are high and suitable control is indicated by a low standard deviation.

10. It is recommended that the testing frequencies for concrete compressive cylinders be reduced to once every 150 cubic yards rather than once every 100 cubic yards as required by ANSI. This reduced rate is in accordance with ASTM C94, ACI 304, ACI 318 and ACI 349. It appears that the ANSI frequency may be higher than is necessary for adequate control. This is particularly true for the larger placements which are frequently encountered on nuclear power plant construction projects.

11. It is suggested that the ANSI frequency for testing of slump is higher than necessary. ANSI slump test frequency is twice as high as their recommended cylinder test frequency. The applicable codes generally call for slump tests

to be performed whenever compressive cylinders are molded. The ANSI requirement seems to be higher than necessary to control the process. The purpose of sampling should be to verify that the process is in control and not to eliminate the need for judgement on the part of the inspector. Slump tests taken when cylinders are cast should be sufficient to verify that the process is in control.

12. In specifying slump requirements it is recommended that the approach which is used on three of the projects in the research study should be employed. The approach stipulates working limits and reject limits and allows an "inadvertency margin" for batches which may occassionally exceed the working limit but are still below the reject limit.

13. It is recommended that the time limit of 90 minutes between mixing and placing concrete which is used on most of the projects be discontinued. The condition of the plastic concrete, rather than an arbitrary time limit, should determine its placeability.

III. Concrete Delivery, Placement and Acceptance (Chapters 7, 8 and 9)

1. References to the ACI Code, in general, should not be included as blanket requirements in the project specifications but rather should serve as guidelines. Although the guidance provided does in fact represent acceptable practice, the Code does not provide the flexibility necessary to address day-to-day problems that result when applied on projects where the Quality Control Program is particularly intensive.

2. Quality Control organizations have extended their area of influence into heretofore nontraditional areas such as review or approval of preplanning activities, ordering of concrete and equipment checks. There is no evidence to suggest that a formalized QC Program will provide any increase in the level of quality, and in fact the opposite effect may be true. The potential for reduced quality appears to be greatest in those programs where

quality control shares overlapping responsibilities with other parties such as field engineering.

3. Mass concrete is not clearly defined by the ACI Code. The Code provisions result from experience gained on gravity dams and should not be applied to nuclear power plant construction because of the reinforcement densities, number of embedments, and the general complexity of the placements. Whether or not a placement is defined as massive will establish the required slump and temperature of the fresh concrete as well as different curing periods and practices. Considering the importance of such decisions, the practice of defining a critical dimension should be abandoned in favor of performing an analysis on each placement to determine the unique characteristics and requirements. This point is discussed in more detail in Chapter 7.

4. The acceptance criterion for slump deserves more attention since the slump requirements will effect consolidation, pumping capabilities, joint quality, durability, testing costs as well as the magnitude of delays at the point of placement. The computation of a running slump average may encourage the production of low slump concrete for initial batches which is not especially desirable. Inadvertency margins should be included in all specifications in lieu of running averages (Chapter 7).

5. Inadvertency margins should be provided for temperature measurements (Chapter 7).

6. The requirements for formwork tolerances, reinforcement placement tolerances and reinforcement fabrication tolerances should be reevaluated with particular attention given to the relationship between each aspect. It appears that nuclear structures should qualify as special structures in accordance with ACI 301 and 318 and that modified tolerances should be considered, at least in certain portions of the plant. The number of nonconformances which are written because these tolerance limits are exceeded in no way indicates the difficulties

and manhours expended in meeting the specification requirements (Chapter 8).

7. Concern over rust on reinforcing bars appears to be over emphasized. Research data has shown that the condition of the bar surface is not nearly as important as the height and number of deformations on the bars (Chapter 8).

8. The testing requirements for cadwelding should be reviewed. The project-supplied test data indicates that essentially all defective cadwelds are identified by visual inspection and hence the tensile testing of production of sister splices could be dramatically reduced or eliminated. An apparent deficiency in existing programs is the absence of user tests for the powder and sleeves. Thus defective cadwelds may be falsely attributed to the cad-welding crew. Considerable attention is paid to the cleaning and heating of bar ends. No correlation can be drawn between the rate of failure during the visual inspection and the level of detail in the construction and quality procedures or the intensity of the QC inspection effort. The data indicates that the cadwelding operations are overinspected, overtested and overdocumented (Chapter 8).

9. All concrete related correlation testing programs observed had their own unique characteristics, objectives, and in most cases, statistical deficiencies. In addition, the data are difficult to analyze, and no information was found to suggest that they were analyzed statistically. There appear to be no industry documents, reports, etc. to suggest how a correlation testing program should be conducted. In view of the time and expense involved in such programs, it appears that a research study should be initiated to establish the methodology to be used in a statistically based correlation testing program (Chapter 9).

10. There are two opposing viewpoints concerning the addition of supplemental water to fresh concrete. The first viewpoint is that water should be allowed in order to minimize the wasting of what appears to be good quality concrete and to facilitate consolidation. The opposite viewpoint is that the properties

of the concrete will be altered and that the addition of water results in needless delays and increased testing costs. This latter approach is favored but must be accompanied by flexible specification requirements with respect to slump and delivery times (Chapter 9).

11. There are several modifications to construction joint practices that could improve production without affecting quality. Keyed joints should be used only when essential since they hinder proper cleaning. The practice of "green cutting" joints for cleanliness prior to an adjacent placement should be evaluated since it appears to be less preferable than sandblasting. Test results have shown that in cleaning operations, the exposure of aggregate to a specified amplitude (i.e., height) does not increase watertightness or bonding and could jeopardize quality if the aggregate is undercut or loosened. The practice of wetting joints should be reevaluated with respect to timing. The grouting of joints should be reassessed in favor of using starter mixes (Chapter 9).

12. The requirements for curing during hot and cold weather should be reviewed since many projects have encountered difficulties in administering the ACI 305 and ACI 306 provisions. There also seems to be some confusion regarding the curing period during cold weather (Chapter 7 and 9).

13. In reviewing the Construction Procedures and the Quality Control Procedures there appear to be three major areas of concern. First the procedures seem to be written in too much detail. By doing so, these provisions tend to draw attention to the overall aspects of the operation being viewed. This is especially true where flexibility is required to meet an unanticipated situation. Flexibility is not allowed because of the manner in which the details are written and emphasized. Secondly, the procedures on several projects appeared to emphasize those practices which were detrimental to concrete. It is felt that the positive approach which emphasizes those good practices which are necessary to produce quality concrete should have been taken on those projects.

Finally there are many instances where quantitative values are substituted for qualitative attributes which must be evaluated during the inspection process. This aspect is felt to be less desirable since it draws attention to details and is another item which must be inspected and documented (Chapter 7 and 8).

LIST OF REFERENCES

1.1 Department of Defense, MIL-Q-9858A, Quality Program Requirements, Government Printing Office, Washington D.C., December 16, 1963.

1.2 Marash, S. A., "Quality Assurance System Requirements for Nuclear Power Plants--Part 1", Journal of Quality Technology, Vol. 5, No. 3, July 1973, pp. 131-134.

1.3 Atomic Energy Commission, "Code of Federal Regulations, 10 CFR Part 50, A-pendix A, General Criteria for Light Water Cooled Nuclear Power Plants", U.S. Nuclear Regulatory Commission, Washington D.C., 1967.

1.4 Atomic Energy Commission, "Code of Federal Regulations, 10 CFR Part 50, Appendix B, Quality Assurance Criteria for Nuclear Power Plants", U.S. Nuclear Regulatory Commission, Washington D.C., 1969.

1.5 "ASME Boiler and Pressure Vessel Code, Section III", The American Society of Mechanical Engineers, N. Y., 1975.

1.6 "Quality Assurance Program Requirements for Nuclear Power Plants, ANSI N45.2", American National Standards Institute, New York, 1971.

1.7 Willenbrock, J. H., Thomas, H. R., Burati, J. L., "A Comparative Analysis of Structural Concrete Quality Assurance Practices on Three Fossil Fuel Power Plant Construction Projects", Research Report to U.S. Department of Energy, The Department of Civil Engineering, The Pennsylvania State University, University Park, Pa., June 1978.

CHAPTER 2

OVERVIEW OF NUCLEAR REGULATORY AND QUALITY ASSURANCE ENVIRONMENT

In Chapter 1 it was briefly noted that as the nuclear power plant industry matured during the 1970's there was a rapid growth of regulatory requirements and industry standards related to quality assurance. It is felt that in order to place the results of the research (found in Chapters 3 to 9) in proper perspective, one must properly appreciate how the above mentioned developments influenced the quality assurance programs that were implemented. Chapter 2 is therefore included to provide that perspective. It provides both a trace of the historical developments as well as a sampling of the comments that were published related to those developments. For individuals who were a part of the total process during the 1970's, this chapter hopefully represents a reasonably accurate review of what occurred. For those not so fortunate, it will provide understanding.

The Chapter is divided in three parts. The first part traces the development of the Regulatory and Standards framework within which nuclear power plants are built. The second part of the chapter, which is primarily based on the published observations of representatives of industry, presents the factors which influenced Quality Assurance programs on nuclear power plants during the 1970's. The chapter concludes with a presentation of the 18 Criteria of 10 CFR Part 50, Appendix B.

REGULATORY AND STANDARDS ENVIRONMENT

For convenience purposes the discussion below will be divided into

separate presentations of the NRC, ANSI, ASME and ACI efforts. It appears that this separation is somewhat artificial, however, since there was a considerable amount of interchange between each of these efforts during the entire developmental period.

I. NRC Efforts

As noted by Langston (1, pp. F1.3)[1] the AEC in 1965 issued a General Design Criteria for light water-cooled nuclear power plants. In 1967 this General Design Criteria was released for comment as Appendix A to Title 10, Part 50, Code of Federal Regulations. It was made effective in 1971. Criterion I--"Quality Standards and Records" of Appendix A required the identification, evaluation and use of appropriate quality standards as well as the establishment of a quality assurance program and the maintenance of records. It appears that Criterion I left a lot of room for interpretation.

The need for more definitive regulations and standards was brought to the forefront in October 1968 when the Atomic Safety and Licensing Board halted public hearings on Commonwealth Edison's Zion Station Units 1 and 2 and stated (1, p. F1.3):

> "In the opinion of the Board, Commonwealth Edison has not presented sufficient evidence pertinent to the provisions that should be made for the assurance of the control of quality needed for the technology and disciplines of the nuclear reactor field, nor has the AEC staff submitted evidence by way of criteria or expert testimony adequate to permit judgment of its evaluation of the quality control program."

This decision expedited the development of the set of 18 basic quality assurance criteria shown in Table 2.1 which first appeared as Appendix B to 10CFR Part 50 (2) in the Federal Register in April 1969. After an extensive period of public review, they became a regulatory requirement for licensing of nuclear power plants on June 27, 1970.

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[1] See List of References at the end of Chapter 2

Table 2.1.--18 Quality Assurance Criteria of 10 CFR Part 50, Appendix B (2)

1.	Organization
2.	Quality Assurance Program
3.	Design Control
4.	Procurement Document Control
5.	Instruction, Procedures, and Drawings
6.	Document Control
7.	Control of Purchased Material, Equipment, and Service
8.	Identification and Control of Materials, Parts, and Components
9.	Control of Special Processes
10.	Inspection
11.	Test Control
12.	Control of Measuring and Test Equipment
13.	Handling, Storage and Shipping
14.	Inspection, Test and Operating Status
15.	Nonconforming Materials, Parts or Components
16.	Corrective Action
17.	Quality Assurance Records
18.	Audits

Appendix B complemented Criterion I of the General Design Criteria and essentially required the applicant (i.e., the Utility) for a construction permit to document quality assurance practices in a more visible manner for regulatory staff evaluation. The 18 criteria applied directly to and made the Utility responsible for the establishment and execution of an overall quality assurance program which encompassed the design, construction and operation phases. The criteria specifically applied to all activities affecting the quality of safety-related structures, systems, and components.

As Langston (1, p. F1.4) notes:

> "...10 CFR Part 50 Appendix B is intended to be a general document which states the criteria to be met, but does not specify how the criteria should be implemented. This approach gave the widest leeway for individual interpretations in implementation of a quality assurance program. This in turn led to uncertainty about what was or was not acceptable to the regulatory staff. Clearly, additional standards and guidelines were needed...".

As a result, several new regulatory procedures were initiated by the AEC beginning in mid-1972 to further insure that utilities implemented effective quality assurance programs. Some of these are reviewed below.

1. Regulatory Reviews. As a result of an Appeal Board's decision related to the Midland hearings in March 1973 the AEC announced (in June 1973) that an application for a construction permit would not be accepted for review until after the quality assurance program of the applicant had been reviewed and found adequate.

2. Regulatory Guides. In order to provide additional guidance for the industry with regard to frequently recurring safety and regulatory questions, the AEC in 1970 began the development and issuance of a series of Safety Guides. The Safety Guide series was expanded in December 1972 and a new series of

Regulatory Guides of much broader scope was established. Regulatory Guides describe acceptable ways of implementing Federal regulations, delineate techniques used by the NRC staff to evaluate specific problems or postulated accidents, and provide guidance to applicants about quality assurance. As noted by Langston (1, pg. F1.5):

> "According to the NRC, Regulatory Guides are not substitutes for regulations and compliance with them is not mandatory; other methods or solutions may be acceptable provided they permit positive findings relative to the licensing process."

The Regulatory Guides (3) are divided into ten divisions, with Division 1 covering "Power Reactor Guides". Over 100 have been issued in Division 1 since the first one on November 2, 1970 and more are under development. Most of the Regulatory Guides are divided into the following three parts: (1) Introduction, (2) Discussion, and (3) Regulatory Position. Several of these guides that are of particular interest to the concrete quality assurance area are shown in Table 2.2.

3. NRC Endorsement of ANSI Standards. The NRC developed an established policy whereby an ANSI standard was reviewed, and, if found acceptable, endorsed by a Regulatory Guide as a way of addressing a licensing issue. If there were differences in the NRC position from the standard, they were described in the Regulatory Guide. As an example, Regulatory Guide 1.28 (4) states under Regulatory Position:

> "The general requirements and guidelines for establishing and executing a quality assurance program during the design and construction phases of nuclear power plants which are indicated in ANSI N45.2-1971, "Quality Assurance Program Requirements for Nuclear Power Plants" are generally acceptable and provide an adequate basis for complying with the program requirements of Appendix B to 10CFR Part 50."

Table 2.2.--Concrete Related Regulatory Guides

1.	Reg. Guide 1.10-Mechanical (Cadweld) Splices in Reinforcing Bars of Category I Concrete Structures (Rev. 1, 1/2/73)
2.	Reg. Guide 1.15-Testing of Reinforcing Bars for Category I Concrete Structures (Rev. 1, 12/28/72)
3.	Reg. Guide 1.28-Quality Assurance Program Requirement (Design and Construction) (Safety Guide 28, 6/7/72)
4.	Reg. Guide 1.55-Concrete Placement in Category I Structures (6/73)
5.	Reg. Guide 1.70-Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants (Rev. 2, 9/75)
6.	Reg. Guide 1.70.6-Additional Information-Quality Assurance During Design and Construction (7/74)
7.	Reg. Guide 1.74-Quality Assurance Terms and Definitions (2/74)
8.	Reg. Guide 1.94-Quality Assurance Requirements for Installation, Inspection and Testing of Structural Concrete and Structural Steel During the Construction Phase of Nuclear Power Plant (4/75)

Regulatory Guide 1.74, "Quality Assurance Terms and Definitions" (5), except for a minor stipulation, similarly endorses ANSI N45 2.10-1973 "Quality Assurance Terms and Definitions" (6). Regulatory Guide 1.94 (7) is an example of one which contains a rather extensive set of stipulations. The Regulatory Position part states:

> "The requirements and guidelines that are included in ANSI N45.2.5-1974... are generally acceptable to the NRC staff and provide an adequate basis for complying with the pertinent quality assurance requirements of Appendix B to 10 CFR Part 50, subject to the following:
>
> 1. Subdivision 1.5 of ANSI N45.2.5-1974 states: 'Other documents that are required to be included as a part of this standard are identified at the point of reference and listed in Section 8 and the Appendix of this Standard'. The specific applicability or acceptability of documents listed in Section 8 has been covered separately in other regulatory guides. Other standards and codes listed in ANSI N45.2.5-1974 provide useful guidance for the installation, inspection, and testing of structural concrete and structural steel. Prior to use of these other referenced codes and standards, however, the suitability of the standard or code should be reviewed for the particular application under consideration.
>
> 2. Subdivision 2.1 of ANSI N45.2.5-1974 includes general provisions for planning the installation, inspection, and testing of structural concrete and structural steel. In this regard the provisions of Subdivision 2.1 of ANSI N45.2.5-1974 should be used in conjunction with Regulatory Guide 1.55, "Concrete Placement in Category I Structures".
>
> 3. Subdivision 4.5 of ANSI N45.2.5-1974 provides, in part, that inspection of concrete placement shall be performed to verify the adequacy of concrete consolidation equipment and technique of operation. ACI 309-72, "Recommended Practice for Consolidation of Concrete," should be used as a basis for determining the adequacy of the equipment for concrete consolidation and of the technique of operation.
>
> 4. Subdivision 4.10 of ANSI N45.2.5-1974 states: "Welded reinforcing bar splices shall be subject to the requirements of Section 5.5, except that provisions of AWS D 12.1 shall apply." In addition, the provisions

of Articles CC4334 and CC4330 of the "Code for Concrete Reactor Vessels and Containments" (ASME Boiler and Pressure Vessel Code, Section III, Division 2, 1975 Edition) for testing of welded reinforcing bar splices should be used as guidance pending endorsement of that code by the NRC staff."

The Implementation part of Regulatory Guide 1.94 states:

"The purpose of this section is to provide information to applicants regarding the NRC staff's plans for using this regulatory guide.

Except in those cases in which the applicant proposes an acceptable alternative method for complying with specified portions of the Commission's regulations, the method described herein will be used in the evaluation of construction permit applications docketed after October 15, 1976. The methods described herein will continue to be used until this guide is revised as a result of suggestions from the public or additional staff review."

4. Standard SAR Format. In the course of reviewing aplications for construction permits and operating licenses in the early 1970's the AEC judged that some Preliminary Safety Analysis Reports (i.e., PSAR's) lacked sufficient information to conclude a review of the applicant's quality assurance program. They then had to request additional information in the form of direct written questions to each applicant. This situation resulted in the issuance of a "Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants" (8). This standard format delineated, among other things, an outline for, and established specific information to be included in, Chapter 17 of the SAR at the construction permit stage review to describe how the applicant's quality assurance program complied with 10CFR Part 50 Appendix B for design, construction and operations.

5. Rainbow Series. As noted by Langston (1, pg. F1.9):

"The nuclear industry as a whole was really not prepared in the early 1970's to comply with 10 CFR Part 50 Appendix B or to implement the ANSI N45.2 quality assurance standards. Few formalized procedures existed. Utility management was not fully committed to establishing and implementing effective quality assurance programs. Most plant owners

did not appreciate their quality assurance responsibility nor did they know how to execute it. More dialogue between industry and regulatory management was needed to better understand what was required to implement effective quality assurance programs in compliance with Appendix B."

As a result, in the latter half of 1973 three guides were issued by the AEC and a series of regional conferences were held which discussed their contents. These three were:

a. Gray Book--Wash 1283: "Guidance on Quality Assurance Requirements During Design and Procurement Phase of Nuclear Power Plants" (9).

b. Orange Book--Wash 1284: "Guidance on Quality Assurance Requirements During the Operations Phase of Nuclear Power Plants" (10).

c. Green Book--Wash 1309: "Guidance on Quality Assurance Requirements During the Construction Phase of Nuclear Power Plants" (11).

The Green Book, for instance, provided a compilation of selected Regulatory Guides, regulatory references (such as 10CFR Part 50, Appendix B, etc.) and draft copies of appropriate ANSI standards that were under development during this period. It was felt that such an educational effort was extremely important at that point in time. The years since 1973 have seen these ANSI Standards adopted in the Regulatory Guides so that the Rainbow Series can now be viewed as an historical document which served its purpose well.

II. ANSI Efforts

It is noted in DOE/ET-0030/4 (77) (12, pg. 24) that in 1966 and 1967 a total of 50 new Nuclear Steam Supply Systems (i.e. NSSS) orders were placed. Writing about this period, Hannon (13, pg. 12) notes: "The rapid growth of industrial power plant projects brought more than 200 new major participating companies and contractors into the nuclear power industry in 1967." As a result, there were a number of people within the industry who realized

that Federal regulations alone were not sufficient and that an entire body of nuclear industry standards were needed to assure safe, reliable, and economical nuclear power. As Langston (1, pg. F1.7) notes:

> "It was very discouraging to the AEC to note that the nuclear industry, particularly the utilities and the architect/engineers, as well as the standards-writing organizations, were slow in responding to repeated urgings for needed nuclear standards activities. In tracing the overall growth of the American national nuclear standards, one finds that prior to about 1969 only a handful of industry standards existed and few new standards had been identified for nuclear applications."

With leadership and financial support provided by AEC to a revitalized American National Standards Institute (i.e., ANSI) organization, the nuclear standards program began to develop. The responsibility for coordinating the development of a body of standards that would define the requirements for the design and construction of nuclear plants was given to the ANSI N45 "Reactor Plants and Maintenance" Committee.

ANSI N45.2 Standard. The first standard that was developed dealt with quality assurance program requirements. The task of preparing this standard was assigned in May 1969 to an ad hoc committee of industry and AEC representatives under ASME sponsorship. It was agreed that the standard would be based on the format of the 18 criteria of 10CFR Part 50, Appendix B and would cover all activities affecting the quality of nuclear plant structures, systems and components from design through construction and operation, exclusive of those activities specifically covered by the ASME Code. The standard applied to nuclear power plant owners and major participating constructors at all levels.

The standard, ANSI N45.2-1971--"Quality Assurance Requirements for Nuclear Power Plants" (14), was issued in February 1972.

N45.2 Daughter Standards. A permanent subcommittee N45.2 was organized during the time in which the above standard was developed with broader

responsibilities and representation to serve as a focal point for development, coordination and review of supplemental "daughter standards". It was divided into 14 Work Groups composed of individuals representing technical societies as well as organizations involved in the regulation, design and construction of nuclear power plants. As noted by Langston (1, pg. F1.7):

> "This cooperative effort has resulted in the issuance to date of about a dozen supplemental or daughter standards, each of which is intended to be consistent and used in conjunction with the parent ANSI N45.2 standard. Development is progressing on about six additional daughter standards."

The ANSI N45.2 daughter standards can be divided into two main groups. The first group consists of about seven quality assurance program management standards which amplify specific sections of ANSI N45.2. An example from this group is ANSI N45.2.12--"Requirements for Auditing of Quality Assurance Programs for Nuclear Power Plants." (15)

The second group contains the quality method standards which are product oriented and concerned with quality control and verification requirements. An example from this group is ANSI N45.2.5-1974--"Supplementary Quality Assurance Requirements for Installation, Inspection and Testing of Structural Concrete and Structural Steel During the Construction Phase of Nuclear Power Plants." (16).

The Role of ANSI N45.2 Standards. As noted above, these standards were designed to be compatible and consistent with NRC quality assurance requirements and the ASME Boiler and Pressure Vessel Code. Hannon (13, pg. 13) points out the following facts about the ANSI Standards:

1. Whereas NRC regulations and the ASME code are mandatory regulations establishing firm requirements for the areas they cover, the ANSI N45.2 series are not self-sufficient regulatory documents. Each is to be invoked

by a regulatory requirement prescribing its use, a power plant applicant's license committment, or by an appropriate procurement document.

2. A significant difference between ANSI standards and NRC regulations is that the ANSI standards apply to features of the plant affecting operational reliability as well as those important to safety.

3. ANSI N45.2 standards specify both requirements and guidelines. The requirements, which almost always use the verb "shall" must be followed to comply with the standard. The guidelines which use the verbs "should" or "may" frequently indicate one or more of a number of acceptable, equivalent practices. To comply with the standard, the specific practice of the organization should be comparable with the guideline though it need not follow precisely the specific practice suggested.

III. ASME Code Efforts.

As noted earlier, during the 1960's the American Society of Mechanical Engineers was developing a more comprehensive body of quality assurance requirements for pressure boundary and pressure-retaining components. In 1963, Section III of the ASME Boiler and Pressure Vessels Code entitled, "Nuclear Vessels" (17) was published. This version was quite different from the then contemporary codes and had major innovations in the areas of: (1) design and (2) materials and fabrication, with regard to reactor pressure vessels. The 1965 edition of the Code contained inspection requirements for nuclear vessels. The Winter 1967 addenda to Section III of the Code included a new Appendix IX which covered quality control and non-destructive examination methods. A manufacturer's quality control program was subject to evaluation and approval by the Society prior to issuance of a Certificate of Authorization to manufacture and Code-stamp a nuclear vessel.

During the next four years the scope of the ASME Code was broadened appreciably. The quality assurance requirements of the Code evolved from a limited quality control program covering a few pressure vessel manufacturers to a more comprehensive quality assurance program encompassing the design, manufacture, and installation of vessels, piping, pumps, valves and other pressure-retaining nuclear power plant components.

In 1971 a new Section III Division 1 of the ASME Code was issued. It provided rules for three classes of vessels, piping, pumps and valves. Class 1 is applied to the reactor-coolant pressure boundary. Class 2 is applied to reactor auxiliary systems that are not a part of the reactor-coolant pressure boundary but which are in direct communication with it. Class 3 is applied to systems that support Class 2 systems without being a part of them. Expanded quality assurance requirements were also included in the 1971 version. They were intended to be responsive to the 18 criteria of 10CFR 50, Appendix B. Also at this time Section III of the Code was made a condition of the construction permit for a proposed plant by the addition of Paragraph 50.55a to 10CFR 50. The 1974 version of the Code as shown in Table 2.3 divided Section III into two divisions: Division 1: Nuclear Power Plant Components, and Division 2: Concrete Reactor Vessels and Containments.

It will be noted from Table 2.3 that Division 1 of Section III was published as a set comprised of seven individual subsections. Section NA, "General Requirements," defines the scope of Section III. It provides component classification philosophy, and defines quality assurance requirements and the responsibilities of the various parties--architect-engineer, component manuracturer, material supplier, plant owner and authorized code inspector. It also defines the various certificates, code stamps and data reports required.

Table 2.3.--ASME Boiler and Pressure Vessel Code Sections-1974 (17)

Section I-Power Boilers
Section II-Materials Specifications
Section III
Division 1: Nuclear Power Plant Components
Subsection NA-General Requirements
Subsection NB-Class 1 Components
Subsection NC-Class 2 Components
Subsection ND-Class 3 Components
Subsection NE-Class MC Components[a]
Subsection NF-Component Supports
Subsection NG-Core Support Structures
Division 2: Concrete Reactor Vessels and Containments
Section IV-Heating Boilers
Section V-Nondestructive Examinations
Section VI-Recommended Rules for Care and Operation of Heating Boilers
Section VII-Recommended Rules for Care of Power Boilers
Section VIII-Pressure Vessels-Divisions 1 and 2
Section IX-Welding and Brazing Qualifications
Section X-Fiberglas Reinforced Plastic Pressure Vessels
Section XI-Rules for Inservice Inspection of Nuclear Power Plant Components

[a]MC=metallic containment

With regard to the area of mechanical equipment (i.e. pumps, valves and pressure piping) it should be noted that the ASME codes are strictly enforced in most states. The quality assurance procedures required for the mechanical phase of construction are fairly well defined. The Society has assured its enforcement by sending out audit teams to verify the existence of a functioning quality assurance program. This is done before a manufacturer or installer is given authorization to use the "N" stamp which must be evident on all installed pressure boundary equipment in the modern nuclear power plants.

IV. ACI Efforts

The National Association of Cement Users was formed in 1905. In 1913, the name of the Society was changed to the American Concrete Institute (ACI) to better fit the actual scope of its activities and aims. These aims are to further engineering education and scientific investigation and scientific research by organizing the efforts of its members for a nonprofit, public service by gathering, correlating, and disseminating information for the improvement of the design, construction, manufacture, use and maintenance of concrete products and structures.

The present-day technical standards related to Portland Cement Concrete for all types of construction are available in a three-part "Manual of Concrete Practice" (18) which is published by the American Concrete Institute (ACI). It contains most of the current concrete standards and ACI technical committee reports which are needed to describe quality concrete.

General Construction. Of particular interest from the point of view of general concrete practice are ACI Standard 301-72 (19) and ACI Standard 318-71 (20). ACI 301-72, entitled "Specifications for Structural Concrete for Buildings", was last revised in 1975. As noted in this document (19, p. 1), "These specifications are a reference standard which the engineer or

architect may make available to any building project by citing them in the project specifications. He supplements them as needed by designating or specifying individual project requirements."

ACI 318-71, entitled "Building Code Requirements for Reinforced Concrete", covers the proper design and construction of buildings of reinforced concrete. It is written as a legal document so that it may be incorporated verbatim or adopted by reference in a general building code.

As noted above, another type of ACI standard which appears in the Manual of Concrete Practice is one which is referred to as a "Recommended Practice" type document. An example of one of these is ACI 305-72 entitled "Recommended Practice for Hot Weather Concreting" (21).

The above type of ACI documents also reference many of the standards of the American Society for Testing and Materials (i.e., ASTM) which deal more specifically with the properties of concrete and its component materials. An example of an ASTM standard related to concrete is ANSI/ASTM C94-74a, entitled "Standard Specifications for Ready-Mixed Concrete" (22).

It should be noted that ASTM C94-74a is one of many ASTM standards that have also been adopted by ANSI.

Although there are other professional and industrial groups which provide technical guidance in the concrete area (National Ready Mixed Concrete Association, etc.) the primary sources of information which define the "state of the art" of general concrete practice in the United States are probably ACI and ASTM.

Nuclear Construction. As will be noted in later chapters of this report, nuclear power plant concrete construction is sufficiently different from general type construction (the existence of heavily reinforced members, mass

concrete conditions, etc.) that problems have developed on a number of projects when the above mentioned, more general, ACI and ASTM documents have been directly applied.

In 1966, ACI organized the ACI 349 Committee in order to address the area of nuclear power plant construction. ASME also organized a committee to study the area of concrete. The ACI 349 Committee "Criteria for Nuclear Containment Vessels" and the ASME Boiler and Pressure Vessel Code Committee, Section III, Division 2, "Subgroup on Concrete Components" submitted completed reports in September 1971 to ACI and ASME respectively. A Joint Committee, whose membership included individuals from both ACI and ASME and many others actively involved in the field was formed in September 1971. The three primary goals established for the Committee were:

(1) To establish rules in the form of a code for the design, construction, inspection, and testing of composite concrete and steel components for reactor vessels and containments for nuclear power reactors.

(2) To interpret these rules when questions arise regarding their intent.

(3) To periodically update code provisions making full use of the expedited procedure for revision of standards as necessary.

The two documents mentioned above were combined into a single document dated January 17, 1972 and entitled "Proposed Standard Code for Concrete Reactor Vessels and Containments" (23). After an extensive review process, the activities of both groups were culminated in 1974 in a joint ACI-ASME standard entitled ACI 359-74 and ASME Boiler and Pressure Vessel Code, Section III (Rules for Construction of Nuclear Power Plant Components), Division 2 (Code of Concrete Reactor Vessels and Containments).

In 1972 while the above activities were proceeding, the original ACI 349

Committee continued its efforts related to the concrete on nuclear projects which was not covered in the joint ACI-ASME Code. In 1976 their activity resulted in ACI 349-76, entitled "Code Requirements for Nuclear Safety Related Concrete Structures" (24). As noted (24, pg. 1):

> "This standard covers the proper design and construction of concrete structures which form part of a nuclear power plant and which have nuclear safety related functions, but does not cover concrete reactor vessels and concrete containment structures (as defined by ACI-ASME Committee 359).
>
> The structures covered by the code include concrete structures inside and outside the containment system.
>
> This code may be referenced and applied subject to agreement between the Owner and the Regulatory Authority.
>
> The format of this code is based on the "Building Code Requirements for Reinforced Concrete (ACI 318-71)" and incorporates recent revisions of that standard.

It should be noted that ACI 349-76 appears to be primarily concerned with design of concrete structures since only three out of a total of 19 chapters deal specifically with material or construction aspects. It should also be noted that because of its publication date it was not applied on any of the nine nuclear projects in this research study.

FACTORS INFLUENCING QUALITY ASSURANCE PROGRAMS

The discussion in the previous section of this chapter has indicated the fact that the ten-year period which began with the issuance of Appendix A of 10CFR Part 50 represented one of rapid growth in terms of the number of regulatory requirements and industry standards that were developed related to quality assurance. Figure 2.1 indicates that rapid growth was also exhibited during this period in terms of the number of Construction Permits and Operating Licenses that were issued. This combined growth pattern, as might be expected, created some extensive dislocation and confusion within the industry as it evolved toward maturity.

If 1978 were considered as a base line from which to examine the status

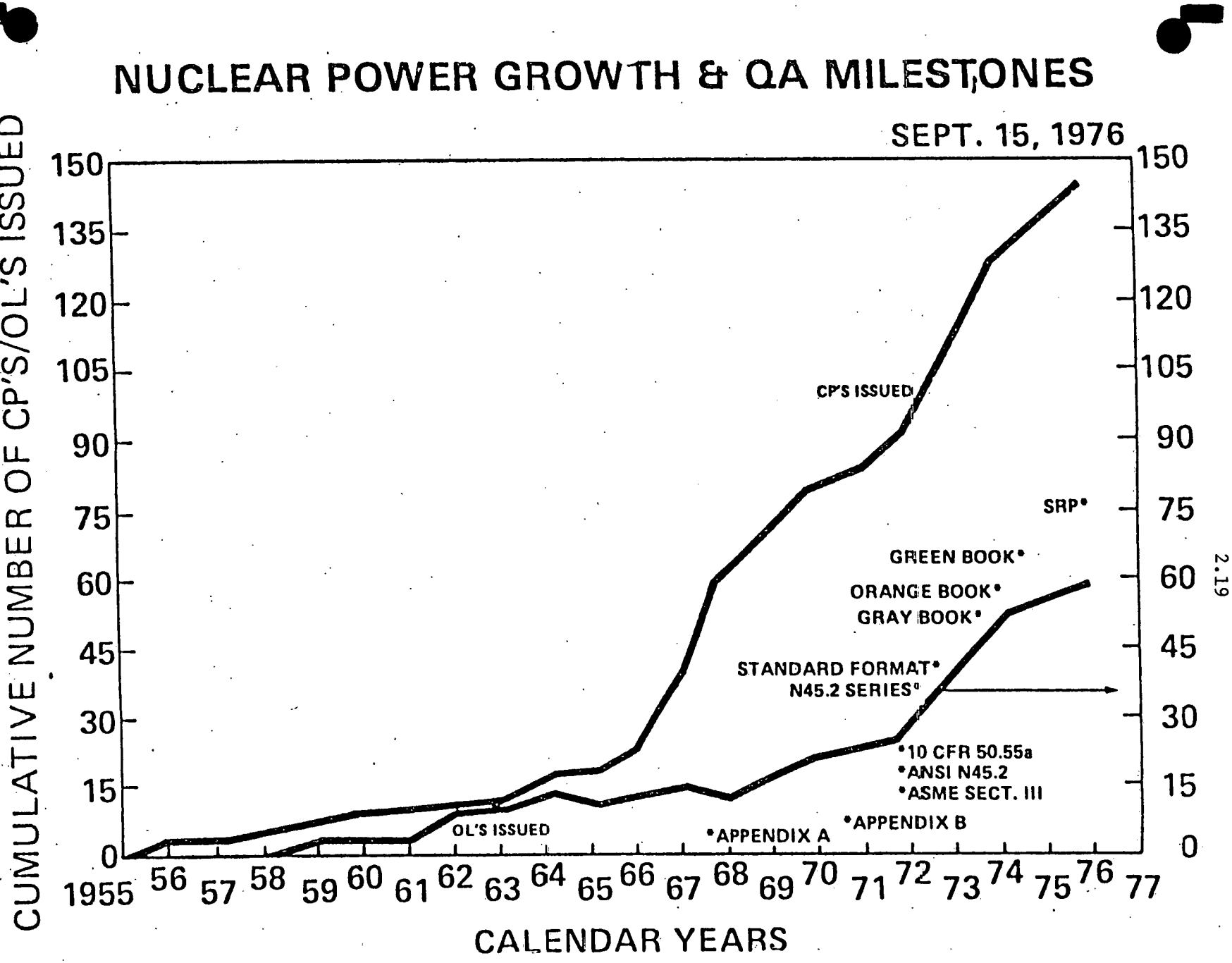

Figure 2.1.--Nuclear Power Growth and Milestones

(from Heltemes (25, pg. 7))

of quality assurance on nuclear projects, the following two remarks made in 1976 by Ben C. Rusche, Director, Nuclear Reactor Regulation, NRC (26., pg. 1.4), could be noted:

> "So where have we come in the six years since Appendix B was published in final form? Today all NRC licensees have QA programs--founded on industry standards and conducted by qualified people. Program definition, though still set out in many documents, seems to be in a relatively advanced state of development. That aspect of the QA effort is near maturity and beginning to achieve the stability and predictability we have long sought. Regulatory QA requirements have also stabilized and we are under strict NRC management control. Thus, while we need to continue the efforts to refine and consolidate program documentation, we must focus our attention next on how to achieve balanced implementation.
>
> At this time, essentially all of the basic industry program QA standards have been published and the few remaining are in draft form. The ASME code has been revised and expanded to sharpen the QA related aspects. The professional societies have supported QA activities--including standards development sessions and meetings such as this one--which have advanced the QA state-of-the-art. So the present reality is that practically all of the elements of the QA program definition are available for use. In short, we have a wealth of guidance on how to formulate and implement controls to achieve quality objectives--probably more than some may really want."

The nuclear power plants that were examined in the research effort were and are being built during this period of rapid expansion. Some of the QA practices which will be discussed in later chapters evolved into their present form as a result of the forces for change (both external as well as internal to each project) which occurred. In order to put the material in later chapters into proper perspective, therefore, it is necessary to examine some of the major factors which developed due to the above mentioned forces for change. These factors have been classified as follows:

1. Development of Standards
2. Difficulties of Interpretation of Requirements
3. The Role of the NRC
4. Documentation Requirements

5. Cost of Quality Assurance

6. Additional Benefits from QA

I. Development of Standards

The enormity of the task of developing the standards which were felt to be required after Appendix B to 10CFR Part 50 was issued was discussed in a speech delivered in 1974 by Ann Savolainen which was reported in Quality Progress (27, pg. 12). Savolainen, the Director of the Nuclear Program for ANSI, described the standards development work of ANSI's Nuclear Technical Advisory Board (NTAB). As noted:

> "In 1972, Savolainen continued, NTAB with assistance from AEC, the National Bureau of Standards, U. S. Public Health Service and National Council on Radiation Protection, prepared a master plan for developing nuclear standards on a priority basis.
>
> The priorities, which are under continuous review and adjustment, reflect needs from the viewpoint of licensing and the needs of the designer, constructor, manufacturer, and utility or other user of radioactive materials and equipment. Approximately 500 priority projects are underway, Savolainen noted...
>
> More than 1000 identified nuclear application standards currently exist, but it has been estimated that approximately 5000 standards are needed to build a nuclear power generation plant. Of these 5000, said Savolainen, about 2000 are for nuts, bolts, resistors, and other similar items; these standards exist and are already proven.
>
> In addition, she pointed out, 400 to 500 military and 500 to 600 tried and useful Federal standards and specifications are applicable. Approximately 1000 other industry standards are applicable, and thus the currently available and useful standards number about 4000.
>
> "This, she said, "leaves about 1000 to be developed and possibly 1000 of the existing standards to be revised and updated. Currently, more than 500 standards projects have been assigned to writing groups and thus there remains a potential need for about 500 additional new standards."

With regard to the development of standards, Muntzing (31, pg. 18) noted in 1975:

> "AEC efforts between 1971 and 1974 to upgrade quality in the nuclear industry were aided by advances made in cooperation with the American Standards Institute (ANSI) and engineering trade associations in the development of nuclear standards. During this time a significant body of standards was developed at an increasing pace.

> In fiscal year 1974 alone, 150 standards were produced, compared with 25 developed in 1972 and 90 in 1973. Plant performance is predicated on sound engineering practices that, when properly formulated and reworded comprise engineering standards. These standards ultimately comprise the parameters of quality assurance."

It should be noted, however, that not all of the above standards related directly to quality assurance aspects. As mentioned in an earlier section of this chapter, the responsibility for quality assurance standards was placed with what became the ANSI N45.2 Committee. The net result of that committee's efforts to date has been the issuance of ANSI N45.2-"Quality Assurance Program Requirements for Nuclear Power Plants" and the drafting and partial issuance of 24 related "daughter standards".

Reactions of Industry. The impact that this era of rapid standard development had on the nuclear construction industry was noted by Silverwood (29, pg. 526) in 1975:

> "The proliferation of standards has resulted in redundant standards which unnecessarily extends our technical and craft labor resources. Additionally, the proliferation of standards has caused the Owner, Architect/Engineer, NSSS Supplier, and Equipment Manufacturer to make commitments based on misinterpretation of standards, thus contributing to stretched schedules and a loss in operating flexibility; and plant availability has not improved.
>
> Professional QA Managers considered the 18 criteria of 10CFR 50 Appendix B and the Standard Review Plan as sufficient guides for establishing Quality Assurance Programs. We did not need additional redundant and nebulous requirements detailing how we must develop our QA plans.
>
> History has shown that the Nuclear Regulatory Commission (NRC) is forced to introduce Regulatory Guides. Why? In some instances because the ANSI N45.2 daughter standards missed the goal of completely specifying the requirements. ANSI N45.2 daughter standards are not consistent. Depending on the individual committee members, some committees develop too stringent a set of guidelines, others reflect permissive guides, or worse yet, there are omissions in certain areas of the defined elements where guidelines were intended to be provided... In other instances, Regulatory Guides state additional interpretive requirements because the NRC believes the original standard is not stringent enough to satisfy its intended purpose."

The effect on the construction schedule of an ever-changing set of

requirements was expressed by Fitch (30, pg. 4) in 1976:

> "Again, the changing quality assurance requirements have posed significant problems in meeting construction schedules. The 18 quality assurance requirements (Appendix B to 10CFR 50) initially established the broad requirements for quality assurance. These criteria were originally proposed in April, 1969, and issued in June, 1970. Over a period of 17 months the industry established what it felt were satisfactory quality assurance programs to satisfy these criteria. In August, 1971, ANSI N.45.2 was issued which further defined and expanded upon the original criteria. Additionally, a lengthy series of daughter standards to the N.45.2 document was initiated which have been published since that time. Construction projects under way during this period have found it almost impossible to establish quality assurance programs which will satisfy these ever-changing requirements. For a given project, a PSAR might have been approved which referenced those ANSI Quality Assurance Standards published up to the time of issuance of a construction permit, but NRC inspectors have generally expected such a project to conform with additional standards as they are published."

Silverwood noted the effect on costs as follows (31, pg. 2):

> "We have started to see some of this where the backfitting of new Quality Assurance Standards and Regulatory Guides into an already implemented quality program has adversely impacted their cost effectiveness. We recently conducted a study for a Client to assess the increase in cost on his project resulting from changes in Codes, Standards and Regulatory Guides. We concluded that the Client paid $4 1/2 million over the last three years updating his project to comply with the changing QA Standards and Regulatory Guides. Here is an instance where "new" is not necessarily better--only more expensive. This has got to stop!"

It should be noted that the development of the ANSI-Standard Review Plans-Regulatory Guides chain is of course only one part of the story. Other professional groups looked at the ANSI Standards and determined that they were not sufficient to satisfy their requirements. IEEE wrote its own standards, which contained quality assurance requirements. So did ACI and AICHE. Some of the requirements were common to the ANSI family, but there appeared to be sufficient differences to confuse the users. In this regard, Vannoy has stated (32, pg. 30):

> "With so many organizations and people involved in standards development this activity is in need of clear direction. At this time, some standards

are incomplete and changes are initiated on an as-needed basis. Some standards are being written before the supporting technology is firm and others need clarification for their interpretation. It is evident that improvement in standards development for nuclear energy requires strong direction and coordination. NRC and ANSI have jointly recognized this need and are bringing leadership to this activity."

Development of a Single QA Standard. The problem of the proliferation and duplication of quality assurance standards was recognized very early in the development stage. As Langston (1, pg. F1.9) notes:

"...the old N45.2 Subcommittee recognized early on in its work that there were internal problems with the series of standards they were developing. It was the judgment of the subcommittee, however, that it was far more important to the industry to get the standards out and in use, even though imperfect, than it was to continue the refining process indefinitely.

Probably the most significant problem with the standards was the reiteration of programmatic requirements in the N45.2 series of daughter standards. Other standards-writing groups in the nuclear industry were also generating QA standards which essentially duplicated the programmatic requirements of N45.2. One viewpoint is that this is permissible provided the requirements are identical. Another viewpoint is that such duplication constitutes a needless proliferation of standards and a waste of time and manpower which could be used more productively on product-oriented quality assurance requirements standards. In an attempt to resolve this situation, the Executive Committee of the former ANSI Nuclear Technical Advisory Board adopted a policy in November 1972 which stated that:

> There should be a single quality assurance program standard covering nuclear activities."

A survey conducted in early 1976 by ASME noted by Langston (1, pg. F1.10) concluded:

1. There is an urgent need within the nuclear industry for a single quality assurance standard.
2. The relationship between the various quality assurance standards needs clarification.
3. The applicability of the standards needs clarification.
4. There are three areas that are controversial--these are:
   - -Inclusion of guidance
   - -Use of checklists
   - -Specificity and depth of requirements

In November 1975, the Executive Committee of the ASME Committee on Nuclear Quality Assurance requested the General Requirements Subcommittee to develop an approach for the consolidation of the programmatic requirements in N45.2 and the daughter standards. This was done and was presented to the Main Committee at its May 1976 meeting in Atlanta. The approach recommended by the General Requirements Subcommittee was that there should be one standard containing all programmatic QA requirements for nuclear facilities. This standard should have a format consisting of basic QA program requirements followed by mandatory supplements then by nonmandatory appendices. As noted by Langston (1 pg. F1.12):

> "The demonstration package has been prepared in draft form. It consists of a melding of the provisions of the N45.2 standard and those daughter standards which are programmatic in nature (i.e., N45.2.6, N45.2.9, N45.2.10, N45.2.11, N45.2.12, N45.2.13, N45.2.14, and N45.2.23). This package is expected to be available for discussion with the Main Committee after the next meeting of the General Requirements Subcommittee.
>
> Once the consolidation of ANSI N45.2 program standards is accomplished, the next step will be to eliminate programmatic requirements from the quality method standards. It is also hoped that the responsibility for maintenance of existing quality method standards and the development of new standards will be assumed by the appropriate technical society.
>
> It is hoped that the ASME Code will eventually endorse the base requirements of the proposed ANSI N45.2 consolidated standard and that NA 4000 will be revised as a supplement. This action need not have any substantive effect on existing ASME-certified quality assurance programs. It should eliminate the practice of maintaining multiple quality assurance manuals and procedures."

The current activity in the industry to consolidate the QA programmatic standards seems a highly desirable one from several standpoints--it offers the potential to reduce the number of documents and thus to help reduce the overlapping of requirements and sources of guidance. Actions to minimize the dependence on multiple documents should also help clarify and focus upon specific requirements needed for effective QA implementation. Most important, consolidation offers the potential of achieving a common set

of requirements.

Summary. The above information should provide a better understanding of the situation that has evolved with regard to quality assurance standards. It appears that eventually the industry will have one source of reference for quality assurance. The caution, however, which is felt by many in the industry is expressed by Silverwood (31, pg. 1) as follows:

> "We understand that several groups within the NRC are urging ASME to develop one broad QA program standard--a programmatic standard that would encompass NA 4000, N45.2 and Appendix B of 10CFR 50. The development and use of such a standard could significantly and favorably contribute to the cost effectiveness of QA programs if this proposed standard would take the place of NA 4000, N45.2 and Appendix B. However, if the proposed standard is intended only for use by the Survey Teams and to supplement the existing QA program requirements, then such a standard could contribute additional adverse effects to the costs of QA."

He also noted (31, pg. 7):

> "Somehow or other, we are accomplishing the Quality Assurance Mission, but I am afraid we are close to drowning in a sea of words. We do not need more standards, by any means; we ought to clean up what we have now! The way the standards have been written, in far too many cases, has resulted in QA programs that have consisted in accumulating paper more than in providing for meaningful quality assurance.
>
> New standards should be able to withstand the following scrutiny:
>
> --Is the standard required?
>
> --Will it result in higher reliability and availability?
>
> --Will it be cost effective?
>
> --Is it practical and workable?"

II. Difficulties of Interpretation of Requirements

Closely associated with the rapid growth of the standards mentioned above was the difficulty which the various parties in the nuclear industry had with regard to the interpretation of the requirements that were promulgated. As Jackson noted in 1973 (33, pg. 16):

> "The past four years has been a period of considerable confusion characterized by the pitfalls attendant to reinventing the wheel

with respect to quality assurance concepts...The result frequently has been failure on the part of the owner and the AEC to interpret correctly the written requirements set forth in the AEC quality assurance criteria. Subjective judgments diametrically opposed could be found on such guidelines as:

--What is the requirement for traceability on concrete reinforcing steel?

--To what extent can nonconforming material be used "as is"?

--What constitutes a valid supplier certification of material?

--Organizationally, is it acceptable to have inspectors under the construction superintendant, the construction manager, the project manager?

The list goes on and on. And believe it or not, there still is no authoritative answer to the above questions. As many involved with nuclear construction already know, there are different practices on each of the above items depending on the particular nuclear plant under construction."

It should be recalled from the previous section which dealt with standards that the problems of interpretation were compounded by the fact that the set of requirements were not fixed, they were constantly changing. An example of the consequence to a utility of such a "floating target" situation was cited by Silverwood (31, pg. 3):

"Beginning in early 1973, utilities wishing to submit Safety Analysis Reports for new projects were informed by the AEC that they had to describe their QA Programs in greater detail than was the case before. I recall that we were assisting one of our Clients to prepare the PSAR for his two unit nuclear project. Only two questions were raised on the initial Chapter 17, "Quality Assurance Program" and it was judged to be generally acceptable. After the Commission developed its new guidelines, we were informed that our Chapter 17 was completely unacceptable and had to be redone. What a waste of resources!"

In this type of an environment it is fairly easy to understand that utilities and other parties often "overreacted" by imposing undue restrictions upon the construction process or by creating an excessive set of documents to define their own quality assurance programs. As Allen (34, pg. 1.2.7) states:

"Too often, we in industry react to a "what if" type of question with another system or another stringent requirement. The time has come when we should respond to the "what if" statement by insisting that

the same stringent requirements be placed on the questions as on the answer.

In many areas, we are reacting too quickly to an allegation with firm and rigid action, without evaluating the allegation or the credibility of the allegation."

Rusche (26, pg. 1.4.3.) addressed himself to this point in 1976 by noting:

"The ability to fine tune the QA program, however, is undoubtedly hampered by the many layers and overlapping of requirements and sources of guidance. We in regulation make constant reference to Appendix B, the Standard Technical Specifications, the Standard Review Plan, Standard Format and the rest. But we know from our experience that the utilities' QA programs are also spread through a plethora of documents--such as the SAR, the Corporate Quality Assurance Manual, the Corporate Instructions, Facility Quality Assurance Manual, QA Implementing Procedures and administrative documents such as operating manuals, procurement manuals, and engineering manuals. This dependence on multiple documents is a real concern to me. It is essential that you evaluate each of these documents and develop a clear, full and detailed understanding of your QA committments and, at the same time that you make those committments, have no doubt that you have the necessary resources and capability to fully satisfy each one."

He went on to note: "Balance is not a matter of writing great QA program committments without the resources and intent to carry them out. The attitude of "Promise Them Anything" to get a license is totally unacceptable when it comes to assuring the quality and safety of nuclear plants."

The period of time between 1973 and 1976 was characterized by C. J. Heltemes, Chief, Quality Assurance Branch, NRC in 1976 as follows (25, pg.1):

"The rapid development of QA guidance in the past three years has caused a major impact. Many plants were either under construction or in the operating license review stage at the time the guidance was published and the resultant QA program reviews within the NRC (then AEC)often resulted in a request for these programs to be substantially revised.

Thus, getting up to speed in the '73-'75 time frame caused a greater impact on industry and regulatory organizations than would have occurred with a normal transition between formulation of the guidance and initiation of the activity covered by it. However, I believe many of these problems are now behind us. The NRC and industry guidance is now reasonably well documented, available and understood by all and --together with the Standard Review Plan and topical report program-- has made it possible to standardize QA programs and to achieve a greater measure of stability and predictability."

As noted, when the quality assurance requirements of 10CFR Part 50, Appendix B were discussed in the previous section, they were designed to be applicable to all activities affecting the safety-related functions of those structures, systems and components which "prevent or mitigate the consequences of postulated accidents that could cause undue risk to the health and safety of the public." This definition presented another area where requirements were difficult to interpret. As noted by Heltemes in 1976 (25, pg. 2):

> "Another problem that has proven troublesome is the lack of a uniform understanding of what items are safety related and therefore subject to Appendix B. We have directed our attention towards the development of improved guidance beyond current regulatory guides and the more classical definition of those plant features "that are necessary to ensure (1) the integrity of the reactor coolant pressure boundary, (2) the capability to shut down the reactor and maintain it in a safe condition, or (3) the capability to prevent or mitigate the consequences of accidents..." Currently, we are pursuing the development of more definitive criteria by which a uniform and informed judgment could be made regarding the application of Appendix B rather than attempting to identify specific items we believe to be safety-related. If more definitive criteria can be developed regarding the breadth and depth to which the QA requirements of Appendix B apply, real gains should be possible in assuring the application of Appendix B in a consistent and proportioned manner. And let me stress "proportioned". We in the NRC believe in balanced or proportional QA, that is, QA controls tailored to the importance, complexity, duration and nature of a given activity. The Director of NRR, Ben Rusche affirmed this principle in San Francisco in October. Too much QA can be as inefficient as too little--both extremes must be avoided."

III. The Role of the NRC

The quality assurance programs which were developed for nuclear power plants as mentioned earlier, are heavily influenced by the Nuclear Regulatory Commission (i.e. NRC). As noted by Carlson (38), the Nuclear Regulatory Commission came into being officially on January 19, 1975, the effective date of the Energy Reorganization Act of 1974, which was signed into law on October 11, 1974. This act dissolved the Atomic Energy Commission (AEC) and created both the NRC and the Energy Research and Development Administration (ERDA).

The NRC is responsible for the regulation of the licensing, design, construction, and operation of nuclear power plants. The NRC is also responsible for enforcing the requirements of 10CFR Part 50, Appendix B. Three of the primary modes for carrying out this responsibility are through (1) design and licensing reviews, (2) inspections of construction operations, and (3) enforcement activities.

The Licensing Process. Before full-scale construction can commence on a nuclear project, a construction permit must be issued by the NRC under the Office of Nuclear Reactor Regulation. A review of the licensing process which is required to obtain this permit will be useful in indicating the depth of review and involvement of the NRC and also the time frame which is involved in the process. This licensing process consists of four major steps.

The first step involves the filing and acceptance of the application, generally consisting of up to fifteen large volumes of material. This document is known as the Preliminary Safety Analysis Report (PSAR). The PSAR, which is developed and submitted by the utility or owner, indicates in detail the design assumptions and limitations of the proposed plant. Chapter 17 of the PSAR outlines the Quality Assurance requirements which the owner commits to in the design and construction of the project. In addition to the PSAR, an Environmental Report (ER) is also filed by the owner. The development of the PSAR and ER by the owner, with the assistance of the designer, can take up to 18 months.

The second stage in the licensing process consists of safety, environmental, safeguards and antitrust reviews of the PSAR and ER by the NRC staff. This review process takes approximately 18 months. It should be noted that this represents a reduction from the 30 month review period which was required

in the early 1970's

The third step is a safety review which is conducted by the Advisory Committee on Reactor Safety (ACRS). The ACRS is commissioned by the NRC, but acts independently of them. This independent ACRS safety review is required by law.

The final step in the licensing process is a mandatory public hearing by an Atomic Safety and Licensing Board (ASLB). The ASLB is composed of three members, including a chairman and two technical advisors with expertise in environmental and nuclear technology. The duration of this public hearing can vary drastically depending upon the nature of the intervenors.

Upon successful completion of the public hearing, a construction permit can be issued. The construction permit basically gives the utility the authority to construct the nuclear plant in accordance with the committments that were made in the PSAR. This point cannot be overemphasized. Inspections during construction (which will be discussed below) as well as review for further licensing, will be based primarily on the PSAR. Since the utility will be held responsible for compliance to the PSAR (even when it later appears that specific parts of the PSAR prove to be more stringent than would otherwise have been required in order to be licensed) the utility must be sure the PSAR contains only what is desired.

The Inspection Process. A second major area of NRC activity consists of inspections of nuclear plants that are either under construction or in operation. The NRC inspection program begins with the utility's quality assurance planning and extends over the plant's entire lifetime. NRC inspections fall into one of four phases of a nuclear power plant's life. These include (1) preconstruction activities, with an emphasis on development of an acceptable quality assurance program; (2) construction activities, including verification of the suitability of materials used, the quality of fabrication, and verification

that quality assurance requirements are being met; (3) preoperational testing and startup, including observation of preoperational tests and examination of the organization, personnel, equipment, and procedures that will be used during operation; and, (4) operational activities, including periodic inspections to determine whether the plant is operating in accordance with NRC requirements.

The Office of Inspection and Enforcement of the NRC manages and directs the five regional offices located throughout the United States. The NRC inspection program includes two components--a routine inspection component and a reactive inspection component.

The routine NRC inspection component is conducted in accordance with a defined program expressed in detailed inspection procedures and is accomplished at prescribed intervals by NRC field inspectors. This NRC inspection effort is essentially the apex of a pyramid of inspections, audits, and controls implemented by the NRC licensee and his contractors. As shown in Figure 2.2, the areas of the pyramid indicate very roughly the relative amount of manpower which each organization devotes to inspection and audit. The position of the areas represents where in time these inspections and audits occur.

As noted by E. Volgenau, Director, Office of Inspection and Enforcement, NRC, in 1976 (36, pg. 4):

> "Thus, the NRC is the last in the series of inspections and audits performed by many different groups. NRC inspection manpower is usually far less than that of licensees and contractors, and NRC inspectors cannot possibly inspect all components and activities. Instead, NRC inspectors take a vertical slice to an appropriate depth through the inspection, audit and control pyramid of these other organizations to see if the licensee's Quality Assurance activities and those of his contractors are being properly performed. NRC inspectors do this by checking the records (i.e., audit trails) associated with the receipt, installation and operation of components; by observing testing or work in progress; and by making direct measurements. That is, NRC inspections are designed to be sure that the overall pyramid is working properly."

The elements considered when the detailed inspection procedures used by NRC

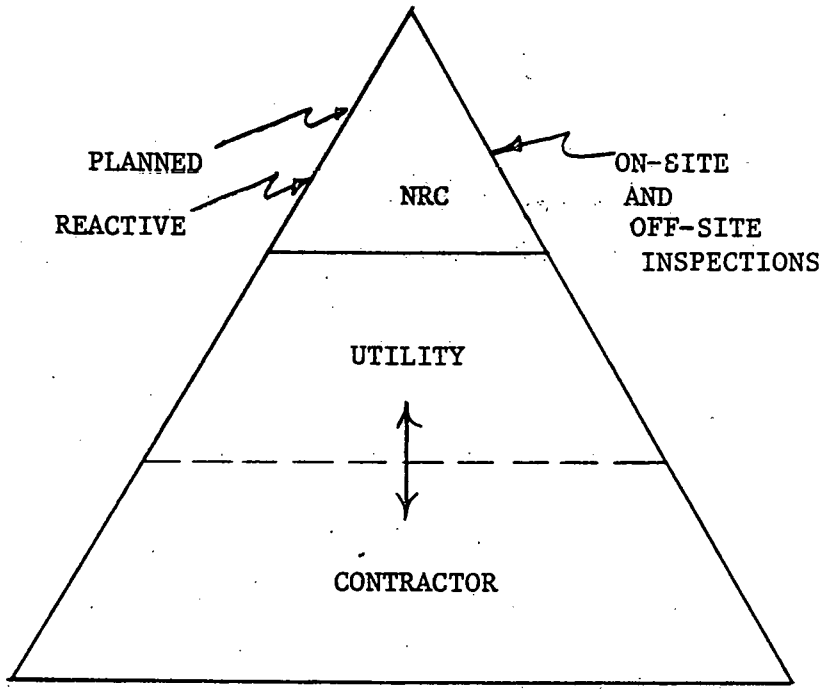

Figure 2.2--Relative Nuclear Power Plant Inspection Efforts
(from Volgenau (36))

inspectors are developed include: regulatory requirements, regulatory guides, industry standards and items which are significant enough to be included in the inspection program. NRC inspectors inspect those activities related to specific regulatory requirements or license commitments. In addition, they look for conditions which may show that licensees are not meeting their responsibility to provide adequate protection.

The reactive NRC inspection component is conducted in response to information received by NRC about the activities related to a particular project which may impact on public health and safety, the environment or the protection of nuclear facilities and materials. Information of such conditions may be received as a result of notification by an applicant, licensee, contractor or supplier, as a result of information or allegations from a licensee employee or other member of the public or as a result of a planned NRC inspection. The extent of the reactive inspection effort depends upon the significance of the particular condition, event or allegation. The principal objective of this effort is to obtain sufficient information through independent indepth examination to establish the significance of the particular condition, event or allegation and to effect corrective action commensurate with the established significance.

The Enforcement Process. The NRC enforcement effort, which was publicly announced in December 1974, consists of a program of deterrents which escalates quickly according to the nature of the offense and the past histories of non-compliance. As shown in Figure 2.3, all matters examined during an inspection or an investigation fall into one of four broad categories: (1) acceptable, (2) noncompliance with Commission rules and regulations or license conditions, (3) deviation from a licensee commitment that is not a specific requirement or license condition, or (4) unresolved to the extent that more information is needed to determine that the finding lies in one of the other three categories.

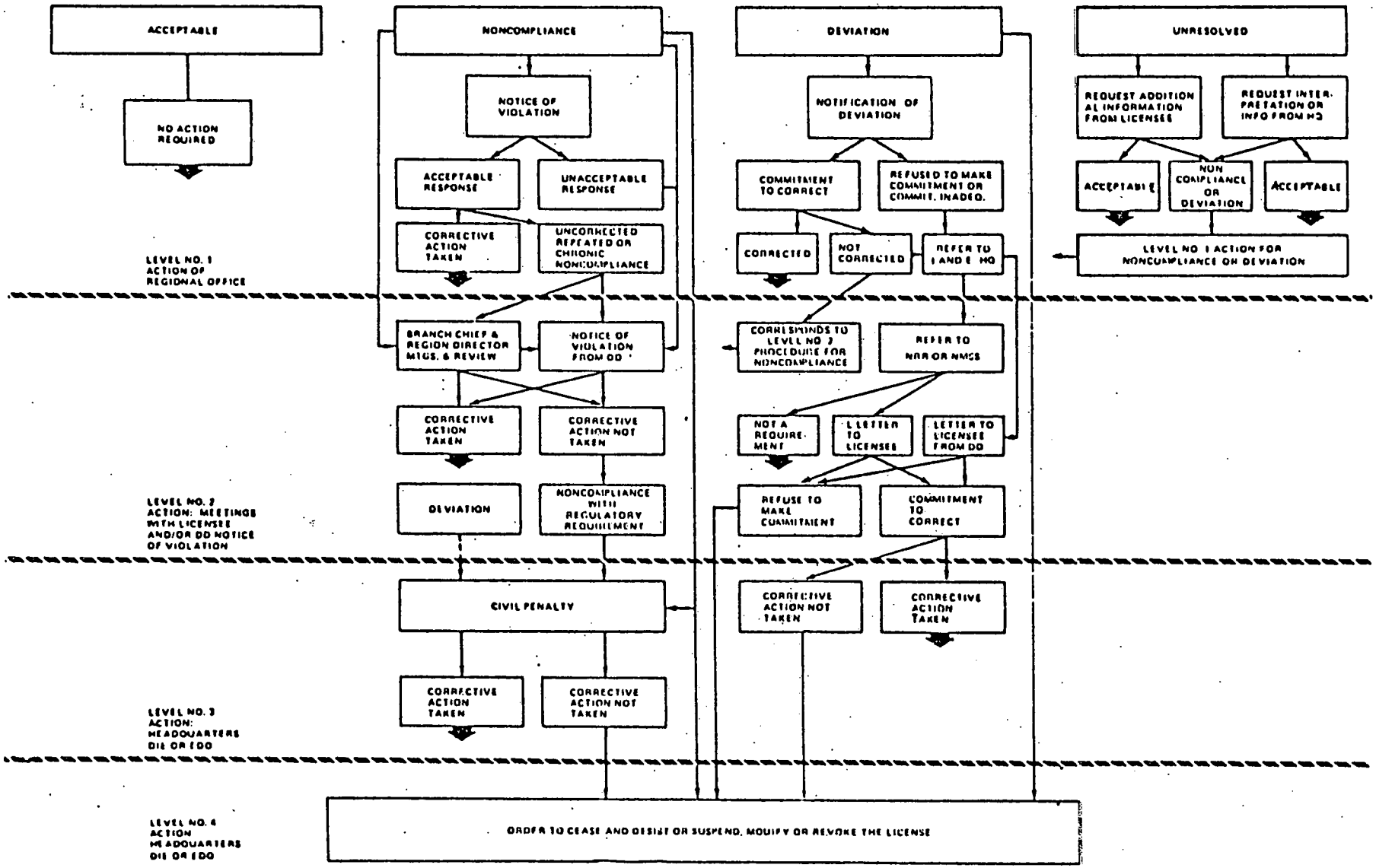

Figure 2.3.--NRC Inspection-Investigation Findings and Enforcement Action (from Carlson (35, pg. 10B.29))

As a means of categorizing the items of noncompliance into an order of importance which expresses their relative significance, NRC has established three categories of items of noncompliance in the following decreasing order of impact on protection provided: Violation, Infraction, Deficiency. As noted in Figure 2.3 the three levels of enforcement which are possible are: (1) Notice of Violation, (2) Civil Monetary Penalties, and (3) Cease and Desist Order. As noted by Volgenau (36, pg. 7):

> "We place great emphasis on the licensee's program to identify items that need corrective action. Enforcement action is not taken for items of noncompliance which are identified by a licensee's internal audit program, provided adequate corrective action is taken and they are of a significance less than "violation" or are not causes of events or occurrences. In most cases, the items of noncompliance identified by licensees are noted by the Office of Inspection and Enforcement in the inspection report. That is, a "Notice of Violation" is not used and a response is not required.
>
> We attach considerable significance to noncompliance items which we directly identify. In view of the requirements for inspections and for audits under a licensee's quality assurance program, the NRC inspections will be at the third level, or even higher, in the inspection hierarchy. Hence, our identification of a noncompliance item carries with it broader implications regarding the effectiveness of the licensee's quality assurance program. For this reason, we require the licensee to effect not only correction of the particular problem identified, but also correction of the more significant programmatic problems, where appropriate. Consequently, we believe that timely and strong enforcement is important in accomplishing the objectives of our inspection program."

Summary. The discussion above should indicate the extent and influence of the NRC on nuclear power plant projects. The scope of their involvement has evolved since the issuance of 10CFR Part 50, Appendix B. It is safe to say that at each milestone event during this evolvement process, the quality assurance activities on most of the projects under construction were probably modified or tightened to conform to the NRC initiatives. The possibility of a civil penalty or a cease and desist order is a strong initiative for making the mandated changes rather than devising extensive alternative approaches.

IV. Documentation Requirements

One of the most common concerns that was felt within the industry when formal quality assurances practices were introduced was the strong emphasis that was placed on documentation.

Source of Requirements. The documentation requirements appear to have come from two sources: the external regulatory environment and the internal quality assurance orientation of the utilities, architect-engineers, etc.

As Muntzing (28, pg. 19) points out:

> "Recurrent complaints persist that regulatory quality assurance requirements demand a burgeoning quantity of paper and that government favors form rather than substance. Both the regulated and the regulator must exercise restraint to avoid unnecessary paperwork and "empty truck" regulation.
>
> However, too many organizations are implementing programs they apparently think will keep them out of trouble with the Nuclear Regulatory Commission. Apparently, they are trying to second guess what the government wants and, in some cases, are going overboard on documentation and the number of inspections so they won't be accused of not going far enough.
>
> What seems to be lacking in some cases is an effort to determine what is important and what isn't in assuring a quality product. If the quality assurance program is not, in fact, improving the quality of the product, industry should determine why and make appropriate corrections. To do otherwise is wasteful and counter productive."

Chezem (40, pg. 6) appears to confirm that documentation is often generated internally when he notes:

> "At the October, 1976 C.A.S.E. (Coordinating Agency for Supplier Evaluation) meeting held in New Orleans, we conducted an informal survey among the QA management personnel in attendance--people who are directly responsible for Quality Assurance in the nuclear industry. Of thirty who responded, twenty-two indicated that they felt that QA programs today are too paper oriented.
>
> These selected examples indicate the concern that is being expressed over excessive paperwork, and when one considers that literally hundreds of thousands of records are accumulated prior to plant startup, not to mention the records generated during operations, the concern appears to be well founded...

But let's not put all the blame on the Regulatory Agencies and the Standards writers. One of the surprising facts which emerged from our survey at the C.A.S.E. meeting was that many of the respondees identified industry overreaction to regulatory requirements and resultant over-specification of documentation requirements as a leading cause of unnecessary paper production.

Of course, this goes hand-in-glove with the problems cited above. Confronted by overlapping and changing requirements and a "wealth" of confusing guidance, a relatively young industry opted for compliance at all costs and went too far in certain areas."

In this regard, Halligan (38, pg. 4) has also pointed out:

"The present situation is characterized by excessive amounts of quality assurance related paper, audits, documentation related delays, and frustration on the part of both Quality Assurance personnel and Production personnel. It is not possible for many of the "Doers" to relate the Quality Assurance Program to the quality of their work. Thus they see little, if any, value in return for the tremendous effort devoted to quality assurance. Quality Assurance personnel cannot avoid becoming identified as an adversary under these conditions.

Company management must direct the emphasis more toward performance. They must integrate performance documentation and audits into their system in a manner that will clearly demonstrate their relationship to the quality of the product. The NRC must take a hard look at its requirements for documentation and audits and the rest of the industry must test their programs and search out points of overreaction to the intent of the NRC."

It was noted above that there were two sources for the documentation requirements. The tie-in between these sources is indicated by Chezen (37, pg. 4) as follows:

"Beginning with the promulgation of Appendix B to 10CFR 50 in 1970, there has been a rapid growth of regulatory documents, industry codes and standards, and guidance intended to provide direction and assistance in the development and implementation of Quality Assurance Programs. We have regulatory guides, The Standard Format and Standard Review Plan, The Rainbow Books, ANSI N45.2 and its daughter standards, and the ASME Code among others. The intent of these documents is admirable, but in some cases they have caused problems.

Among the most frequently heard complaints are the proliferation of the documents, their overlapping requirements, lack of specificity, and frequent revision; the lack of guidance as to their applicability; and their preoccupation with form rather than substance.

Obviously, reiteration of identical requirements in different documents is unnecessary. Conflicting requirements applying to the same area

> are even worse. Frequent revisions of documents cause confusion, particularly when requirements are "ratcheted up" and backfitting is necessary. Lack of guidance as to applicability leads to overspecification of requirements. Overemphasis on form (documentation) rather than substance (quality hardware, services and performance) puts the cart before the horse. All these things exacerbate the problem of excessive paperwork."

Need for Documentation. One of the fundamental points that must be kept in mind is that there is some "base" or "optimum" level of documentation which is required from the standpoint of good management practice. Many people within the industry agree with this. As Hannon (13, pg. 13) notes:

> "Some consider the regulations and associated standards so preoccupied with the quality and quantity of paper that the quality of hardware is overlooked.
>
> Although a cursory reading of the ANSI standards could lead one to that conclusion, the need for documentation cannot be dismissed because quality assurance demands visibility and, hence, documentation. To assess the significance of a quality-related activity, it is necessary to be cognizant of the method or procedure employed to perform the activity (i.e., inspection or tests) and to obtain some assurance that the individuals conducting and reporting the activity were capable of understanding and conducting the operation according to prescribed requirements.
>
> The standards however, particularly ANSI N45.2, do acknowledge that procedures, reports and other data may be contained in a variety of documents. At the present time, it is unrealistic to establish industry-wide standardized procedures, instructions and report forms or formats for such documentation and records. Instead, the emphasis is on the existence of adequate documentation, whatever its format, and that it is visible and accessible to the user and those who audit it for the purpose of assuring compliance with the standards."

Chezem also addresses this point as follows (40, pg. 5):

> At this point, perhaps we should take the time to state clearly that there can be no doubt that the proper paperwork-documentation and records-is not only necessary; it is vital to the goal of designing, constructing and operating nuclear power plants in a safe and efficent manner. These activities are too complex, too demanding, to rely on verbal direction and the hope that everyone knows what they are doing and what is required. The methodology must be documented and the operations conducted in accordance with prescribed requirements. It must be possible to verify, validate and corroborate accomplished activities. There must be a documentary evidence of the acceptability of the hardware. All of these things require paperwork--essential paperwork."

Possible Solutions. Chezem (37, pg. 7) presents several ways in which the problem of excessive documentation can be corrected. He points out that the steps that can be taken to alleviate the problem are not difficult to ascertain. Implementation, however, will take a great deal of effort on the part of all concerned. He notes:

> "A good first step would be standardization of requirements in a manner to make them easier to understand and to meet. Efforts are being made in this direction...
>
> Another step which can be taken is for management to review their QA Programs on a continuing basis and to instigate action to eliminate unnecessary paperwork requirements. Judgment must be exercised to decide what is needed and to eliminate that which is not needed. Documentation requirements should be a function of the importance of the activity being documented.
>
> Finally, it is necessary to communicate to the Regulatory Agencies and the Standards writers just where the problems lie. Certainly no one is in a better position to know than those who utilize the standards and implement the requirements."

Rusche (26, pg. 1.4.4) of the NRC sums up to the topic fairly well by noting:

> "Another real concern to us is the evidence that QA paperwork has been stressed to a point where an imbalance is created. The primary focus of all QA activity must be on product quality. The paperwork is important only to the extent that it gives assurance of quality in the product. Good QA records do **not** substitute for a good QA program, and paper audits do not in themselves assure good products. It's possible to paper over a poor program, but only for a while--usually a short while."

V. Benefits Derived from Quality Assurance

The objectives of the AEC, when it issued 10CFR Part 50 and related documents in the early 70's, was to increase the attention given to basic quality by the nuclear industry and to assure that the practices used were consistent with requirements for the protection of public health and safety. One of the undeniable facts that has been proven over this period of time

is that commercial reactors have operated and continue to operate with a truly remarkable safety record.

Public Acceptance. The climate in the late 1970's has, however, been one in which the public has increasingly questioned the inherent safety and advisability of nuclear power. The above-mentioned safety record, which has become a convincing counter-argument of the nuclear industry, has been one of the primary benefits that have been derived from the quality assurance emphasis. As noted by Nemzek (39, pg. 3):

> "Presently, nuclear power is under an attack of the most vicious kind--the kind that history tells us can change the destiny of great nations--an attack from within, by a few against the will of the majority. In such a climate QA must serve an ever more important function. The precision to which a nuclear plant complies with specifications must now be a matter of record:
>
> --a record able to stand the scrutiny of management, regulators, private citizens and the courts.
>
> --a record able to uphold the facts about the nuclear plant during onslaughts of inuendo and emotion.
>
> --a record which will demonstrate that facts do not cease to exist because they are ignored.
>
> The importance of this dimension of QA becomes more evident as the effectiveness of QA in nuclear is specifically, repeatedly, and publicly challenged by those who oppose nuclear power. An effective QA program, in addition to assuring ourselves, our regulators and the public that we build a good plant, then also becomes a bulwark for nuclear power in the never ending critic-created public debate."

With regard to the area of public acceptance, Vannoy (32, pg. 28) has noted:

> "To fulfill its promise, the nuclear power industry must achieve public acceptance, technical excellence and business viability. These areas of performance are closely allied and quality assurance crosses all disciplines needed to accomplish all these objectives. It is my belief that if we concentrate on technical excellence, public acceptance and business viability will follow more readily. Quality assurance provides management the means to measure and control performance against our own standards of technical excellence."

Improved Performance. Another benefit which has been derived from the quality assurance emphasis appears to lie in the area of plant performance. As noted by Vannoy (32, pg. 28)

> "Much progress has been made and the industry is now ready to move to the next stage of maturity and capitalize on the QA base that has been built. Let's look at the changing role of quality assurance, or perhaps more appropriately, changing the role of quality assurance from a regulatory process to a management process--from emphasis on compliance to emphasis on performance...
>
> One of the principal rewards of quality assurance is the reliability of operating units. A measure of technical excellence is the operating performance of the total nuclear plant. The economic benefits of reliability are so great that the market must give recognition to a proven record of performance. Only those organizations that achieve quality performance will survive the competition."

Rusch (26) points out that most unscheduled outages, reportable events and breakdowns in performance represent a breakdown in quality assurance. The average unit capacity factor for nuclear power plants which hovers around the 60% level is an indication to him that improvements in the implementation of quality assurance practices must still be made. He notes (26, pg. 1.4.3):

> "I realize, as I'm sure you do, that the effectiveness of the current QA programs is very difficult to assess. The current guidelines and requirements have existed for too short a time, and no nuclear plants now operational have been completely designed and built to Appendix B. I also know that Appendix B is not a panacea and that the older nuclear plants have operated with remarkable safety and reliability without the benefit of Appendix B. But I note that the nuclear industry is in general much more conscious today of the need for and payoff from a well formalized and equally well executed quality assurance program. With the high cost of new plants, the tremendous cost of downtime, and the crucial national need for power, there is a new awareness of the economic value of effective QA, above and beyond its unquestioned value to safety. It has been estimated that the cost of plant downtime for a 1000 MWe nuclear facility ranges from $250,000 to $400,000 per day. At one utility, nuclear power plant outages of 6 to 7 days were needed to correct steam condenser difficulties, a non-safety related item, and the total cost was in the neighborhood of $4 million. So it's easy to see why industry officials with extensive operating experience appreciate as never before that a proportioned investment in QA can be an investment in the finest kind of insurance--the kind that protects by preventing trouble."

Muntzing goes a step further by comparing the cost of maintaining an effective quality assurance program with the cost of forced outages. He notes (28, pg. 19):

> "In 1973, for example, operating nuclear plants experienced about 400 forced outages causing almost 36,000 hours of plant downtime. The same year turned in more than 100 construction deficiency reports. Remedying these deficiencies was costly but had they not been identified until after the plant went into service, significant outage time probably would have resulted. Many failures experienced by the operating plants could and should have been prevented through careful inspection during construction.
>
> Evidence demonstrates that quality assurance programs at the construction stage do not significantly delay project schedules. While the programs may add from five to ten percent to the total construction cost, the costs of forced outages at the operating stage are financial albatrosses.
>
> One utility executive has stated that if industry had established adequate quality assurance programs in the first phases of nuclear plant development, it might have collectively saved in excess of three quarters of a billion dollars in repair expenses and costs for substitute power."

VI. Cost Aspects of Quality Assurance

If the viewpoints expressed above were not balanced with viewpoints regarding the cost aspects of quality assurance, a one-sided picture would be presented. Quality assurance, as practiced in nuclear construction, represents a substantial investment of financial as well as human resources for a utility and the other parties involved.

Evaluation of Cost Effectiveness. Halligan (38) feels that in order to realize a cost benefit from a quality program, the objectives of the program must be examined. Is it to assure a quality product at a reasonable cost and on schedule? Or to assure that Federal regulations, codes, standards and procedures are complied with and visible evidence exists to support that fact? Or, is it a means of communication between the performance elements and management? He feels that a cost effective program should consider all of

these, with each of the three parts in perspective. He notes (38):

> "For the most part, industry members have developed quality assurance programs as a reaction to the NRC, and few have a well thought out and planned program which will focus on the objectives to the same degree as they do for other functional disciplines. This stems, some from the abruptness with which the NRC's requirements were developed and imposed on the industry and, some to the ensuing reaction to staff, organize and plan to match the requirements- in a manner not necessarily consistent with the company's own objectives...
>
> Each of the above documents seeks to formalize the quality assurance program adding to paperwork and costs. If suddenly they were all swept away, the need for effective formalized QA programs would still exist--as good business practice--, and to provide the proof that nuclear power plants are safe."

Allen (34) feels that the answer to the basic question: "Are We Getting What We Pay For?" has the following two primary parts: (1) Are we getting the proper quality? and (2) Is the quality assurance/quality control being done in an effective manner? With regard to the first question, he notes (34, pg. 1.2.5):

> "There are many factors to be considered in answering this question. Perhaps the most important is: have we defined <u>what</u> optimum quality is?
>
> Unfortunately for the nuclear industry, over the past 20 years we have repeatedly redefined and re-redefined quality. Certainly we are closer to a definition today than we were 5, 10, or 15 years ago. But we are still in the state of flux. Thus, the evaluation of whether or not we have <u>optimum</u> quality changes as the criteria changes.
>
> It is my belief that many years ago we had already reached a standard of reliability in the quality of nuclear power plants that made them the safest industry in the country... if not in the world.
>
> However, continuous pressure, continuing public concern, and continuing regulatory concern have resulted in additional requirements, additional criteria, and additional standards being imposed. I don't believe that these have resulted in safer nuclear power plants. They have, rather, resulted in what may be called a greater <u>margin of safety</u>. Since there is little, if any, systematically organized failure data, the evaluation of the margin of safety is almost impossible. Is it an inadequate margin of safety? Or an excessive-and hence excessively expensive-margin of safety? Or is it just right?"

With regard to the second question, he notes (34, pg. 1.2.6):

> "Is quality assurance/quality control being performed in a cost-effective manner? Do we get the quality we pay for? The growth of quality assurance

> and quality control in the nuclear industry has not been based, as in other industries, on cost-effectiveness. In other industries, quality control and quality assurance grew as a response to such problems as excessive scrap, warranty claims, liability claims, etc. In other words, quality assurance was the remedy for specific failures and direct costs to the corporation.
>
> In the nuclear industry, this has not generally been the pattern. Many nuclear quality control requirements have simply been legislated. And all too often, the legislation has been born of fear, emotionalism and lack of knowledge.
>
> We all recognize that there are cost advantages to a quality assurance/ quality control program, and that safety factors make a quality assurance/ quality control program an absolute must for nuclear plants. But it is my belief that, in many areas, we have gone far beyond the point of diminishing returns. In these cases, we are inspecting where the inspection does little to improve the quality of the job. You probably recognize discrete examples of such techniques or inspection requirements from your own past experiences. But even if not, you will agree that they very likely exist in conjunction with such vast numbers of inspections where little cost, economic, or reliability analyses have ever been done.
>
> Thus, the answer to the second sub-question, "Is quality assurance/ quality control being done in a cost-effective manner?" is that no one knows at the present time. So little data is available that we cannot respond to this question."

Quantification of Costs. Rabenold (40) attempts to quantify the costs added by a formalized QA/QC program due to the greatly expanded scope of inspection and documentation by first noting that they may essentially be considered in two categories: (1) the identified, or "visible" non-manual manhours, material, equipment and subcontracted services for QA activity; and (2) the unidentified, or "invisible," costs of the program as a result of interrupting and/or delaying construction work activities, and in support of other quality-related requirements. He notes (40, pg. 10):

> "Visible costs are directly posted to cost centers. These amounts have relatively finite limits as to minimum and maximum to be expected. The identified QA program non-manual manhours are normally up to 20% of the total non-manual manhours. Since the relation of the non-manual to manual manhours is about 20%, this is equivalent to approximately 4% of the manual manhours required.

> The invisible QA/QC program costs are much more difficult to assess. In this category we include delays associated with craftsmen waiting for inspections to be performed before resuming work activities. This is particularly true in the welding area where several inspection hold points may be required in a given welding process and the men cannot be reassigned to other work during the period. If delays, as a result of these interruptions, have to be compensated for by overtime or additional manpower, the cost implications increase substantially. An evaluation of the invisible costs by making a subjective judgment on a weighted craft-by-craft basis indicated an additional 18% of the craft manhours is required to offset these interruptions--a ratio of 4.5:1 for the invisible vs. visible. If we assume the case as stated, adding 4% visible to 18% invisible equals a total of 22% of the craft manhours. Further, if we assume a 1,000 MWe station and 12 craft manhours per KWe, the resultant exposure of the QA/QC program may range up to 2.6 million manhours. This computes (without IDC and escalation) to approximately 39 million dollars (based on $15/ Manhour) plus the costs of materials, equipment, and off-site testing services as the cost impact of the total QA/QC program for the construction phase."

18 CRITERIA OF 10 CFR PART 50 APPENDIX B

As noted in both Chapter 1 and earlier in this chapter, the basic framework for the Quality Assurance Programs which are developed for the design, construction and operation of nuclear power plants is provided by the 18 Criteria of 10 CFR Part 50, Appendix B. Appendix B begins with the following statement:

> "Every applicant for a construction permit is required by the provision of 50.34 to include in its preliminary safety analysis report a description of the quality assurance program to be applied to the design, fabrication, construction, and testing of the structures, systems, and components of the facility.

The 18 Criteria serve as points of reference against which the Quality Assurance Program defined in the PSAR and later implemented in the project, will be evaluated. Table 2.1 only provided a listing of these criteria. In order to complete this "Overview" chapter and allow it to be self-sufficient, it seems advisable to present the complete text of these 18 Criteria.

It should be noted that for some of the 18 Criteria presented below, the sentences or phrases which were thought to be particularly significant in relation to the Quality Assurance aspects of the concrete construction phase have been underlined. This should provide some indication of the areas and topics upon which the remainder of the report will focus.

Chapters 3 and 4 will indicate how the parties involved in the various projects in the research study responded to these criteria. At the point at which each criterion is discussed, supplemental information from the following documents (which provided additional guidance for the industry for that particular criterion) will be provided: (1) Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants (8), (2) ANSI N45.2: Quality Assurance Program Requirements for Nuclear Facilities (14) and (3) ANSI N45.2.5: Supplementary Quality Assurance Requirements for Installation, Inspection and Testing of Structural Concrete and Structural Steel during the Construction phase of Nuclear Power Plants (16).

10 CFR Part 50, Appendix B (41)

Introduction

> Every applicant for a construction permit is required by the provisions of Section 50.34 to include in its preliminary safety analysis report a description of the quality assurance program to be applied to the design, fabrication, construction, and testing of the structures, systems, and components of the facility. Every applicant for an operating license is required to include, in its final safety analysis report, information pertaining to the managerial and administrative controls to be used to assure safe operation.
>
> Nuclear power plants and fuel reprocessing plants include structures, systems, and components that prevent or mitigate the consequences of postulated accidents that could cause undue risk to the health and safety of the public. This appendix establishes quality assurance requirements for the design, construction, and operation of those structures, systems, and components. The pertinent requirements of this appendix apply to all activities affecting the safety-related functions of those structures, systems, and components;

these activities include designing, purchasing, fabricating, handling, shipping, storing, cleaning, erecting, installing, inspecting, testing, operating, maintaining, repairing, refueling, and modifying.

As used in this appendix, "quality assurance" comprises all those planned and systematic actions necessary to provide adequate confidence that a structure, system, or component will perform satisfactorily in service. Quality assurance includes quality control, which comprises those quality assurance actions related to the physical characteristics of a material, structure, component, or system which provide a means to control the quality of the material, structure, component, or system to predetermined requirements.

I. Organization

The applicant[1] shall be responsible for the establishment and execution of the quality assurance program. The applicant may delegate to others, such as contractors, agents, or consultants, the work of establishing and executing the quality assurance program, or any part thereof, but shall retain responsibility therefor. The authority and duties of persons and organizations performing activities affecting the safety-related functions of structures, systems, and components shall be clearly established and delineated in writing. These activities include both the performing functions of attaining quality objectives and the quality assurance functions. The quality assurance functions are those of (a) assuring that an appropriate quality assurance program is established and effectively executed and (b) verifying, such as checking, auditing, and inspection, that activities affecting the safety-related functions have been correctly performed. The persons and organizations performing quality assurance functions shall have sufficient authority and organizational freedom to identify quality problems; to initiate, recommend, or provide solutions; and to verify implementation of solutions. Such persons and organizations performing quality assurance functions shall report to a management level such that this required authority and organizational freedom, including sufficient independence from cost and schedule when opposed to safety considerations, are provided. Because of the many variables involved, such as the number of personnel, the type of activity being performed, and the location or locations where activities are performed, the organizational structure for executing the quality assurance program

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[1] While the term "applicant" is used in these criteria, the requirements are, of course, applicable after such a person has received a license to construct and operate a nuclear power plant, or a fuel reprocessing plant. These criteria will also be used for guidance in evaluating the adequacy of quality assurance programs in use by holders of construction permits and operating licenses.

may take various forms provided that the persons and organizations assigned the quality assurance functions have this required authority and organizational freedom. Irrespective of the organizational structure, the individual(s) assigned the responsibility for assuring effective execution of any portion of the quality assurance program at any location where activities subject to this Appendix are being performed shall have direct access to such levels of management as may be necessary to perform this function.

II. Quality Assurance Program

The applicant shall establish at the earliest practicable time, consistent with the schedule for accomplishing the activities, a quality assurance program which complies with the requirements of this appendix. This program shall be documented by written policies, procedures, or instructions and shall be carried out throughout plant life in accordance with those policies, procedures, or instructions. The applicant shall identify the structures, systems, and components to be covered by the quality assurance program and the major organizations participating in the program together with the designated functions of these organizations. The quality assurance program shall provide control over activities affecting the quality of the identified structures, systems, and components, to an extent consistent with their importance to safety. Activities affecting quality shall be accomplished under suitably controlled conditions. Controlled conditions include the use of appropriate equipment; suitable environmental conditions for accomplishing the activity, such as adequate cleanness; and assurance that all prerequisites for the given activity have been satisfied. The program shall take into account the need for special controls, processes, test equipment, tools, and skills to attain the required quality, and the need for verification of quality by inspection and test. The program shall provide for indoctrination and training of personnel performing activities affecting quality as necessary to assure that a suitable proficiency is achieved and maintained. The applicant shall regularly review the status and adequacy of the quality assurance program. Management of other organizations participating in the quality assurance program shall regularly review the status and adequacy of that part of the quality assurance program which they are executing.

III. Design Control

Measures shall be established to assure that applicable regulatory requirements and the design basis, as defined in Section 50.2 and as specified in the license application, for those structures, systems, and components to which this appendix applies are correctly translated into specifications, drawings, procedures, and instructions. These measures shall include provisions to assure that appropriate quality standards are specified and included in design documents and that deviations from such standards are controlled. Measures shall also be established for the selection and review for suitability of application of materials, parts, equipment, and processes

that are essential to the safety-related functions of the structures, systems, and components.

Measures shall be established for the identification and control of design interfaces and for coordination among participating design organizations. These measures shall include the establishment of procedures among participating design organizations for the review, approval, release, distribution, and revision of documents involving design interfaces.

The design control measures shall provide for verifying or checking the adequacy of design, such as by the performance of design reviews, by the use of alternate or simplified calculational methods, or by the performance of a suitable testing program. The verifying or checking process shall be performed by individuals or groups other than those who performed the original design, but who may be from the same organization. Where a test program is used to verify the adequacy of a specific design feature in lieu of other verifying or checking processes, it shall include suitable qualification testing of a prototype unit under the most adverse design conditions. Design control measures shall be applied to items such as the following: reactor physics, stress, thermal, hydraulic, and accident analyses; compatibility of materials; accessibility for inservice inspection, maintenance, and repair; and delineation of acceptance criteria for inspections and tests.

Design changes, including field changes, shall be subject to design control measures commensurate with those applied to the original design and be approved by the organization that performed the original design unless the applicant designates another responsible organization.

IV. Procurement Document Control

Measures shall be established to assure that applicable regulatory requirements, design bases, and other requirements which are necessary to assure adequate quality are suitably included or referenced in the documents for procurement of material, equipment, and services, whether purchased by the applicant or by its contractors or subcontractors to provide a quality assurance program consistent with the pertinent provisions of this appendix.

V. Instructions, Procedures, and Drawings

Activities affecting quality shall be prescribed by documented instructions, procedures, or drawings, of a type appropriate to the circumstances and shall be accomplished in accordance with these instructions, procedures, or drawings. Instructions, procedures, or drawings shall include appropriate quantitative or qualitative acceptance criteria for determining that important activities have been satisfactorily accomplished.

VI. Document Control

Measures shall be established to control the issuance of documents, such as instructions, procedures, and drawings, including changes thereto, which prescribe all activities affecting quality. These measures shall assure that documents, including changes, are reviewed for adequacy and approved for release by authorized personnel and are distributed to and used at the location where the prescribed activity is performed. Changes to documents shall be reviewed and approved by the same organizations that performed the original review and approval unless the applicant designates another responsible organization.

VII. Control of Purchased Material, Equipment, and Services

Measures shall be established to assure that purchased material, equipment, and services, whether purchased directly or through contractors and subcontractors, conform to the procurement documents. These measures shall include provisions, as appropriate, for source evaluation and selection, objective evidence of quality furnished by the contractor or subcontractor, inspection at the contractor or subcontractor source, and examination of products upon delivery. Documentary evidence that material and equipment conform to the procurement requirements shall be available at the nuclear power plant site prior to installation or use of such material and equipment. This documentary evidence shall be retained at the nuclear power plant site and shall be sufficient to identify the specific requirements, such as codes, standards, or specifications, met by the purchased material and equipment. The effectiveness of the control of quality by contractors and subcontractors shall be assessed by the applicant or designee at intervals consistent with the importance, complexity, and quantity of the product or services.

VIII. Identification and Control of Materials, Parts, and Components

Measures shall be established for the identification and control of materials, parts and components, including partially fabricated assemblies. These measures shall assure that identification of the item is maintained by heat number, part number, serial number, or other appropriate means, either on the item or on records traceable to the item, required throughout fabrication, erection, installation, and use of the item. These identification and control measures shall be designed to prevent the use of incorrect or defective material, parts, and components.

IX. Control of Special Processes

Measures shall be established to assure that special processes, including welding, heat treating, and nondestructive testing, are controlled and accomplished by qualified personnel using qualified procedures in accordance with applicable codes, standards,

specifications, criteria, and other special requirements.

X. Inspection

A program for inspection of activities affecting quality shall be established and executed by or for the organization performing the activity to verify conformance with the documented instructions, procedures, and drawings for accomplishing the activity. Such inspection shall be performed by individuals other than those who performed the activity being inspected. Examinations, measurements, or test of material or products processed shall be performed for each work operation where necessary to assure quality. If inspection of processed material or products is impossible or disadvantageous, indirect control by monitoring processing methods, equipment, and personnel shall be provided. Both inspection and process monitoring shall be provided when control is inadequate without both. If mandatory inspection hold points, which require witnessing or inspecting by the applicant's designated representative and beyond which work shall not proceed without the consent of its designated representative are required, the specific hold points shall be indicated in appropriate documents.

XI. Test Control

A test program shall be established to assure that all testing required to demonstrate that structures, systems, and components will perform satisfactorily in service is identified and performed in accordance with written test procedures which incorporate the requirements and acceptance limits contained in applicable design documents. The test program shall include, as appropriate, proof tests prior to installation, preoperational tests, and operational tests during nuclear power plant operation, of structures, systems, and components. Test procedures shall include provisions for assuring that all prerequisite for the given test have been met, that adequate test instrumentation is available and used, and that the test is performed under suitable environmental conditions. Test results shall be documented and evaluated to assure that test requirements have been satisfied.

XII. Control of Measuring and Test Equipment

Measures shall be established to assure that tools, gages, instruments, and other measuring and testing devices used in activities affecting quality are properly controlled, calibrated, and adjusted at specified periods to maintain accuracy within necessary limits.

XIII. Handling, Storage and Shipping

Measures shall be established to control the handling, storage, shipping, cleaning and preservation of material and equipment in accordance with work and inspection instructions to prevent damage or deterioration. When necessary for particular

products, special protective environments, such as inert gas atmosphere, specific moisture content levels, and temperature levels, shall be specified and provided.

XIV. Inspection, Test, and Operating Status

Measures shall be established to indicate, by the use of markings such as stamps, tags, labels, routing cards, or other suitable means, the status of inspections and tests performed upon individual items of the nuclear power plant. These measures shall provide for the identification of items which have satisfactorily passed required inspections and tests, where necessary to preclude inadvertant bypassing of such inspections and tests. Measures shall also be established for indicating the operating status of structures, systems, and components of the nuclear power plant, such as by tagging valves and switches, to prevent inadvertent operation.

XV. Nonconforming Materials, Parts, or Components

Measures shall be established to control materials, parts, or components which do not conform to requirements in order to prevent their advertent use or installation. These measures shall include, as appropriate, procedures for identification, documentation, segregation, disposition, notification to affected organizations. Nonconforming items shall be reviewed and accepted, rejected, repaired or reworked in accordance with documented procedures.

XVI. Corrective Action

Measures shall be established to assure that conditions adverse to quality, such as failures, malfunctions, deficiencies, deviations, defective material and equipment, and nonconformances are promptly identified and corrected. In the case of significant conditions adverse to quality, the measures shall assure that the cause of the condition is determined and corrective action is taken to preclude repetition. The identification of the significant condition adverse to quality, the cause of the condition, and the corrective action taken shall be documented and reported to appropriate levels of management.

XVII. Quality Assurance Records

Sufficient records shall be maintained to furnish evidence of activities affecting quality. The records shall include at least the following: Operating logs and the results of reviews, inspections, tests, audits, monitoring of work performance, and materials analyses. The records shall also include closely-related data such as qualifications of personnel, procedures, and equipment. Inspection and test records shall, as a minimum, identify the inspector or data recorder, the type of observation, the results, the acceptability, and the action taken in connection with any deficiencies notes. Records shall be identifiable and retrievable. Consistent with applicable regulatory requirements, the applicant shall establish

requirements concerning record retention, such as duration, location, and assigned responsibility.

XVIII. Audits

A comprehensive system of planned and periodic audits shall be carried out to verify compliance with all aspects of the quality assurance program and to determine the effectiveness of the program. The audits shall be performed in accordance with the written procedures or check lists by appropriately trained personnel not having direct responsibilities in the areas being audited. Audit results shall be documented and reviewed by management having responsibility in the area audited. Followup action, including reaudit of deficient areas, shall be taken where indicated.

SUMMARY

Chapter 2 can be summarized as follows:

I. Background

The first part of this chapter provided a brief historical perspective of the Regulatory and Standards Development environment in the 1970's under which the nuclear power plants included in this research study were being designed and built. The efforts of the AEC (and later the NRC) were discussed with regard to the regulations which they first promulgated and later further defined with documents such as the Regulatory Guides, the Rainbow Series, etc. The ANSI Standards, which were developed in response to the nuclear industry's need for both technical as well as Quality Assurance standards, were also discussed. It was noted that these ANSI standards were not self sufficient regulatory documents until they were either invoked by a regulatory requirement prescribing their use (i.e., in an NRC Regulatory Guide, etc.) or by a power plant applicant's commitment in the Safety Analysis Report. The efforts of the ASME which led to Section III, Division 1 of the ASME Boiler and Pressure Vessel Code (which dealt with Nuclear Power Plant Components) and the joint efforts of ASME and ACI which led in 1974 to Section III, Division 2 of the same code (which dealt with Concrete Reactor Vessels and Containments) were also discussed. With regard to the structural concrete phase of construction,

it should be noted that the joint ASME/ACI code effort mentioned above (also called ACI 359-74) and the related ACI 349-76 code (entitled "Code Requirements for Nuclear Safety Related Concrete Structures") were developed too late in the period to greatly affect many of the nuclear plants which were examined. Most of these are being, or were, built under the ACI Codes, "Recommended Practices", etc., which applied to "General Construction" rather than specifically to "Nuclear Construction". Some of the results of this situation will be discussed in Chapters 3 to 9 of this report.

II. Quality Assurance Program Factors

The second part of the chapter examined some of the factors which influenced the Quality Assurance Programs that were developed during the time frame mentioned above.

a. Development of Standards

Both the perspective of ANSI with regard to the need for additional standards and some of the reactions of the industry about the effects of an ever increasing number of new standards on (1) Technical and craft labor resources, (2) Construction schedules, (3) Updating requirement costs on existing projects, etc., were provided. It was noted that a clear direction for future standards development was needed and that the possible consolidation of the many existing standards into one reference source was felt to be desirable by some industry personnel.

b. Difficulties of Interpretation of Requirements

The difficulties which the nuclear industry faced with regard to an interpretation of the regulatory requirements and standards (particularly since some of these were in a state of flux during this period) were cited. These difficulties are probably one of the reasons why (as illustrated later in this report) the parties on

some of the nuclear projects in this research study adopted what appears to be overly restrictive Quality Assurance practices related to the structural concrete phase.

c. The Role of the NRC

The licensing, inspection, and enforcement role of the NRC was explained in order to indicate the influence which they have on any Utility engaged in the design and construction of a nuclear power plant. It was noted for instance that the Utility must essentially live with the commitments it has made in the PSAR, even if they are more stringent than required. It was also noted that the NRC inspections on project construction sites are superimposed on all of the layers of inspection, auditing, etc., which already exist. An item of noncompliance which an NRC inspector identifies, therefore, raises questions about the effectiveness of the overall Quality Assurance Program which is being implemented.

d. Documentation Requirements

Some of the representatives of the nuclear power plant construction industry appear to be concerned about the strong emphasis on documentation which is prevalent throughout the industry. Examples of the type and extent of the documentation requirements for the structural concrete phase will be provided in later chapters of this report. It was noted that both the regulator and the regulated (i.e., the parties involved in the project) are often responsible for the level of documentation which exists.

e. Need for Documentation

A point of defense for a certain "base level" of documentation was made because of the complexity and scope of work which must be

controlled. It was pointed out, however, that paperwork is important only to the extent that it gives assurance of quality in the product. Examples will be cited later in this report which illustrate cases where the parties involved have taken the need for documentation beyond that goal.

f. Benefits Derived from Quality Assurance

There appears to be a growing awareness within the nuclear industry about the benefits that are derived from an effective Quality Assurance effort, particularly in the realm of public acceptance of nuclear power as a safe source of electricity and, in the area of improved levels of performance of operating facilities. The basic question which must therefore be addressed (and hopefully is addressed in later chapters) is not whether Quality Assurance is necessary on nuclear power plants, but rather, at what point has a satisfactory commitment to Quality Assurance been made.

g. Cost Aspects of Quality Assurance

The basic question about the cost effectiveness of the Quality Assurance programs which were practiced on nuclear plants currently under construction appears to be related to Topic (f). Several opinions from industry representativeswere presented and one estimate of the costs which are involvedwas cited.

III. 10 CFR Part 50, Appendix B Criteria

(3) The last part of the chapter presents the 18 criteria of 10CFR Appendix B and highlights those particular sentences and phrases which are of particular interest in this research study.

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CHAPTER 3

IMPLEMENTATION OF 10 CFR PART 50, APPENDIX B CRITERIA I, II, V, X, XVIII

Chapters 3 and 4 of this report present a comparative analysis of the organizational and managerial aspects of the Quality Assurance Programs being implemented on the nine nuclear power plant construction projects in the research study. Chapter 3 presents an analysis of the information presented in the Case Studies of the nine projects (which are located in the Appendix A of this report). Chapter 4 presents an analysis of those topics which could not easily be incorporated into the Case Studies.

Each Case Study in Appendix A is divided into the following three sections: (1) Project Organization, (2) Quality Assurance Program, and (3) Quality Assurance Documents. The topical emphasis in the Case Studies results in a coverage of the following parts of 10 CFR Part 50 Appendix B: (1) Introduction, (2) Criterion I: Organization, (3) Criterion II: Quality Assurance Program, (4) Criterion V: Instructions, Procedures, and Drawings, (5) Criterion X: Inspection, and (6) Criterion XVIII Audits. In order to provide a proper introduction to the analysis of these Case Studies, the first part of Chapter 3 is devoted to a presentation of the guidelines which were available to some of the parties on the individual projects when they implemented these Criteria.

The Appendix to this report provides a reference point for each nuclear project in the research study which allows the material found in later chapters to be related back to the project from which it originated.

APPENDIX B CRITERIA EXAMINED IN THE NINE CASE STUDIES

An overview of each of the Criteria examined in the Case Studies is presented below. It was noted in Chapter 2 that in addition to the 18 Criteria

of 10 CFR Part 50, Appendix B, the industry also had access to related supplemental material which provided guidance with respect to the implementation of Quality Assurance programs. The overview of each Criterion, therefore, attempts to reference these guidelines whenever appropriate. These guidelines consist of: (a) Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants (1),[1] (b) ANSI N45.2: Quality Assurance Requirements for Nuclear Facilities (2), and (c) ANSI N45.2.5: Supplemental Quality Assurance Requirements for Installation, Inspection, and Testing of Structural Concrete and Structural Steel during the Construction Phase of Nuclear Power Plants (3).

The final section for each Criterion presents, whenever possible, some observations related to the topic covered by the Criterion.

I. Appendix B Introduction

1. Appendix B

The introduction to Appendix B requires each applicant to include in the PSAR a description of the Quality Assurance Program for the project. It also defines the portion of the project to which the requirements of Appendix B are applicable as: all activities affecting the safety related functions of those structures, systems and components that "prevent or mitigate the consequences of postulated accidents that could cause undue risk to the health and safety of the public." In addition, a definition of Quality Assurance and Quality Control is provided.

2. ANSI N45.2 and N45.2.5

In both of these standards, it is noted that the quality assurance

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[1] See List of References at the end of Chapter 3

requirements apply to those structures (expanded in N45.2 to include systems and components) whose satisfactory performance is required: (1) For the plant to operate reliably, (2) To prevent accidents that could cause undue risk to the health and safety of the public; or (3) To mitigate the consequences of such accidents if they were to occur. It is noted in N45.2.5 that these requirements may be extended to other appropriate parts of nuclear power plants when specified in contract documents. N45.2.5 is applicable to:

> "..the plant owner, major contractors, such as the nuclear steam supply system designer or supplier, the architect-engineer or plant designer, and the plant constructor, and other organizations participating in activities affecting quality" (3)

N45.2.5 is applicable to the work of any organization or individual participating in the production, preparation, placement, inspection and testing of structural concrete.

3. Observations

The Introduction to Appendix B, as indicated above, provides a broad definition of those structures, systems, and components which must be placed under the Quality Assurance program. This stipulation has caused the parties involved on most nuclear power plants to establish either a Q List or a Category I classification for those portions of the project which are "safety related". The "Balance of Plant" (i.e,, B.O.P.) is viewed differently on each project; in some cases a modified QA effort is instituted for the B.O.P., in other cases conventional construction practices are followed. This is particularly true with respect to concrete, as will be noted when the Case Studies are analyzed.

The need to use a "graded approach" to Quality Assurance efforts on the B.O.P. was noted in 1975 by Muntzing (4), a former Director of Regulation for the A.E.C., as follows:

"Finally, there is an apparent failure of industry to implement a "graded" approach to quality assurance. Everyone understands the importance of a fullblown stringent quality assurance program for the critical portions of the plant such as those affecting the reactor coolant system.

In too many cases, however, an all-or-nothing approach is followed. Can we afford to have a full-blown stringent quality assurance program similar to that applied to reactor coolant systems applied to all activities of the plant? We cannot.

But we also cannot afford to ignore some of the systems, which--while not as critical as the reactor coolant system--could shut the plant down when malfunctions occur. This is why a graded approach should be followed. Controls are needed which are commensurate with the importance of each activity."

In this regard, Rusche (5), the Director of Nuclear Reactor Regulation of the NRC, noted in 1976:

"Responsibility means decision. All of us, in fulfilling our responsibilities, must make a conscious decision on the measures needed to assure quality. The application of the QA program need not be full-on or full-off. There are many variations and shadings, depending on the nature of the item or activity you're dealing with. Appendix B elements can be selected, expanded, and used as necessary to provide an emphasis and detail of QA attention that is proportional to the relative importance of the activity involved. For example, several of the recent problems encountered by utilities have been traced to a failure to properly control items that NRC did not require to be covered by the QA program. The scope of the balanced QA program should integrate NRC's requirements and your own goals and requirements. Personally, I see no reason why each item should not have tailored QA controls which would be reviewed and defined in advance, whether or not a safety-related activity is involved. We in the NRC have attempted to recognize this reality by establishing QA guidance for activities which may be important to safety such as fire protection and waste systems--where some higher level of QA is needed beyond standard commercial practice, but where a full Appendix B program may be very excessive.

The approaches which have been taken in regard to the above discussion will be noted, whenever possible, in the Case Studies found in the Appendix A of this report.

II. Criterion I: Organization

1. Appendix B

a. Responsibility. Criterion I clearly indicates that the applicant (i.e., the Utility) is responsible for the Quality Assurance program.

As noted, "The applicant may delegate to others, such as contractors, agents or consultants, the work of establishing and executing the quality assurance program, or any part thereof, but shall retain responsibility therefor."

b. QA Functions. The Quality Assurance functions are those of "(a) Assuring that an appropriate quality assurance program is established and effectively executed, and (b) Verifying, such as checking, auditing and inspecting, that activities affecting the safety-related functions have been correctly performed."

c. Independency. Criterion I also establishes the need for independence of personnel performing verification actions as follows: "Such persons and organizations performing quality assurance functions shall report to a management level such that this required authority and organizational freedom, including sufficient independence from cost and schedule when opposed to safety considerations, are provided".

d. Organizational Structure. With regard to the type of organizational structure which is required, it is noted: "...the organizational structure for executing the quality assurance program may take various forms provided that the persons and organizations assigned the quality assurance function have this required authority and organizational freedom."

2. Standard Format and Content of SAR

With regard to "Organization", some of the important points indicated are:

a. Organizational Responsibility of Parties Involved

> "The PSAR should describe clearly the authority and duties of persons and organizations performing the QA functions of assuring that the QA program is established and executed and

of verifying that an activity has been correctly performed. The PSAR should provide organization charts and functional responsibility descriptions that denote the lines of responsibility and areas of authority within each of the major organizations in the project, including those of the applicant, the architect-engineer, the nuclear steam system supplier, the constructor, and the construction manager (if other than the constructor)."

b. Utility Control Responsibility

"The PSAR should describe the method by which the applicant will retain responsibility for and maintain control over those portions of the QA program delegated to other organizations and should identify the organization responsible for verifying that delegated QA functions are properly carried out."

3. ANSI N45.2

The "Independency" concept is defined in N45.2 as follows:

"The organizational structure and the functional responsibility assignments shall be such that:

(1) attainment of quality objectives is accomplished by those who have been assigned responsibility for performing work; e.g., the designer, the welder, or the power plant operator. This may include interim examinations, checks, and inspections of the work by the individual performing the work.

(2) verification of conformance to established quality requirements is accomplished by those who do not have direct responsibility for performing the work; e.g., the design reviewer, the checker, the inspector, or the tester."

4. ANSI N45.2.5

No new information presented.

5. Observations

The major points listed above with regard to Criterion I provide part of the framework around which the Case Studies in Appendix A of this report have been written. Observations with respect to each point will be made below in order to set the stage for the Case Studies.

a. The Utility's Role. One of the most basic issues which a Utility must address when a new nuclear plant is being contemplated is its role with regard to Quality Assurance/Quality Control, In

order to indicate the alternatives which are available, the following definitions provided in ANSI N45.2.10 (6) should be noted:

. Quality Assurance--All those planned and systematic actions necessary to provide adequate confidence that an item or a facility will perform satisfactorily in service.

. Quality Control--Those quality assurance actions which provide a means to control and measure the characteristics of an item, process or facility to established requirements.

. Inspection--An element of quality verification by means of examination, observation, or measurement to determine the conformance of items or service to predetermined requirements.

. Surveillance--A review, observation, or inspection for the purpose of verifying that an action has been accomplished as specified.

. Audit--A documented activity performed in accordance with written procedures or checklist to verify, by examination and evaluation of objective evidence, that applicable elements of the Quality Assurance Program have been developed, documented and effectively implemented in accordance with specified requirements. An audit should not be confused with surveillance or inspection for the sole purpose of process control or product acceptance.

The total QA program is often viewed as consisting of three levels. The First Level, called Quality Control and Inspection, could, as noted by the definitions above, include inspection of materials, fabrication, and site work. The Second Level, called Quality Assurance Surveillance, could as noted by the definitions above, include a review of specifications and procedures as well as a surveillance of the First Level Quality Control. The Third Level,

called Quality Assurance Auditing, could, as noted by the definition above, include a periodic analysis of the total Quality Assurance Program which would include the First and Second Level noted above.

At the one extreme of Quality Assurance involvement, the Utility can choose to have a relatively limited level of influence by only performing a Third Level auditing function in order to supplement the quality control and Inspection, Surveillance and Auditing functions which it has delegated to the firm responsible for the Construction effort on the project.

Muntzing (4) notes the problems that can develop under a limited Utility QA influence as follows:

> "While utility managers talk a good quality assurance game and no doubt want to build a quality product, they sometimes make the mistake of believing they can delegate complete responsibilities to contractors. One utility that made this mistake had to stop certain construction work because of inadequacies. In this case, both quality assurance and the utility suffered because the utility failed to audit the effectiveness of the contractor's work."

The need for a reassessment of a Utility's role is mentioned by Dellon (7):

> "...it is becoming even more important for the Owners to take a more active role in managing their projects. The effects of this trend are validated as an increasing number of projects experience selective scope of services being reduced from existing or future engineering and design service-oriented contracts, while the utility takes direct charge of these areas. Examples of the types of services which are being surgically reduced are site QC, site QA, vendor surveillance, record systems, construction management and startup services.
>
> Unless A.E. Firms and others become introspective and learn from their experiences, I anticipate that utilities will increase the frequency with which scope of services are being reduced. The pressures of performance, efficiency and sensitivity to the client's needs are among the driving forces strongly influencing the increased role of the utility."

At the other extreme of Quality Assurance involvement, the Utility can choose to have the maximum level of influence by being directly responsible for all of the three levels of Quality Assurance mentioned above. With regard to the concrete construction phase, this stance could involve the Utility in the responsibility for the Concrete Testing Laboratory as well the responsibility for preplacement, placement, and postplacement inspection.

A review of the Case Studies in Appendix A will indicate that both extremes as well as a number of alternatives in between are represented by the projects in the research study.

b. Quality Assurance Independency. It was noted in Criterion I that those persons and organizations performing quality assurance functions are to be independent of the influences of cost and schedule. This concept was reiterated and given clearer definition in the citation from ANSI N45.2, which is presented above. On most nuclear projects, this requirement has greatly influenced the location of the Quality Assurance and Quality Control groups within the organizational structure of both the Utility as well as the Firm responsible for construction. Some of the alternatives which attempt to satisfy the "independence" requirement will be illustrated in the Case Studies found in Appendix A of this report.

It should be noted that the topic of "independency" will be addressed again in relation to Criteria X and XVIII.

c. Organizational Structure. Criterion I appears to indicate that various forms of organizational structure with regard to the Quality Assurance program are acceptable providing that the persons and

organizations assigned the quality assurance functions have the required authority and organizational freedom. As noted in (b) above, some of the alternatives will be illustrated in the Case Studies.

III. Criterion II: Quality Assurance Program

1. Appendix B

a. Planned and Documented Program. Criterion II notes that the applicant's Quality Assurance Program shall be:

> "...documented by written policies, procedures, or instructions and shall be carried out throughout plant life in accordance with those policies, procedures, or instructions. The applicant shall identify the structures, systems, and components to be covered by the quality assurance program and the major organizations participating in the program together with the designated functions of these organizations. The quality assurance program shall provide control over activities affecting the quality of the identified structures, systems, and components, to an extent consistent with their importance to safety."

b. Need for Verification. It is also noted that the program shall take into account the need for special controls, processes, test equipment, tools and skills to attain the required quality, and the need for verification of quality by inspection and test.

c. Management Review of QA Program. The responsibility of the Utility and the other parties is further defined as follows: "The applicant shall regularly review the status and adequacy of the quality assurance program. Management of other organizations participating in the quality assurance program shall regularly review the status and adequacy of that part of the quality assurance program which they are executing."

2. Standard Format and Content of SAR

a. Written Policies, Procedures, or Instructions. This document provides

some further definition of the policies, procedures, and instructions and requires a tie-in for each Appendix B Criteria, by noting:

> "The PSAR should describe how the QA program is documented by written policies, procedures, or instructions and how it will be implemented in accordance with these policies, procedures or instructions. The PSAR should include a listing of QA program procedures or instructions that will be used to implement the QA program for each major activity such as design, procurement, construction, etc. The procedure list should identify which criteria of Appendix B to 10 CFR Part 50 are implemented by each procedure."

b. Utility Responsibility. This document also provides a further definition of the Utility's responsibilities with regard to the QA programs of other organizations by noting: "The PSAR should describe the measures that assure that the QA organization of the applicant will (1) review and document agreement with the QA programs of the principal contractors, and (2) conduct or have conducted audits of the contractors' QA program activities.

3. ANSI N45.2

a. Technical Aspects. The need for the incorporation of engineering codes, standards, etc., into the Quality Assurance program is noted as follows: "The establishment of the program shall include considerations of the technical aspects of the activities to be performed. The program shall contain provisions to assure identification of and compliance with requirements of pertinent ANSI and other recognized and appropriate engineering codes, standards, requirements, and practices."

b. Levels of Quality Assurance. ANSI N45.2 indicates that different levels of QA can be applied by noting:

> "This program shall identify the items and services to which this and other standards apply. Since items and services will differ in regard to relative safety, reliability, and performance importance, various methods or levels of control and verification may be used to assure adequate quality. Regardless of the

methods or levels used, the program shall provide for the assurance of quality consistent with applicable codes, standards, and other requirements. As a guideline, some factors to be considered in assigning methods or levels of quality assurance are as follows:

(1) The importance of malfunction or failure of the item to plant safety or reliability

(2) The design and fabrication complexity or uniqueness of the item

(3) The need for special controls and surveillance over processes and equipment

(4) The degree to which functional compliance can be demonstrated by inspection or test

(5) The quality history and degree of standardization of the item."

4. ANSI N45.2.5

a. Planned and Documented Program. It is noted that:

"Measures shall be established and implemented for documenting installation, inspection, and testing operations to verify conformance to specified requirements.

Planning shall take into account the need for the preparation and control of procedures and work instructions necessary to comply with requirements for installation, inspection, and testing."

ANSI N45.2.5 defines Qualified Procedures as follows: "Procedures which incorporate applicable codes and standards, manufacturer's parameters and engineering specifications."

5. Observations

As noted above, the Quality Assurance Program for a particular project is defined and documented by a set of written procedures, or instructions. The QA Program must include the Verification of quality by inspection and testing activities. ANSI N45.2 indicates that various methods of control and verification may be used (depending on relative safety, etc., of an item) to assure that adequate quality is achieved. The Utility, in addition to being required to regularly review the status and adequacy of the QA program must also: (1) review and document agreement with the QA programs of

the principal contractors and (2) conduct (or have conducted) Audits of the contractor's QA program activities. Each of these contractors must also regularly review the status and adequacy of the part of the quality assurance program which they are executing.

The requirements above indicate that QA programs are based on an extensive system of documentation. Some of the reactions of industry representatives to these requirements were presented in Chapter 2. This point will be further addressed when Criterion V is presented. The requirements also indicate that QA programs are based on both Verification and Auditing type activities. These will be discussed in more detail when Criteria X and XVIII are presented. It should be noted, however, that an unnecessary overlap of review and auditing activities with regard to the QA program can easily occur based on the above requirements.

IV. Criterion V: Instructions, Procedures, and Drawings

1. Appendix B

   a. Documented Description. Criterion V notes: "Activities affecting quality shall be prescribed by documented instructions, procedures, or drawings, of a type appropriate to the circumstances and shall be accomplished in accordance with these instructions, procedures, or drawings."

   b. Inclusion of Acceptance Criteria. It is also noted that: "Instructions, procedures, or drawings shall include appropriate qualitative or quantitative acceptance criteria for determining that important activities have been satisfactorily accomplished."

2. Standard Format and Content of SAR

   a. Document Description. This document defines the activities affecting quality which must be documented, as follows:

"The PSAR should describe measures that assure that activities affecting quality such as design, procurement, manufacturing, construction and installation, testing, inspection, and auditing are prescribed by appropriately documented instructions, procedures, or drawings and that these activities will be conducted in accordance with these documents".

b. Inclusion of Acceptance Criteria. This document defines the qualitative and quantitative acceptance criteria as follows:

"The PSAR should describe the system whereby the documented instructions, procedures, and drawings will include appropriate quantitative (such as dimensions, tolerances, and operating limits) and qualitative (such as workmanship samples and weld radiographic acceptance standards) acceptance criteria for determining that prescribed activities have been satisfactorily accomplished."

3. ANSI N45.2

a. Documented Description. ANSI N45.2 provides the following clarification of the types of instructions, procedures and drawings which may be used:

"The activity may be prescribed in job specifications, work instructions, shop construction drawings, job tickets, planning sheets, operating or procedure manuals, test procedures, or any other type of written form, provided that the activity is adequately described. Quantitative criteria, such as dimensions, tolerances, and operating limits, and qualitative criteria, such as comparative workmanship samples, shall be specified, as appropriate, for determining satisfactory work performance and quality compliance."

4. ANSI N45.2.5

a. Documented Description. The type of information which should be included in procedures and instructions and the need to keep them current is noted in ANSI N45.2.5 as follows:

"Installation, inspection and test procedures, and work instructions shall be prepared and documented for those activities falling within the scope of this standard. These documents shall be kept current and revised as necessary to assure that installation, inspections, and tests are performed in accordance with latest information and shall include as appropriate:

1. Installation specifications
2. Inspection and test objectives and requirements
3. Precautions to avoid component or system damage during

installation, inspection, and following inspection but prior to use.
4. Inspection and test equipment required.
5. Sequence of tests (if applicable).
6. Sequential actions to be followed.
7. Frequency of inspections and tests.
8. Prerequisites.
9. Approvals.
10. Data report form.
11. Identification of test equipment and date of required recalibration where required for interpretation of test results.
12. Inspection and test acceptance limits.

5. Observations.

The above mentioned documentation requirements clearly represent a rather substantial departure from conventional construction practices. The above guidance with respect to Criterion V indicates that documented instructions, procedures or drawings are required for the: (1) Construction and Installation, (2) Inspection, and (3) Auditing phases. These documents must include appropriate qualitative and quantitative acceptance criteria so that it can be determined if the prescribed activities have been successfully completed. As noted above, ANSI N45.2 indicates the types of documents which may be used to satisfy the requirements and ANSI N45.2.5 indicates the type of information that must be included in them. In addition, ANSI N45.2.5 stipulates that "they shall be kept current and revised".

Rabenold (8) provides some guidance with regard to procedures by noting:

> "To implement the commitments of the PSAR and the requirements of 10 CFR 50, additional procedures must be written to control the quality of nuclear and safety-related items--by the Owner, Engineer, Nuclear Steam Supplier, Constructor and Quality Assurance. If we couple the fact that the QA/QC organization is free from cost and schedule restraints with a program rooted in cumbersome, unworkable procedures, we have real problems. All procedures--QA, QC, and Construction must be workable on site. Procedures that are not workable have a large negative effect on schedule and cost."

In addition to being workable, all of the procedures must be compatible. Figure 3.1 indicates an "Ideal" model which indicates how these documents may be satisfactorily related.

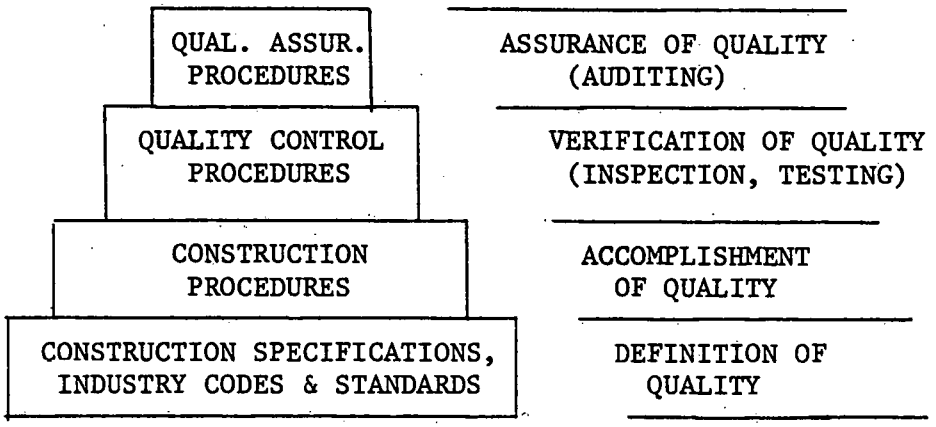


Figure 3.1.--Relationship of Quality Related Documents

The role of each of them in the ideal model is:

a. Construction Procedures (i.e., C.P.'s). C.P.'s, developed by the Construction group describe the methods of performing the related construction activity and outline the responsibilities for the involved parties. The appropriate project specifications, and the industry codes and standards which are committed to in the specifications, may first receive a joint interpretation by Construction and QC and/or QA personnel. These documents should then be incorporated in such a fashion that compliance with the Construction Procedures also assures compliance with the specifications, codes, and standards. A review by QA/QC personnel, as well as other parties, may be made before issuance in order to establish "hold points", determine if the results can be achieved with a reasonable verification effort, etc.

As Rabenold (8) notes:

"The resolution process relative to the finalizing of construction procedures involves satisfying not only the QA/QC requirements and the Constructor but also the Engineer and the Manufacturer/Supplier. It is much better to discuss and resolve differences in advance than to make the lazy, non-controversial decision to resolve

procedural problems when the concrete trucks are backed up and the high-priced workmen are standing around waiting for direction. To this end a procedural review system must be established for all procedures, whether new or revised. The QA/QC program and the construction program need not be at odds. The main mechanism to avoid conflict is planning at all levels and in detail. If we fail to plan, we plan to fail."

b. Quality Control Procedures (i.e., QCP's). QCP's and their related Inspection Plans and Inspection Report Forms are then developed in response to the Construction procedures. They are really parallel documents since they provide guidance to QC personnel in their verification role of inspection and testing.

c. Quality Assurance Procedures (i.e., QAP's). QAP's are more general in nature, they define the overall QA program and the role of QA personnel in the performance of the Auditing role which assumes that the overall QA program is operating as specified.

It should be noted that a section of each Case Study found in Appendix A will deal with the Quality Assurance documents that were developed for the project in the Case Study.

V. Criterion X-Inspections

1. Appendix B

a. Establishment and Execution of Inspection Program. Criterion X notes: "A program for inspection of activities affecting quality shall be established and executed by or for the organization performing the activity to verify conformance with the documented instructions, procedures, and drawings for accomplishing the activity."

b. Independence of Inspectors. The basic question about the identity of the inspection group is addressed as follows: "Such inspection shall be performed by individuals other than those who performed the activity being inspected".

c. Option of Inspection or Monitoring. Criterion X notes:

> "Examinations, measurements, or test of material or products processed shall be performed for each work operation where necessary to assure quality. If inspection of processed material or products is impossible or disadvantageous, indirect control by monitoring processing methods, equipment, and personnel shall be provided. Both inspection and process monitoring shall be provided when control is inadequate without both."

d. Recognition of Hold Points. With regard to "Hold Points", it is noted:

> "If mandatory inspection hold points, which require witnessing or inspecting by the applicant's designated representative and beyond which work shall not proceed without the consent of its designated representative are required, the specific hold points shall be indicated in appropriate documents".

2. Standard Format and Content of SAR

a. Inspection. In addition to the above information, the document notes:

> "The PSAR should describe measures that assure that (1) inspection procedures and instructions are made available with necessary drawings and specifications for use prior to performing the inspections, (2) inspectors' qualifications or certifications are kept current, (3) replaced or reworked items are inspected in accordance with original inspection requirements, and (4) modified or repaired items are inspected by methods that are equivalent to the original inspection method."

3. ANSI N45.2

a. Independence of Inspectors. ANSI N45.2 provides a further definition of "independence" by relating it to the organizational structure as follows: "Inspection activities to verify the quality of work shall be performed by persons other than those who performed the activity being inspected. Such persons shall not report directly to the immediate supervisors who are responsible for the work being inspected."

b. Sampling Procedure. The following reference to the use of sampling to evaluate acceptability of a group of items is made:

> "Examinations, measurements, or tests of items processed shall be performed for each work operation where necessary to assure quality. Where a sample is used to verify acceptability of a group of items, the sampling procedure shall be based on recognized standard practices and shall provide adequate justification for the sample size and selection process."

4. ANSI N45.2.5

ANSI N45.2.5 provides a rather extensive discussion of the inspection requirements related to structural concrete. A brief explanation of the major areas which are covered is provided below. Additional, more specific, information will be provided in Chapters 5, 6, 7, and 8 of this report.

a. Preconstruction Verification: Materials. Included in this category are the Qualification Tests which are performed on concrete materials prior to their initial use as well as verification inspection which is made to insure that the quality of the materials has not been altered since its initial receipt inspection and storage.

b. Preconstruction Verification: Construction Processes. A recognition that the inspection of the construction must begin with a verification that the prerequisites for control have been established is noted as follows:

> "Inspections shall be performed to verify that the prerequisites for control of construction processes such as welding, bolting, structural reinforcement splicing, and concrete measuring, mixing, transporting, placing, and curing have been accomplished. These inspections shall include:
>
> 1. Verification that the process has been qualified as required.
> 2. Verification that process controls are in effect.
> 3. Verification that qualified procedures, instruction manuals, or both, if required for specific equipment, are available for use during construction
> 4. Verification that the process is suitable for the particular application.
> 5. Verification that manpower, equipment, and materials are readily available and adequate to perform the work in accordance with drawing and specification requirements.

c. Inspection of Concrete Construction. The basic framework for the inspection programs of the concrete construction phase on most of the projects in the research study is developed in ANSI N45.2.5. The seven basic inspection areas which are addressed are:

1. Protection of Materials
2. Measuring, Mixing, and Transporting Materials
3. Preplacement Preparations
4. Concrete Placement
5. Finishing and Repair
6. Curing
7. In-process Tests on Concrete and Reinforcing Steel

5. Observations

Criterion X covers a number of points which are also addressed in the Case Studies in Appendix A of this report. Some of these are:

a. Independence of Inspectors. Criterion X requires that a program of inspection of those activities affecting quality be established to verify conformance with the relevant documented instructions, procedures, and drawings. It should be noted that the inspection may be executed by the organization performing the activity. It may also be executed for the organization by some other group. The only stipulation in Criterion X is that the individuals who perform the inspection must not be the same ones who performed the original activity. This requirement is further defined in ANSI N45.2 which stipulates that the persons who are verifying the work shall not report directly to the immediate supervisor who is responsible for the work being inspected.

Independence of the Inspection effort can be achieved within an organization in many ways. Some of these alternative approaches are illustrated in the Case Studies found in the Appendix to this report.

b. Option of Inspection or Monitoring. Criterion X indicates that either inspection or process monitoring, or both (in those cases where

one method will not suffice to achieve control) are viable alternatives which may be used. A possible overlap of Quality Assurance responsibilities can easily result, however, because of this stipulation. The three levels of Quality Assurance (i.e., Inspection, Surveillance, and Auditing) were discussed in relation to Criterion I. The definitions of Inspection and Auditing indicate a clear distinction between the two and on most projects they are implemented by different groups within the project organization. The middle level, i.e., Surveillance, appears to be the area which is often performed by more than one group. Surveillance may be defined as one of the responsibilities of the QA group that is also involved with Auditing. It may also be the responsibility of the QC group as a supplement to the direct inspection function.

The basic question that must first be addressed with regard to a particular construction activity is whether or not Surveillance is necessary. If it is, then it would seem reasonable that it should be assigned only to one group in order to avoid duplication of effort. This contention is believed to be particularly true with regard to nuclear power plants since every function which is performed must be documented and supported by a procedural system.

c. Quality: A Construction or Inspection Responsibility? Another basic point which should be noted is the one which addresses the question of whether the responsibility for quality rests with the Construction group or with the Quality Control Inspection group. Examples of how different projects have viewed this issue will be indicated in the Case Studies in Appendix A of this report as well as in Chapters 5, 6, 7, and 8.

The effects of a major emphasis on inspection, as indicated in Criterion X, have been noted by several representatives of industry. Muntzing (4) stated:

> "A second problem of some quality assurance programs occurs when attention is focused almost exclusively on inspection and paper reports rather than on performance. Construction quality cannot be kept high solely through inspection or record keeping. Quality Assurance can not be papered into a plant. Assumptions that the craftsmen on the job knows what is required and how to deliver it have largely contributed to what is commonly called the put-it-in-then-take-it-out syndrome. Worse yet, such assumptions cause costly delays."

Rusche (5) has noted:

> "Balance is not achieved by super cops who only inspect hardware or investigate problems. High quality products are not a direct result of good inspectors or excellent inspection procedures or NRC rules and regulations. Such products result from capable people working in a planned and systematic way to produce the desired product and thus to prevent or minimize future problems--and not just to catch current ones."

The tendency to shift the responsibility for quality away from the construction group is noted by Rabenold (8) as follows:

> "Inspection per se causes problems. Unfortunately, we, in Construction, have occasionally detected a drift by some Construction Supervisors to abdicate the responsibility for the inspection of work. This is obviously due to their assumption that the responsibility of inspection lies with QA or QC. Not so! It is Construction's responsibility to do it right the first time! Construction forces must inspect their own work, as they have traditionally done, while in progress, and when completed, before QC performs their inspections."

Rice (9) provides the following observations with regard to the true responsibility for quality when he notes:

> "At J.A. Jones, QA personnel perform and document all official acceptance inspections and verifications. By policy we do not relieve the craft foreman of performing his own inspections he feels necessary, to assure all work performed by his crew is complete, in compliance with the latest design documents, and is of acceptable quality workmanship. If your methods and procedures fail to involve and recognize the craftsman responsibility for quality workmanship, you're in for a lot of self-imposed problems. Quality Assurance people better understand that quality

is built in, not inspected or tested into a product. Quality Assurance's primary functions are to assure that the quality requirements are disseminated to the people doing the work and verify that the required quality is achieved.

An area of concern is a trend toward duplication of inspections, tests, and verifications. I have seen QA people outnumber the craftsmen performing the activities. On one of our projects, after our inspections, the client's QA personnel performed 100% duplicate inspections. Is it any wonder when these conditions exist, that the craftsmen feel, with all this duplicate inspection and overchecks, that there is no need for them to be concerned with the quality of their work? Contractually required to or not, successful and responsible companies have and will continue to perform their own inspections and verifications necessary to assure that their products conform to established requirements. If they did not, their reputation and business would soon go down the drain. Making the company responsible for producing a product, also responsible for assuring and verifying the quality of his product, to me is just good business. The purchaser and end user of the product should perform sampling overchecks, surveillance and audits only to the extent necessary to assure they are receiving the specified product of the required quality. To perform 100% reinspection or when the QA representatives outnumber the craftsmen defies logic and cannot be explained or defended to upper management."

The Case Studies in Appendix A will, whenever possible, indicate how the responsibilities for quality and the responsibilities for quality control are divided for the project covered by the Case Study.

d. Concrete Inspection. It should be noted that the Quality Control coverage in the concrete area from the "Preconstruction Verification" stage to the "Postplacement" stage, as required by ANSI N45.2.5, is far broader than found on conventional construction projects. The Case Studies located in Appendix A of this report will indicate how various projects have attempted to implement these requirements.

VI. Criterion XVIII Audits

1. Appendix B

a. Documented Planning of Audits. Criterion XVIII notes: "A comprehensive system of planned and periodic audits shall be carried out to verify

compliance with all aspects of the quality assurance program and to determine the effectiveness of the program."

b. Audit Performance and Responsibility. The conduct of Audits is explained as follows: "The audits shall be performed in accordance with the written procedures or check lists by appropriately trained personnel not having direct responsibilities in the areas being audited."

c. Documentation and Follow-up Action. With regard to the reporting requirements and necessary follow-up action, Criterion XVIII notes: "Audit results shall be documented and reviewed by management having responsibility in the area audited. Followup action, including reaudit of deficient areas, shall be taken where indicated."

2. Standard Format and Content of SAR

a. Audit Responsibility. This document defines the responsibilities for Audits as follows:

> "The PSAR should describe the program of the applicant and of the principal contractors for conducting comprehensive planned and periodic audits to verify compliance with all aspects of the quality assurance program and to determine the effectiveness of the program."

b. Audit Program Features. This document provides the following additional details that must be considered when the Audit program is developed:

> "The PSAR should describe the program features that cover the functions listed below and should identify the positions or organizations that perform these functions.
>
> 1. External audits to be performed by the applicant and his principal contractors on their respective suppliers.
> 2. Internal audits to be performed by the applicant and his principal contractors within their respective organizations.
> 3. The planning and scheduling of audits to assure that they are regularly scheduled on the basis of the status and safety importance of the activities being performed and are initiated early enough to assure effective quality assurance during design, procurement, manufacturing, construction and installation, inspection and testing.

4. Conduct of audits in accordance with written procedures or checklists by appropriately trained and qualified personnel not having direct responsibility in the area being audited, and,
5. Documentation of audit results with review by management responsible for the area audited and, where indicated, followup action taken, including re-audit of the deficient areas."

3. ANSI N45.2

a. Scope of Audits. The total scope of Audits is defined in N45.2 as follows:

"Audits should be performed:
(1) to provide an objective evaluation of compliance with established requirements, methods and procedures;
(2) to assess progress in assigned tasks
(3) to determine adequacy of quality assurance program performance, and
(4) to verify implementation of recommended corrective action.
Deficient areas should be re-audited until corrections have been accomplished.

Audits should include an evaluation of quality assurance practices, procedures and instructions; the effectiveness of implementation; and conformance with policy directives. In performing this evaluation, the audits should include evaluation of work areas, activities, process, and items; and review of documents and records."

b. Audit Planning. The planning which is required prior to the performance of an Audit is noted as follows: "An audit plan should be developed to provide information about the audit, such as the functional areas to be audited, the names and assignments of those who will perform the audit, the scheduling arrangements, and the method of reporting findings and recommendations."

4. ANSI N45.2.5

Audits are not mentioned in N45.2.5.

5. Observations

Criterion XVIIIis included in Chapter 3 of this report in order to define the Auditing function which was mentioned in the discussion related to Criteria I and II. It should be noted that the "Independence" concept is

reiterated in Criterion XVIII since it is noted that "Audits are to be performed... by appropriately trained personnel not having direct responsibilities for the areas being audited."

Examples of the different approaches to Auditing being implemented on the projects in the research study will be presented in Chapter 4 of this report.

INTRODUCTION TO THE NINE NUCLEAR PLANTS

It was noted in Chapter 1 that the selection of the nine nuclear power plant projects for this research study were based on the following criteria: a) The Construction Permit dates should be reasonably spread over the entire ten-year time frame from 1968 to 1978, b) They were constructed under the jurisdiction of several different NRC regional offices, and c) They were constructed using different types of organizational relationships (i.e., Construction Management, EPC, Owner Design and Construction, etc.). A brief description of the projects was provided in Table 1.1 on page 1.8.

Table 1.1 indicated that with regard to the Type of Management on the projects three distinct modes were apparent. These three modes are indicated in Table 3.1.

Table 3.1 Management Modes on Nuclear Projects in Research Study

Mode Class	Mode Description	Project Identity
1. EPC Mode	Engineering, Procurement, and Construction by one Firm	C, D, G, I
2. C.M. Mode	Management by a Construction Manager	A, B, F, H
3. Owner Mode	Owner Design and Construction	E

The individual project Case Studies are presented in alphabetical order in Appendix A of this report There are a number of approaches which would result in a comparative analysis of these projects. The one that has been selected for the topics which are covered in the remainder of this Chapter consists of a comparative analysis between projects within the same Mode Class. It is felt that this approach would be most beneficial to a Utility, since the selection of the management mode that will be adopted for a new nuclear power plant project is one of the earliest basic decisions that must be made. A Utility would therefore be most interested in the alternatives which are being used within the industry for the particular Mode Class which it has selected.

It should be noted however that the material related to the nine projects which is presented in Chapter 4 is not presented according to Mode Class. The presentation follows the more conventional topical classification approach. That approach was selected because it was felt that the topics which are covered in Chapter 4 are relatively independent of the management mode which is used.

One final point should be made with regard to the comparative analysis which follows. It has not been designed to provide a detailed presentation complete with Tables, Figures, etc. That would essentially duplicate the information in the individual Case Studies found in Appendix A. The comparative analysis will, however, provide a general orientation to the different alternatives which are being used. The reader is referred to the Case Studies for detailed information about the individual organizational and managerial practices related to Quality Assurance.

E.P.C. MODE

As noted above, the four projects which are being constructed using the E.P.C. Mode are Projects C, D, G and I. Of the three modes shown in Table 3.1, the E.P.C. approach probably represents the one in which the Utility has

the least direct influence on the overall project. This is probably by choice, since the majority of the engineering, procurement and construction has been delegated by the Utility to a firm that can supply all of these services. As will be noted below, the primary Quality Assurance role of the Utility on site under the EPC mode is that of Auditing and perhaps Surveillance. In each case, the responsibility for the Quality Control phase has been delegated to the E.P.C. Firm.

Table 3.2 presents some additional information about Projects C, D, G, and I, particularly with regard to the concrete construction phase. It should be noted that the same E.P.C. Firm is involved on Projects C, D, and G, although Project G is being administered through a different regional office than Projects C and D. Projects G and I are actually facilities which will serve a group of Utilities. In the Project G case, one of the Utilities in the group has been assigned the "owner" responsibility for the project. A "Service Corporation" of the Utility group is responsible for Project I during the engineering and construction stages.

It should be noted that on all four projects, the E.P.C. Firm is directly involved in the concrete construction phase, but that only on Projects C and D is it also responsible for the operation of the concrete batch plant. An independent Concrete Testing Laboratory is responsible for the quality control testing of concrete on Projects D and G. On the other two projects, the E.P.C. Firm is in charge of this activity.

I. Project Organization (EPC Mode)

1. Utility.

An examination of the individual Case Studies will indicate that on Projects C, D, and G, the Quality Assurance function within the Utility is separated from the "Project Management" function at the organizational level

Table 3.2.--Description of Projects Built Under E.P.C. Mode

	C	D	G	I
1. Description	Two Unit BWR	Two Unit BWR	Two Unit BWR	Single Unit PWR
2. Percent Complete	Unit 1--32% (12/77) Unit 2--22%	Unit 1--51% (12/77) Unit 2--40%	Unit 1--57% (12/77) Unit 2-- 2%	19% (7/77)
3. Ownership	Utility "C"	Utility "D"	Utility "G"[1]	Utility "I"[2]
4. Engr., Procure., Construction.	E.P.C. Firm #1	E.P.C. Firm #1	E.P.C. Firm #1	E.P.C. Firm #2
5. Concrete Construction	E.P.C. Firm #1	E.P.C. Firm #1	E.P.C. Firm #1	E.P.C. Firm #2
6. Batch Plant Operation	E.P.C. Firm #1	E.P.C. Firm #1	Independent Concrete Supplier	Independent Concrete Supplier
7. Concrete Testing	E.P.C. Firm #1	Independent Test Laboratory	Independent Test Laboratory	E.P.C. Firm #2[3]

[1]Acting as the agent for a group of Utilities.

[2]Actually a group of Utilities.

[3]Concrete Mix Design and some tests contracted to an Independent Testing Laboratory.

immediately below that of the Vice President. On Project I it is separated immediately below the Service Corporation Level. This division of responsibility is reflected at the project level, since the field QA personnel are essentially independent of the Utility's lead representative at the project site (i.e., the Project Construction Manager).

Each Utility has also assigned a Project Manager at the home office level to provide overall project coordination. The location of the Project Manager within the organization varies from project to project.

It is of interest to note that on Projects C and D the Utilities both have a Construction group at the home office level which provides technical and administrative assistance to the Utility's Site Construction Manager. The direct influence of the Utility on the construction process is therefore probably greater on these projects than it is on either Project G or I, where such a group does not exist. On Project G, since the Utility does not maintain a large engineering and construction staff, the Project Construction Supervisor reports to a Project Manager who will also ultimately be responsible for operating the facility.

It is interesting to note that although the Utility site group on each project is involved with monitoring the construction progress, (providing on-site liason between the Utility and the contractors, etc.,) they do not become directly involved in Quality Control testing and inspection activities.

2. E.P.C. Firm

Both of the E.P.C. Firms (Firm 1 is responsible for Projects C, D, and G; Firm 2 is responsible for Project I) are organized in a Matrix format, with a Project Manager at the home office level responsible for the overall coordination of engineering, construction, and quality assurance personnel. These personnel also report to their functional managers for direction. The lead representative

of each firm on the project site is a Field Construction Manager who reports to a home office level Construction group.

At the home office level, both firms have a Manager of Quality Assurance who is completely independent of the Engineering or Construction groups. A major difference between the two firms appears to occur, however, with regard to the organizational location of the Quality Control group. For the case of E.P.C. Firm #1, the Quality Control group ultimately reports to the Manager of Construction at the home office level. One advantage of this approach is perhaps that it allows more direct organizational contact between the "doer's" (i.e., the Field Construction group) and the "inspector's" (i.e., the Field Quality Control group). This arrangement could conceivably allow for a more efficient resolution of problems. E.P.C. Firm #2 has chosen to place the Quality Control group and the Quality Assurance group under the same Manager of Quality Assurance at the home office level. One advantage to this approach perhaps is that it avoids unnecessary duplication of effort in those QA areas where both groups are involved (i.e., surveillance, etc.). It also centralizes the development of all QA and QC procedures, instructions, etc., under the same manager.

II. Quality Assurance Program (E.P.C. Mode)

1. Quality Assurance

Table 3.3 summarizes some of the major activities of the Quality Assurance groups of both the Utilities as well as the E.P.C. Firms on Projects C, D, G, and I.

As indicated in Table 3.3, E.P.C. Firm #2 on Project I represents the only case where an organization does not have both a project site as well as a home office QA group. In the Project I case, the Program Audits, Site

Table 3.3.--Quality Assurance Group Activities

	Note: "X" indicates YES							
	Project C		Project D		Project G		Project I	
	Utility	E.P.C. #1	Utility	E.P.C. #1	Utility	E.P.C. #1	Utility	E.P.C. #2
1. Location								
a. Project Site	X	X	X	X	X	X	X	No
b. Home Office	X	X	X	X	X	X	X	X
2. Project QA Group Responsibilities								
a. Formal Audits of E.P.C. QA	X	-	X	-	X	X	X	-
b. Formal Audits of E.P.C. QC	X	X	X	X	X	X	X	X
c. Formal Audits of E.P.C. Construction	X	X	X	X	X	X	X	X
d. Formal Audit of Concrete Batch Plant	X	X	X	X	X	X	X	X
e. Formal Audits of Concrete Test Lab	X	X	X	X	X	X	X	X
f. Formal Audits of Other Contractors	X	No	X	No	X	No	X	X
g. Formal Inspections	No	No	No	No	X	No	No	No
h. Informal Day-to-day Surveillance	X	X	X	X	X	X	X	No

Audits (which include audits of other contractors), and Quality Control Audits are performed by E.P.C. Firm #2's home office group which is only present on the project site for the duration of the Audit. A Site Audit, for example, occurs on Project I once every three months and attempts to cover 25% of the 18 Appendix B Criteria, so that all 18 of them are covered each year. This practice removes the informal day-to-day Surveillance responsibility from E.P.C. Firm #2's QA group and perhaps eliminates some of the overlap of QA activities which is discussed below.

Analysis of Auditing. It will be noted in Table 3.3 that Formal Audits (which include an Audit Plan, a Pre-Audit and Post Audit Conference and the Audit itself) are performed by both the Utility and the E.P.C. Firm on organizations (2b), (2c), (2d), and (2e). In addition, on each project the utility's QA group also audits the E.P.C. QA group as well as the programs of other contractors. It would appear worthwhile on future projects for the Utility and the E.P.C. Firm to form a "working partnership" of their individual QA groups so that a clear division of auditing responsibility is established. This point is not raised to either suggest that auditing is unnecessary or that the size of the two site QA groups should be reduced (the site QA groups on all projects are already considerably smaller than the site QC groups). It is raised with regard to the interferences, both in terms of time and human resources (i.e., manhours of effort to review and respond to audit findings etc.), which are experienced by the organization being subjected to Audits from a number of QA groups.

The above point can be illustrated by considering the case of the independent Concrete Testing Laboratory on one of the projects listed in Table 3.3. The E.P.C. Firm Audit of the laboratory included a 22-page

"Checklist" which covered every conceivable item found in that organization's QA Manual. Two of the items on the Checklist related to the fact that the laboratory's own QA Manager is committed to: (1) Audit the laboratory's QA program at least once a year, and (2) Perform an internal audit of the entire operation. When the Utility's QA group Audit, as well as an occasional NRC Audit, is superimposed on this situation, the possibility for overlap of effort becomes apparent. The impact of this situation is particularly felt with respect to the amount of documentation which must be reviewed during an Audit and the amount of documentation which is generated because of an Audit.

Auditing vs. Surveillance - Table 3.3 also indicates that for all projects except Project I, both the Utility and E.P.C. Firm QA groups are also involved in informal day-to-day Surveillance type activity. On Project D, for instance, the three quality verification functions of the Utility D site QA group are: (a) Auditing, (b) Random Impromptu Monitoring, and (c) Site Surveillance. On Project G, which appears to represent the project in Table 3.3 with the greatest Utility QA involvement, the equivalent functions are (a) Auditing, (b) Inspections, and (c) Surveillance. Utility G's QA group, in fact, has a broader scope of involvement in the concrete area than the E.P.C. Firm's QC group. Whereas the E.P.C.'s QC group witnesses concrete placements for non Q-listed placements on a limited basis, the Utility G QA group observes all phases of non-Q concrete operations, e.g., preplacement, placement and post placement. The E.P.C. Firm's QA group is also responsible for B.O.P. operations but concentrates primarily on Q items. Inspections on Project G are formal activities in that detailed "Checklists" are used to cover not only the inspection of actual construction practices but also the analysis of QA, QC and EPC documents.

It may validly be argued that it is in the Utility's best interests to perform more than just the auditing function. It may also be argued that the E.P.C.

Firm must have a more frequent assessment of the Quality Control and Construction efforts than can be provided by the periodic Audits. It is felt, however, that on some of the projects these more frequent independent observations could be more effectively meshed to avoid duplication of efforts between all parties concerned.

2. Quality Control

Project C appears to be the only one that included a Utility QC group on the project site. On that project, however, Utility C's QC efforts were directed toward non-Q listed items in the Mechanical, Electrical, and Welding areas. Although Projects D, G, and I did not have Utility QC involvement, it should be recalled from the discussion above that on Project G, the Utility's QA group was involved in an Inspection activity which elsewhere might have been identified as a QC type activity.

With regard to the E.P.C. Firm's QC effort on Projects C, D, G, and I, it should be noted that all of them had project site QC groups which were considerably larger than the project site QA groups and that all were organized into functional specialties (i.e., Civil, Mechanical, etc.). All of these QC groups were responsible for "First Level" Quality Control and Inspection and the preparation of detailed Inspection Plans and Inspection Reports. In addition, on Projects C, D, and G, the E.P.C. Firm's QC group was also responsible for Second Level Surveillance on the quality related activities of other contractors on the project site.

Table 3.4 indicates the involvement of the QC group on each project in the Concrete phase.

As noted, in all cases the E.P.C. Firm's QC group must "sign off" the Concrete Pour Card for all "Safety Related" concrete placements before they can be released. This action is only taken after the QC inspector has established compliance using a Pre-Placement Inspection Report. For the B.O.P. concrete,

Table 3.4.-- EPC Mode: Quality Control Involvement in the Concrete Phase

Note: "X" indicates YES

	Project C	Project D	Project G	Project I
E.P.C. Firm Project QC				
1. Safety Related Concrete				
a. Preplacement Inspection	(QC "Signoff" of Concrete Pour Card) [1]			
b. Placement Inspection	X	X	X	X
c. Concrete Testing	(E.P.C.-QC)	No	No	(E.P.C.-QC)
d. Post Placement Inspection	X	X	X	X
2. B.O.P. [2] Concrete				
a. Preplacement Inspection	(Const. "Signoff" of Concrete Pour Card)			
b. Placement Inspection	X	No	No	No
c. Concrete Testing	(EPC-QC)	No	No	(EPC-QC)
d. Post Placement Inspection	X	No	No	No
3. Batch Plant Inspection	X	X	X	X
4. Concrete Test Lab Inspection	EPC-QC Lab	X	X	EPC-QC Lab

[1] On Project C, QC does not "signoff" the concrete pour card but assures that it is completely signed off by field engineers and superintendents prior to releasing concrete. QC performs preplacement inspection of safety related concrete.

[2] B.O.P. = Balance of Plant.

this responsibility rests with the Construction Engineering group. The E.P.C. Firm's QC group is not involved with Concrete testing on Projects D and G because an independent Testing Laboratory is responsible on these projects. In general, except for the testing responsibility on Project D and the witnessing of placement activities on Project G, the E.P.C. Firm's QC group is not involved in B.O.P. concrete on Projects D, G, and I. For Project C, however, the EPC Firm's QC group is involved in all phases of B.O.P. concrete except the postplacement phase. As noted in Table 3.4, both the Concrete batch plant as well as the testing laboratory are inspected by the E.P.C. Firm's QC group on all projects.

It should be noted that the direct involvement which the QC group has on the concrete process varies from project to project. There appears to be a point of involvement however beyond which there is a subtle shift of the direct responsibility for quality from the Construction group to the QC group. When this occurs, then the QC group is placed in a much broader role than simply "verifying" that the required quality has been obtained. This point may have been reached in one of the projects shown in Table 3.4.

III. Quality Assurance Documents (E.P.C. Mode)

An examination of the section entitled "Quality Assurance Documents" in each of the Case Studies for Projects C, D, G and I located in the Appendix will indicate that they generally follow the model shown in Figure 3.1, (which was presented earlier in this chapter when Appendix B Criterion V: "Instructions, Procedures and Drawings" was discussed). The magnitude of the documentation required to define all of the aspects of the Quality Assurance system should be apparent from a review of these Case Studies.

Project G appears to contain a modification to the general above mentioned document framework, however, because a formalized Work Plan and Inspection Report

(i.e., WP & IR) system for the Construction group is included. For the concrete phase for example, a separate WP & IR must be prepared for each concrete placement. The WP & IR is a self-contained document which is used to: (1) Pre-plan construction activities, (2) Control installation, (3) Assure verification, inspection, and acceptance, and (4) Provide objective evidence after the work is complete. A typical WP & IR for a Q-listed concrete placement requires that a total of approximately 52 Work or Inspection activities be individually "signed off" by the responsible Superintendent, Field Engineer and Quality Control Engineer during the preplacement, placement, and post-placement stages. The Construction group on Projects C, D, or I is not as involved in such a formal planning and quality verification process.

One of the problems which is coupled with the indicated level of documentation is the requirement that the latest revision of these documents must always be used. The scope of this problem is illustrated in each of the Case Studies by noting the number of pages involved in each of the major concrete related specifications as well as the number of revisions or addenda which each one has undergone. The fact that must be recognized is that all of the "Instructions, Procedures, and Drawings" which define the required documentation under Criterion V are in a constant state of flux, they are changed either in a minor or a major fashion many times during the construction phase of a typical project.

The basic question related to the extent to which all activities performed on a nuclear construction site must be documented as well as the method which will be used to incorporate changes to these documents should be seriously considered by both the Utility and the E.P.C. Firm on future projects.

C.M. MODE

As noted in Table 3.1, the four projects which are being constructed using the

C.M. Mode are Projects A, B, F, and H. It appears that the C.M. mode allows the Utility, if it desires, to have a greater influence on the overall construction process in general and the Quality Assurance/Quality Control aspects in particular.

Table 3.5 presents some additional information about Projects A, B, F, and H, particularly with regard to the concrete construction phase. The different levels of Utility involvement, as well as the different combinations of responsibility which can be assumed, are readily apparent from Table 3.5.

On Project A, for example, (which incidentally is one of the "oldest" projects in the research study), the Utility provided its own Engineering/Design services as well as its own Concrete Testing Laboratory. C.M. Firm #1 was responsible for general C.M. coordination of all contractors as well as serving as the Concrete constructor and the Concrete Supplier and Batch Plant Operator.

On Project B, the same C.M. Firm that was used on Project A served in only a C.M. capacity and as the Concrete Constructor. A separate A.E. Firm was responsible for the Engineering/Design phase and an independent Concrete Supplier and an independent Testing Laboratory were retained to complete the organizational design.

On Project F, both the Engineering/Design and the C.M. responsibilities were supplied by the same firm (called A.E./C.M. Firm #2 in Table 3.5). It is interesting to note that the A.E./C.M. Firm #2 is the same firm that was designated as E.P.C. Firm #2 in Table 3.2. On Project F, the Utility is providing the Concrete Testing Laboratory services, but has retained an independent Concrete Constructor and an independent Concrete Supplier.

Project H presents perhaps the most complicated arrangement found in Table 3.5. In this case, A.E. Firm #2 has been retained to provide Engineering/Design services. The C.M. function is provided by a combination of Utility H,

Table 3.5.--Description of Projects Built Under C.M. Mode

	A	B	F	H
1. Description	Two Unit PWR	Unit #2, PWR	Unit 2-PWR	Two Unit-BWR
2. Percent Complete	Unit 1-Operating Unit 2-86% (6/77)	100%	15% (12/77)	15% (12/77)
3. Ownership	Utility A	Utility B	Utility F	Utility H
4. Engineering	Utility A's Eng. Dept.	A.E. Firm #1	A.E./C.M. Firm #2	A.E. Firm #2
5. Construction Management	C.M. Firm #1	C.M. Firm #1	A.E./C.M. Firm #2	Combination[1]
6. Concrete Construction	C.M. Firm #1	C.M. Firm #1	Independent Construction Firm	3 Independent Construction Firms
7. Batch Plant Operation	C.M. Firm #1	Independent Concrete Supplier	Independent Concrete Supplier	Independent Concrete Supplier
8. Concrete Testing	Utility A's Test Lab	Independent Test Lab	Utility F's Test Lab	Independent Test Lab

[1]Combination = Utility H and C.M. Firm #3 and A.E. Firm #2

C.M. Firm #3 and A.E. Firm #2 personnel. The overall project is divided into a number of "Work Packages" which results in the fact that three separate construction firms are involved in the concrete phase of the project. An independent Concrete Supplier and an independent Testing Laboratory round out the total organizational design.

The discussion below will indicate how the Quality Assurance/Quality Control functions are implemented on these projects.

I. Project Organization (C.M. Mode)

On all four of the projects in this group, the role of Quality Assurance is kept independent by having the managers of: Engineering, Project Direction, Quality Assurance, etc., report to either a Vice President of Engineering and Construction, a Vice President of Engineering, etc. The method of insuring independence of the Quality Control function from the Construction function or in some cases from the Quality Assurance function is generally dependent on how the responsibilities have been divided on each project.

1. Project A

For the Project A case, for example, the field QA group of Utility A (which ultimately reports back to the home office Quality Assurance Manager) is responsible for the Third Level Auditing function as well as the Second Level Surveillance function. The First Level Quality Control and Inspection function is the responsibility of the C.M. Firm field QC group which is under the direction of a Field Superintendent of Quality Control. This group is also responsible for a Second Level Surveillance function with regard to the above mentioned First Level function. Organizational independence from the Construction group on the project site is achieved because the QC group reports to a home office QA Manager for technical direction. This QA Manager is organizationally

independent of the home office Project Manager of Project A.

It is interesting to note that Utility A has not completely delegated the above mentioned functions to the C.M. Firm. It has in fact placed a Utility A QC Division Head on the project site to provide technical direction to the C.M. Firm's Field Superintendent of Quality Control as well as to provide owner visibility at the level in the organization at which quality-of-construction type problems first become apparent.

It should be noted that although there appears to be an overlap of Second Level Surveillance activity, there is no overlap of Third Level Audit activity since the Utility A field QA group is solely responsible for the latter function.

2. Project B

Another example of owner involvement and the elimination of the overlap of quality related activities is provided on Project B. In this case, a Utility B Service Corporation (i.e., Utility B(SC)) is responsible for the Engineering and Construction phase of the project. The Site QA group of Utility B(SC), which reports to a home office QA Manager, is solely responsible for the Third Level QA Auditing function on the project. Utility B(SC) is, however, also directly involved in the other functions within the total QA/QC system.

With regard to First Level Quality Control and Inspection, Utility B (SC) has achieved this involvement by placing a Utility B (SC) employee in direct managerial control of the C.M. Firm's Construction Quality Control (i.e., CQC) and Construction Quality Assurance (i.e., CQA) groups. Since the technical and administrative direction for the CQC and CQC groups has been removed from the C.M. Firm (although C.M. Firm employees are utilized in these groups), the "Independence" requirement is satisfied. In addition, and perhaps to a greater degree than on Project A, the Utility has visibility at the organizational level at which

quality related problems first become apparent.

3. Project F

Perhaps the most direct influence of a Utility on the overall QA/QC effort exists on Project F. As noted from Table 3.5, both the Engineering and the Construction Manager functions are the responsibility of A.E./C.M. Firm #2. The original overall management design also placed the majority of the Field Quality Assurance and Quality Control responsibility with the same A.E./C.M. Firm. This was changed in 1976, however, when Utility F assumed direct responsibility for both of these areas.

The Utility F corporate QA Manager is located on the project site and is in direct control of the major QA group as well as the major QC group (under a Utility F Site Director-Quality Control) on the project. One of the major responsibilities of the QA group is performing Audits of the various organizations and practices at the project site. Since the only Auditing which is performed rests with the Utility F QA group, the Appendix B "Independence" criterion is automatically satisfied.

With regard to Quality Control and Inspection, as related to the Concrete phase for example, it should be noted that the Concrete Construction Firm does not have its own independent QA/QC program, it operates under the Utility F QA program. This is accomplished by requiring the Concrete Construction Firm QC Supervisor (who directs the field QC inspectors) to report for QC technical guidance and direction to a Utility F Senior Structural QC Engineer. Again, the Appendix B "Independence criteria" is satisfied because Utility F is in effect managing the QC effort.

It is felt that a key to the success of the program on Project F, with regard to the elimination of the duplication of the activities of the QA and QC groups, is caused by the fact that both of these groups report to the same

QA Manager.

A review of the Project F Case Study will indicate that Utility F is accomplishing the management of the QA/QC effort without using many permanent employees; it has chosen instead to create an organization of personnel which are generally on loan from a number of consulting firms.

4. Project H

The direct involvement of the Utility which was indicated on Project F is also apparent on Project H. Utility H's direct involvement in the Construction Management area, which was noted in the discussion related to Table 3.5, is also apparent in the QA/QC areas.

It should first be noted that each of the three Concrete Construction Firms is responsible for its own First Level Quality Control and Inspection for all safety related concrete. The QC inspectors must be organizationally independent of the Construction group which is performing the work.

The Utility's influence is felt through the home office QA Manager who directs the activities of both a Site Construction Quality Assurance (i.e., CQA) group as well as a site Construction Quality Control (i.e., CQC) group. It should be noted that these groups are staffed by a mix of Utility H, C.M. Firm, and A.E. Firm personnel. The CQC group performs a Second Level Surveillance activity with regard to the First Level Programs of each of the Concrete Contractors. The CQA group performs a Third Level Auditing function.

It should be noted that the Appendix B "Independence" criterion is satisfied for these groups and that, as in the Project F case, duplication of effort is avoided by having the Utility H CQC and CQA groups both reporting to the same QA Manager.

II. Quality Assurance Program (C.M. Mode)

1. Quality Assurance

One of the major points of similarity between Projects A, B, F and H is that in each case the site QA group of the Utility is the one which performs the majority of the formal pre-planned Audits of the Second and First Level quality related functions. It is interesting to note that on Project A, the responsibilities of the Utility QA group also includes the activity of Surveillance. Approximately 25% of a typical QA Engineer's time is devoted to Audits and 20% is devoted to the overall Surveillance of site Construction activity. In the concrete area, these activities are restricted to "Q"-listed concrete placements. A daily site surveillance schedule is prepared by the QA Division Head and includes a detailed survey of individual construction activities.

The Utility's QA group that is responsible for the Auditing function on Project B does not also perform the Surveillance function. For the concrete phase of the project, the A.E. Firm provides Second Level Surveillance on the C.M. Firm's First Level Quality Control and Inspection activities.

On Project F, the Utility site QA group, in addition to performing pre-planned and scheduled Audits, also performs random unscheduled Audits in a number of situations, one of which occurs whenever the safety, performance, or reliability of an item or items is suspect because of the number of deficiencies and nonconformances found. Such a circumstance indicates a possible breakdown in the effectiveness of the QA Program.

Project H, which includes a number of contractors in each of the construction phases (due to the Work Package approach which is used) presents a unique situation from a QA standpoint. The five primary activities of the CQA group on Project H are defined as: (1) Procedure review, (2) Auditing, (3) Configuration control, (4) Nonconformance control, and (5) Quality Records.

With respect to Procedure Review, it should be noted that the CQA group must perform a primary review of all of the quality related detailed procedures and/or instructions of each construction firm. This group is also responsible for "Status Tracking" of all of the contractor procedures. The enormity of the task can be appreciated when it is realized that there are over 25 major contractors and over 300 contractor procedures which are in a constant state of flux due to changes, etc.

It would appear that the Work Package approach, with its preponderance of contractors, each with their own set of procedures and instructions, presents a peculiar set of problems when it is applied on nuclear power plant construction projects. Additional analysis by the industry (from both a legal as well as an economic standpoint) is suggested in order to determine if it would be feasible and to the Utility's advantage to develop a set of standard procedures and instructions which would apply to all contractors or at the very least to all of the contractors who are performing a specific phase of construction.

2. Quality Control

It is not as easy to make general statements about the Quality Control function on "C.M. Firm" projects as it was on E.P.C. Firm projects since the organizational responsibilities for individual QC activities vary between Projects A, B, F, and H. Table 3.6 provides an analysis which attempts to indicate these responsibilities.

It is interesting to note that for Project A, the C.M. Firm QC group is responsible for both First Level Concrete Inspection as well as Second Level Surveillance of the First Level and Construction activities. It should be recalled from the discussion of the responsibilities of Utility A's QA group that they were also extensively involved in the Surveillance function. This probably indicates somewhat of a duplication of effort unless the parts of the program which receive Surveillance are different for each group.

Table 3.6.--C.M. Mode, Quality Control Group Involvement in the Concrete Phase

	Project A	Project B	Project F	Project H
1. First Level QC Responsibility	CM Firm QC[2]	CM Firm QC[2]	Utility F QC	Individual Contractors
2. Source of First Level QC Personnel	CM Firm	CM Firm	Concrete Contractor	Individual Contractors
3. First Level Concrete Inspection	CM Firm QC	CM Firm QC	Utility F QC	Individual Contractors
4. Second Level Surveillance of First Level and Construction (Concrete)	CM Firm QC	AE Firm	Not Applicable	Utility H CQC
5. Second Level Surveillance of Other Contractors On Site	CM Firm QC	CM Firm QC	Not Applicable	Utility H CQC
6. Concrete Batch Plant Inspection	CM Firm QC	CM Firm QC	Utility F QC	Utility H CQC
7. Concrete Test Lab Operation	Utility A	Independent Test Lab	Utility F QC	Independent Test Lab
8. Safety Related Concrete				
a. Preplacement Inspection	CM Firm Construction	CM Firm QC	Utility F QC	Individual Contractors
b. Placement Inspection	CM Firm QC	CM Firm QC	Utility F QC	Individual Contractors
c. Concrete Testing	Utility A Lab	Independent Test Lab	Utility F Lab	Independent Test Lab
d. Post Placement Inspection	CM Firm QC[3]	CM Firm QC	Utility F QC	Individual Contractors
9. B.O.P.[1] Concrete				
a. Preplacement Inspection	CM Firm Const.	CM Firm Const.	Utility F QC[5]	Utility H CQC
b. Placement Inspection	CM Firm Const.	CM Firm Const.	Utility F QC[5]	Utility H CQC
c. Concrete Testing	Utility A Lab	Indep. Test Lab	Utility F Lab	Indep. Test Lab
d. Post Placement Inspection	CM Firm Const.	CM Firm Const.	Utility F QC[5]	Utility H CQC

[1] B.O.P. = Balance of Plant

[2] On Project A, a Utility A Division Head provides technical direction to the C.M. Firm QC group.

[3] Post placement inspection by the C.M. Firm QC group is more limited on Project A than on other projects in the study.

[4] On Project B, a Utility B(SC) QA Manager is directly in charge of the C.M. Firm QC group.

[5] The Utility F QC group performs First Level Inspection on B.O.P. concrete to a somewhat lesser degree. Fewer "4 attributes" are verified.

It will be noted from Table 3.6 that on Project B (which involves the same C.M. Firm as on Project A) the responsibility for Second Level Surveillance has been placed with the A.E. Firm. It would appear for the Project B case that if Surveillance were deemed necessary, it might have been more cost effective and efficient for Utility B(SC) to have placed this responsiblity with its own QA group that was involved with Auditing. This statement is made in light of the need for documented procedures and instructions requirement stated in Criterion V of Appendix B. It must be realized on nuclear power plant construction projects that every time a new organization interfaces with the project, it must also implement a new set of procedures, etc. in order to define the responsibilities of the personnel that will be involved on the project.

On Project F, it appears that the First Level Quality Control and Inspection function encompasses the Surveillance function. Utility F's QA group is not extensively involved in Surveillance activities because of the depth of involvement of the QC inspectors in each of the stages of a concrete placement. This division of responsibility is possible because, as noted earlier, both the QC and the QA groups report to the same Utility F QA Manager.

On Project H, the Second Level Surveillance activity on concrete placements which are safety related is the responsibility of Utility H's CQC group. On B.O.P. concrete placements, this group performs the First Level QC functions since the individual concrete contractors are not responsible for this function.

It should be noted from Table 3.6 that for Safety Related Concrete on Project A, the C.M. Firm QC group is primarily involved in the placement inspection phase, the Utility A Testing Laboratory is involved in the testing of the concrete. For B.O.P. Concrete placements, the primary responsibility for all phases rests with the C.M. Firm's Construction group.

On Project B, the C.M. Firm's QC group is involved in all three phases related to concrete placement. An independent Concrete Testing Laboratory is

involved with the concrete testing responsibility. For B.O.P. concrete placements, the primary responsibility for all phases rests with the C.M. Firm's Construction group.

On Project F it will be noted from Table 3.6 that the Utility F QC group is involved in both the Safety Related as well as B.O.P. Concrete placements, although fewer "Attributes" are verified in the latter case. The Utility F QC group is also directly involved in all concrete testing through its own Concrete Testing Laboratory.

On Project H, as noted earlier, each of the three Concrete Construction firms is responsible for its own First Level QC Inspection on Safety Related Concrete Placements. This division of responsibility for the concrete phase of the project places the responsibility for the Quality Control and Inspection of the Batch Plant with Utility H's CQC group. It should also be noted from Table 3.6 that Utility H's CQC group is also responsible for all pre-placement, placement, and postplacement of B.O.P. concrete.

III. Quality Assurance Documents (C.M. Mode)

An examination of the section entitled "Quality Assurance Documents" in each of the Case Studies for Projects A, B, F and H (which are located in Appendix A will indicate that they generally follow the model shown in Figure 3.1 (which was presented earlier in this chapter on page 3.16 when Appendix B Criterion V: "Instructions, Procedures and Drawings" was discussed). Several additional points should, however, be made with regard to Projects A, F and H.

1. Project A

On Project A, which is the "oldest" project in the research study, it appears that the level of detail found in the documents is considerably less than was found on later projects. With regard to the concrete specifications, for instance, the information about reinforcement, formwork, etc., is brief. It was

probably assumed that the references to the various ACI Codes and Recommended Practices, etc., which are made in the specifications, would insure the incorporation of these requirements into the construction effort. This concept placed a considerable reliance on the ability of the Construction group and the QC group to incorporate (without the benefit of a definite statement of the details) all of the important details into the concrete construction process. This same level of emphasis is carried over into the Construction and Quality Control Procedures. In the Quality Control Procedure related to Concrete, for instance, the detailed guidance provided regarding the acceptability of the various attributes related to concrete is minimal when compared with the level of guidance provided on later vintage projects.

The above discussion raises an important point with regard to Quality Assurance Documents which deserves serious consideration by all of the parties involved on a nuclear power plant project. The basic question is, "How much detail is sufficient to insure that the required quality is achieved without providing written requirements which address items of inconsequential importance?" These inconsequential items can easily become stumbling blocks to an efficient construction and inspection operation.

2. Project F

The interested reader is referred to the Case Study of Project F for a more detailed analysis of the Quality Assurance Document model originally presented in Figure 3.1. It is felt that the document system which has been developed by the QA Manager on Project F represents an excellent example of how the needs of all parties can be meshed into a series of documents which insure that the commitments which the Utility makes in the PSAR, etc., will be implemented in a satisfactory manner.

3. Project H

Several interesting points were found with regard to Project H. Project H is the only project in the study which has two basic concrete specifications, one entitled "Placement of Structural Concrete-Safety Class Structures" and one entitled, "Placement of Structural Concrete-Non Safety Related Structures". An analysis of these two specifications will indicate only minor differences, the most important of which appear to be a reference in the "Safety Related" specification to: (1) Quality Program Requirements, (2) Documentation requirements, and (3) The need for qualified Construction Procedures. On the one hand, particularly in light of the problems associated with insuring that the latest revision of a specification is always used, it may be reasoned that one basic concrete specification is more efficient. On the other hand however, the two specification approach permits a more selective application of the more vigorous quality program requirements, documentation and procedures to those placements which are the most critical.

The second point about the document system on Project H which should be made concerns the fact that each concrete contractor is permitted to develop his own set of QA, QC and Construction Procedures. Each of these procedures must initially be reviewed and approved by Utility H's CQA group. Each of these procedures is also subject to a stream of revisions by the Contractor over the life of the project. In addition, when the Second Level Surveillance function is performed, the Utility H CQA personnel must be familiar with the different details found in each of these procedures. It would appear to be to the advantage of a Utility that is contemplating a "Work Package" approach similar to the one being used on Project H to seriously consider, after weighing the legal and economic ramifications, the development of one standard set of construction procedures for all contractors performing a particular type of construction. If these procedures were incorporated into the Contract Documents in the same fashion as the specifications, it would probably eliminate a considerable amount of confusion and extra QA

tracking effort over the life of the project.

OWNER MODE

As noted in Table 3.1, Project E is the only one in the research study which involves the Utility over the entire spectrum of Engineering, Construction, and Operation. The "Owner Mode" which is described below, when contrasted with the E.P.C. Mode, represents the other end of the scale with respect to Utility involvement.

Table 3.7 provides some additional information with regard to Project E.

Table 3.7.--Description of Project Built Under Owner Mode

	E
1. Description	Two Unit PWR
2. Percent Complete	Unit I--58 (3/78) Unit II--42 (3/78)
3. Ownership	Utility E
4. Engineering	Utility E
5. Construction	Utility E
6. Concrete Construction	Utility E
7. Batch Plant Operation	Utility E
8. Concrete Testing	Utility E

I. Project Organization (Owner Mode)

The Office of Engineering, Design and Construction (i.e., DEDC) of Utility E, through separate Directors of: (1) The Division of Engineering/ Design (i.e., DED), and (2) The Division of Construction (DEC), is responsible for Project E. An OEDC QA Manager is responsible for the overall QA program within OEDC. The field QA group, however, is directly responsible to a Chief of QA who is in a home office staff position directly within the Division

of Construction. This type of an arrangement represents a unique alternative among the projects in the research study to the Appendix B "Independence" criterion.

On Project E, the Utility E Project Manager is in charge of both a Construction group (under the direction of a Construction Superintendent) and a Construction Engineering group (under the direction of a Construction Engineer). The First Level Quality Control: Inspection, Verification and Field Test functions have been placed, (along with the typical Field Engineering functions,) directly within the Construction Engineering group. This arrangement also represents a unique alternative to the Appendix B "Independence" criteria among the projects in the research study.

II. Quality Assurance Program (Owner Mode)

1. Quality Assurance

The QA effort within OEDC can be viewed from two levels, the one being the responsibility of the OEDC QA staff reporting directly to the QA Manager, the other being the responsibility of the QA staff which is located directly within the Division of Construction (i.e., DEC).

One of the primary functions of the OEDC QA staff is to perform both announced and unannounced formal Management Audits of the DEC organization. The scope of an OEDC Audit consists of the following four major elements: (1) Examination of procedures and instructions, (2) Observations of activities (i.e., concrete mixing and placement, reinforcing steel installations, etc.) product inspections and personnel interviews, (3) Examination of representative quality assurance records, (4) Collection of objective evidence to support findings and recommendations.

The QA effort at the DEC level is also primarily focused on the performance

of planned formal Audits of the various quality related activities on the project site. In addition, the site QA group also reviews QA and QC procedures to insure compliance to the commitments in the PSAR, performs informal Surveillance of site operations to insure that appropriate procedures and quality requirements are followed, etc.

2. Quality Control

As noted earlier, the Field Engineering and the Quality Control and Inspection groups are both under the direction of the site Construction Engineer. On Project E a "Concrete Pour Card" is used as an inspection and control record for each concrete placement. It appears that the major quality effort during the preplacement stage is the responsibility of the Construction Superintendents and Engineers. The QC group does not of itself generate its own Inspection Reports, etc., it merely signs off four items on the "Pour Card" to officially release the concrete placement after the responsible parties have indicated that a placement is ready.

Quality Control inspectors are present during each concrete placement, both for concrete testing as well as inspection purposes. With regard to the testing function, the same Quality Control group mentioned above is also responsible for the concrete batch plant inspection function, testing of all concrete component materials, and the performance of sampling and testing of concrete with regard to slump, air content, compressive strength, etc.

It appears that the problems of duplication of effort which were cited with regard to some of the E.P.C. Mode projects does not exist on Project E. Utility E has had considerable experience in the construction of both nuclear as well as fossil plants and appears to have used this experience to establish an organizational structure and Quality Assurance program which most effectively

meets their own internal needs while at the same time satisfying the external requirements imposed upon them by the NRC regulatory environment.

III. Quality Assurance Documents (Owner Mode)

The section entitled "Quality Assurance Documents" in the Project E Case Study indicates that the document model shown in Figure 3.1 generally describes the types of quality related procedures, instructions, etc., which are used on Project E. It is worthwhile to note, however, that Utility E does not revise its basic specification as often as has been found on other projects in the research study. The major specification entitled "Plain and Reinforced Concrete", for instance, which is applied to all nuclear power plant projects, has only been subjected to one revision over the past six year period.

The underlying reason for this continuity of the technical requirements in the concrete area is probably due to the extensive concrete related experience of Utility E. It is interesting to note that this specification relies heavily on references to the industry standards. The only reference to reinforcing steel, for instance, states: "All details of reinforcement shall be in accordance with the latest ACI Standard Building Code Requirement for Reinforced Concrete". Mutually satisfactory interpretations of these industry codes and standards, by both the Construction as well as the Construction Engineering groups, probably has occurred internally in Utility E so as to avoid unnecessary problems on the project site.

Site Quality Control Procedures (i.e., QCP's) directly related to Project E are prepared by the Construction Engineering group at the project site and approved by the site Quality Assurance group. These consist of two types: Test QCP's (for example, "Concrete Slump and Air Content Testing") and Inspection QCP's (for example, the ones covering the preplacement, placement, and post placement phases).

SUMMARY

Appendix A of this report contains the detailed Case Studies of the nine nuclear power plants that were included in the research study. Chapter 3, which is devoted to a comparative analysis of these Case Studies, can be summarized as follows:

1. The first part of Chapter 3 provided an overview of the particular Appendix B Criteria that were addressed in the Case Studies. The section devoted to each Criterion includes the related material found in the ANSI standards and the NRC documents which served to supplement the information found in the original 10 CFR Part 50 Appendix B document. Included with each Criterion are some general observations which were obtained as a result of the research effort as well as the observations of the industry which appeared in the literature with regard to the Criterion being examined.

Some of the basic issues that were highlighted in the first part of Chapter 3 are:

a. The applicability of the Quality Assurance Program outlined by the Appendix B Criteria to the "safety related" part of the nuclear power plant.
b. The spectrum of roles which the Utility can assume with regard to the Quality Assurance and Quality Control aspects of the construction phase.
c. The need for establishing organizational independency for those groups which are performing Quality Assurance and Quality Control activities.
d. The requirement that all aspects of the Quality Assurance Program must be defined by a set of documented policies, procedures, and instructions.
e. The presentation of an "Ideal" model of the interrelationship that exists between the most commonly used quality related documents.
f. The relationship between Surveillance and the Inspection and Auditing functions.

g. The respective responsibilities of the Construction and Inspection groups towards Quality.

2. The remainder of the chapter was devoted to a comparative analysis of the nine Case Studies. The projects were divided into three groups according to the "Management Modes" which were used on each project. These groups were entitled: (1) E.P.C. Mode, (i.e., Engineering, Procurement, and Construction by one firm), (2) C.M. Mode, (i.e., Management by a Construction Manager), and (3) Owner Mode (i.e., Owner design and construction).

For each group the analysis was divided into the following three sections: (1) Project Organization, (2) Quality Assurance Program, (3) Quality Assurance Documents. Some of the points which were emphasized in the comparative analysis are summarized below.

E.P.C. MODE

The projects in this group represent the ones which are felt to exhibit the least direct influence of the Utility on the overall project, particularly from a Quality Assurance/Quality Control standpoint. One of the points of commonality on all four projects using this management mode is that the Utility is primarily placed in a Third Level Auditing role. The primary responsibility for the First Level Quality Control and Inspection function is assumed by the E.P.C. Firm.

Two additional observations which were made are: (1) There appears to be a certain amount of duplication of effort with regard to the Audit function since, in general, the E.P.C. Firm QA group is also involved in this activity, (2) The Surveillance function is in need of further definition on the projects in this group since it is often assumed by both the Utility QA group, the E.P.C. Firm QA group, and sometimes also by the E.P.C. Firm QC group. This situation did not exist for one of the four projects in this group since the E.P.C. QA group was located in the home office and therefore was only at the project

site during formal Audits.

With regard to the Quality Control groups of each of the E.P.C. Firms, it was noted that on only one of the four projects were they involved in the Balance of Plant Concrete (i.e., non "Q"-list) operations. These placements were generally under the direct control of the Construction group.

A point was also made with regard to the large number of quality related documents which are required on nuclear power plant projects in order to define responsibilities, etc. This is particularly important because there are many revisions made to these documents over the life of a project. This point was highlighted in reference to the number of revisions to the Concrete Specifications on each project.

C.M. MODE

The C.M. Mode appears to allow the Utility to have a somewhat greater influence on a project, particularly with respect to the Quality Assurance/ Quality Control functions. Each project illustrates he assumption of different role by the Utility. On all projects, however, the Utility, to varying degrees, appears to be directly involved in the Third Level Auditing phase as well as the Second Level Surveillance and First Level Quality Control and Inspection phases. On one of the projects in this group, for instance, the Utility has chosen to be in direct charge of all of the Quality Assurance/Quality Control activities on the project. This has in fact been accomplished without utilizing many permanent Utility employees.

It appears that there is less overlap of quality related activities on the projects in this group. This is probably due to the fact that the Utility has been the prime mover in assuring that each party is involved in only a portion of the total spectrum of quality related activities. This is illustrated by the fact that in all cases, the Utility QA group is the one

which is involved in the majority of the formal preplanned Audit activity. Also, on only one of the projects was the Utility QA group also heavily involved in a Surveillance role.

An important point was made with regard to the Work Package approach which was implemented on one of the projects in the group. It was felt that if the concrete work were divided among three independent contractors, it may be to the Utility's benefit to develop a standardized set of construction procedures, instructions, etc., which would apply to all of these contractors. The task of reviewing a vast number of procedures and tracking the changes to them could perhaps lead to problems which could be avoided if the Utility adopted a standardization approach.

OWNER MODE

Only one project in the research study is being constructed under the Owner Mode. Several unique organizational solutions to the Appendix B Independence criterionfor the Quality Assurance and Quality Control groups occur on this project. There appears for instance to be very little overlap of quality related activities. This is understandable, since only one party, the Utility, is involved. It seems that as more organizations become involved, the need for increased Auditing and Surveillance also arises. It is certainly not feasible for every Utility to adopt the role of the Utility in this group. Some of the practices, however, deserve serious consideration. There does appear to be a strong attempt to leave the prime responsibility for quality in the hands of the Construction group, a place where it traditionally has existed in the construction industry. The Quality Control group has clearly been placed in the role of verifying that the required quality has been achieved through inspection and testing.

Note

The interested reader is encouraged to examine each of the individual Case Studies found in the Appendix of this report in order to obtain additional information about the projects.

List of References

3.1 "Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants - L.W.R. Edition," U.S. Nuclear Regulatory Commission, Washington, D.C.

3.2 "Quality Assurance Program Requirements for Nuclear Power Plants, ANSI N45.2," American National Standards Institute, New York, 1971.

3.3 "Supplementary Quality Assurance Requirements for Installation, Inspection and Testing of Structural Concrete and Structural Steel During the Construction Phase of Nuclear Power Plants, ANSI N45.2.5," American National Standards Institute, New York, 1974.

3.4 Muntzing, L.M., "Partners in Nuclear Power," Quality Progress, Vol. 3 , No. 11, November 1975, pp. 18-20.

3.5 Rusche, B.C., "A Balanced Program--Where Does the Emphasis Belong?", Proceedings: ASQC Third Annual Conference in Nuclear Power, San Francisco, October 1976.

3.6 "Quality Assurance Terms and Definitions, ANSI N45.2.10-1973", The American Society of Mechanical Engineers, New York, 1974.

3.7 Dellon, R.E., "How to Specify and Translate Product and Service Requirements: Project Communication or Lack of It," Proceedings of Third Annual National Conference on Nuclear Power, ASQC, San Francisco, California, Oct. 1976.

3.8 Rabenold, C.F., "The Green Book: Quality Assurance and the Construction of Nuclear Power Plants," AIF Conference on Nuclear Quality Assurance, Dallas, Texas, April 1975.

3.9 Rice, H.E., "How to Prepare an Acceptance Nuclear QA Program Implementing an Accepted Quality Assurance Program," Proceedings of Third Annual National Conference on Nuclear Power, ASQC, San Francisco, Calif., Oct. 1976.

CHAPTER 4

ANALYSIS OF 10CFR PART 50 APPENDIX B

CRITERIA III, VI, XV, XVI, AND XVIII

This chapter is devoted to an analysis of the implementation of the following Appendix B Criteria: (1) Criterion III--Design Control, (2) Criterion VI--Document Control, (3) Criterion XV--Nonconforming Materials, Parts or Components, (4) Criterion XVI--Corrective Action, and (5) Criterion XVIII--Audits, on the nine nuclear power plant construction projects in the research study. A Case Study for each of these nine projects is presented in Appendix A of this report. Chapters 3 and 4 together provide a comparative analysis of the organizational and managerial aspects of the Quality Assurance programs being implemented on these projects. The remaining chapters of the report will deal with the Quality Assurance aspects of Structural Concrete on these same projects from a technical viewpoint.

CRITERIA III AND VI: DESIGN CONTROL, DOCUMENT CONTROL

This section of the chapter will discuss the implementation of Design Control and Document Control from a somewhat broader perspective than is provided by the text of the actual Appendix B Criteria statements. The discussion will focus on the following issues:

I. Introduction: Regulatory Guidelines

II. Review of Project Specifications

III. The Use of General Construction Codes and Standards

IV. Incorporation of Codes and Standards Into Specifications

V. Quantification of Specification Requirements

VI. Engineering Changes

VII. The Impact of Engineering Changes

An attempt is made, whenever possible, to indicate the influence of the Utility, the Engineer, and the Constructor on each of these issues.

I. Introduction: Regulatory Guidelines

A brief overview of the regulatory guidelines related to Criterion III and Criterion VI is presented below to indicate the framework within which the procedures related to Design Control and Document Control were developed.

A. Criterion III: Design Control

1. Appendix B

a. Translation of Design Requirements into Design Documents. Criteria III states:

> "Measures shall be established to assure that applicable regulatory requirements and the design basis, as defined in Section 50.2 and as specified in the license application, for those structures, systems, and components to which this appendix applies are correctly translated into specifications, drawings, procedures, and instructions."

b. Control of Deviations from Design Requirements and Quality Standards. With regard to the control of deviations, Criterion III states: "These measures shall include provisions to assure that appropriate quality standards are specified and included in design documents and that deviations from such standards are controlled."

c. Control of Design Changes. For those cases where a design must be changed, the following note is made in Criterion III:

> "Design changes, including field changes, shall be subject to design control measures commensurate with those applied to the original design and be approved by the organization that performed the original design unless the applicant designates another responsible organization."

2. Standard Format Content of SAR

This document essentially presents a repetition of the above information.

3. ANSI N45.2

a. Translation of Design Requirements into Design Documents. It is noted in ANSI N45.2 that:

> "Measures shall be established and documented to assure that the applicable specified design requirements, such as design bases, regulatory requirements, codes, and standards are correctly translated into specifications, drawings, procedures, or instructions."

b. Control of Deviations from Design Requirements and Quality Standards. ANSI N45.2 states:

> "Changes or deviations from specified design requirements or quality standards shall be identified, documented, and controlled. Records of implementation of these design control measures shall be available for review."

c. Control of Design Changes. ANSI N45.2 states:

> "Design changes, including field changes, shall be governed by design control measures commensurate with those applied to the original design. It is the intent of this standard that design changes be reviewed and approved by the organizations that performed the original design, review, and approval. In the event that it is not practical for the original organizations to perform the required review or approval,

other responsible design organizations may be designated, provided the designated organizations have access to pertinent background information, have demonstrated competence in the specific design area of interest, and have adequate understanding of the requirements and intent of the original design."

B. Criterion VI: Document Control

1. Appendix B

a. Review, Approval and Release of Documents. Criterion VI states:

"Measures shall be established to control the issuance of documents, such as instructions, procedures, and drawings, including changes thereto, which prescribe all activities affecting quality. These measures shall assure that documents, including changes, are reviewed for adequacy and approved for release by authorized personnel and are distributed to and used at the location where the prescribed activity is performed."

b. Change Control. With regard to the control of changes to the documents, Criterion VI states:

"Changes to documents shall be reviewed and approved by the same organizations that performed the original review and approval unless the applicant designates another responsible organization."

2. Standard Format Content of SAR. It is noted that the PSAR should describe those measures established to assure that the following are considered:

a. Adequacy of Documents.

"Documents are reviewed for adequacy (i.e., information is clearly and accurately stated) and are approved by authorized personnel for issuance and use at locations where the prescribed activity will be performed before the activity is started."

b. Obsolete Documents.

"Means such as use of updated master document lists exist to assure that obsolete or superseded documents are replaced in a timely manner by updated applicable document revisions."

c. Change Control

"Document changes are reviewed and approved by the same organizations that performed the original review and approval unless delegated by the originating organization to another responsible organization."

3. ANSI N45.2

a. Document Control Responsibility. ANSI N45.2 notes:

> "Those participating in an activity shall be made aware of and use proper and current instructions, procedures, drawings, and engineering requirements for performing the activity. Participating organizations shall have procedures for control of the documents and changes thereto to preclude the possibility of use of outdated or inappropriate documents."

II. Review of Project Specifications

The first aspect of Criteria III and VI which will be discussed is the extent to which the project specifications developed by the Engineer are reviewed, with particular attention focused on the role of QA/QC in the review process.

1. Extent of Specification Review. It was found that on most of the projects in the research study, the technical specifications were subjected to a formal review process.

On Project B, for instance, the AE Firm submitted a preliminary draft for review to the Utility B(SC), the C.M. Firm, and other affected organizations. The specifications were given an extensive review by the Engineering, Construction, Quality Assurance/Quality Control groups within these firms. Comments related to the specifications were returned within 18 working days after they were received. The AE Firm was responsible for the resolution of the comments (by incorporating them if agreement was immediate, by resolving the differences with the originator of the comments, or by indicating that the comments would not be incorporated). The AE Firm was required to issue the final specification within 15 days after receipt of the comment letters.

An extensive review of the technical concrete specifications was also made by Utility H and the CM Firm on Project H. Within Utility H, for instance, comments were received from the "Responsible Engineering Department", the

"Concerned Departments" and the "Quality Assurance Department".

The specific review areas which are typically examined can be illustrated by the following objectives listed in Utility C's "Document Review Instructions" which appear in the Quality Assurance Manual for Project C:

a. To ensure that necessary Quality Control, test, and inspection requirements are included.

b. To ensure that pertinent codes, standards, and seismic criteria are clearly invoked.

c. To ensure that various PSAR commitments are included.

d. To ensure that necessary Quality Assurance requirements have been invoked.

An insight into the type of review that can be provided by a Constructor's QA group is indicated by Rice (1, pg. A4.4), who noted:

> "We make it a practice, and it is a procedural requirement for all technical documents to be reviewed by QA Engineering. This QA Review determines the actual level of QA effort required such as manpower, facilities and equipment needed to assure that inspections and test can and will be accomplished at the proper time and place.
>
> This document review provides and assures that:
> --Inspection and test acceptance, tolerance and limits are established.
> --Quality classification of items and materials are properly established.
> --A list of the applicable codes and standards for the work to be performed are known and obtained for the project.
> --Inspection and test equipment required is procured and calibrated.
> --In-process inspection and test methods of instruction are formulated.
>
> Any absence or misapplication of codes, standards or tolerances noted during this QA activity are documented and request for additional information or clarification is processed back to the responsible design group. It constantly amazes me, from our reviews of approved for construction documents, how many misapplications and how frequently no reference is made to the appropriate codes, standards, and supporting specifications or drawings."

It was found in the research study that the extent of the review varied on each project, being partially dependent on the technical resources of the Utility involved. On Project H, as noted above, there was an extensive review of the technical content of the concrete specifications. The number of changes

which were made at the insistence of Utility H were considerable and included detailed items such as the preparation of construction joints, the use of curing compounds and their compatability with nuclear coatings, etc. A similar detailed review by the Utility occurred on Project D.

The above depth of review did not occur on Project E. On that project, for instance, (as noted in the Case Study of Project E which is located in Appendix A of the report) the concrete specification is identical to the one that is used on all of Utility E's projects. On Project G, there were also very few changes made to the EPC Firm's concrete specification as a result of direct comments of Utility G. This was probably due to the fact that Utility G has a very small Engineering and Construction staff.

The Role of QA/QC. The review of the specifications which is made by the QA/QC group of both the Utility and the Constructor appears to be of primary importance. This is particularly true if the role of QA/QC is viewed as one which attempts to prevent quality related problems from occurring as well as identifying those that have already occurred. The most important input which QA/QC can probably provide is one which indicates either: (1) The problems which they foresee with verification that a particular specification commitment is actually being implemented, or (2) The cost that will be required to perform the inspections which are indicated. Rice (1, pg. A4.4) a representative of a constructor, illustrates the latter point very well by indicating:

> "Another problem we find in technical documents is the requirement for unnecessary inspections and tests. Requiring inspection and test to be performed and documented that are not necessary or serve no useful purpose is, to say the least, costly. Let me give you an example of what I mean. A couple of years ago, we received approved specifications for clearing, grubbing, excavation, backfilling and compaction. Part of the excavation specification, for preventing erosion, required the use of hay bales. In the QA section of the specification, it required verification that the bales of hay did not deflect or break when they were lifted for placement. It also required that the placed bales be monitored for deterioration,

no accept/reject criteria or limits were provided. To make matters worse, we could not get anyone to consider removing these requirements from the specification, which we believed to be unnecessary and costly. To prove our point, we developed an Inspection and Test Instruction with our own accept/reject limits and a cost estimate of inspection man-hours and equipment required for verification. When project management was presented with the QA cost to perform these verifications, the requirements were removed from the specification without hesitation. This example is an extreme case, but not as rare as you might believe."

The above discussion has indicated that project specifications generally undergo a comprehensive review process before they are finally approved. This should indicate that quality related problems with the specifications at a later date are not always entirely the fault of the Engineer.

III. The Use of General Construction Codes and Standards

One of the areas of concern which was expressed on a number of projects was the use of specification references to concrete related industry codes and standards which were originally developed for "general construction" applications. It will be recalled from Chapter 2 that the two ACI codes specifically related to concrete applications on nuclear power plants, ACI 359 and ACI 349, were not issued until 1974 and 1976, respectively. It was also noted in Chapter 2 that both of these documents are design oriented with a lesser emphasis placed on construction aspects. It appears therefore that the typical specification writer obtains concrete guidance from ACI, ASTM, etc. publications which do not directly apply to the nuclear construction situation.

A number of the specific technical areas of concrete which have caused confusion and concern will be discussed in detail in Chapters 5 through 8. Some of these areas are:

1. Cold Weather Concreting Requirements
2. Definition, and Practices Related to, Mass Concrete
3. Formwork Tolerances
4. Clearance Requirements for Reinforcing Steel

5. Placement Practices Related to Reinforcing Steel Congestion, etc.

It was frequently noted that one of the reasons why construction problems in areas such as those cited above have not previously surfaced is because in the "general construction" industry, a "literal" interpretation of the requirements is often not made. It was felt that in many cases, the committees that originally wrote the documents (some of which are called "ACI Recommended Practices", etc.) never intended them to receive a "literal" interpretation, since a great deal of emphasis was placed on "Engineering Judgment". In the nuclear construction field, the use of "Engineering Judgment" often plays a secondary role to the QA/QC verification role which determines if the quality commitments which have been made are being "literally" implemented. Such a literal interpretation of an industry code or standard which has been referenced in the PSAR or a project specification (and hence "committed to") is usually made by Quality Assurance personnel when Audit plans are developed and by Quality Control personnel when Inspection Plans are written.

Difficulties usually arise when: (1) A requirement in the "general construction" codes and standards is not directly applicable to the nuclear construction situation, (2) A requirement in the code or standard is not clearly presented, or (3) There is a conflict between two concrete related codes, both of which are referenced in the specifications. A number of these instances will be cited later in the report. When such a case arises on a project, QA and QC personnel are often placed in an "interpretive" role. If this interpretation is unduly severe or is not made on the basis of sound construction experience, it can result in an unwarranted expenditure of both project time and project resources being devoted to inspection and testing.

This raises an extremely important point about the responsibility which the

Engineer (whether it be a separate AE Firm, a part of the EPC Firm organization, etc.) has with regard to the interpratation of the requirements in the types of "general construction" codes and standards noted above. The Engineer is probably in the best position to clearly define the applicability of all the pertinent requirements to the project.

As noted by Rice (1, pg.A4.5), who represents the constructor's viewpoint:

> "An item that would be very helpful to the constructor is to provide classification and identification on the drawings of those items which the Owner/Designer requires to be controlled, verified and documented. We have and can do this ourselves during materials, items and workpackage takeoffs for procurement, and construction, but I believe it should and can be done more effectively by those people who are involved in the design phase of a project. Leaving it to the constructor or manufacturer to determine which materials, items, structures and/or systems require applying all, or part of a referenced codes, standards and specifications, all too often results in too little or too much quality effort being applied during manufacturing and construction. Making reference to a general code, standard or specification which references other more specific standards, consumes a significant amount of time on our part. Surely during the design phase, someone has had to research and determine the appropriate section and paragraph of a code or standard applicable to the item. If so, provide us with the specific requirement, not just reference the general top document. Consistently defining the specific requirements you need, along with the accept/reject criteria and tolerances on the technical working documents would expedite our work and assure obtaining the required quality more effectively."

If this assumption about the Engineer's role with regard to interpretation is valid, then the services which the Engineer currently provides in the quality area on most projects should probably be expanded during the period when the project specifications are being developed. Such an increase of effort could almost be viewed as a reallocation rather than an increase of effort. This is true because on most projects, whenever a disagreement of viewpoint occurs during the construction phase between the QA/QC and the Construction groups (i.e., a Nonconformance report, etc. is written) the Engineer is usually the one that is finally placed in the interpretive role. The Engineer's involvement during the construction phase will probably be reduced if the interpretation role is effectively performed when the project

specifications are written.

It would probably be extremely beneficial to the nuclear power industry to utilize the data presented in Chapters 5 to 9 as a starting point toward the identification of those sections of the current "general construction" codes and standards which require additional interpretation or revision by the concrete industry. Concrete codes and standards more directly related to the nuclear construction situation, which might result from such a reassessment, would probably greatly assist the Engineer in fulfilling his interpretive role. It should be recognized however that new and different circumstances which require additional interpretation will constantly arise as the state of the art of concrete construction develops.

IV. Incorporation of Codes and Standards Into Specifications

A review of the projects in the research study indicates that a number of approaches have been taken with regard to the incorporation of the applicable industry codes and standards into the concrete specifications. The ramifications of these different approaches are discussed below.

1. Blanket Reference Approach. One approach appears to include minimum of specific detail about each particular aspect of concrete (i.e., formwork, reinforcing steel, etc.) in the specification because a blanket reference is made to the industry code or standard which applies to the topic. This approach is efficient from the Engineer's viewpoint since it minimizes the length and complexity of the project specification and also possibly eliminates the need for the Engineer to make a critical analysis of every section of the referenced code or standard. It also possibly reduces the number of revisions to the specification because specific construction practices can be changed without changing the specification.

One of the biggest problems with this approach is that it results in the incorporation of parts of the code or standard which may not necessarily be

applicable to the project under consideration. QA and QC's role is to assure that the commitments which are made are also implemented. They therefore quite naturally refer back to these reference documents when they prepare their QA Audits and QC Inspection Plans. Problems have developed on a number of projects because: (1) Certain parts of a particular code were "never intended" to be applied, (2) A conflict existed between two codes that were both referenced in a blanket fashion, etc. As Tuthill (2, pg. 672) notes:

> "Another shortcut that has often proved troublesome is to say that all aspects of the work shall be done in accordance with pertinent (or numbered) ACI Codes and recommended practices. Only the part required should be carefully included. It is found that some inspectors can be literal to a degree the recommending committee never intended. For instance, where a slump of 2 in. ± 1 in. was recommended to indicate a practical range of slump for massive concrete, overzealous inspections rejected the better, drier concrete with a slump less than 1 in., even when with a little attention it could often just as well have been used."

2. Selective Reference Approach. Another approach involves a selective incorporation of direct quotations (or expanded versions thereof) from the parts of the codes and standards which are felt to be applicable to the project under consideration. This approach requires a great deal more effort on the part of the Engineer, but provides a clearer guidance to construction as well as QA and QC personnel when they prepare their procedures. The specification in effect acts as their "filter" between the industry codes and standards and the procedures which they will use as guides.

This type of an approach sometimes results in a rather lengthy concrete specification, since it really represents a repetition of the various parts of many codes and standards. A larger number of revisions can probably be anticipated with this approach, since every change to construction practices must be documented with a change to the related parts of the specification.

3. Blanket Reference Approach With Exceptions. The third approach involves the blanket adoption of a particular code or standard with a related

presentation of the exceptions which have been taken to specific parts of that code or specification.

4. Role of Engineering. The Engineer plays a crucial role with regard to the QA/QC related problems which will arise during the construction phase. If he has made an adequate effort to anticipate where the quality-related problems of interpretation and application will occur and has provided appropriate guidance in these areas, then the field problems will be minimized. Such an attitude would probably result in the rejection of the "Blanket Reference Approach" cited above, unless a careful examination of the code or standard had first been made.

Such attention to detail on the part of the Engineer might also result in a placement-by-placement presentation of such information as formwork tolerances, (if they can be "looser" or must be "tighter" than the ACI tolerances), definition of mass concrete, designation of placing temperature, etc. Such a presentation could perhaps best be made directly on the engineering drawings. A thorough knowledge of construction practices is required, but it must be recognized that if the Engineer does not assume the "interpretive" responsibility, then it will be assumed by the field personnel in Construction or QA/QC, who quite often do not have the same information available to them that is available to the Engineer.

Such an approach, if it can be achieved without presenting cluttered or confusing drawings, would more directly place the responsibility for quality with the Construction Engineer who interprets the Engineer's drawings. QA/QC is then correctly placed in the role of verifier rather than in the role of interpreter.

5. Level of Detail. A final point which should be made relates to the fact that the level of detail of technical information which is provided in the specifications probably directly influences the level of detail which will

later be found in the QA/QC procedures. If, for example, a statement is made in the specification that "the concrete forms shall conform accurately to the dimensions on the drawings," there is a possibility that the QC inspection effort may not directly incorporate the tolerance requirements found in ACI 347 (a document which is applicable to all types of construction). If, however, the table for formwork tolerances in ACI 347 is included directly as a part of the project concrete specification, then it will become the guidance by which QA/QC will evaluate every formwork installation. Such a universal application of the formwork tolerances would result in an extensive expenditure of both labor as well as time in order to achieve a level of quality which might not always be necessary. It might therefore be cost effective for the Engineer to designate (perhaps directly on the drawings) the critical placements for which these formwork tolerances apply. For less critical placements, the allowable deviation from the tolerance table in ACI 347 could also be noted.

V. Quantification of Specification Requirements

A number of the examples from projects in the research study which are cited in Chapters 5 to 9 will indicate the emphasis which is sometimes placed on the quantification of acceptance criteria related to all aspects of the concrete operation. This is probably due in part to the QA/QC generated need for the inclusion of explicit acceptance criteria in either the project specifications or the industry codes and standards which they reference. This is understandable from their viewpoint since there is difficulty in verifying that "excessive" segregation of aggregates does not exist, that reinforcing rods are not coated with an "excessive" amount of rust or mill scale, etc.

Unnecessary quantification of specification requirements, however, has caused problems on some projects. It is worthwhile to evaluate this emphasis with regard to concrete before the specific projects are discussed later in this report.

1. The Impact of Quantification. As noted by Tuthill, (2, pg. 677):

> "On some of our most important work, a numbers game is played in the name of quality control and quality assurance. This fetish of numbers to put in the records of QC and QA, and the ensuing wasteful connotation created when one falls short of some largely arbitrary although specified value, tends seriously to detract from and to treat too lightly the daily reports and the importance of ongoing, day-to-day, competent field inspection and concrete engineering. This uneven coverage and emphasis is highly inconsistent with the true objective of proper QC and QA."

Tuthill cites several examples to illustrate his point. One of these (4, pg. 3) concerned a large containment wall placement which "hung in the balance" awaiting the outcome of a test of the percent of "3/4 inch rock" passing the 3/8 inch screen. A previous test had indicated that 18 instead of the 20 percent minimum required by ASTM C33 had passed. He notes:

> "Happily, in that case it passed and the lost time and expense was averted. But it was a completely ridiculous crisis because it made no difference whatsoever in the concrete properties if it had not been quite 20 percent. But QC and QA had no alternative; they had to go by the number stipulated; no judgment or common sense allowed."

Another example cited by Tuthill (4, pg. 2) concerned a concrete specification which stated that the average slump could not exceed a certain "working limit". He noted that the nuclear inspectors quickly demonstrated the danger of this approach by encouraging lower than preferable slump at the start so as to have low numbers in their books to average with any higher ones that might appear later. This, of course, is the worst way to start a concrete placement, but the practice made sure the right average number not exceeding the working limit would appear in the book.

As Tuthill notes (4, pg. 3):

> "Perhaps still worse is the use of some number in a referenced ACI, ASTM or other standard. These standards and by implication the numbers in them should never be used as part of a code or specification by an unqualified reference. Whatever is needed in the job specification should be so stated like any other requirement. This applies particularly where there should be no number anyway, such as a distance limit on lateral movement, or a free or unconfined fall of the concrete into place, when all that is needed is to say that these shall be limited and controlled as necessary to avoid separation. But I have seen nuclear concrete operations hung up on these items."

2. Non-Quantifiable Characteristics. Tuthill (2, pg. 677) also notes that a "number criteria" like psi of strength, percent of air, inches of slump, etc. is not available to measure all of the important aspects of concrete construction performance. He feels that the daily reports of competent and diligent inspectors organized to determine that these aspects are as they should be is also needed as a record of quality assurance. Some of the criteria which he feels are in this category are:

a. Quality of cleanup and construction joints.

b. Correct amount and location of reinforcement

c. Sufficiency of vibration, particularly in congested areas away from forms, etc.

He feels that engineers and architects take a chance with their reputation when they don't establish a reliable confirmation of these basic but un-number-valued aspects of quality. As he noted (4, pg. 10):

> "Is there not an implied lesser importance of inspection of construction performance where no numbers can be recorded to show it? May not emphasis on proper construction performance become insufficient because in its nature it has no assignable numbers by which to judge it? Certainly not--to both questions. Common sense assures that quality of the completed structure depends on all the construction operations being performed up to standards fully as high as those indicated by the numbers for the materials used. Despite all the noisy, troublesome, and expensive attention to and confirmations about the numbers, we must not let this squeaky wheel beg more than its share of inspection insistence on good workmanship."

The above discussion highlights the fact that both the quantifiable as well as the non-quantifiable aspects of the total concrete process must be properly considered by the Engineer, Constructor and QA/QC.

VI. Engineering Changes

One of the basic facts of life in the construction industry is that situations, unanticipated by the Engineer, will occur which require changes to certain aspects of the engineering and construction approach which was originally

proposed. On "general construction" projects, these changes are often made informally by Construction Engineers based on "engineering judgment" or by Design Engineers who issue either informal (i.e., verbal) or formal directives covering the changes.

On a nuclear power plant construction project, the informal alternatives do not exist, well-defined procedures and documentation requirements govern the "Engineering Change" process. The system for controlling Engineering Changes which is implemented on a project can have a great impact on both project schedule and cost. A poorly designed system for instance can be detrimental to the smooth flow of progress on a project.

Rice (1, pg. A4.5) points this out by noting;

> "Finding a design error, omission or interface problem during construction which requires processing a Design Change is a real construction bottleneck. When a design problem is determined by the constructor, a Field Design Change Request is processed for the designers approval and/or resolution. Inflexible field design change procedures can, and often do, cause several days delay in construction, waiting for the official change documents. The Owner, Designer, Constructor design change interface procedure can and should acknowledge the fact that design errors and problems will occur and will not be detected until construction is in progress. Provisions should be made for intermediate methods which allows construction to progress in a controlled manner, prior to receipt of the official change document."

It was found that all of the projects in the research study had some sort of a system for implementing Engineering Changes to the project specifications, engineering drawings, etc. A few of these will be presented in this section in order to indicate the basic elements of such a system. This section will be concluded with a brief explanation of some of the possible reasons why so many Engineering Changes occur on nuclear construction projects.

1. Project F. It will be recalled from Chapter 3 that on Project F, the Utility was directly involved with both the QA and QC functions. The AE/CM Firm served in the capacity of both the Engineer and the Construction Manager but was not directly involved in the QA and QC functions at the

project site.

On Project F, the three authorized methods which are used to change the project specifications and drawings are:

a. Formal revision of a drawing or specification or the issuance of a formal addendum to a specification.

b. Authorization for a change by issuance from the Engineer of an Engineering and Design Coordination Report (i.e., E & DCR)

c. An approved disposition to a Nonconformity and Dispositon Report (i.e., N & DR)

As noted in the Concrete Specification:

> "No change to this specification shall be binding on any party until an addendum to the specification has been issued, or until a written authorization is issued by the Engineers. No change to this specification shall be authorized by the Purchaser's inspector until he has in his possession, properly approved, and Engineering and Design Coordination Report or a Nonconformance and Disposition Report, or a statement in writing from the engineers that one of these reports has been approved as required by the Engineers' standard procedure."

An E & DCR is used by the AE/CM Firm to make immediate changes to the project specifications. It is initiated by the AE/CM Firm whenever they believe a change is necessary. This can result because of an "Engineering Design Change" or as a result of conditions encountered in the field during construction which are brought to their attention through a Request for Information (i.e., RI) from the Concrete Constructor. An RI is usually prepared when the constructor reaches an impasse, i.e., he is unable to proceed as indicated on the engineering drawings or in the project specifications. An E & DCR provides a remedy when changes can still be made (i.e., the concrete has not yet been placed).

Problems have, however, occurred with the E & DCR approach. The quantity of E & DCR's has become so great on Project F (i.e., a total of 85 have, for instance, been issued against the "Concrete Mixing and Delivery" specification)

that tracking them has become a difficult task. Reference by anyone to the specification is extremely difficult because of the great number of changes. The danger of using obsolete specifications has therefore increased. Utility F has attempted to remedy the situation by requiring the AE/CM Firm to make formal specification and drawing changes within five days after a particular E & DCR has been issued.

If a non-conformance or deviation is encountered after the fact during construction (i.e., after the concrete has been placed) the Utility F's QC inspector issues an N & DR to the AE/CM Firm for resolution. Sometimes the resolution is for "Use As Is" which will require a change in the specifications or drawings. However, not all resolutions of N & DR's, whether "Use as Is" or "Repair" become E & DCR changes to the specification. In that case, the AE/CM Firm will use the E & DCR to permit use and thus conform to the revised drawings and specifications when they deem a change appropriate.

2. Project H. Project H is another project which is being constructed under the CM Mode with an active involvement of Utility H in the entire construction phase. On Project H, one of the methods for implementing Engineering Changes is also the formal revision process (which includes the issuance of addenda) to specifications and drawings. In addition, there are three other methods of "Configuration Control" which may be used. These are (a) Field Questions, (b) Field Variance Authorizations, and (c) Engineering Change Notices.

a. Field Questions (i.e., FQ's) are a method of documenting all questions presented to the Utility H site organization. The FQ's may interpret, but may not alter safety-related drawings and specifications. FQ's may be originated by contractors as well as Utility H QA and QC personnel. The Utility H Site Technical Engineer is responsible for providing the evaluation of FQ's and coordinating responses with the responsible AE Firm Design Engineer.

b. Field Variance Authorizations (i.e., FVA's) are initiated to permit a specific waiver of Engineering requirements for Safety-Related work. FVA's are a design change and are not necessarily incorporated into revisions of specifications or drawings. Each Safety-Related FVA initiated on Project H requires Utility H's QA group to review, accept, and/or comment on the request. Additionally, a request for a Safety Analysis Report Deviation (SARD) may be initiated by the reviewer. The reviewer will identify the need for additional procedures, and specify any additional inspections which are necessary. Utility H's QA group may provide verification activities to assure that the contractor has complied with the FVA by requesting a special Utility H QC inspection or performing a Utility H QA verification by initiating a process audit. Utility H's QA group is responsible for the logging, filing, and maintaining of FVA's. Quality Engineering provides Quality Trend Analysis of FVA requests.

c. Engineering Change Notices (i.e., ECN's) are initiated to authorize changes affecting safety-related specifications or drawings which were approved and released to Contractors or Suppliers for construction or fabrication. Utility H's QA group logs, maintains and files ECN's. Utility H's Quality Engineering group verifies implementation of the ECN's providing Utility H has approved the change and the contractor has received appropriate notification. Contractor's Contract Administrators receive advance notification from the AE Firm's QA group that an ECN is being prepared, and this allows contractors to prepare revisions to their Programs/Procedures accordingly so as to minimize the time between ECN approval and contractor procedure revision preparation, submittal and approval.

3. Project C. Project C is being constructed under an EPC Mode. The EPC Firm's Engineering Change procedure is defined in a Field Inspection

Procedure entitled "Design Document Control". This procedure notes that interim revisions to approved engineering drawings are made by the Project Engineering group by means of a Design Change Notice (i.e., DCN) and are requested by the field by means of a Nonconformance Report (i.e., NCR) or a Field Change Request (i.e., FCR).

The NCR provides the EPC Firm's Field Engineering group with a means of reporting to the home office Project Engineering group the physical existence of a condition, an item or work operation not in agreement with the engineering drawings. The FCR provides the EPC Firm's Field Engineering group with a means of reporting to the home office Project Engineering group discrepancies in project drawings, such as interferences or changes in arrangement required by job conditions. Project drawings may be revised in the field, incorporating DCN's and approved FCR's. The revisions are logged and issued under a Field Revision Number when authorized by the Project Superintendent.

Project specifications either undergo a formal revision or are changed by the issuance of an addendum. Interim changes often result because of an FCR (which provides a means which the Field Engineering group can use to report to the home office Project Engineering group any discrepancies in the project specifications.

4. Reasons for Engineering Changes. The above examples have indicated some of the approaches which have been taken with regard to Engineering Changes. One of the concerns expressed on a number of the projects in the research study involved the large number of revisions that were made to the project specifications over the life of a project. This fact is illustrated by the data regarding specification revisions which is presented in several of the Case Studies located in Appendix A of this report. The magnitude as well as some of the causes for design changes is noted by Jackson (5, pg.17) as follows:

"On plants where the formal quality assurance approach is used, it is not uncommon to have more than 2000 design changes. Certainly these changes are minor and may be attributed to unavoidable causes, such as modifications due to material unavailability or construction blockouts to accomodate an equipment delay. However, a significant number of changes result from unrealistic design requirements which have been imposed for years but now for the first time are being enforced. Only through a program of formal quality assurance that "involves" the design engineer in the disposition of field problems will unwarranted design requirements be eliminated in future construction."

A certain number of revisions to engineering documents, as noted earlier, are to be expected on any construction project. The problems related to Engineering changes on nuclear projects are more acute, however, because of the Appendix B "Document Control" criterion which specifies that assurance must be provided that all obsolete and superseded documents are being replaced in a timely manner.

One of the possible reasons for the large number of revisions in some project specifications, as noted above by Jackson, may be due to the excessively tight and sometimes unobtainable inspection and test tolerances which appear in the specifications. Changes are often required after a trend analysis of nonconformances generated in the field indicates that a problem exists. As noted by Rice (1, pg. A4.5):

"A continuous problem is the requirement for excessively tight and sometimes unobtainable, inspection and test tolerances in construction drawings. It makes us wonder, when from our review we have questioned the need for a tight tolerance and are told it is necessary, only to find out, after the craftsmen have spent hundreds of man hours trying to meet a design tolerance without success, that, all of a sudden, 4 or 5 times the original specified tolerance is acceptable. This apparent lack of understanding of what is really necessary and obtainable in the field by designers, specification writers, and those who review and approve these documents, has a significant cost and schedule impact on construction and in many cases is actually detrimental to the quality of the end product."

Another one of the reasons for a large number of revisions which has been expressed is that the experiences gained on one project are never transmitted from the field back to the Engineering group so that they may be utilized on the

next project. There appears to be a need to strengthen the "feedback loop" between Construction and Engineering on many projects. As noted by Dellon (6, pg. B4.4):

> "Let me address the area of feedback, the fundamental element of learning from experience. Here again the elusive reputation plagues the AE-type firms. Due to the transient nature of the project teams, both home office and site, and the lack of sophisticated data gathering and trend techniques, the positive and negative experiences derived from a given project are not being effectively incorporated into the AE's overall capabilities. I hasten to add that the AE's, of course, are not the only organizational element of our industry subject to this particular dilemma.
>
> Interface, cross fertilization, and feedback, the very fabric of a company's ability to improve from one project to the next, or even within a project, often takes a back seat to fire drills, management by crisis, and political in-fighting. All responsible managers need to personally commit to opposing these dysfunctional effective management abnormalities."

This problem of lack of feedback is particularly acute if there are separate AE and Constructor Firms involved on a project. Even within an EPC Firm, however, it may be difficult to benefit from field experiences because these experiences must somehow be transmitted between different "Project" organizations who are often performing services for different Utilities.

A scenario which hopefully does not occur very often is one in which the Engineering Firm begins with a "Standard Specification" for a technical area such as concrete. As problems arise on the project to which it applies (i.e., perhaps via a series of nonconformance reports, etc.) the Engineering Firm issues revisions to the specification which are more representative of the realities on the project. After a series of these revisions, the project specification finally evolves into a workable document. The problem that occurs, however, particularly if an active feedback loop does not exist, is that on the next project, the Engineering Firm goes back to its original "Standard Specification" and starts the process all over again.

Tuthill adds another perspective to the above situation when he notes (2, pg. 671):

> "Obviously there is much specification language that can be used word for word as it was used for similar work. No apology is needed for this; it is senseless to start with a blank sheet of paper. However, such repetition will lead to trouble and inadequacies unless this text is carefully edited and supplemented to fit exactly the requirements for the given job. These are never exactly the same, even for parts of the same project. This is the reason that so-called standard specifications so often contain inadequate or unsuitable requirements, despite the effort to correct them with the specifics in cumbersome special requirements and supplemental notices."

This section has presented some of the aspects related to Engineering Changes. Examples from several projects have been provided and some of the possible reasons why so many revisions to design documents occur have been indicated. The next section of this chapter will discuss the impacts that Engineering Changes can have on a project.

VII. The Impact of Engineering Changes

As noted in the previous section, there are typically a large number of changes to the engineering documents on nuclear construction projects. The impact of these changes is felt in many ways. A few of these will be discussed below.

1. Incorporation of Latest Revision. One of the most significant impacts of a change to a project specification involves the need for "Document Control", i.e., the assurance that the latest revision is being used by all parties involved. The problem does not end, however, with the recall of all outdated specifications following the issuance of a revision. It also affects all of the Construction, Quality Assurance and Quality Control procedures which reference the specification that is being revised. All of these must be reviewed and if necessary altered to reflect the new changes. This task is complex enough in the EPC Mode of Management; it becomes even more complex

in a C.M. Mode situation such as that found on Project H where there are a number of concrete constructors, each of whom has their own set of procedures and documents.

An example from one of the projects in the research study (it was not Project H) will illustrate the point. Construction Procedures and Quality Control Inspection Procedures on the project are the documents which provide a planned and orderly sequence for the assembly, installation, test and inspection operations necessary to assure incorporation and acceptance of the applicable Engineering requirements. They are controlled at the point of work operation and must be maintained up to date with the latest revisions recognized. Completed Construction and Inspection reports are reviewed by Quality Control personnel to assure that drawing and specification revisions are the latest and that applicable Engineering Changes are accounted for.

To verify compliance with the above requirements, Quality Assurance personnel conducted a review of 11 safety related Construction and Inspection Reports which had been signed off as complete and filed in the QC vault. These reports, which documented work performed over a period of 8 months were compared to Document Control records, engineering drawings and project specifications to determine if the latest revisions and Engineering Changes had been accounted for. The following summarizes the discrepencies that were found:

a Of 204 drawings listed, 36 had an incorrect revision. These included three drawings which had not been issued and seven which had no revision listed, were scratched out with no explanation or were simply marked "Latest Revision".

b. The Construction and Inspection Reports listed 11 notices for Engineering Changes against the 204 drawings. Document Control reflected 127 against those drawings.

c. Of 102 project specifications listed, 81 had incorrect revisions noted.

d. Four of the 41 Vendor drawings listed were of the incorrect revision.

e. Seven of the 48 Company Construction Standards were of the wrong revision.

A cursory review of non-safety related Construction and Inspection Reports indicated that similar problems existed.

The above situation lead to a major change in the Document Control procedures which were used on the project. These changes required an extensive re-education program to be implemented. It also resulted in an extensive review of the Construction and Inspection Reports over the period in question which indicated that "no construction deficiency which, were it to have remained uncorrected, could have affected adversely the safety of the nuclear power plant at any time throughout the expected lifetime of the plant."

The above example is cited to indicate a problem which affects, in one fashion or another, every project in the research study. It arises from the large number of Engineering Changes which take place as well as from the large number of procedures, instructions, etc. which are affected by these changes. A Utility that is in the early stages of development for a new nuclear project should become seriously involved in the design of the Document Control system to assure itself that a situation similar to the one described above cannot occur on its project.

2. Interface Between Engineering Changes and PSAR Commitments. A second impact of an Engineering Change on a nuclear construction project occurs because of the interface between the requirements in the engineering documents and the commitments which have been made in the PSAR. There must be compatibility between them. The Quality Assurance procedures usually specify the responsibilities for the review of design documents to assure that PSAR commitments have been met. This responsibility becomes more demanding when the need for Design Changes becomes apparent. A few examples will indicate the level

of detail which is required to insure that the compatibility requirement is met. On one of the projects in the research study, the following PSAR commitments were made:

a. "The following routine concrete control tests will be made on the concrete at the point of placing in the forms".

b. "Four full-size bars, of sufficient length to permit a bend test, will be selected at random from the largest size in the heat. The purpose of these specimens is to verify the capability of each heat".

c. ACI 318 was one of the codes listed in the PSAR which "established the standards of construction procedure."

Several reviews of the concrete specifications over a period of time during QA Audits indicated the following:

a. The specification indicated that routine concrete tests would be performed at the batch plant.

b. The specification only required one bend test for reinforcing bars.

c. A revision to the specification had reduced the air content requirements for concrete to the range from 3 to 6 percent for all sizes of coarse aggregate because project experience had indicated that higher air contents resulted in low compressive strengths at the 28 day cylinder break stage. A QA review of the pertinent paragraphs of ACI 318 (7) indicated that for concrete "subject to freezing temperatures while wet" air contents between 4 and 8 percent, for 3/4" aggregate, and 3 and 6 percent, for 1-1/2" aggregate should be maintained.

The above example illustrates several problems which also affect every project in the research study. The first is the difficulty involved with assuring full compatibility of the PSAR and the engineering documents, both

of which include an extensive amount of technical detail. One of the projects in the research study has approached this problem by developing a computerized License Commitment Tracking System which will insure that all PSAR commitments are met in the engineering documents. The enormity of this task can be appreciated by noting that it was estimated that approximately 8400 pages of text had to be included in the review search and that approximately 3000 identifiable commitments would be generated.

A second problem which is illustrated by the example above is that a blanket reference to an ACI Code in the PSAR reduces the flexibility which both the Engineering and Construction groups have to make validly based changes as conditions arise during the construction stage. In the example cited, the Utility chose to file a request with the NRC for an exception to this particular ACI 318 commitment so that the design change could be used.

This entire topic of the compatibility of the PSAR and the engineering documents should be given serious consideration by the entire industry as well as the NRC. It could have been quite possible in the above example for the Utility to refuse to file a PSAR change request with the NRC, perhaps for fear that it would bring other commitments in the PSAR under review. If that had occurred, then the Construction group would have been faced with an extensive set of field problems, not because there wasn't a good engineering solution available but because the bureaucratic "red tape" made it advisable to ignore the engineering solution. The basic question which can be asked in this regard is whether or not this type of a regulatory environment is always conducive to good engineering practice.

3. Waiver of Specification Requirements. The above impacts have considered the complications which result when an Engineering Change is made. Another aspect of the situation must also be considered. This occurs when an Engineering Change is not made, i.e., the organization responsible for the

Engineering function on a project decides to waive certain specification requirements on a case-by-case basis rather than make immediate changes to the engineering documents. This practice often avoids the basic issue of recognizing that either the specification requirement in question or the industry code and standard from which it was obtained are unrealistic for the nuclear power plant construction situation.

A case in point concerns the tolerances which are allowed on a particular project for the placement of large size reinforcing bars, particularly in tightly congested locations. If the concrete constructor anticipates difficulty in meeting the specification requirements for a particular placement, he will in essence request a waiver for that case. This appears to be more expeditious than attempting to promote a change in an industry code or standard. This practice in essence undermines the entire QA/QC philosophy which assumes that the commitments which are made in the design documents will always be met. As Dellon notes (6, pg. A4.6):

> "One significant improvement in the specifying process could be realized if we committed to not specifying that which can, should, or will be waived. We need to mean what we say and stick by it. As far as I am concerned, if a requirement is waived, it never should have been specified in the first place or else it never should have been waived for subsequent expediency."

A situation occurring on many projects which bears a close resemblance to the one explained above concerns the disposition of nonconformances. One of the options with regard to nonconformances which is usually available to Engineering is to "Accept As Is". On one project, a total of approximately 500 nonconconformance reports had been written by the QC group. A total of 56 of these had been written against the concrete construction for such infractions as: (1) Formwork tolerances exceeded, (2) Premature stripping of forms, (3) Excessive rust on reinforcing bars, (4) Insufficient concrete cover over reinforcing bars, etc. All of these were dispositioned "Accept As

Is" by Engineering.

On the same project, a total of 38 had been written against the concrete batch plant operation; of these 21 were associated with a fly ash problem which the project was experiencing and the remainder were associated with the gradation of the aggregates, primarily the percent of material passing the No. 200 sieve. All of these nonconformances were dispositioned "Accept As Is" after the 28 day concrete cylinder breaks indicated sufficient strength for the affected placements.

A question might very well be asked with regard to the net result of such a complex process of acceptance, particularly in light of the investment in human resources and documentation which was made. For the batch plant situation involving aggregate gradation for instance, it was clear that the really significant "acceptance test" for concrete was compressive strength, not gradation. Perhaps a re-evaluation of the specification requirements related to aggregate gradation should have been made.

This section has indicated some of the impacts which are placed on a project because of Engineering Changes. It is extremely important for all parties on future nuclear construction parties to critically examine and then conscientiously develop a Document Control System which will avoid some of the problems that were cited.

CRITERION XV: NONCONFORMING MATERIALS, PARTS AND COMPONENTS

Nonconformance Control is given extensive coverage in this section of Chapter 4 because it represents one of the facets of nuclear power plant construction which is dramatically different from what is observed on conventional construction projects. It is also a facet which is often referenced when mention is made of excessive documentation requirements or procedures

which tend to adversely affect the smooth progress of construction. The comparative analysis of Nonconformance Control practices presented in this section should provide some valuable insight for those within the industry who are concerned about the impact of Criterion XV.

Background material which establishes the ground rules for Criterion XV will first be presented. The remainder of this section will provide examples of how Criterion XV is being implemented on some of the projects in the research study. The Nonconformance Control procedure which is used on Project A will first be presented as a typical example. The modifications to the Project A procedure which have been adopted on several of the other projects will then be presented.

I. Introduction: Regulatory Guidelines

A brief overview of the regulatory guidelines related to Criterion XV is presented below to indicate the framework within which the procedures related to Nonconforming Materials, Parts and Components were developed.

1. Appendix B

a. Control of Nonconforming Items, Processes and Activities. Criterion XV begins by indicating that "Measures shall be established to control materials, parts or components which do not conform to requirements in order to prevent their inadvertent use or installation."

b. Key Elements of Nonconformance Control. It is also indicated that the above measures shall include, as appropriate, procedures covering the following key elements: (1) Identification, (2) Documentation, (3) Segregation, (4) Disposition, and (5) Notification to affected parties. These key elements provide the basic framework for Nonconformance Control on most of the projects in the research study.

c. Disposition of Nonconforming Items. Criterion XV provides the following guidelines for disposition: "Nonconforming items shall be reviewed and accepted, rejected, repaired or reworked in accordance with documented procedure". It should be noted that the alternatives which are underlined present the basic options which are utilized on most of the projects in the research study.

2. Standard Format and Content of SAR. In addition to the above topics, it is also noted in the "Standard Format..." that:

a. The PSAR should describe measures that control further processing, delivery or installation pending proper disposition of the deficiency.

b. The PSAR should state whether periodic analyses of nonconformance reports are performed to show quality trends and whether such analyses are forwarded to management.

The latter statement has probably provided the impetus for formal "Trend Analysis" computations of the nonconformance data on a number of projects.

3. ANSI N45.2

ANSI N45.2 amplifies the requirements of the Appendix B Criterion XV as follows:

> "...The responsibility and authority for the disposition of nonconforming items shall be defined. Repaired and reworked items shall be reinspected in accordance with applicable procedures.
>
> Measures which control further processing, delivery, or installation of a nonconforming or defective item pending a decision on its disposition shall be established and maintained. Non conforming items may be disposed of by acceptance "as is," by scrapping or repairing the defective item, or by rework to complete or correct to a drawing or specification. Such measures shall provide assurance that the item is identified as nonconforming and controlled. The measures shall require documentation verifying the acceptability of nonconforming items which have the disposition of "repair" or "use as is". A description of the change, waiver, or deviation that has been accepted shall be documented to record the change and denote the as-built condition.

As a guideline, control of nonconforming items by tagging, marking, or other means of identification is acceptable where physical segregation is not practical, although physical segregation and marking are preferred."

4. Definition of Terms

A number of terms which are used quite frequently in the examples should be defined. These terms, as indicated in ANSI N45.2.10-1973, are:

a. Characteristic

"Any property or attribute of an item, process, or service that is distinct, describable, and measurable, as conforming or nonconforming to specified quality requirements. Quality characteristics are generally identified in specifications and drawings which describe the item, process, or service."

b. Defective Material--A material or component which has one or more characteristics that do not comply with specified requirements.

c. Deviation--A nonconformance or departure of a characteristic from specified requirements.

d. Nonconformance

"A deficiency in characteristic, documentation, or procedure which renders the quality of an item unacceptable or indeterminate. Examples of nonconformance include: physical defects, test failures, incorrect or inadequate documentation, or deviation from prescribed processing, inspection or test procedures."

e. Repair

"The process of restoring a nonconforming characteristic to a condition such that the capability of an item to function reliably and safely is unimpaired, even though that item still may not conform to the original requirement."

f. Rework

"The process by which a nonconforming item is made to conform to a prior specified requirement by completion, remachining, reassembling, or other corrective measures."

g. Use As Is

"A disposition which may be imposed for a nonconformance when it can be established that the discrepancy will result in no adverse conditions and that the item under consideration will continue to meet all engineering functional requirements including performance, maintainability, fit, and safety.

II. Project A Nonconformance Control Procedure of CM Firm

The responsibility for Nonconformance Control on Project A has been given to the CM Firm's Field Quality Control Group. It will be recalled from the Case Study for Project A (i.e., located in the Appendix to this report) that the CM Firm is also directly responsible for the concrete construction phase and that Utility A is providing its own Engineering services. The presentation below will be divided into the: (1) Identification, (2) Documentation, (3) Segregation, (4) Disposition, and (5) Notification phases outlined in Appendix B, Criterion XV.

1. Identification

   a. By site personnel--nonconformance is reported to the CM Firm's QC group who prepares a Deficiency Report (i.e., DR) of the type shown in Exhibit 4.1.

   b. During an Inspection or Surveillance--CM Firm's QC representative notifies appropriate Discipline Superintendent in charge of work. If nonconformance can be corrected immediately (i.e., within 3 days) in accordance with the original specified process, it is recorded on the inspection/surveillance report. If it: (1) can not be corrected immediately in accordance with the original specified process or (2) can not be corrected in accordance with the original specificied process, a DR is prepared by the CM Firm's QC group.

2. Documentation

   The CM Firm's QC group is responsible for the initiation of DR's. All DR's are numbered and a log is maintained by the QC group. A DR is kept "open" until the indicated disposition is completed and reinspected by QC (a list of open DR's is published monthly). The information on the DR describes the nonconformance, the required limits of acceptability, the

Exhibit 4.1.--Project A Deficiency Report

No. _____

PTN No. _____

QC No. _____

CHARGES				ITEM:	DWG. NO.
TO		AGAINST			
VENDOR		SPECIFICATIONS		VENDOR	P.O. NO.
CONST.		CONST. PROC.			
		O.C. PROC.		SYSTEM & CODE NO.	SPEC. NO.
		DRAWING		SERIAL NO.	J.O. No.
		OTHER			

DEFICIENCY DESCRIPTION: LOCATION:

DATE DISPOSITION REQUIRED BY: _____

Q.C. ENGINEER _____ DATE

DISPOSITION

DATE WORK TO BE COMPLETED BY: _____

NSSS REP. (RECOMMENDATION) CONSTRUCTION DATE EED SITE REP SPON. ENGR

ACTION:

CONST AREA REP DATE CONST. MGR. REP. DATE

DISPOSITION ACTION VERIFIED AND ITEM REINSPECTED

WORK PERFORMED AND ACCEPTABLE ☐

LETTER NO. _____

INSPECTION REPORT NO. _____

SURVEILLANCE REPORT NO. _____

documents which provide those acceptance requirements or criteria and other pertinent data.

3. Segregation Procedure

A "Hold" tag is placed on the nonconforming item. All work and activities on the item and work affecting or affected by the item is suspended until disposition has been determined, unless the work can be performed without compromising the rework, repair, test or retest that will be needed as a result of the approved DR disposition.

4. Disposition Procedure

a. The C.M. Firm QC group transmits the DR to the CM Firm Discipline Superintendent who is responsible for specifying the disposition. Copies are also sent to Utility A's Project, Construction, and Engineering groups, etc. When the disposition specified by the Discipline Superintendent can be accomplished utilizing standard repair procedures, Field Procedures, specifications, directives or drawings, the DR will be signed only by him. When the disposition specified by the Discipline Superintendent cannot be accomplished utilizing standard repair procedures, Field Procedures, specifications, directives or drawings, the DR will be transmitted to the Site Engineering Representative for his approval signature. The original DR will then be returned to the Discipline Superintendent.

b. The dispositioning action must fit into one of the following categories:

--Repair or Rework. Repair and rework activities must be performed and inspected in accordance with approved written procedures. If a procedure is not available, it must be prepared.

--Reject. Item must be removed from site.

--Accept As Is. This disposition must list the specific requirements for which relief is provided. Initiation of a specification or

drawing change must be indicated if a change is required.

c. After the disposition decision has been made, the DR is returned to the CM Firm QC group for approval. Corrective action can begin after QC distributes the approved DR and a copy is in the possession of the CM Firm supervisory personnel responsible for correcting the deficiency.

d. After the corrective action is completed, the CM Firm's Discipline Superintendent returns a signed copy of the DR to the CM Firm's QC group. The DR is "closed" after the originator of the DR within the QC group has verified that the activity has been accomplished per the approved disposition and affixed his signature to the DR.

5. Notification Procedure

The CM Firm's QC Superintendent must daily review all DR's submitted and provide status information to the Utility A Site Division Head of QA by 8:30 in the morning the next day. A telex of all DR's is foreworded daily to Utility A's: (1) Home Office Manager of Quality Assurance and (2) Home Office Project Manager. Significant deficiencies are reported immediately to the home office Manager of Quality Assurance by telephone.

III. Project B Nonconformance Control Procedure of CM Firm

It will be recalled from the Case Study of Project B (i.e., located in Appendix A of this report) that the CM Firm on Project B is the same CM Firm that is responsible for Project A. The CM Firm on Project B is also responsible for the concrete construction phase. One of the differences found on Project B is that two documents are used for the control of nonconforming conditions. These are: (1) a Deviation Report (i.e., DR) which is used to describe a "nonconformance to engineering specifications, approved drawings, code requirements and process procedures that cannot be made to conform to the original requirements", and (2) a Procedure Violation Report (i.e., PVR) which is used to record the failure of construction or QC/QA personnel to

comply with prescribed written processing, inspection or test procedures/ instructions (i.e., provided that these failures do not establish a nonconformance).

A major difference on Project B is that a Deviation Review Board (composed of the Utility B(SC) Resident Engineer, the AE Firm Site Liason Engineer, the Utility B(SC) QA Site Representative, and the CM Firm's Resident Construction Manager) is responsible for the dispositioning of all Deviation Reports and the determination of necessary corrective action to preclude a reoccurrence. The Utility B(SC) QA Manager or the CM Firm Resident Construction Manager is responsible for the disposition of all PVR's. The CM Firm's QC group is responsible for initiating, processing and following to the required conclusion all PVR's and DR's to assure compliance with the indicated dispositions. The CM Firm's QC group is responsible for maintaining a log of both the PVR's and the DR's.

Another difference on Project B is that when the CM Firm QC group initiates a DR, it must also obtain, as shown in Exhibit 4.2, a statement of proposed corrective action from the CM Firm Resident Construction Manager. The corrective action statement must include measures to be taken to preclude the recurrence of similar deviations. The signature of the CM Firm Resident Construction Manager indicates concurrence with the assigned change. The Deviation Review Board disposition of a DR must include a review of the proposed corrective action both from the technical viewpoint and from the viewpoint of the elimination of repetitive deviations. The signature of the Deviation Board members signifies that the corrective action statement is satisfactory. If it is not deemed satisfactory, the DR is returned to the CM Firm Resident Construction Manager for additional information. A similar type of procedure is followed in the case of PVR's.

Exhibit 4.2.--Project B Deviation Report

Est. Cost $100.00
Approvd.
Date 1/3/77

Distribution	Item:	Dwg. No.
	Concrete Free Fall (CB-287)	N/A
	Vendor	P.O. No.
	N/A	N/A
	System	Spec. No.
	Structural	2555-60, Amdnt. #34
	Serial No.	J. O. No.
	N/A	9459.02

Deviation Description — Applicable Codes, Standards Specifications

2555-60, Section 3A-22, para. 4.8, states, "Concrete shall not be allowed to drop freely more than five feet in un-exposed work."

During placement of temporary blockout, East Side of Interior Wall, Elevation 305', Control Building on 12/13/76, (CB-287), the concrete was allowed to "free fall" approximately 8 to 10 feet w/o the use of a tremie.

Approximately five (5) cubic yards were placed in this manner.

Engineer_____ Date Field Supv.-Q.C._____

Corrective Action: Will be provided at time of disposition

The Civil Superintendent has reinstructed the general foreman and foreman in the requirements of Spec. 2555-60. Further incidents of this type will not be tolerated.

Signature Date

Disposition: Forms shall be removed from pour CB-287 and readings shall be taken utilizing a swiss hammer to verify concrete strength. Swiss hammer reading shall also be taken from adjacent pours for comparison. All readings shall be submitted to the DRB for final disposition.
See Supplement #1 (attached) dtd. 1/7/77.

Chargable Deficiency	Yes	No	Charges		
To			Against		
Q/C			Specification		
Constr.			Const. Proc.		
Subcontractor			Q/C Procedure		
Vendor			Drawing		
A/E			B/M		

Const. Date A/E Site Engr. Date Engr. Date QA Date

Disposition Action Verified and Item Reinstated:

Site QC engineer Date Field Supv. QC

All DR's are maintained in an open file until disposition has been resolved by the Deviation Review Board, corrective action has been taken and a satisfactory reinspection has been completed by the CM Firm QC group. A DR and PRV status report is issued monthly.

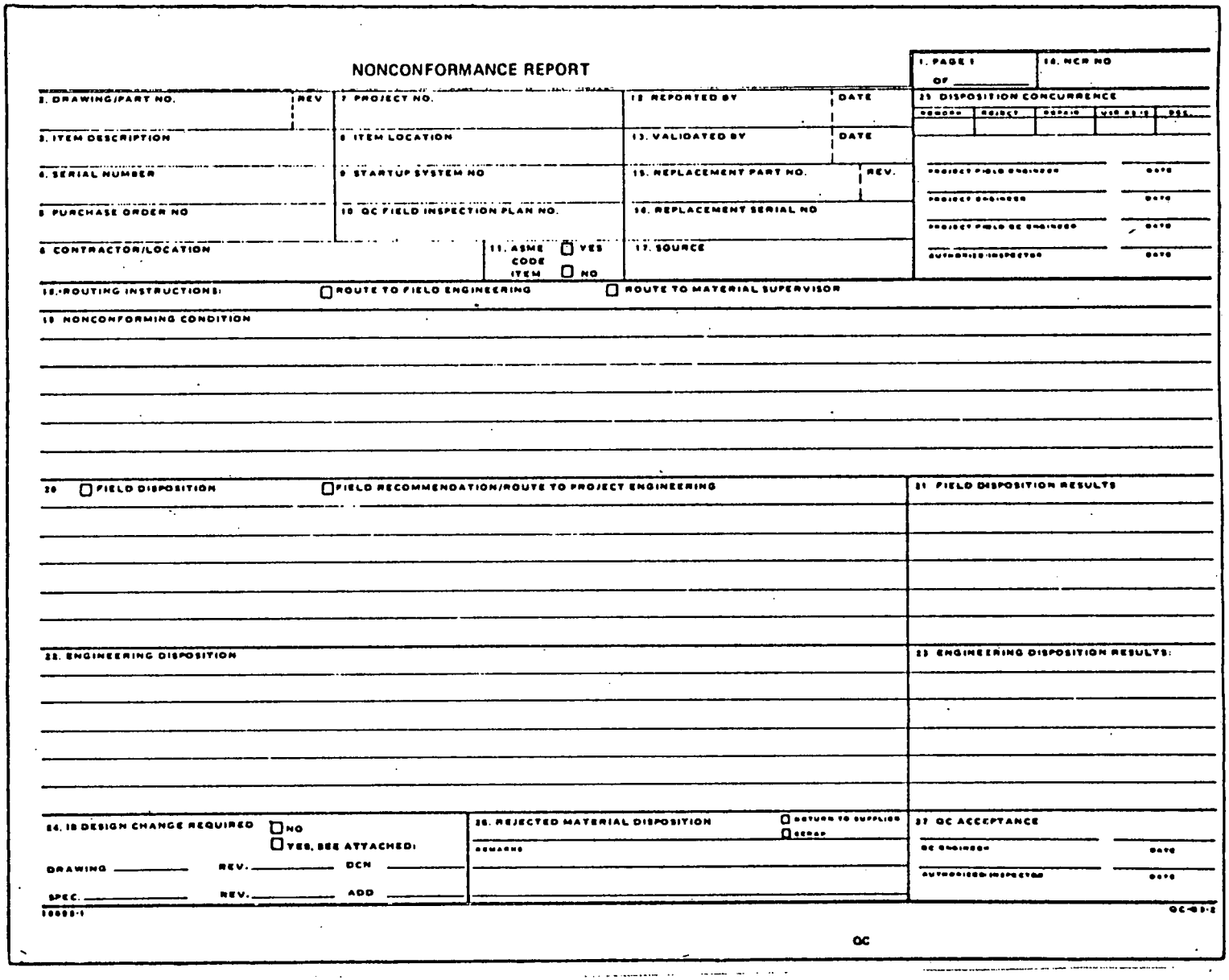
IV. Project C Nonconformance Control Procedure of EPC Firm

On Project C, the EPC Firm QC group on the project is responsible for Nonconformance Control. Nonconformances are identified by site personnel during the performance of inspection activities as well as through general observations while other activities are being performed. The disposition of Nonconformance Reports (i.e., NCR's) (see Exhibit 4.3) is primarily performed by the home office Project Engineering group. The Project Field Engineering group also is involved in a more limited fashion. All dispositions must receive Field QC concurrence prior to implementation. All "Use As Is" as well as "Repair" dispositions require home office Engineering approval, must include engineering rationale and must reference detailed design evaluations where such evaluations are required.

If a design document revision is required to accomodate a disposition, the revision must be identified on the NCR. In such cases, the reinspection by the EPC QC group cannot be completed until the affected design document has been revised and received at the jobsite.

A provision is made for the conditional release of nonconforming items. They may be conditionally released for installation in permanent plant construction only when it is a considered decision by the Project Field Engineer, Project Field Quality Control Engineer, and (for Q List and ASME Code Items) the Project Quality Assurance Engineer. Specific written approval from each of the above persons must be obtained and documented on the NCR along with the basis for the decision to permit installation of the

Exhibit 4.3.--Project C Nonconformance Report



NONCONFORMANCE REPORT

1. PAGE 1 OF _____
16. NCR NO
2. DRAWING/PART NO. | REV
7. PROJECT NO.
12. REPORTED BY | DATE
23. DISPOSITION CONCURRENCE
REMARKS | PROJECT | REPAIR | USE AS IS | REJ.
3. ITEM DESCRIPTION
8. ITEM LOCATION
13. VALIDATED BY | DATE
4. SERIAL NUMBER
9. STARTUP SYSTEM NO
15. REPLACEMENT PART NO. | REV.
PROJECT FIELD ENGINEER | DATE
5. PURCHASE ORDER NO
10. QC FIELD INSPECTION PLAN NO.
16. REPLACEMENT SERIAL NO
PROJECT ENGINEER | DATE
6. CONTRACTOR/LOCATION
11. ASME CODE ITEM ☐ YES ☐ NO
17. SOURCE
PROJECT FIELD QC ENGINEER | DATE
AUTHORIZED INSPECTOR | DATE
18. ROUTING INSTRUCTIONS: ☐ ROUTE TO FIELD ENGINEERING ☐ ROUTE TO MATERIAL SUPERVISOR
19. NONCONFORMING CONDITION
20 ☐ FIELD DISPOSITION ☐ FIELD RECOMMENDATION/ROUTE TO PROJECT ENGINEERING
21. FIELD DISPOSITION RESULTS
22. ENGINEERING DISPOSITION
23. ENGINEERING DISPOSITION RESULTS:
24, 25 DESIGN CHANGE REQUIRED ☐ NO ☐ YES, SEE ATTACHED:
DRAWING _____ REV. _____ DCN _____
SPEC. _____ REV. _____ ADD _____
26. REJECTED MATERIAL DISPOSITION ☐ RETURN TO SUPPLIER ☐ SCRAP
REMARKS
27 QC ACCEPTANCE
QC ENGINEER | DATE
AUTHORIZED INSPECTOR | DATE
10003-1
QC-83-2

QC

nonconforming item. The Project Field Engineer shall be responsible for determining and indicating on the NCR the method of installation, i.e., by bolting, welding, grouting, etc. Two of the conditions which are required for such approval to be granted are:

a. Traceability and identification as a nonconforming item are maintained by tagging.

b. The nonconforming item can be removed or corrected at a later date (prior to use) without damage or contamination to the associated permanent plant equipment or structures.

V. Project F Nonconformance Control Procedure of Utility F

On Project F, Utility F's QC group on the project is responsible for Nonconformance Control. The AE/CM Firm's Engineering Department at the home office is responsible for the disposition of the Nonconformance and Disposition Reports (i.e., N & D's) which Utility F's QC group prepares. If the N & D is given a "Repair" or "Rework" disposition, then the affected item must be reinspected by Utility F's QC group for compliance with the requirements of the assigned disposition. Repair or rework operations must be accomplished in accordance with approved instructions, procedures, or drawings.

One of the sources of N & D's are the inspection activities of the Utility F QC group which are performed in accordance with an Inspection Report which evaluates the predefined attributes of a particular construction operation. If a particular Attribute is judged to be unsatisfactory, (i.e., UNSAT) and it is determined by the QC group that it can not be reworked within the scope of the project specificaitons, drawings, procedures or codes, then an N & D is prepared. A contractor may also request an N & D if he feels that he is unable to comply with the engineering document requirements related to a particular construction activity.

N & D's also arise in a more informal manner. It is the responsibility of all Quality Control Personnel to report any possible Nonconformance to their Supervisor or Quality Control Engineer, who shall investigate the situation and initiate an N & D Report if a Nonconformance exists.

Any person other than QC Personnel, who discovers a possible unsatisfactory condition has the responsibility of notifying a Senior QC Engineer in Utility F's Site Quality Control Section, who will initiate an investigation and an N & D Report if a Nonconformity is found to exist. If after an investigation is made, the Senior QC Engineer establishes that a Nonconformance does not exist, the person making the original report shall be so informed in writing.

It should be noted that the issuance of an N & D Report is considered to be a "Stop Work Order" on that particular activity if continued work could cause damage, prevent further inspections or prevent remedial action.

A disposition of a nonconformance is prepared, as noted above, by the AE/CM Firm's Engineering Department. It must contain clear engineering instructions and indicate the acceptance criteria by which the nonconformance can be resolved. The completed disposition is returned to Utility F's QC group for review to assure that the recommendations are acceptable. If the N & D is found to be unacceptable, it is returned to the AE/CM Firm's Engineering Department with written objections which indicate the modifications that must be made. After the differences are resolved, the N & D is transmitted to the responsible contractor by the Utility QC group. The contractor must acknowledge that he can perform the work indicated by affixing his signature to the N & D. The N & D is formally closed upon completion of the work required by the disposition and subsequent reinspection by Utility F's QC group.

An example of an N & D from Project F is shown in Exhibit 4.4. It represents the type of N & D which was repeated every time an aggregate gradation test would not meet the in-process sieve analysis tolerances provided in the Concrete specifications. The standard procedure which was followed included a waiting period until the compressive strength tests indicated that acceptable concrete had been placed even though the gradation analysis created a Nonconformance. At that point, the N & D would be dispositioned "Accept As Is".

Exhibit 4.4 perhaps indicates an example of the generation of extra paperwork since a revision to the basic quality procedures could have made the gradation test results independent of the N & D procedure. The argument for such an approval might be that if concrete is actually accepted on a compressive strength basis, then only the failure to meet that required strength should justify an N & D.

VI. Project G Nonconformance Control Procedure

On Project G, the control of Nonconformances and the identification and correction of discrepancies in the overall Quality Assurance program is achieved through the use of a number of documents and reports. Contrary to the practice on other projects, these documents and reports can be initiated by a number of organizations including: (1) Utility G QA, (2) EPC Firm QA, and (3) EPC Firm QC. Table 4.1 indicates the generic designation of each report or form.

The applicability of each of these documents is defined as follows:

"1. Nonconformance Reports (NCR).--The NCR establishes a means of the identification, segregation, control, and disposition of parts, materials, components, systems, processes, tests and documentation that do not conform to the requirements of design drawings, procedures, specifications, or standards. They are usually initiated by the EPC Firm QC group, however they may be initiated by any EPC Firm employee who observes or becomes aware of a nonconforming condition. The NCR is validated and then routed to the Project Field Engineer for disposition.

Exhibit 4.4 PROJECT F NONCONFORMANCE AND DISPOSITION REPORT

Project F
NONCONFORMANCE & DISPOSITION REPORT

Page 1 of

No.

IR/RIR/TR: S-0395,S-0572

Spec. No.: ASTM-C-136

Building/Activity/Item: Retaining Wall Ground Cooling Tower

System Release No.

System

Location: In-Place

Contractor

Drawing No.: N/A ☐ Vendor

Issue: N/A

Vendor

P.O. No.: N/A

Mark/Piece No.

CAT ☐1 ☐2 ☐3

A.S.M.E. Class ☐1 ☐2 ☐3

Hold/Reject Tag No.: N/A

Initiator Date 1 | Approved A.S.M.E. QA Mgr. Date 2 | Approved /SQC Date 3

Condition Details: Attach Supplemental Sheets, if required, with this N & D No. applied.

The fine and coarse aggregate used in the concrete placed in Manhole #2 and the retaining wall around the cooling tower, on 5/10/77, failed to meet the in-process sieve analysis.
This was reported on Report of Concrete Aggregate Tests #143.

FOR INFORMATION ONLY

Remarks:

DISPOSITION OTHER SIDE

Disposition Details: Attach Supplemental Sheets, if required, with this N & D No. applied.

No.

Page 2 of

The concrete is accepted based on the seven day concrete cylinder breaks of F'c = 3430 PSI, 3180 PSI which exceeds f'c = 3000 PSI @ 28 Days.

4.45

Dispositioner Date 4

Disposition
Accept as is ☒ Scrap ☐ Repair ☐ Rework ☐ Return to Vendor ☐

SAR Change ☐ Yes ☐ No
☐ Drawing Change
☐ Specification Change
☐ Procedure Change
☐ Eng. Serv. Scope of Work Change

Change WILL ☐ be incorporated
WILL NOT ☐ in the following documents

for CAT 1 only
Evaluated to 10 CFR 50.55 (e) and 10 CFR 21

Reportable Not Reportable
(delete one)

Project Engineer Date

Project Eng. Date 5

S & W Resident Eng. Date 6

SQC Approval Date 7

ASME QA Mgr. Date 8

ANI Review Date 9

Designee for ACTION | Contractor Review | Date 10

☐ DC
☐ SC
☐ SI
☐
☐ Other

Inspector ☐SAT ☐UNSAT Date 11

N & D Closed Date 12

New N & D

Remarks:

Table 4.1.--Project G Nonconformance Control Documents

	Utility G	EPC Firm
QA	1. Corrective Action Request (CAR) 2. Discrepancy and Correction Report (D&CR)	1. Quality Audit Finding (QAF) 2. Management Corrective Action Report (MCAR)
QC	Not Applicable	1. Nonconformance Report (NCR) 2. Condition Report (CR)

2. Condition Report (CR)--Nonconforming items discovered during monitoring or verification activities which do not require Field or Home Office Project Engineering disposition are documented on a Condition Report (CR). Items of incomplete work observed during installation do not consititute a nonconformance. Items which are discovered during receiving inspection or prior to installation to be potentially nonconforming because of incomplete or missing documentation are recorded and controlled on a CR. CR's shall be initiated against construction subcontractors for noncompliance with their EPC Firm approved Quality Assurance programs and routed to Field Contracts for resolution.

   CR's are submitted to the EPC Firm QC group for review. QC reviews each item to determine if the condition can be resolved on the CR or if it warrants the initiation of an NCR. Thus it can be concluded that the Condition Report is intended to be used on items that are less severe than nonconformances or have not progressed to a severe enough stage to involve the Field Engineering or Home Office Project Engineering groups.

3. Quality Audit Findings (QAF)--Quality Audit Findings are generated by the EPC Field Quality Assurance group as a result of problems identified during their auditing activities. These are forwarded to the appropriate department for action and must be approved by Field QA once satisfactory corrective action has been initiated. NCR's may result from Quality Audit Findings.

4. Management Corrective Action Report (MCAR)--It is possible that on occasion a condition may go undetected for a sufficient period of time such that it may be considered as a breakdown in the QA program. It is therefore necessary for management level personnel to be involved in correcting the problem. The MCAR is a means of

identifying, reporting, and correcting conditions that are sufficiently adverse to quality that management level personnel are required to be involved.

The MCAR form provides for identification of the condition, its cause, the corrective action taken, and the follow-up verification. Each person associated with the project (engineering, construction, procurement, support groups, etc.) is responsible to report to the Project QA Engineer situations considered warranting an MCAR. The MCAR will be issued at the discretion of the Project QA Manager.

The following examples (but not limited to) are situations which would warrant issuing an MCAR:

a. Failure to obtain appropriate approval before making changes to organization, policy, procedures, etc.

b. Repeated failure to follow approved procedures.

c. Extremely serious or repetitive nonconformances.

d. Repeated failure to resolve by the commitment date deficiencies discovered in QA management audits.

e. Negligence or repeated disregard of the requirements for the transmittal of vendor documentation.

5. Discrepancy and Correction Report (D&CR)--The Discrepancy and Correction Report (D&CR) is generated by Utility G Field Quality Assurance and is used to document and report component and system discrepancies and minor Quality Assurance program deficiencies identified as a result of inspections, surveillances, audits, or reviews. The D&CR is issued primarily when a discrepancy is noted which is not general in nature and can be corrected by action taken to a particular component, system, document, etc.

6. Corrective Action Request (CAR)--The Corrective Action Request (CAR) is used to document nonconformances of a general nature, a major Quality Assurance program nonconformance or significant conditions adverse to quality.

It appears that on Project G the number of documents which can be used allows for a classification of Nonconformances. This approach, as recommended by Rice (1) earlier in this section, expedites the resolution procees. It may, however, create greater documentation problems if all of these documents must be separately logged and closed out.

VII. Project H Nonconformance Control Procedure of Utility H

On Project H, the Utility H Construction Quality Assurance (i.e., CQA) group, assisted by the Utility H Construction Quality Control (i.e., CQC) group, has the primary responsibility for Nonconformance Control. CQA activities such as reviews, observations, and audits are conducted in accordance with the applicable procedures. Deficiencies discovered during these procedural activities and during impromptu observations are analyzed and a decision is made as to the necessary corrective action measure. This decision is based upon the QA observer's judgment of the condition with regard to the magnitude and end product effect of the nonconformance.

The deficiency requests for identification/corrective action mechanisms of the Utility H Quality Assurance Program are:

a. The Nonconformance Report (NR)

b. Audit Action Request (AAR)

c. The Corrective Action Request (CAR)

It will be recalled from the Case Study of Project H (located in the Appendix A of this report) that the project is being administered under the C.M. Mode, with a number of contractors responsible for individual "Work Packages". The CQA group requires, through the contract documents, that the contractors involved with safety related work establish QA programs to control their own nonconforming conditions and effect corrective actions. These required measures include the utilization of the CQA standard Nonconformance Report (i.e., NR) form and generic procedure.

NR's can therefore be independently generated by either CQA, CQC or the individual contractor QC personnel. Since an overall coordination effort is required under a "Work Package" approach, the QA group has the responsibility for status tracking and reporting of all generated NR's to the affected parties.

The presentation below will define the applicability of the various documents mentioned above and will also highlight some of the more important aspects of the Nonconformance Control system of Project H.

1. Nonconformance Control Documents

As noted above, the pertinent documents are:

a. Nonconformance Report (i.e., NR)--This is the document used to identify hardware deficiencies. It lists the condition observed and the requirement which has not been satisfied. After evaluation by the originating organization, it further provides a mechanism for proposing the disposition; to the responsible QA and Engineering organizations and in the case of a recommended disposition, "Use As Is," "Repair", and "Scrap" will further require an engineering and quality assurance evaluation and approval.

b. Audit Action Request (i.e., AAR)--The document utilized to identify systematic and programmatic (software) discrepancies, inadequacies or noncompliance. The AAR form provides for: Identification of the requirements; description of the actual condition; proposed resolution; response from the responsible organization; response acceptance and close out (verification). The AAR is mainly associated with documentation of audit and program review findings but can also be utilized for items noted through casual reviews or informal observations of discrepant conditions outside of formal audits.

c. Corrective Action Request (CAR)--The document used to identify: Major system and program (software) noncompliances; repetitive discrepancies; and breakdown of one or more QA/QC programs. The form provides for: Identification of the requirements; description of the actual condition; proposed resolution; response from the

responsible organization; response acceptance and close out (verification). The CAR can be utilized in combination with "Stop Work" Notifications, Nonconformance Reports, or issued individually.

The NR, AAR, and the CAR are capable of reporting deficiencies and requesting corrective action with or without formal audit, or program review. Their intent is to identify a specific nonconforming condition that requires immediate response.

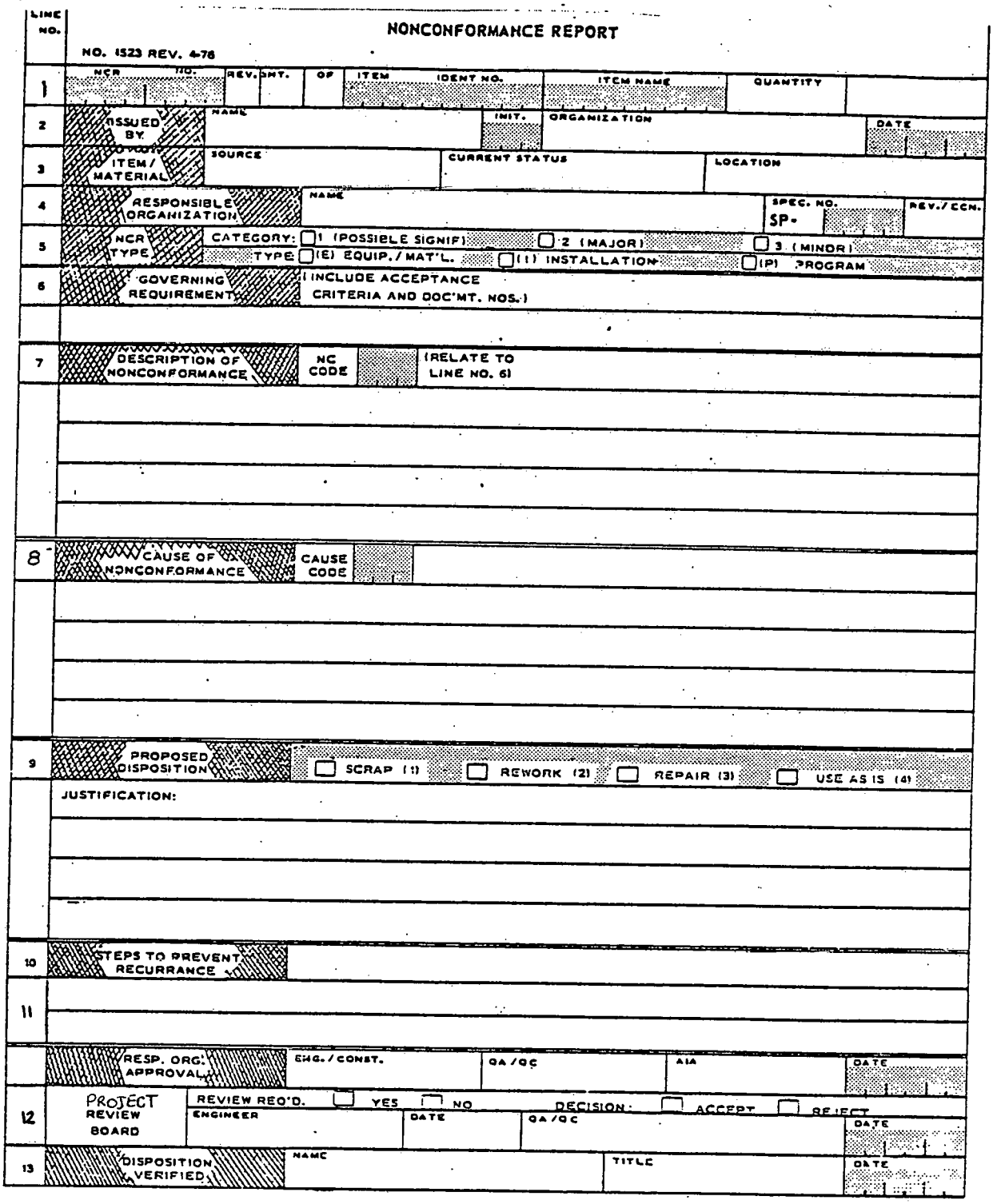
It should be noted that for minor system or program deficiencies, the identification, control and resolution mechanisms provided by Audit Action Requests for audits and inspection activities, and the review forms for review activities are sufficient. However, nonconforming or indeterminate hardware deficiencies require the Nonconformance Report to expedite resolution and segregate, as necessary, the nonconforming item. When the analysis of the nonconformance indicates that not only the nonconforming item requires correction, but that the system or condition that caused it requires correction to preclude repetition, a Corrective Action Request or an Audit Action Request may be issued.

2. Nonconformance Report Processing

As noted earlier, the Nonconformance Report form for Project H, which is shown as Exhibit 4.5, may be initiated by several parties. The initiator is responsible for completing lines 1-8. NR's initiated by Utility H's CQA group are logged in and then sent directly to the affected contractor. The recipient of the NR must complete line 9 by indicating the "Proposed Disposition" as well as a justification for the choice which has been made. The additional corrective actions to be taken to preclude repetition must also be indicated on line 10.

The justification should include any test data or engineering analyses

Exhibit 4.5.--Project H Nonconformance Report



LINE NO.

NONCONFORMANCE REPORT

NO. 1523 REV. 4-76

1 — NCR NO. | REV. | CHT. | OF | ITEM IDENT NO. | ITEM NAME | QUANTITY

2 — ISSUED BY | NAME | INIT. | ORGANIZATION | DATE

3 — ITEM / MATERIAL | SOURCE | CURRENT STATUS | LOCATION

4 — RESPONSIBLE ORGANIZATION | NAME | SPEC. NO. SP- | REV./ECN.

5 — NCR TYPE | CATEGORY: ☐ 1 (POSSIBLE SIGNIF) ☐ 2 (MAJOR) ☐ 3 (MINOR)
TYPE: ☐ (E) EQUIP./MAT'L. ☐ (I) INSTALLATION ☐ (P) PROGRAM

6 — GOVERNING REQUIREMENT (INCLUDE ACCEPTANCE CRITERIA AND DOC'MT. NOS.)

7 — DESCRIPTION OF NONCONFORMANCE | NC CODE | (RELATE TO LINE NO. 6)

8 — CAUSE OF NONCONFORMANCE | CAUSE CODE

9 — PROPOSED DISPOSITION ☐ SCRAP (1) ☐ REWORK (2) ☐ REPAIR (3) ☐ USE AS IS (4)
JUSTIFICATION:

10 — STEPS TO PREVENT RECURRANCE

11

RESP. ORG: APPROVAL | ENG./CONST. | QA/QC | AIA | DATE

12 — PROJECT REVIEW BOARD | REVIEW REQ'D. ☐ YES ☐ NO | DECISION: ☐ ACCEPT ☐ REJECT
ENGINEER | DATE | QA/QC | DATE

13 — DISPOSITION VERIFIED | NAME | TITLE | DATE

necessary to justify the disposition. Also included are any instructions or supportive procedures necessary to complete the disposition. For example, concrete joint preparation for concrete repair or detailed instructions for weld repair. The Nonconformance Report recipient organizations's authorized personnel then sign off the disposition on line 11 of the Nonconformance Report and return it to the issuer.

The NR's which are dispositioned "Rework" or "Scrap" only require the concurrence of the QA issuer of the NR. Those dispositioned "Repair" or "Use As Is" require concurrence of a Project H Review Board, whose functions will be explained below in more detail. The affected contractor is notified of the disposition acceptance by the QA initiator, who is also responsible for the verificaton activity once the disposition has been completed by the contractor.

3. Project H Review Board

On Project H, proposed Nonconformance dispositions consisting of "Use As Is" or "Repair" are considered to constitute design changes since their ultimate configuration will not be in accordance to specification and/or drawing requirements. As a design change, the disposition must be approved by a Project H Review Board (which consists of Utility H Construction, Utility H Construction Quality Assurance (i.e., CQA) and AE Firm representatives) in order to maintain design control.

A "Review Board Comment Sheet" is used to document any comments related to acceptance or any comments related to rejection of the disposition of the NCR. Some of the items reviewed are: (1) Was the Nonconformance appropriately categorized for significance?, (2) If a "repair" is proposed, are special repair/inspection procedures appropriate?, (3) Are Utility H CQA and CQC witness or hold points for the repair appropriate?, (4) Are

steps to prevent reoccurrence adequately addressed with respect to the cause of the nonconformance? and (5) Is it a repititive nonconforming condition requiring additional steps to prevent reoccurrence?

4. Nonconformance Analysis

On Project H, an attempt is being made to provide a classification system for the "Description of Nonconformance" data and the "Cause of Nonconformance" data which must be indicated on all NCR's. This classification system allows Nonconformances to be analyzed in order to identify trends, etc.

Nonconformance Codes are provided for a total of 8 different areas (i.e., Concrete, Rebar, Mechanical, Coatings, Structural Steel, Electrical, Testing, Examination, and Miscellaneous and General). The codes for the Concrete and Rebar areas are shown in Table 4.2.

Table 4.2.--Project H Nonconformance Codes

CONCRETE	REBAR
01 Materials	10 Materials Grade
02 Incorrect Mix	11 Identification
03 Physical Properties (Slump, Air Temp., Strength, Permeability)	12 Physical/Chemical
	13 Rust/Contamination
	14 Dimension
04 Dimensions or Location	15 Placement (location)
05 Placement Technique (Vibrator, Placement Rate)	16 Cadwelding
	17 Lap Splices
06 Curing	18 Quantities
07 Post Pour Visual (Voids, Honey Comb, etc.)	

Cause Codes are provided for a total of four areas as shown in Table 4.3.

The above classification system for NCR's has resulted in the summary information shown in Table 4.4 regarding the Concrete related NCR's which required Project H Review Board Action as of December 1977.

VIII. Project I Nonconformance Procedure of EPC Firm

On Project I, the EPC Firm's Quality Assurance Department, through its Field Quality Control (i.e., FQC) group is responsible for initiating, issuing, distributing, reviewing and closing out all of the Nonconformance and Disposition Reports (i.e., N & D's). The N & D report represents the major Nonconformance document which is used on Project I. The home office Engineering group of the EPC Firm is responsible for indicating the disposition of the N & D's.

On Project I, the N & D process is begun when the EPC Firm Construction Department indicates that an Engineering disposition is required. This occurs whenever it becomes evident that the corrective action required to resolve an unsatisfactory condition cannot be made within the scope and requirements of the specification, drawing or engineering requirements. Upon receipt of an Unsatisfactory Inspection Report from the Construction Department with a request for an Engineering disposition, the EPC Firm's SQC group initiates an N & D using the form shown in Exhibit 4.6.

N & D reports may be supplemented by photographs, sketches, test reports, inspector's reports, telegrams or other appropriate information, as required to make the report complete and accurate.

The N & D report is then sent to the home office Engineering group for disposition. After the N & D with the assigned disposition from the Engineering group is returned to the FQC group, it is reviewed to ensure that all Quality

Table 4.3.--Project H Cause Codes

OPERATIONS	
01	Operator Error
02	Inadequate Indoctrination and Training
03	Unqualified Personnel
04	Insufficient Personnel
DESIGN	
11	Specification--Wrong Revision
12	Specification--Misinterpretation
13	Drawing--Wrong Revision
14	Drawing--Misinterpretation
15	Inadequate Procedure
16	Cannot install per drawing (interference)
17	Improper installation (drawing or specification)
18	Hanger, support, mounting problem
GENERAL	
21	Environmental
22	Damage-By Others
23	Malfunction/Failure of Construction, Inspection or Test Equipment
25	Vendor Supply Problem
26	Material Inadequate
27	Mishandling
28	Improper Storage
29	Inadequate Status Control
30	Inadequate Documentation
31	Lack of Identification
32	Improper Cure
33	Equipment
34	Does not meet Specification Requirements
35	Violation of Procedure
36	Does not meet Drawing Requirements
37	Undeterminate/Unknown
FUNCTIONAL	
40	Failed Test

Table 4.4.--Summary of Concrete Related Nonconformance Reports on Project H

Concrete			
NR Code	Total	Cause Code	Total
Materials	5	Drawing-Misinterpretation	1
		Vendor Supply Problem	1
		Material Inadequate	2
		Failed Test	1
Incorrect Mix	2	Operator Error	1
		Doesn't Meet Spec. Req.	1
Physical Properties (Air, Slump, Strength, Temp., Permeability)	61	Operator Error	1
		Inadequate Training	1
		Failure of Construction, Inspection, or Test Equipment	2
		Vendor Supply Problem	7
		Material Inadequate	11
		Mishandling	1
		Inadequate Status Control	1
		Inadequate Documents	1
		Lack of Identification	1
		Failure to Meet Specs	33
		Violation of Procedure	2
Dimension or Location	9	Operator Error	2
		Drawing Misinterpretation	1
		Failure of Construction, Inspection, or Test Equipment	5
		Failure to Meet Drawings	1
Placement Technique (Vibrator, Placement Rate)	4	Operator Error	2
		Environmental	1
		Failure to Meet Specs	1
Curing	35	Operator Error	2
		Inadequate Training	1
		Failure of Construction, Inspection, or Test Equipment	1
		Improper Cure	25
		Failure to Meet Specs	4
		Violation of Procedure	2
Post Pour Visual (Voids, Honeycomb, etc.)	32	Operator Error	14
		Damage By Others	2
		Failure of Construction, Inspection, or Test Equipment	6
		Failure to Meet Specs	5
		Failure to Meet Drawings	5

Table 4.4.--Summary of Concrete Related Nonconformance Reports on Project H (continued)

NR Code	Total	Cause Code	Total
Concrete (cont.)			
Placement (Location)	2	Failure of Construction, Inspection, or Test Equipment	2
Testing	10	Operator Error	3
		Inadequate Training	1
		Insufficient Personnel	1
		Failure of Test Equipment	1
		Improper Storage	1
		Inadequate Status Control	1
		Failure to Meet Specs	1
		Violation of Procedure	1
Calibration	1	Equipment	1
Inspection	5	Inadequate Training	5
Damage	14	Environmental	10
		Damage by Others	1
		Material Inadequate	1
		Mishandling	1
		Improper Storage	1
Cement			
Materials	11	Vendor Supply Problem	2
		Failure to Meet Specs	9
Incorrect Mix	1	Vendor Supply Problem	1
Aggregate			
Materials	11	Material Inadequate	3
		Failure to Meet Specs	8
Reinforcing Steel			
Physical/Chemical	6	Unqualified Personnel	1
		Damage-By Others	1
		Failure of Construction, Inspection, or Test Equipment	2
		Vendor Supply Problem	2

Table 4.4.--Summary of Concrete Related Nonconformance Reports on Project H (continued)

Reinforcing Steel (cont.)			
Rust/Contamination	1	Improper Storage	1
Dimension	11	Vendor Supply Problem	5
		Material Inadequate	5
		Failure to Meet Specs	1
Placement (Location)	11	Operator Error	1
		Drawing Misinterpretation	2
		Improper Installation	2
		Failure of Construction, Inspection, or Test Equipment	3
		Failure to Meet Drawings	3
Quantities	1	Failure to Meet Drawings	1
Documentation	3	Inadequate Training	1
		Inadequate Documents	2
Storage and Handling	1	Mishandling	1
Damage	6	Damage--By Others	1
		Vendor Supply Problem	3
		Violation of Procedure	1
		Failure to Meet Drawings	1
Cadwelding			
Cadwelding	6	Operator Error	1
		Failure of Construction, Inspection or Test Equipment	2
		Vendor Supply Problem	2
		Failure to Meet Specs	1
Documentation	1	Inadequate Documents	1

Exhibit 4.6.--Project I Nonconformance and Disposition Report

SHOP ☐ FIELD ☐ OTHER ☐ — JOB ORDER NUMBER — N&D NUMBER № 1023

SITE OR SHOP

4 SYSTEM OR PART NAME	5 MATERIAL LOCATION	6 DATE – MONTH / DAY / YEAR	RELATED I R NUMBER 7
8 VENDOR NAME	9 P.O. NO. (S & W)	10 NONCONFORMANCE RESPONSIBILITY: ENG ☐ CONST ☐ VENDOR ☐ TRANSPORTATION ☐ NOT ASSIGNED ☐	
11 VENDOR CODE	12 SUBVENDOR CODE	13 SPEC VIOLATED	14 DRAWING VIOLATED ☐ S & W ☐ VENDOR — ISSUE — 15 CODE VIOLATED NAME / SECTION / PARAGRAPH
16 MARK NO	17 SYSTEM DESIGNATION	18 REJECT TAG NO	INITIATOR 19 SIGNATURE — DATE
20 REQUEST DISPOSITION FROM ENG BY _____ DATE	21 COMPLETION DATE TO MEET SCHEDULE _____ DATE	22 CONDITION DETAILS APPROVED BY _____ REVIEWER	DATE APPROVED
23 CONDITION DETAILS			

PROJECT

DISPOSITION

24 DISPOSITION ASSIGNED BY	DATE	25 ACTION: ACCEPT AS IS ☐ SCRAP ☐ REWORK ☐ REPAIR ☐ RETURN TO VENDOR ☐
26 DISPOSITION DETAILS		

APPROVALS							
27 LEAD ENGINEER	DATE	28 CHIEF ENG MATL'S ENG	DATE	29 EQUIP SPECIALIST	DATE	30 PROJECT ENGINEER	DATE
REVIEW							
31 CHIEF ENG. CSD	DATE	32 QUALITY ASSURANCE	DATE	33 CONSTRUCTION	DATE		
REWORK							
34 PLANNED COMPLETION DATE		35 REWORK COMPLETE SIGNATURE		DATE COMPLETE			
INSPECTION							
36 REWORK INSPECTION ACCEPTABLE — QC SIGNATURE		37 REWORK INSP UNACCEPTABLE — QC SIGNATURE		38 NEW N & D REPORT NO ISSUE			
39 Q.C. INSPECTION DEVICE ID. NO. & DESCRIPTION				NONCONFORMANCE CLOSED 40 QC SIGNATURE		DATE	

REMARKS (ADDITIONAL SUPPLEMENTS, ETC.)

N&D NUMBER № 1023

requirements have been included. If the N & D does not contain the necessary requirements, it is returned to Engineering, along with a statement delineating the necessary Quality requirements. A satisfactory N & D disposition is then signed by the Superintendent of FQC and sent to the Construction group for correction action where it is determined if the deposition can be implemented. After the corrective action has been completed, it is signed by the Construction group and returned to the FQC group who is responsible for performing rework inspection. If the work is acceptable and "signed off" by FQC, the N & D is considered closed. If the rework is not in accordance with the Engineering Disposition, the Construction Department may do one of the following:

a. Re-attempt to resolve the unsatisfactory condition in accordance with the disposition and forward the N & D Report to FQC for re-inspection.

b. Indicate in the remarks section of the N & D Report that a new Engineering disposition is required and forward the N & D Report to FQC.

Monthly N & D status reports are issued by the EPC Firm's QA Department which indicate the N & D's which have been issued, dispositioned, closed, not dispositioned within 30 days, not closed within 90 days, and unresolved. The data is analyzed to determine: (1) Adverse quality trends, (2) Repetitive nonconformances, and (3) The identity of "Accept As Is" dispositions.

With regard to "Accept As Is" dispositions, it is interesting to note the results that were obtained when 435 N & D reports on Project I were examined during the Summer of 1977. A total of 107 of these were related to the Concrete, Reinforcing Bar, etc. areas. It was found that many of the nonconformances, particularly with regard to aggregates and curing practices, were repetitive in nature. It also appeared that most coarse aggregate

problems involved the percentage passing the No. 200 screen and most curing problems involved temperature readings or no documentation. The disposition of these nonconformances, as shown in Table 4.5, resulted in 84% of them being "Accept As Is".

Table 4.5.--N & D Sample Data: Project I

Number of N & D's	Disposition	Percentage
4	Rework	3.7%
6	Void	5.6%
7	Repair	6.5%
90	Accept As Is	84.2%
Total - - 107		

CRITERION XVI: CORRECTIVE ACTION

It will be recalled that Criterion XV was primarily concerned with the identification and satisfactory disposition of Nonconformances which had already occurred. Closely tied to the activities which are reactive (i.e., they react to an existing Nonconformance) however, are those activities which attempt to prevent a reoccurrence of similar Nonconformities in the future. These are called "Corrective Actions".

Two facets of the Corrective Action Programs on most of the projects in the research study are: (1) Corrective Action Reports and (2) Trend Analyses. A few brief examples of these facets are presented below to indicate how Criterion XVI can be implemented.

I. Introduction

Criterion XVI of Appendix B may be divided into the following three parts:

1. Prompt Identification and Correction of Conditions Adverse to Quality

> "Measures shall be established to assure that conditions adverse to quality, such as failures, malfunctions, deficiencies, deviations,

defective material and equipment, and nonconformances are promptly identified and handled."

2. Determination of Causes of Adverse Quality Conditions

"In the case of significant conditions adverse to quality, the measures shall assure that the cause of the condition is determined and corrective action taken to preclude repetition."

3. Documenting and Reporting of Corrective Action

"The identification of the significant condition adverse to quality, the cause of the condition, and the corrective action taken shall be documented and reported to appropriate levels of management."

Based on the above description, it appears that the first part of Criterion XVI reinforces the guidelines which are presented in Criterion XV. The last two parts of Criterion XVI appear to focus in more closely on the "Corrective Action" phase.

It should be noted that on many of the projects in the research study, the activities corresponding to Criterion XV and Criterion XVI are so closely meshed that an artificiality is introduced if an attempt is made to separate the two. This is indicated by the fact that the discussion of Criterion XV in the preceding section has already indicated the "Corrective Actions" which are being implemented on a number of projects. These instances will not be repeated in this section.

It appears, however, that on some projects (not necessarily those in this research study) there is a gap between Criterion XV and Criterion XVI activities. As noted by Heltemes (8, pg. 5):

"A final item on consolidation concerns the need to have an effective corrective action system. Far too often a deficiency will be identified and reported to management, yet no real action will be taken to prevent a similar occurrence. In fact, our inspection reports show instances where management has not followed through to implement the corrective action identified in their own audits. These examples illustrate where the cost of QA has been paid, but the benefit was not fully realized. Prompt and effective corrective action both in terms of the specific instance and its generic implications remains one of the most serious problems facing all of us."

Peters (9, pg. 11) reiterates this point when he notes:

"Another deficiency that is far too prevalent is the lack of analysis of noncompliance and disposition reports. It does little for the quality of the job to constantly find and write up items that are repetitive in nature. Rather, analysis should be made on a continuing basis to determine why certain deficiencies reoccur. Is it because the job is done at night? Is there a certain work crew that is responsible? Is there an individual who is responsible? Is there a procedure that should be changed? There should be enough analysis made to determine what can be done to systematically improve the operation where the noncompliances occur and reduce them to a minimum rather than allow them to reoccur without action being taken."

It should be noted that the pattern related to background material which has been followed for the other Appendix B Criteria is not applicable for Criterion XVI since both the "Standard Format and Content of SAR" and "ANSI N45.2" essentially repeat, word for word, the guidelines of Criterion XVI presented above.

II. Corrective Action Procedure: Project A

On Project A, Corrective Action Requests (i.e., CAR's) are initiated by the C.M. Firm's QC group when:

"1. The CM Firm Site Construction Department is operating in such a way as to violate the Quality Program Requirements. This need not be limited to a written quality control or construction procedure violation.

2. A site construction activity is progressing in such a way that it will lead, in the opinion of the Field Superintendent-Quality Control, to repetition of a previously reported deficiency; and informal efforts have not been successful in altering the course of the activity.

3. A Group external to the C.M. Firm, such as the Engineer (Utility A) subcontractor or a vendor, is operating in such a manner that the C.M. Firm Quality Control/Assurance programs cannot be implemented as required.

4. Surveillance, auditing or inspection activities uncover practices which indicate that repeated problems of the same nature are occurring, or could occur."

The CAR form which is used is shown in Exhibit 4.7. As indicated, it is fairly similar to the "Deficiency Report" which is used for Nonconformance

Exhibit 4.7.--Project A Corrective Action Request

CORRECTIVE ACTION REQUEST

DATE _____

TO: _____

CONTRACT/P.O. NO. _____

SPEC./DWG. NO. _____

DEFICIENCY CLASSIFICATION: _____ NO. _____

1. IDENTIFICATION

DESCRIPTION OF DEFICIENCY:

REPLY REQUESTED BY: _____ DATE _____ QUALITY CONTROL ENGINEER _____ DATE

2. CONSTRUCTION DEPARTMENT RECEIPT

_____ SUPERVISOR _____ DATE

SUPERVISOR'S ACTION: STATE PROBABLE CAUSE AND ACTION TAKEN, OR TO BE TAKEN, TO PREVENT RECURRENCE AND DATES WHEN ACTION WILL BE EFFECTIVE INCLUDE ACTION TO BE TAKEN ON COMPONENTS AFFECTED PRIOR TO DISCOVERY.

3. CONSTRUCTION DEPARTMENT REPLY

☐ ACKNOWLEDGES DEFICIENCY WITH ACTION TO BE TAKEN

☐ DOES NOT ACKNOWLEDGE DEFICIENCY

_____ CONST. DEPT. REP. _____ DATE

4. ACTION TAKEN

☐ SATISFACTORY

_____ QC REPRESENTATIVE _____ DATE

☐ UNSATISFACTORY AND RETURNED TO CONST. DEPT.

_____ QC REPRESENTATIVE _____ DATE

5. FEEDBACK

ACTION TAKEN BY CONSTRUCTION DEPT. CONSIDERED: ☐ SATISFACTORY ☐ UNSATISFACTORY

_____ QC - SUPERINTENDENT _____ DATE

Control on Project A, since it provides space for: (1) Identification, (2) Construction Department Reply, (3) Action Taken, and (4) Feedback. CAR's are logged and tracked in a similar fashion as DR's. The C.M. Firm QC group must, within a certain time period, receive a reply to the CAR which indicates the probable cause of the adverse condition, the immediate corrective action to be taken, the subsequent actions to be taken to prevent reoccurence and the dates when action will be effective. If the corrective action specified is not adequate, or doesn't meet the intent of the request, the Field Superintendent-Quality Control meets with or contacts the party involved to determine a corrective action that is satisfactory to the Field Superintendent-Quality Control.

When the actual corrective action has been satisfactorily implemented, the C.M. Firm QC group initiator must verify that the results are satisfactory. If it is later found that the corrective action did not correct the deficiency, another CAR is initiated.

III. Corrective Action Procedure: Project H

On Project H, the Corrective Action Request (i.e., CAR) is the most serious deficiency report mechanism of the QA program for nonconformance control. Its usage is reserved for unique or more significant problems. As such, it maintains a great impact value and demands immediate attention and response.

CAR's are normally issued:

1. When nonconforming conditions are repetitive, thereby indicating that previous controlling measures are inadequate or insufficient.

2. When analyses of findings and nonuniformities indicate a declining quality trend (an increase in discovered deficiencies not commensurate with the work load, etc.)

3. To correct those conditions that have warranted the initiation of QA Stop Work Authority.

4. To correct significant deficiencies.

The CAR is initiated by the Utility H Construction Quality Assurance (i.e., CQA) group and is logged and tracked until the appropriate changes are made. These changes are specified by the affected contractor and approved by the CQA group before they are implemented.

IV. Trend Analysis Procedure: Project H

Trend Analysis procedures were being implemented on a number of projects in the research study with regard to not only Nonconformance document data but also with regard to Inspection report data. The brief explanation of these procedures for the Project H situation will indicate the types of results which may be obtained.

On Project H, the Quality Trend Analysis is a convenient procedure for determining when certain processes may be out of control. NR's, FVA's, AAR's, and other data such as concrete cylinder strength or slump records are being used to evaluate whether or not assignable causes have entered the process. If justified, an audit of the process will be performed to identify the causes. It should be noted that on most other projects, the mode used to accomplish this task is second level surveillance.

The analysis of trends in quality systems may be performed in many ways. An increase in the quantity of nonconformances, with respect to a given contractor, may for instance warrant a careful review of those nonconformances. It is the responsibility of each individual Utility H Quality Engineer to determine the need for a trend analysis and the scope of the investigation. Trend analysis reports may be used to provide information,

initiate a Corrective Action Request, justify a special inspection or audit, or warrant rejection of a procedure or nonconformance.

It will be recalled from the Criterion XV discussion related to Project H that a classification system of Nonconformance Codes and Cause Codes had been developed. The graphical use of these codes is indicated in the Trend Analysis Report which is presented as Exhibits 4.8. 4.9, and 4.10.

CRITERION XVIII: AUDITS

The topic of Audits was briefly discussed in Chapter 3 of this report in order to define the Auditing function. The background material regarding the: (1) Appendix B, (2) Standard Format and Content of SAR, and (3) ANSI N45.2 coverage of Audits was also presented in Chapter 3. The material presented below will therefore concentrate on the procedures that were developed on some of the projects in the research study in response to the Criterion XVIII requirements.

I. Introduction

It was found that all of the projects in the research study had a formal Auditing program. On some projects, audits were only performed by the Utility's QA group, on others they were also performed by the EPC Firm's QA group. In order to indicate some of these practices, the first part of this section of Chapter 4 will present a condensation of the Audit Procedure which is used on Project B since it is believed to be fairly typical of the procedure which is used on the other projects in the research study. This presentation will be followed by an indication of the modifications to the Project B procedure which have been adopted on several of the other projects.

Exhibit 4.8.--Project H Trend Analysis Report

TREND ANALYSIS REPORT
January 31, 1978

CONTRACTORS: Concrete Testing Laboratory (i.e., CTL)
Concrete Batch Plant Operation (i.e., CBP)

AREAS ANALYZED:

1. Nonconformance Reports (NR's) issued against the Concrete Testing Laboratory during 1977.

PURPOSE:

Determine if negative quality trends exist.

ANALYSIS:

1. Nonconformance Reports

   A. Concrete Testing Laboratory--Ten NR's were issued during 1977. Of the ten NR's, four were issued by CTL and six by Utility H's CQC group. The majority (60%) of the nonconformances were in the "testing" area (NC Code 100). Causes of nonconformances were fairly evenly distributed among five cause codes (See Exhibit 4.9 for details).

   B. Concrete Batch Plant Operation--Sixteen NR's were issued against CBP during 1977. All sixteen NR's were issued by CBP. Two of every three NR's (68.75%) were on "materials" (NC Code 01). The major causes of NR's were divided between "material inadequate" (37.50%) and "no cause code" (31.25%). The high percentage of NR's without a "cause code" made evaluation of NR causes difficult and conclusions questionable. (See Exhibit 4.10 for details).

SUMMARY:

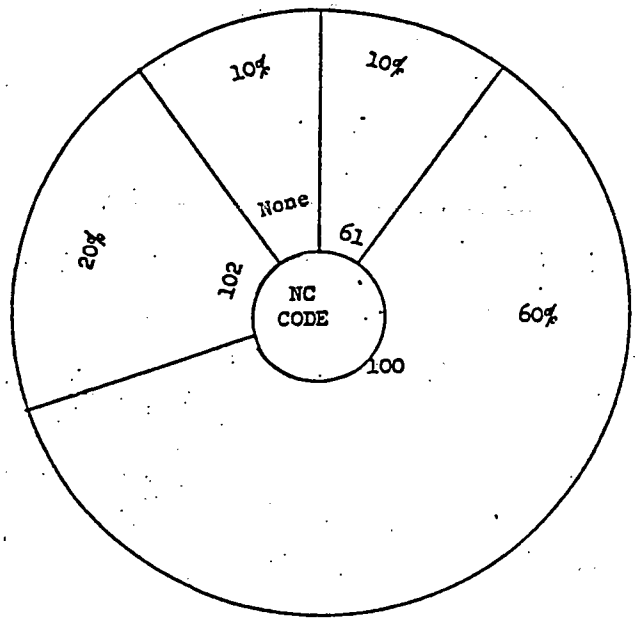
1. Nonconformance Reports

   A. Concrete Testing Laboratory--No negative quality trends were evident. Large percentage of NR's in the "testing" area is not unusual considering CTL's primary on-site activity is testing.

   B. Concrete Batch Plant Operation--No negative quality trends were evident. Seven of the eleven NR's against "materials" were for No. 67 coarse aggregate gradation failures. The difficulties with the No. 67 stone are well known on-site, particularly exceeding maximum allowable to be retained on the No. 200 sieve. Limited success of corrective actions taken by CBP are evidenced by only on NR against failing No. 200 sieve requirement during last four months of the year. Missing data (no cause code entry) made evaluation of NR causes inconclusive. For future NR's, the contractor has been requested to provide "cause codes".

Exhibit 4.9.--1977 Project H Trend Analysis of NR's Against CTL

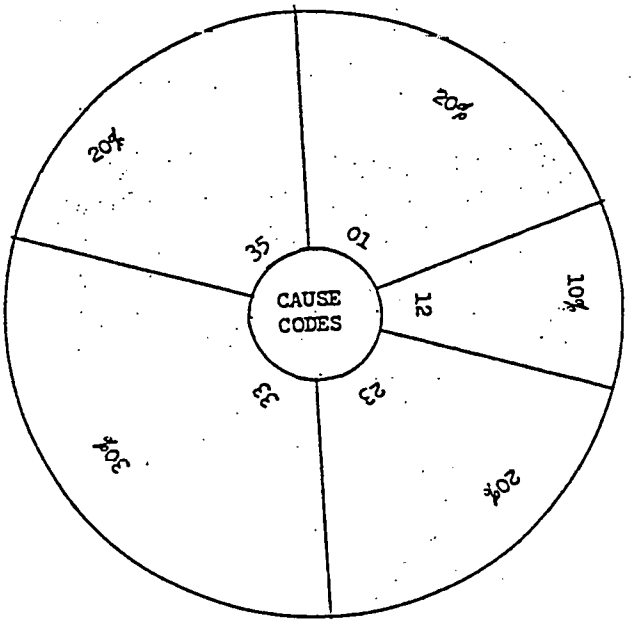
A. Nonconformance Codes



NC CODES

61—Instrument/
Certification/
Calibration
100—Testing
102—Calibration

B. Cause Codes

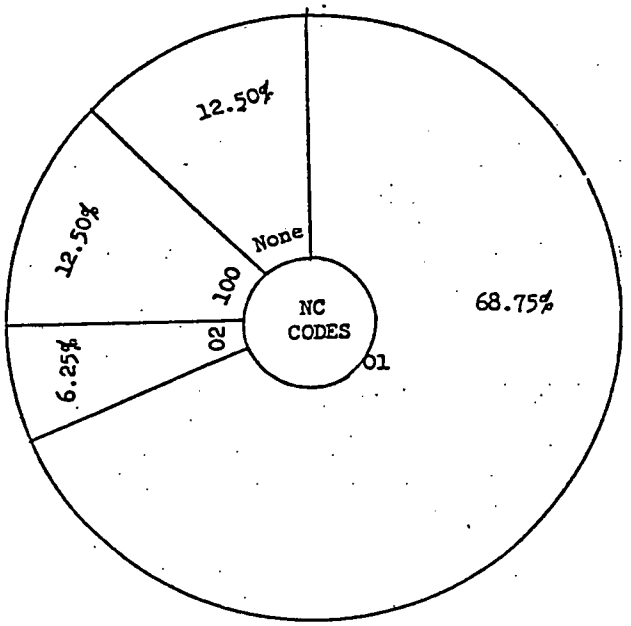


CAUSE CODES

01—Operator Error
12—Specification-
Misinterpretation
23—Malfunction-
Failure of
Construction,
Inspection and
Test Equipment
33—Equipment
35—Violation of
Procedure

Exhibit 4.10--1977 Project H Trend Analysis of NR's Against CBP

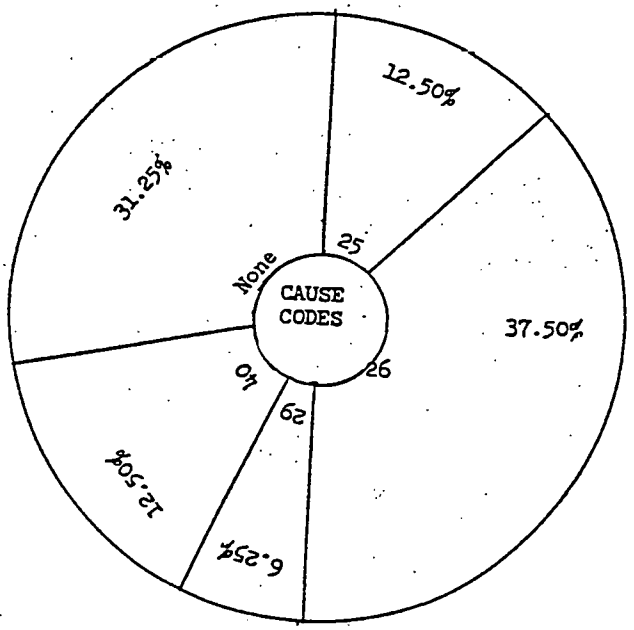
A. Nonconformance Codes



NC CODES

01--Materials
02--Incorrect Mix
100--Testing

B. Cause Codes



CAUSE CODES

25--Vendor Supply Problem
26--Material Inadequate
29--Inadequate Status Control
40--Failed Test

II. Project B Audit Procedure of Utility B(SC)

The Project B Audit Procedure, which is presented below in the same format as it actually appears (but in an abbreviated fashion), consists of the following parts: (1) Scope, (2) Purpose, (3) Procedure, (4) Conclusion of Audit, (5) Audit Report, and (6) Follow-up of Audit.

A. Scope

The procedure provides guidelines for performance of Quality Assurance Audits by Utility B(SC) of nuclear related portions of site construction work for Project B and for follow-ups of the Audit to ensure that all findings are appropriately resolved...

B. Purpose

The intent of these audits is to check that the overall quality assurance system, consisting of the site construction contractor's quality control system and the second level surveillance program, is functioning adequately, and as required by the applicable specifications and procedures. Normally, any one audit will be limited to checking a specific operation, system or structure at the site, i.e., piping fabrication, structural concrete, etc. The check points listed below are not all inclusive or mandatory...

C. Procedure

1. Pre-Audit Preparation. Preparation for the audit normally consists of reviewing the following documents to determine the requirements applicable to given portions of the site construction work and to become knowledgeable with regard to past experience with this work and the site construction contractor:

   a. PSAR/FSAR--Including the technical description section and answers to any applicable questions.

b. The contractual or purchase order technical requirements including all charges thereto, including applicable specification requirements, referenced codes, drawings, system schematics, block diagrams, etc.

c. Relevant fabrication, quality control and quality assurance procedures.

d. Correspondence regarding applicable specifications or other technical requirement documents and procedures.

e. Reports of previous audits of the site in the same or similar areas which are to be audited.

2. Audit Agenda. An agenda is normally prepared and forwarded to the Project Superintendent and other appropriate persons to permit site personnel to make any necessary administrative arrangements, e.g., have radiographs on hand for review, etc. The agenda indicates the general areas planned to be audited but need not list all specific items to be checked; the agenda in no way limits the scope of the audit and does not prevent the auditor from checking items not on the agenda.

3. Audit Notification. Upon commencement of the audit, the auditor or audit team leader shall notify the Project Superintendent and shall verify arrangements for the audit with the Utility B(SC) Site Quality Assurance and the Utility B(SC) Field Supervisor-Quality Control.

4. Audit Coverage. The audit consists of spot-checking items such as the following:

a. Site Construction Contractor's Quality Control Systems

- General Review of Quality Control System (includes: organization and operation of QC system; control of procedures, specifications and drawings; control of in-process and final inspections and tests, etc.)

- Planned Inspections, Examinations and Tests (includes: review of the material, in-process and formal inspections that are planned to be used by the contractor and a comparison of them with the pertinent codes, standards, and PSAR requirements)

- Previously Noted QC System Discrepancies. (includes a review of the status and/or resolution of all outstanding discrepancies or deficiencies resulting from previous audit visits)

- Audit of QC Records, Procedures and Results. (includes a spot-check of documents such as: material certification and test results; in process material testing records; procedure, specificaton and drawing control procedure (to check that current, approved revisions are being used) etc.)

- Audit of Fabrication Procedures. (includes a check of fabrication operations related to structural concrete, cad-welding, erection of pipe, etc., to: (1) ensure that approved procedures are being followed and (2) to verify that the procedures are adequate)

- Non-Destructive Examination

- Construction Related Testing. (includes an evaluation of: compliance with specified procedures; compliance with stated acceptance standards; demonstrated qualification of the operators to perform and evaluate the tests; adequacy of the test report; control and documentation of waiver of specifications, associated test procedure revisions, etc.)

- Audit of Storage Procedures

- Audit of Site Cleanliness

b. Second Level Quality Assurance Surveillance. The surveillance being provided by the second level surveillance agent may be evaluated. If performed, this evaluation is based on the results of the audits of the site construction contractor's quality control and the following additional areas:

- Extent of Surveillance Effort

- Qualification of Surveillance Personnel

- Basis for Surveillance

- Documentation of Surveillance

- Corrective Action

D. Conclusion of Audit

1. Audit Finding Report. An Audit Report Finding Form, a copy of which

is shown in Exhibit 4.11, must be completed for each finding. The "Finding or Recommendation" section should indicate the observed facts; the signature of the cognizant supervisor should be obtained to indicate agreement as to the facts. If disagreement exists, the specific areas of disagreement should be indicated and the supervisor's signature then obtained.

The recommended action and responsible person for resolving the finding should be entered on the Audit Report Finding Form.

2. Exit Review. Prior to departure from the site, all findings are reviewed with the C.M. Firm Project Superintendent and the Utility B(SC) Field Supervisor and QA Representative. Whenever possible, findings should be resolved, i.e., the action to be taken (if any) should be agreed upon, and entered on the form. If resolution is not reached, the steps to be taken to arrive at resolution should be entered. Each Audit Report Finding Form should then be signed by the originator, the Project Superintendent, and the Field Supervisor-QC.

E. Audit Report

A written report of the audit is prepared and sent to the Utility B(SC) Project Manager and others as appropriate. The report should contain in addition to identifying information such as the purpose of the audit, personnel contacted, etc., the following information:

1. A narrative summary section which highlights the results of the audit and indicates the chief conclusions such as any major deficiencies found, and any conclusions regarding the effectiveness of the first level quality control program and of the second level surveillance.
2. A detailed narrative description section which gives details of information obtained, items checked and found to be satisfactory, and any

Exhibit 4.11.--Project B Audit Report Finding Form

Date:_____

Place:_____

Subject:_____

Finding or recommendation:

Agreement as to Reported Facts
(Indicate Areas of Disagreement, if any)

_____
Cognizant Supervisor

Recommended Action:

Cognizant Group or Activity:_____

Resolution:

Signatures

_____	_____	_____
Originator	Project Superintendent	Field Supervisor QC

findings, e.g., deficiencies noted or recommended improvements.

3. A section listing the current status of any findings reported in previous audits.

4. A section describing any findings noted and resolved during the audit and indicating the agreements reached as part of this resolution.

5. A section containing the Audit Report Finding forms for findings.

F. Follow-Up of Audit

1. The audited organization is required by Utility B(SC) to respond to all audit reports and to document the resolution of each previously unresolved audit finding. The auditor or audit team leader should check to make sure that such response is received within a reasonable period of time. If such response is not received within a reasonable period (about two months), then correspondence should be initiated regarding the need for satisfactory response. The resolution should be reviewed by the auditor or audit team leader, and correspondence initiated if further action is necessary.

2. During subsequent audits, the status of any unresolved findings from previous audits should be reviewed.

III. Audit Procedure Modifications

1. Project C Audit Procedure of Utility C. The Audit Procedure used by Utility C is almost identical to that used on Project B in terms of both format and text.

2. Project D Audit Procedure. The Audit Procedure used by Utility D generally follows the same pattern as the one used on Project B. The Audit Procedure used by the EPC Firm QA group, however, includes the following additional factors:

a. Master Audit Plan (i.e., MAP). A MAP is prepared for the project which

identifies the areas to be audited, the corresponding audit scopes, and the basic control document applicable to each audit. It also identifies the areas that will be audited during each quarter for a lead time of one year.

b. Quarterly Audit Schedule. This schedule is prepared each quarter based on the information provided in the MAP.

c. Audit Checklists. The EPC Firm's procedure specifically requires a Quality Audit Checklist (i.e., QAC) to be prepared and used for each Audit. Assurance must be provided that the QAC correctly reflects the current revisions to the control documents.

d. Audit Reports. The auditor is required to complete a project audit report (which consists of an audit report form and a separate Quality Assurance Finding (i.e., QAF) form for each deficiency requiring further action) within one week after the audit. Responsibility for action on the QAF is assigned to the organizational level with the appropriate functional authority to insure compliance. The action to be requested on the QAF is dependent upon the nature of the finding. The three types of action that may be necessary are:

- Remedial Action--Steps taken to correct the specific instance of nonconformance, error or violation of procedures.
- Investigative Action--Steps taken to further examine the problem to determine the extent, depth and cause.
- Corrective Action--Steps taken to preclude (or reduce the possibility of) recurrence.

e. Audit Closeout. The EPC Firm specifically requires its QA Engineer to verify that the actions required by the QAF are completed and acceptable after the audited organization gives notice that the actions

have been taken. The Audit is not considered closed until the required actions have been completed, implemented and verified by the QA Engineer.

3. Project E Audit Procedure of Utility E. The Audit Procedure used by Utility E generally follows the same pattern as the one used on Project B. Some additional points which are emphasized are:

   a. Intermediate Conferences. It is noted that intermediate conferences may be held at various intervals during the Audit to bring a deficiency to the immediate attention of the management having responsibility for the area being audited.

   b. Deficiency Sheets. A Deficiency Sheet (See Exhibit 4.12) is used to record the data which substantiates the encountered deficiencies. The Audited Organization Representative (i.e., AOR) must sign each Deficiency Sheet to indicate understanding but not necessarily agreement with the deficiency. If the AOR disagrees, he may request up to 10 working days to further investigate the deficiency implications and propose an alternate course of corrective action. In such a case, the AOR receives an extension to the normal 10 working day period within which he must initiate corrective action on the deficiency.

   c. Follow-Up Action. The auditor must verify that the corrective action indicated in the Deficiency Sheet has been implemented or completed before "closing" the deficiency.

4. Project F Audit Procedure of Utility F. The Audit Procedure used by Utility F generally follows the same pattern as the one used on Project B. Some additional points which are emphasized are:

Exhibit 4.12.--Project E Audit Deficiency Sheet (front side)

QUALITY ASSURANCE AUDIT	DEFICIENCY SHEET	AUDIT NO.: _____ DEFICIENCY NO.: _____

1. AUDITING ORGANIZATION: ☐ OEDC ☐ EN DES ☐ CONST _____

2. AUDITED ORGANIZATION: _____
LOCATION: _____
ACTIVITY: _____

3. REQUIREMENT(S):

4. DEFICIENCY(S):

CONTACT(S):

Auditor(s): _____ Date: _____

Audited Organization Representative: _____ Date: _____

Title: _____

(Signature signifies understanding, not necessarily, agreement)

Exhibit 4.12.--(cont.)--(back side)

AUDIT NO: _____ DEFICIENCY NO: _____

5. AUDITORS RECOMMENDED CORRECTIVE ACTION(S):

6. CORRECTIVE ACTION PROPOSED AND IMPLEMENTED (including scheduled completion dates):

CORRECTIVE ACTION VERIFIED:

Name: _____

Date: _____

a. Objective of an Audit. An audit should determine the following:

- The existence of requirements and a systematic approach toward meeting those requirements
- An awareness of the requirement and system by the personnel implementing the system.
- The actual implementation of the system by the personnel
- The presence of documentation which demonstrates that the above conditions exist.

b. Audit Checkist. On Project F, there is a definite requirement for the QA Engineer to prepare a formal Audit Checklist based on the information which he gathers during the Pre-Audit Preparation phase. These checklists can be quite lengthy and detailed. The one which is used to audit the Concrete Batch Plant, for instance, is 18 pages long and covers approximately 60 different commitments which must be investigated. A typical page from that Audit Checklist is shown in Exhibit 4.13.

c. Intermediate Notification. The Audit team leader is required to notify the management of the audited organization immediately, when a major nonconformance is discovered that requires immediate attention. If the audited organization does not begin appropriate corrective action, the audit team leader shall issue a Corrective Action Request.

d. Audit Report. An audit report which documents the pertinent information concerning the conduct of an audit and the findings (as to the adequacy and adherence to established procedures and instructions and the effectiveness of implementation) must be issued between 2 and 4 weeks after the audit.

Exhibit 4.13.--Typical Project F Audit Checklist Page

ORGANIZATION AUDITED: Project F Concrete Batch Plant (C.B.P.)	LOCATION: Project F	PREPARED BY:	AUDIT NO. 2-77-8
DATE: April 25, 1977		AUDITORS:	PAGE 13 OF 18 PAGES
			APPROVED BY:

CHAR. NO.	AUDIT CHARACTERISTIC	REFERENCE DOCUMENT	COMPLIANCE: PROCEDURE ACC.	PROCEDURE DEF.	ACTIVITY ACC.	ACTIVITY DEF.	OTHER	COMMENT NO.
	E. Identification & Control of Material (Continued)	C.B.P.QA Manual						
E.12	Does the Quality Control Site Manager verify that the water reducing agent is stored in the correct containers, and is properly identified?	CPQA-13.0 Para. 4.6						
E.13	Does the Quality Control Site Manager verify that the ice is being stored under proper conditions to preserve it from melting, and keep it clean?	CPQA-13.0 Para. 4.7						
E.14	The mixer trucks used to deliver the concrete will conform to the requirements of ASTM C-94. Are the trucks approved by the ENGINEER prior to use on the project?	CPQA-13.0 Para. 5.1						
E.15	Does the Quality Control Site Manager verify that the Batch Plant Operator has received the proper mix design prior to batching of the concrete?	CPQA-13.0 Para. 5.3						
E.16	Does the Quality Control Site Manager perform free water determinations of the representative aggregates to be used in the concrete batching? Does he also confirm that the Batch Plant Operator is using the correct moisture compensation? Are re-test of aggregate moisture and any necessary adjustments to the correction setting performed at least twice per day, and more frequently if required?	CPQA-13.0 Para.						

When corrective action is required on audit deficiencies, the transmittal letter shall request a written response within (30) thirty days of the receipt of the audit that addresses:

- The action taken to correct the nonconforming conditions(s)
- The action taken to prevent the recurrence of the nonconforming condition(s), and
- If corrective action has not been accomplished at the time of the response, the schedule date when corrective action will be completed

e. Audit Follow Up Reports (i.e., AFR's). An additional level of documentation appears to be required on Project F because the QA Engineers are responsible for generating formal AFR's which evaluate the responses to Audit findings and verify implementation of corrective action when it is necessary. The AFR (as shown in Exhibit 4.14) must include a statement of the finding, the response which has been received and an evaluation of the response. A log of all the AFR's must be kept. Each AFR can not be closed until the response is judged to be acceptable

SUMMARY

The contents of Chapter 4 are summarized below in the order in which the individual Appendix B Criteria were discussed.

CRITERIA III AND VI: DESIGN CONTROL, DOCUMENT CONTROL

The discussion in the first section of Chapter 4, although based on the requirements outlined in Criteria III and VI, included several related topics. With regard to the Review of Project specifications, for instance, it was indicated that a number of parties are typically involved in the review

Exhibit 4.14.--Project F Audit Follow-Up Report

QUALITY ASSURANCE DEPARTMENT
AUDIT FOLLOW-UP REPORT

AFR NO. (d)

VIZATION AUDITED (a)

AUDIT NO. (b)

FINDING NO. (c)

RESPONSE LETTER NO. (g)

16.1.2
Rev. 4
August 15, 1976
Attachment 6.1
Page 8

FINDING

(e)

RESPONSE

(f)

REMARKS

(l)

	EVALUATION	BY	DATE	QA NO.
(h)	ACCEPTABLE	(i)	(i)	(j)
	VERIFICATION REQUIRED			
	VERIFICATION UNSAT.			
	INCOMPLETE RESPONSE			
	FINDING NOT ADDRESSED			
	UNACCEPTABLE			
	AFR CLOSED			

(k)
NEW AFR GENERATED
NO. _____
BY. _____
DATE. _____

process but that the level of involvement varies from project to project. It was noted that the QA/QC groups were in a unique review position because they could indicate the portions of the specification which would give them the most difficulties during the construction phase.

With regard to The Use of General Construction Codes and Standards, it was noted that for the concrete situation, the codes and standards which are used were probably never intended for the "literal" interpretation stance which occurs on nuclear construction projects. In the nuclear situation, it was noted that the Engineer must assume a very active "interpretive" role if later quality related problems are to be avoided. A point was also made that an industry-wide assessment of the current situation in the concrete area is needed to determine if the codes and standards should be revised to more closely reflect the nuclear construction situation.

Several different approaches to the Incorporation of Codes and Standards into Specifications were presented. The "Blanket Reference" of a concrete code was indicated to require less Engineering effort during the specification development stage, but was one which could create later problems when a "literal" interpretation of certain sections of the cited code were made by QA/QC. The "Selective Reference" method and the "Blanket Reference With Exceptions" methods were also discussed. The crucial role of the Engineer was again emphasized with regard to the clear interpretation of the requirements for a project. If the Engineer does not assume this interpretive role, then the QA/QC and Construction personnel must assume it by default. An example of the selective designation of ACI 347 Formwork Tolerances was cited to indicate the role which an Engineer must assume.

With regard to the Quantification of Specification Requirements in the concrete area, it was noted that on some projects, too much emphasis is

probably being placed on those process characteristics which can be quantified and not enough emphasis is being placed on the more qualitative aspects of the concrete process.

Engineering Changes were discussed by first citing examples of the Engineering Change documents which were used on three of the projects in the research study. The problem that has arisen on one project because of the lag between Engineering Changes and formal revisions to the specifications was cited. Several reasons for the extensive number of specification changes which occur on nuclear construction projects were presented. These are: (1) The development of specifications with unrealistic requirements, (2) The lack of a feedback loop between the Construction and Engineering groups which could be used to make the specifications more responsive to the construction situation, and (3) The reuse of an Engineering Firm "Standard Specification" at the beginning of each new project.

The last part of this section discussed The Impact of Engineering Changes. One of the impacts that was cited was the need to revise supportive Construction and QA/QC procedures whenever a specification is revised. An experience on one project which was based on this point was cited. A second impact arises because of the need for strict compatibility between the PSAR and the specifications. Another project example was cited to illustrate this point. The practice of "waiving" a specification requirement rather than attempting to revise either the specification or the related industry code and standard was also discussed. The disposition of Nonconformances by the "Use As Is" choice was also discussed as a possible example of the "waiver" of specification requirements.

CRITERION XV: NONCONFORMING MATERIALS, PARTS AND COMPONENTS

The discussion in the second section of Chapter 4 presented an extensive

coverage of the different systems which are being implemented in response to Criterion XV. Table 4.6 summarizes some of the more important aspects of the Nonconformance Control systems on the projects which were discussed.

A few additional points which are not shown in Table 4.6 should be made about the major impacts of Criterion XV as well as about the innovative steps which have been taken on some projects to reduce the detrimental effects caused by these impacts.

1. It appears that on most projects, the Nonconformance document must travel through a number of organizations (sometimes more than once) before a Nonconformance event is finally "closed". This practice not only consumes the resources of a large number of people, it also increases tremendously the time which is required between the identification of the Nonconformance, the receipt of an approved disposition and the completion of the corrective action. The length of time also appears to be influenced by the location of the organizations which are involved in the process. It would appear advantageous to have the personnel who are responsible for the dispositioning of the Nonconformance documents permanently assigned to the project site, for instance, since a routing of the document to a "Home Office Engineering group" does not appear to be time-effective.

It would also appear to be advantageous to require a definable team such as the "Deviation Review Board" on Project B or the "Project H Review Board" to meet on a day-to-day basis if necessary, in order to obtain the immediate resolution of most of the Nonconformance documents which are written. It is felt that such meetings would reduce the decision-making time (which represents time during which construction has essentially stopped) to a minimum.

2. A comparison of some of the Nonconformance documents which were

Table 4.6--Nonconformance Control Systems[a,b]

		PROJECT A	PROJECT B	PROJECT C [b]	PROJECT F	PROJECT H	PROJECT I
1.	Nonconformance Identification Responsibility	All site personnel	All site personnel	All site personnel	All site personnel	All site personnel	All site personnel
2.	Documentation	Deficiency report	Deviation Reports Procedure Violation Report	Nonconformance Report (NCR)	Nonconformance and Disposition Report	(c)	Nonconformance and Disposition Report
3.	Documentation Iniation Responsibility	CM Firm QC	CM Firm QC	EPC Firm QC	Utility F QC	Utility H CQA or Individual Contractors	EPC Firm QC
4.	Segregation Procedure	CM Firm QC Hold Tag	CM Firm QC Hold Tag	EPC Firm QC Hold Tag, Hold Storage	Utility F QC Hold Tag, Hold Storage	Utility H CQA Hold Tag	EPC Firm QC Reject Tag
5.	Disposition Responsibility	CM Firm Discipline Supt. & Utility A Engineering	Deviation Review Board	EPC Firm Field or Home Office Engineering	AE/CM Firm Engineering	(d)	EPC Home Office Engineering
6.	Disposition Categories						
	a. Rework	X	X	X	X	X	X
	b. Repair	X	X	X	X	X	X
	c. Reject	X	X (Scrap)	X	X	X (Scrap)	X (Scrap)
	d. Use As Is	X	X	X	X	X	X
	e. Salvage		X				
7.	Corrective Action Specified on Documentation (to prevent recurrence)	No	Yes	No, but closed NCR sent back to org. causing NCR	No	Yes	No
8.	Reinspection Responsibility (before close out)	CM Firm QC	CM Firm QC	EPC Firm QC	Utility F QC	Utility H CQA	EPC Firm QC
9.	Status Log Maintained	Yes (CM Firm QC)	Yes (CM Firm QC)	Yes (EPC Firm QC)	Yes (Utility F QC)	Utility H CQA	EPC Firm QC

[a] Project G situation is not presented in the Table due to the number of documents which are used. Reference to the text description is suggested.

[b] Project D is not shown since it closely resembles Project C.

[c] Nonconformance Reports, Audit Action Reports and Corrective Action Requests

[d] Project H Review Board approves disposition which has been indicated by the affected Contractor.

presented will indicate that there is a considerable amount of information that must be recorded every time one of these documents is initiated.

Some of the data input practices which were noted in the discussion should be recommended as additions to the Nonconformance documents which are used on some of the projects in the research study. The practice implemented on Projects B and H, for instance, which requires the affected party to indicate the corrective action which will be taken to prevent the reoccurrence of the nonconformity, is one which is recommended. Another is the input of the Nonconformance Code and Cause Code information for each nonconformity which is required on Project H. This practice would appear to provide an excellent basis for later Trend Analysis activities.

It is also suggested, however, that the Nonconformance documents on a number of projects should be scrutinized in great detail to determine if all of the required information is really necessary (and in fact ever used). A reduction in the time required to fill out the forms could possibly be achieved on a number of projects if such a study were made.

3. A number of projects have adopted a set of forms for Nonconformance situations which consider the relative severity of the Nonconformance. This appears to be a response to the situation which was recognized by Rice (1, A4.7) when he stated;

> "It appears to me that most of us in the QA discipline have overreacted to section XV, "Nonconforming Materials, Parts or Components" and section XVI, "Corrective Actions" of 10 CFR 50, Appendix B, criteria in developing our procedures, methods and systems. The problem as I see it, is the various points of view. What is a "significant adverse condition" to the fabricator and constructor may or may not be significant to the Designer. What is significant to the Designer may or may not be significant to the Owner/Operator and so on to the Owner and NRC. This really becomes a probem when the nonconformance and corrective action system and procedures are written so restrictive that "all" discrepancies must be reported on an approved form to the responsible designer for corrective action disposition, especially when the RESPONSIBLE authorized designer is several hundred miles from the job site...

> Requiring minor type in-process discrepancies, which occur continually in welding, concrete and steel structures, equipment erection, and wiring circuits, to be locked into the formal Nonconformance Reporting and Corrective Action Procedures is not practical or efficient. We have not had much success in getting our client's QA representatives to accept the philosophy of classifying defects and having a simple, fast track, minor discrepancy reporting method and procedure. I believe there is a real need for a mutually acceptable definition and guideline for classifying major and minor discrepancies...
>
> I would suggest three types of classifications to be established for discrepancies, such as Major, Minor and Incidental with mutually accepted guidelines for classifying them. Only the Major classified discrepancies would be required to be fed into the formal nonconformance reporting and corrective action system. The Minor and Incidental classified discrepancies should be documented and dispositioned by the lowest competent level of personnel. I have used such a system in the past and it provided an effective and efficient system."

The concept of several types of Nonconformance documents to record several levels of severity should be given serious consideration by the industry. One of the problems with this approach, however, appears to be that each of the types of Nonconformance documents will require separate logging and tracking by either the QC or the QA group. This could tend to compound rather than improve the documentation tracking problems which already exist.

4. The final point that should be made concerns the "Use As Is" dispositioning category. From the limited amount of data that was made available on the projects in the research study, it appears that a large percentage of the Nonconformance documents on most projects receive this type of a disposition. If this is true, then it would appear that in many cases, it is not necessary for all of the requirements which appear in the engineering documents to be rigidly adhered to in all cases.

It is recommended that an industry wide study be initiated in order to identify a number of generic areas which are consistently dispositioned "Use As Is". When the cost of a typical Nonconformance document in terms of both manpower and project time is considered, it seems that a reassessment of some of the requirements in the engineering documents which cause this type of

a disposition would be extremely cost effective for the entire industry.

CRITERION XVI: CORRECTIVE ACTION

The section related to Criterion XVI: Corrective Action, provided a brief overview of the Corrective Action practices on two of the projects which were in the research study. The practices which were discussed, (i.e., Corrective Action Reports and Trend Analysis), appear to be fairly typical of the practices on most of the other projects in the study.

One of the practices which was indicated, (i.e., the Project H approach to coding Nonconformances as well as Causes on Nonconformance Reports), appears to be an excellent method of collecting the basic data which is needed for Trend Analysis reporting. It should be noted that additional information about the Corrective Action procedures which are used on other projects in the research study can be found in the discussion related to Criterion XV.

CRITERION XVIII: AUDITS

The final section of Chapter 4 provided an analysis of the procedures which implement the requirements of Criterion XVIII: Audits, on a number of the projects in the research study. The Audit procedure used on Project B was presented in detail in order to indicate the depth of coverage which is provided in a typical QA Audit. It also indicated the various phases of an Audit, from the Pre-Audit Preparation phase to the Follow-up phase.

Examples of the Auditing procedures from several other projects in the research study were also presented in order to indicate some of the modifications to the Project B approach which are being implemented. It was indicated, for instance, that on a number of projects an Audit Checklist is required, which in some cases can be extremely lengthly. Several examples of the type of Audit Finding Reports which are used were also presented. It was also noted that on some projects, "Intermediate Conferences" are held to allow

deficiencies to be brought to the attention of management while the Audit is still taking place.

No recommendations are made about the "best" type of an Auditing procedure to use (i.e., there probably is not one best type). It is felt, however, that the information about Audits which has been presented will provide guidance to anyone interested in the different approaches which are currently being implemented.

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2. Tuthill, L.H., Games People Play With Concrete", ACI Journal, Vol. 73, No. 12, December 1976, pp. 671-678.

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8. Heltemes, C.J., "The NRC Perspective on QA--Progress and Problems," The AIF Workshop on Reactor Construction and Operation--A Current Assessment, Atlanta, Ga., 1976.

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CHAPTER 5

PROCUREMENT AND TESTING OF CONCRETE COMPONENTS

Introduction

The requirements for high quality concrete for a two-unit nuclear power plant can exceed 500,000 cubic yards. Due to their nature, projects of this type require materials of the highest quality to insure the integrity of the structures. The components which are used in the production of concrete must be of acceptable quality if the finished product is to be acceptable. This chapter investigates the specification limits and testing requirements which are imposed upon the materials which are used in producing concrete on the projects which were studied. Specification limits are compared with applicable codes and standards which govern the production of concrete for non-nuclear work, as well as on a project-by-project basis. One point which should be kept in mind while considering these comparisons is that the requirements for high quality concrete are the same whether the concrete is to be used in nuclear or non-nuclear applications. This chapter covers the requirements for the materials which are needed for the concrete. The concrete production requirements of the various projects will be discussed in chapter 6.

Cement

The cement requirements on a two-unit nuclear power plant can reach 120,000 tons. Even though there is a large quantity required, since cement is produced under such a controlled process, it does not appear to be a major contributor to problems during construction. There are some areas, however, which, although may not be considered major problems, are worth commenting upon. These areas will be brought out below in the comparative analysis of the cement requirements of the projects studied.

As can be seen from Table 5.1, all of the projects in the study use Type II portland cement with the exception of Project E. Project E uses Type I portland

Table 5.1.--Testing Requirements for Portland Cement

Project	A	B	C	D	E	F	G	H	I	ANSI	ASME
Cement Type	II	II	II	II	I[a]	II	II	II	II		
Reference ASTM C150	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Optional Tests	-[d]	chemical	-	chemical	chemical physical	chemical	chemical	chemical	-		
Additional Requirements	-	mortar cubes 1250 @ 3 2250 @ 7 4375 @ 28	-	-	mortar cubes 5400 @ 28 $\sigma \leq 300$	mortar cubes 3400 @ 7 safety related structures	-	mortar cubes 4500 @ 28	-		
In-Process Testing Frequency	new silo	376 tons C190 and C191 monthly	5000 CY or 3 months	5000 CY or 3 months	376 tons	1200 tons	5000 CY	1200 tons	1200 tons	1200 tons	1200 tons
Retesting	b	-	-	-	-	cement stored 90 days	-	cement stored 6 months	cement stored 3 months		
Maximum Cement Temperature @ Delivery	170°F	None	140°F	130°F	None[c]	150°F	140°F	140°F	150°F		

[a]Additional requirement that C_3A content does not exceed 10.5%.

[b]Cement must be retested if the batch plant does not operate for 2 weeks.

[c]Cement cannot be delivered until after a successful 7-day mortar cube test. Delivery temperature usually is between 130°F and 150°F

[d]Indicates that the item is not required on the project.

cement with the additional requirement that the tricalcium aluminate (C_3A) not exceed 10.5%. Type II cement provides moderate sulfate resistance and moderate heat of hydration. One of the major contributors to heat of hydration is C_3A, which is limited to a maximum content of 8% in Type II cement. The 10.5% C_3A limit which Project E places on Type I cement would appear to be a reasonable compromise for areas where Type II cement was not readily available in the large quantities required for nuclear power plants.

Material Qualification. All of the projects in the study stipulate that cement will meet the requirements of ASTM C150. This requirement is recommended by all of the applicable codes and standards, including ACI 301, ACI 318, ASME Boiler and Pressure Vessel Code, and ANSI N45.2.5. In addition to the standard tests in ASTM C150, six of the projects, B, D, E, F, G and H, require at least some of the optional chemical requirements. The required qualification tests for each project are indicated in Table 5.1.

Several of the projects studied impose additional requirements on the cement beyond those stipulated in ASTM C150. These additional requirements are in the area of the required strengths of mortar cube specimens. Project B requires mortar cube strengths of 1250 psi at 3 days, 2250 psi at 7 days, and 4375 psi at 28 days. Project H requires strengths of 4500 psi at 28 days. Project F has an additional requirement for mortar cube strengths of 3400 psi at 7 days for safety related structures only. In contrast to these requirements, ASTM C150-77 requires 2500 psi at 7 days with an optional requirement of 4000 psi at 28 days.

One other Project, E, also places an added mortar cube strength requirement on cement. Project E requires an average 28 day strength of 5400 psi with a maximum standard deviation of 300 psi. Cement which does not meet this requirement, but which exceeds 3500 psi (this requirement is from ASTM C150-73a) is accepted but at a reduced payment. This is very significant because it is one

of the very few instances among the projects studied that the natural variability of materials was considered. On the whole, there was an obvious lack of application of the statistical concepts that are available for describing the natural variability of materials. These statistical techniques, along with areas where they might be employed in nuclear concrete construction, will be discussed in detail later in this chapter. At first glance, it might appear that the mortar cube requirements of Project E are unnecessarily stringent when compared with those of the other projects in the study. This does not appear to be the case however, since Project E had no difficulty in obtaining a supplier who would commit to the requirements.

Receiving Inspection. As can be seen from Table 5.1, most of the projects studied place a maximum allowable temperature on cement upon its delivery. These maximum delivery temperatures range from 170°F down to 130°F. Only one project allows the cement shipment to stand overnight if the temperature is too high, thus allowing the cement to cool. The other projects reject the entire load if the cement temperature is above the upper limit. At one site, approximately ten truckloads of cement have been rejected due to delivery temperatures of either one or two degrees above the upper limit. At another site, approximately three truckloads per month are rejected due to high delivery temperatures.

It would appear that some of the projects in the study have implemented unnecessarily severe temperature limitations on the cement at the time of delivery. ACI 305-72, "Recommended Practice for Hot Weather Concreting", states in paragraph 2.4.2:

> "2.4.2--Hot cement results from heat generated mechanically during grinding. Heat is lost slowly during storage so cement may be delivered at relatively high temperatures. Changes in cement temperature produce significantly less change in initial concrete temperatures than the other ingredients. However, it does exert an effect and it is considered prudent to place a maximum limit on temperature as it enters the concrete.

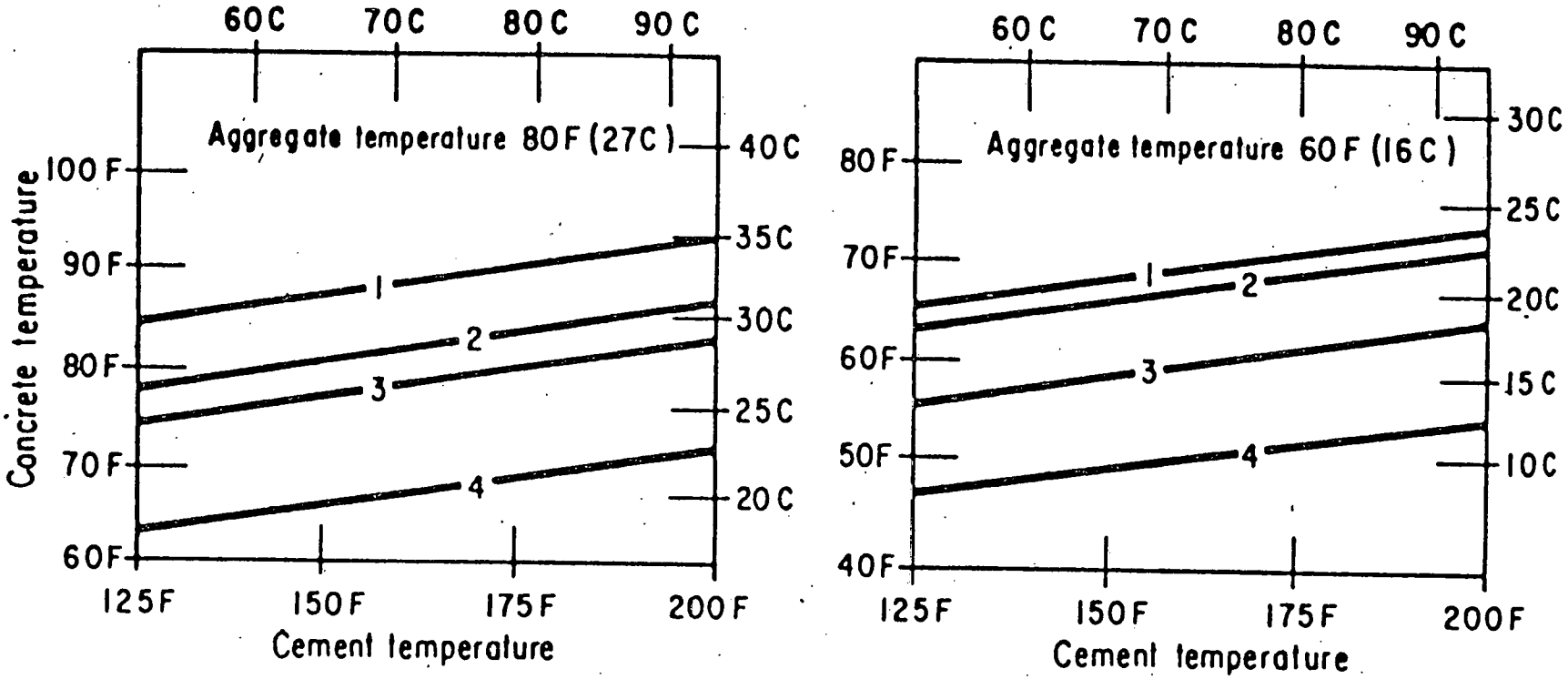
Cement should not be used at temperatures in excess of 170°F (77°C). In mixing concrete, high cement temperature appears to have no detrimental effect other than raising the concrete placing temperature."

This paragraph contains some fairly significant statements. It states that cement should not be mixed in excess of 170°F and also states that since heat is lost during storage, cement may be delivered at relatively high temperatures. These statements seem to be incongruous with project specifications placing maximum delivery temperatures at 130°F and 140°F. The last sentence in paragraph 2.4.2 is also significant since it indicates no direct detrimental effect of high cement temperature.

The paragraph quoted above is from practice for hot weather concreting. None of the projects stipulating maximum delivery temperatures make any allowance in the specifications for cement that is delivered during cold weather conditions. There are also no provisions in any of the specifications which provide for the cooling of the cement during its retention time in the storage silos at the project site, perhaps because cement looses heat very slowly and because extra facilities for cooling are generally not available.

Rejecting cement for delivery temperature in the 130°F-150°F range may be a questionable practice in view of the fact that changes in cement temperature have significantly less effect than changes in either water or aggregate temperature. Referring to Figure 5.1, it can be seen that, holding all other factors constant, a reduction in aggregate temperature of 20°F produces a decrease in the concrete temperature of about 16°F. On the other hand, a reduction in the cement temperature from 175°F to 125°F produces a reduction in the concrete temperature of approximately 5°F. The figure clearly indicates that the temperature of the aggregate and the mixing water is far more important than the cement temperature.

Project E has no ceiling on the cement temperature at the time of delivery.



Curve (1) - Mixing water at temperature of aggregate

Curve (2) - Mixing water at 50 F (10 C)

Curve (3) - Mixing water at temperature of aggregate; 25 percent of mixing water by weight replaced by ice

Curve (4) - Mixing water at temperature of aggregate; 50 percent of mixing water by weight replaced by ice

Figure 5.1.--Influence of Temperature of Concrete Ingredients on Concrete Temperature

(Source: ACI 305-72)

The delivery temperature is indirectly controlled on this project by requiring that positive results of the 7 day mortar cube test must be obtained before cement can be shipped by the manufacturer. This approach seems quite satisfactory since it verifies that the compressive strength is satisfactory and at the same time provides time for the cement to cool before it is delivered to the site. Most of the cement which is delivered to the site is between 130°F and 150°F. Using this approach there is no danger of having to reject cement which is one or two degrees above the limit.

In-Process Testing. In order to verify that the cement which is being supplied to the project meets the specifications, all of the projects studied require periodic testing of the cement being delivered. In addition to this periodic testing, all of the projects require the supplier to furnish certified copies of mill test reports showing the chemical composition of the cement in order to verify that the cement being furnished is in accordance with the specifications. The testing frequency varies from plant to plant with the highest frequency being every 376 tons on Projects B and E. ANSI N45.2.5 and ASME Boiler and Pressure Code require that in-process tests be performed every 1200 tons of cement used, and this is the frequency used on four of the projects studied.

In addition to the periodic tests mentioned above, several of the projects studied stipulate additional retesting for cement that has been in storage. Projects F and I require that cement that has been stored for three months be retested before use. Project G requires that cement which was stored elsewhere than in the bins at the mills for more than four months after being tested be retested before use. These restrictions have failed to cause any problems since cement is used so rapidly that it very rarely has the opportunity to remain in storage for three months. Project B requires ASTM C109 and C191 to be performed

monthly to verify that storage conditions are not adversely affecting the cement. Project A requires that when the batch plant does not operate for a two week period that the cement stored on site be retested by ASTM C109 and C266.

Two of the projects in the study, C and H, use what might be referred to as a "sealed silo" program; that is, all of the cement delivered to the site is from a silo which was tested and sealed and reserved for that particular project. A representative of the owner samples and tests the cement each time the manufacturer fills one of his storage silos. Cement from this silo cannot be used until tests performed on the sample confirm compliance with ASTM C150. Such a sealed silo program should, in theory, lead to reduced testing since all of the cement comes from silos which were tested and approved upon filling. This expected reduction in required testing was not found on the projects in the study which used a "sealed silo" program. Project C and H, which have sealed silo programs, have approximately the same testing frequency of cement as do the other projects studied.

Aggregate

Because of the large volumes of concrete placed on nuclear power plant projects, there is a great demand for high quality aggregate. On a typical two-unit nuclear project, there is a need for 250,000 tons, or more of fine aggregate and 350,000 tons, or more, of coarse aggregate. The fine aggregate used on the projects studied is either natural or manufactured sand or a combination thereof. The coarse aggregate consists of crushed stone or gravel. Due to the many heavily reinforced, congested areas on nuclear power plant projects, a large quantity of one inch or smaller aggregate is needed.

In order to assure that aggregate of acceptable quality is being furnished,

there are extensive aggregate testing programs in effect on all of the projects studied. There are two phases to these aggregate testing programs. The first phase, qualification testing, is performed only once at the beginning of the project. The second phase, material verification, referred to as periodic or in-process testing, is performed throughout the concrete production phase of the project. Qualification tests are usually complete before any concrete is placed at the project site. The material verification tests are carried out periodically throughout the project to assure that aggregate which is received at the site is of the same quality as the material which was originally qualified. A comparison and discussion of the material qualification and material verification systems employed on the projects in the study is presented herein.

Material Qualification. The process of qualifying a supplier for use as an aggregate source on a nuclear power plant project is very detailed and can be very time-consuming. On one of the projects studied, it was commented that the qualification of an aggregate source took six to seven months. Due to this long lead time required for qualification, a number of the sites studied qualified more than one aggregate source in the event that a second source became necessary once the project was underway. A second source could become necessary in the event that the primary source could not supply material rapidly enough to meet the project's demands, or in the event that the material of the primary supplier began to have difficulty in meeting the specification requirements. In lieu of the lost production time which could be involved in such a situation, the extra expense involved in qualifying a secondary aggregate source could prove to be money well invested.

The requirement for qualification testing is stipulated in both ANSI N45.2.5 (ANSI) and ASME Boiler and Pressure Vessel Code (ASME). In section 3.2

of ANSI it states: "Verification that materials meet specified requirements shall be accomplished through qualification tests and in-process tests". Both ANSI and ASME require that aggregate for use on nuclear power plants meet the requirements of ASTM C33, Standard Specifications for Concrete Aggregates. All of the projects studied reference ASTM C33 in their specifications. One problem which has arisen on several of the sites is the fact that the specifications reference just ASTM C33, whereas other sites reference a specific issue of the standard. For example, Project A referenced ASTM C33-66, which was the current issue of the standard when the project specifications were being developed. This approach finalizes the requirements which must be met for the entire project. On the other hand, by referencing simply ASTM C33 in its specifications, a project inadvertently commits itself to revising its requirements every time a new version of the standard is issued. The specification reference to ASTM C33 for each project is shown in Table 5.2.

A comparison of the qualification test requirements of the projects in the study is also given in Table 5.2. The table shows the qualification tests required on each project, and in addition shows the tests and some of the acceptance limits of ASTM C33-77. Whenever the project specifications indicate requirements similar to ASTM C33 a check mark is shown. Where the project specifications are more stringent than ASTM C33 the acceptance limits are shown for comparison with ASTM C33-77. As can be seen from the table, project B has limits on some tests which are somewhat more severe than those of ASTM C33. In addition, this project is the only one studied which required the test for water soluble chlorides, ASTM D1411. The limits on some of the tests do not appear to be unreasonable even though they are tighter than those of ASTM C33. The U.S. Bureau of Reclamation Concrete Manual recommends values for 5-cycle Sodium Sulfate Soundness

Table 5.2.--Aggregate Qualification Tests

Project		A	B	C	D	E	F	G	H	I	ASTM C 33-77
Reference in Specifications		C33-66	C33-66	C-33	C33-74a	C-33	C-33	C-33-71a	C33-71a	C-33	-
Test	ASTM #										
Gradation	C 136	✓[c]	✓	✓	✓	✓	✓	✓	✓	✓	✓
Material finer than #200	C 117	✓	FA-3%[a] CA-1%	✓	✓	✓	✓	✓	✓	✓	FA-5% CA-1%
Soundness	C 88	✓	FA&CA Na-8%	✓	✓	✓	✓	✓	✓	✓	FA-Na 10% Mg 15% CA-Mg 15%
Abrasion	C 131 C 535	✓	40%	✓	40%	✓	✓	40%	✓	✓	50%
Organic Impurities	C 40	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Mortar Strength	C 87	-[d]	✓	✓	✓	✓	✓	✓	-	✓	✓
Fineness Modulus	C 125 C 33	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Flat and Elongated Particles	C 125 CRD-C 119	-	✓	✓	✓	✓	✓	✓	✓	-	-
Clay Lumps	C 142	-	FA-1%[a] CA-0.25%	✓	✓	-	✓	✓	✓	✓	FA-3% CA-2%
Coal and Lignite	C 123	-	FA-0.5%[a] CA-0.25%	✓	✓	-	✓	-	✓	✓	0.5%
Soft Fragments	C 235	-	CA-5%	✓	✓	-	✓	✓	✓	-	-
Unit Weight	C 29	✓	✓	-	✓	✓	✓	✓	-	✓	✓
Water Soluble Chloride	D1411	-	0.001	-	-	-	-	-	-	-	-
Specific Gravity and Absorbtion	C 128	✓	✓	✓	✓	✓	✓	✓	✓	✓	-
	C 127	✓	✓	✓	✓	✓	✓	✓	-	✓	-
Alkali Reactivity	C 227	-	✓	-	-	-	✓	-	-	✓	✓
Potential Reactivity	C 289	✓	✓	✓	✓	-	✓	✓	✓	✓	✓
Petrographic Examination	C 295	-	✓	✓	✓	-	✓	✓	-	✓	✓

[a] Sum of these may not exceed 3%.

[b] In the case of crushed aggregates, if the material finer than the No. 200 (75-μm) sieve consists of the dust of fracture, essentially free of clay or shale, this percentage may be increased to 1.5. A greater amount of dust of fracture passing the No. 200 sieve may be permitted provided the amount passing the No. 200 sieve in the fine aggregate (Table 1) is less than the specified maximum. In such case, the sum of the amounts finer than the No. 200 sieve from the separate fine and coarse aggregates shall not exceed the sum of the weighted maximum amounts permitted for the coarse plus fine aggregate.

[c] ✓ indicates test limits in accordance with ASTM .

[d] Indicates that the test is not required.

of 8% for sand and 10% for gravel. This manual also recommends a Los Angeles Abrasion limit of 40% (5.1). This 40% limit has been adopted by three of the projects in the study.

Most of the qualification testing requirements on the various projects are similar since all of the projects reference ASTM C33. Two areas where there are discrepencies among the individual project specifications, the requirements for Flat and Elongated Particles and for Fineness Modulus, are discussed in detail below in the section on material verification.

Material Verification. In-process testing is necessary to verify that the material which is being delivered to the site is of the same quality as the material which was originally qualified. Both ANSI and ASME have recommended frequencies for in-process testing. These recommended frequencies, along with the testing frequencies on each of the projects in the study, are indicated in Table 5.3. The testing frequencies from the proposed 1976 draft revision to ANSI are included in parentheses in Table 5.3. It should be noted that this draft would have brought the testing requirements of ANSI in line with the ASME requirements. While this standardizing of requirements is a good idea, one must wonder whether the ANSI requirements were considered for change because the committee felt the higher frequencies were necessary, or just to bring them in line with the ASME requirements. If the testing frequencies were adequate to produce good concrete in 1974 when ANSI N45.2.5 was issued, it might be questioned why they are not adequate for the same purpose in 1976, or 1978.

A brief perusal of Table 5.3 will indicate the wide variation among the projects in the study both in the area of what in-process tests are required and in the frequency of performance of the various tests. The later projects in the study, particularly Projects F and H, follow the ANSI guidelines either exactly or very closely. Some of the earlier projects in the study, Projects B, C and D

Table 5.3.--In-Process Aggregate Tests

Project		A	B	C	D	E	F	G	H	I	ANSI	ASME
Test	ASTM #											
Gradation	C 136	250 Tons	250 Tons	CA-1/shift FA-2/shift	CA-1/Day 1000 CY FA 2/Day 1000 CY	Daily	Daily	Daily or 1000 CY	Daily	Daily	Daily (2/day if over 200 CY)[c]	Daily (2/day if over 200 CY)
Moisture Content	C 566	-[d]	-	Daily	CA 1/Day 1000 CY FA 2/Day	Daily	Daily	Daily or 100 tons	2/Day	Daily	Daily (2/Day)	2/Day
Material Finer than #200	C 117	Q[b]	Daily	5000 CY	1/Day 1000 CY	Monthly	Daily	Q	Daily	Daily	Daily	Daily
Soundness	C 88	Q	a	5000 CY	5000 CY	Q	6 Months	3 Months	6 Months	6 Months	6 Months	6 Months
Abrasion	C 131 C 535	Q	a	5000 CY & 300 Tons	5000 CY	Q	6 Months	3 Months	6 Months	Yearly	6 Months	6 Months
Organic Impurities	C 40	250 Tons	Daily	1/Shift	1000 CY 1/Day	-	Weekly	Daily or 100 Tons	Daily	Monthly	Weekly (Daily)	Weekly
Mortar Strength	C 87	-	a	Q	Q	Q	Q	Q	-	Monthly	-	-
Fineness Modulus	C 125 C 33	250 Tons	250 Tons	2/Shift	1000 CY	Daily	-	-	Daily	Daily	-	-

(continued)

[a] Whenever it appears type or grading has changed

[b] qualification test only

[c] Values in parentheses are from the proposed 1976 draft revision.

[d] Indicates that the test is not required.

Table 5.3.--In-Process Aggregate Tests (Continued)

Project		A	B	C	D	E	F	G	H	I	ANSI	ASME
Test	ASTM #											
Flat and Elongated Particles	C 125 CRD-C119	-	Weekly	Weekly	Daily	Q[b]	6 Months	Q	6 Months	-	6 Months (Monthly)	Monthly
Clay Lumps	C 142	-	Daily	Q	Q	-	Monthly	Q	Monthly	6 Months	Monthly	Monthly
Coal and Lignite	C 123	-	Daily	Q	5000 CY	-	Monthly	-	Monthly	6 Months	Monthly	Monthly
Soft Fratments	C 235	-	-	Q	Q	-	Monthly	Q	Monthly	-	Monthly	Monthly
Unit Weight	C 29	Q	-	-	5000 CY	Q	Q	Q	-	Q	- (Daily)	-
Specific Gravity and Absorption	C 128	Q	Weekly	Q	5000 CY	Monthly	6 Months	Q	Monthly	6 Months	- (Monthly)	Monthly
	C 127	Q	Weekly	Q	5000 CY	Monthly	6 Months	Q	-	6 Months	- (Monthly)	Monthly
Alkali Reactivity	C 227	-	Q	-	-	-	Q	-	-	Yearly	-	-
Potential Reactivity	C 289	Q	Q	5000 CY & 300 Tons	Q	-	6 Months	3 Months	6 Months	FA-6 Mos. CA-Yearly	6 Months	6 Months
Petrographic Examination	C 295	-	Q	Q	5000 CY	-	Q	Q	-	Q	-	-

[b] Qualification test only

in particular, have some testing frequencies that are quite a bit higher than those in ANSI. These more frequent testing requirements are probably due to the fact that there was no national standard for this type of construction at the time the project specifications were developed, and these projects overreacted to 10CFR 50 and imposed tighter restrictions than were really necessary. Such an overreaction to perceived or anticipated requirements can only lead to added testing and expense which has no effect on improving the quality of the final product.

If one compares some of the testing frequencies of projects C and D with those recommended by ANSI, it would appear that they are unnecessarily high. Unless the aggregate which was used at these sites was particularly suspect, it would seem that these frequencies are higher than is necessary to verify the quality of the material. Some rough calculations on just one of the tests will indicate the added expense which may be adding very little, if any, to the quality of the concrete. The prices which are used in these calculations are quotes from an independent testing laboratory which works extensively in the nuclear power plant construction field. A petrographic analysis of both the fine and coarse aggregates costs about $750. On Project D, this analysis is required every 5000 cubic yards of concrete produced, whereas on all other projects this analysis is either not performed or is only used as a qualification test. Petrographic analysis is certainly an important examination which should be run on any new aggregate source, but once production has begun it is probably not justified unless the material being quarried is significantly different from the material that was qualified. This could usually be determined by visual inspection of the quarry and aggregate. The estimated concrete demand for Project D is 335,000 cubic yards, which, at one per 5000 cubic yards would require 67 petrographic analyses. At the previously quoted price, this would be an expense

of approximately $50,000 for this one requirement alone.

Table 5.4 indicates the requirements for flat and elongated particles for the projects in the study along with the requirements of ASME and ANSI. It should be noted that the proposed 1976 draft of ANSI N.45.2.5 increases the frequency to monthly in accordance with ASME. There is a wide range among the projects in the definition of a flat and elongated particle, in the maximum allowable percentage of these particles in the aggregate, and in the frequency of the testing. The definition of flat and elongated varies from a maximum to minimum length ratio of 3:1 to 5:1. Project E, which has a 5:1 ratio, allows only 3% of flat and elongated particles by weight or number. Most of the projects studied, along with ANSI and ASME, use an allowable ratio of 3:1 or 4:1 and allow a maximum of 15% of these particles. Project B, which is one of the earlier projects in the study and whose specifications were written before ANSI or ASME were issued, has by far the most stringent specification requirement. This could be indicative of a strong concern for producing high quality concrete, but probably more realistically represents an overreaction to perceived or anticipated standards. The maximum allowable limit of 15% would appear to be quite acceptable. The Portland Cement Association (PCA) recommends a limit of 15% (5.2) and the U.S. Bureau of Reclamation Concrete Manual states:

> "The chief objection to flat or elongated particles of aggregate is the detrimental effect on workability and the resulting necessity for more highly sanded mixes and consequent use of more cement and water. A moderate percentage (on the order of 25 percent of any size) of flat or elongated fragments in the coarse aggregate has no important effect on the workability or cost of concrete." (5.1)

The area where there is the most discrepancy among the projects concerning flat and elongated particles is in the frequency of in-process testing. The testing frequency varies from once every six months to once per day on one project. Two of the projects test weekly, whereas two other projects use flat and elongated

Table 5.4.--Test for Flat and Elongated Particles

Project	Reference CRD-C119	Frequency	Definition Flat (w/t)	Definition Elongated (l/w)	Maximum Allowable Percentage
A	-	-	-	-	-
B	-	Weekly	3:1	3:1	5%
C	Yes	Weekly	4:1	4:1	15%
D	-	Daily	4:1	4:1	15%
E	-	Qual. Only	5:1	5:1	3%
F	Yes	6 Months	3:1	3:1	15%
G	-	Qual. Only[a]	4:1	4:1	15%
H	Yes	6 Months	3:1	3:1	15%
I	-	-	-	-	-
ANSI	Yes	6 Months	3:1	3:1	15%
ASME	Yes	Monthly	3:1	3:1	15%

[a]Or as directed by the Engineer

particles only as a qualification test. Specifications with daily or weekly testing frequencies appear to be totally unnecessary overreactions. All of these specifications were developed before ANSI was published with its recommended frequency of 6 months. It should be noted that the more recent projects in the study use frequencies more in line with the ANSI requirements.

Fineness modulus is another area where the specifications for the projects in the study vary widely. The allowable range for Fineness Modulus in ASTM C33 is 2.3 to 3.1. As can be seen from Table 5.5, a number of the projects in the study stipulated much tighter limits on fineness modulus than does ASTM C33. The projects also stipulated various limits on the variability of the sample test results. These limitations are also shown in Table 5.5. Fineness modulus limits did not appear to be a major problem, although several of the sites studied did experience occasional instances where fine aggregate failed to meet required fineness modulus limits.

Two areas worth commenting on regarding fineness modulus deal with things which were not done. Project E uses a fineness modulus requirement of 2.7-3.3. The reason that this value is so high is that this project uses fly ash in many of its concrete mixes, and flyash contains a large amount of fines. Other projects in the study which used flyash, some of which experienced significant problems related to flyash, did not raise their specification limits above ASTM limits. The other area concerns one of the provisions of ASTM C33. ASTM allows fine aggregate which fails to meet the sieve analysis and fineness modulus requirements to be accepted provided it can be demonstrated that concrete of the class specified, made with the fine aggregate under consideration, will have relevant properties at least equal to those of concrete made with a fine aggregate which satisfies the established requirements. None of the projects studied used this provision or

Table 5.5.--Fineness Modulus Requirements

Project	Frequency	Limits	Additional Requirement
A	250 Tons	2.3-3.1	-
B	250 Tons	2.3-2.8	B
C	2/Shift	2.5-2.8	D
D	W/Gradation (1000 CY or daily)	2.5-3.1	C
E	W/Gradation (Daily)	2.7-3.3	A
F	W/Gradation (Daily)	2.3-3.1	-
G	W/Gradation (Daily)	2.35-2.75[a] 2.55-2.95[b]	-
H	Daily	2.3-3.1	A
I	W/Gradation (Daily)	2.3-3.1	A
ASTM C33-77		2.3-3.1	B

A--Fineness Modulus in 9 out of any 10 consecutive samples shall not vary from the average of the 10 test samples by more than 0.20.

B--No individual sample may vary from the average of all previous samples by more than 0.20 unless adjustments are made in concrete proportions.

C--At least 4 of 5 successive samples shall not vary by more than 0.20 from the average.

D--One fineness modulus determination out of ten is permitted to be in the range 2.45 to 2.85.

[a]Requirement for one sand supplier

[b]Requirement for other sand supplier

included it in their specifications.

It must be remembered that this ASTM standard was written for general construction and not necessarily for nuclear projects. Since the nuclear industry is accustomed to literal interpretations, it may be difficult to employ this provision on nuclear work. It would probably be difficult to 'prove' to the NRC that concrete made with aggregate not satisfying ASTM requirements for fineness modulus or gradation has the same 'properties' as concrete made with conforming aggregate. It would be difficult to determine which properties should be considered, and how they should be evaluated. Would the evaluation of strength be sufficient, or would other hard-to-determine properties such as durability, water-tightness and resistance to creep and shrinkage also have to be considered? Such a situation as this is encountered quite frequently in the nuclear industry which has been conditioned to think literally, and not necessarily logically, when interpreting the provisions of standards.

There are several problem areas and other points worth considering as a result of this study. These areas will be pointed out and discussed in detail.

One point which is clearly obvious, particularly in the area of aggregate gradation, is the indicated lack of application of statistical concepts for describing the natural variability of materials that was exhibited on nearly all of the projects that were studied. On none of the projects studied is there any indication of any type of formal or informal random sampling plan. On no site are multiple sampling techniques employed to reduce the variability involved in estimating the population central tendency. It is suggested here that a formal random sampling process based on multiple samples taken from the day's production would give a much better description of the true properties of the materials being

sampled, and may alleviate the necessity for such frequent testing as is currently taking place. Employing statistical concepts to determine the properties of construction materials may seem radical to the nuclear construction industry, but such techniques have been employed in the highway industry for a number of years. Many state highway agencies have developed statistically based specifications and acceptance plans for such construction materials as aggregates, portland cement concrete, bituminous concrete and soils excavation and embankment (5.3). The incorporation of these statistical concepts into nuclear project specifications is certainly a promising area for future research.

One area where statistical concepts could readily be employed in nuclear construction is in the area of aggregate gradation. This is one area where the specifications of the projects in the study appeared to be lacking. Most of the specifications studied base acceptance of aggregate gradation on the results of a single gradation analysis. Concerning this subject, the ACI Manual of Concrete Inspection (5.4) states:

> "It must be recognized that aggregates, particularly coarse aggregates, vary considerably within stockpiles and bins; hence the significance of any single test is limited. Each new analysis should be averaged with at least two immediately preceding analyses of the same material to obtain a more representative analysis of its general run on which to base mix adjustments or to determine if grading requirements are met."

This approach is commonly referred to as a "running average" or "moving average" approach. ACI 304, "Recommended Practice for Measuring, Mixing, Transporting, and Placing Concrete", recommends the use of a running average of from 5 to 10 gradation tests for the purpose of both quality control and mix proportioning. Only one of the projects in the study used this running average approach for aggregate gradation acceptance. The specifications for that project state:

> "The gradation results of aggregate sieve tests shall be averaged with the nine most recent test results, and that average shall satisfy gradation requirements, including fineness modulus, of ASTM C33."

This approach takes into account the natural variability of the material by recognizing that even in the best material it is possible for an isolated test

result to be outside the limits even though the vast majority of the material is acceptable.

Another technique for aggregate gradation acceptance which is employed at two of the projects studied is highly questionable. The specifications for one of these projects states:

> "Sufficient material shall be obtained for three samples, two of which shall be held as reserve for retest in the event of failure of the first sample tested...
>
> If the initial sample tested fails to meet the gradation requirements, the two reserve samples shall be tested. Failure of either of the reserve samples to meet the gradation requirements shall be cause for rejection of the material represented."

This approach does not have the sound statistical basis to support it as does the running average approach discussed previously. At first glance it would appear that this approach is based upon multiple sampling. This is not the case, however, since two samples are thrown away in the event that the first sample meets the specified limits. If the first sample fails but the two retests are acceptable, then the material is considered acceptable. This would imply that acceptable results on two out of three tests would be sufficient grounds to accept the material. If this is, in fact, the appropriate acceptance criteria, then problems arise when the first sample is acceptable. Suppose that three samples are taken and that one of these is acceptable and the other two are not. If the acceptable sample is tested first, then the two unacceptable samples will never be tested. This acceptance criteria does not appear to be founded upon any basic statistical concept, and its use as a specification requirement is questionable.

Another problem that deals with aggregate gradation is centered around the

fact that it is a daily in-process test. Since it is an in-process test, it is possible that concrete with unsatisfactory aggregates will have been placed at the time when the results of the test become available. All of the concrete which has been placed must be written up as nonconforming to the specification. This situation arose quite frequently on one of the projects studied due to the poor process control of the batch plant contractor. The only way of handling this type of nonconformance is to show that the concrete is, indeed, competent and does not require removal even though the aggregate gradation was not within specification limits. This can be verified by the results of the compressive strength cylinders that were cast from the suspect concrete. On the project mentioned above, a policy has been set up that if the 28-day compressive strength of the concrete is satisfactory then the nonconformance will be closed based on "Accept as is because of adequate compressive strength". This process is quite simple, but it does result in a great deal of paperwork and effort being expended.

The problem stated above is not particularly significant in its own right. It can be solved in a number of ways--by adequate process control, or, simply by sampling and testing the aggregate either the night before or in the morning far enough ahead of the shift so that concrete production does not begin before the test results are available. The method of handling the nonconformances generated by the problem does, however, bring out a very important point. That is, if the concrete is accepted on the basis of strength, how critical is it that the aggregate gradation, fineness modulus, etc. conform exactly to the specified ranges? The use of these values as partial acceptance criteria should be questioned. These tests are certainly important, and should not be eliminated. On the other hand, consideration should be given for using these tests for process control tests and not as acceptance criteria. Specification limits would still

be given for gradation and fineness modulus, but these would be treated as guidelines for the contractor's process control. Acceptance would be based upon the stipulated acceptance criteria, such as compressive strength, only. Using such an approach, much time, effort, and paperwork could be saved since a nonconformance report would not be required every time the gradation was out of the specification limits. This approach would not adversely affect quality, since the vast majority of these nonconformances are already being closed out "use as is" because the compressive strengths are acceptable. Such a program, where the contractor is responsible for process control while the owner performs only acceptance testing is an integral part of the statistically based specifications currently employed by state highway agencies. (5.3.)

A potential disadvantage with such an approach was identified by a member of the Engineering Firm on one of the projects who stated:

> "Using specifications for fineness modulus or gradation as a guideline rather than as a rigid requirement is certainly reasonable. But an unacceptable situation could develop when a less than conscientious batch plant operator loses control of his aggregate to the extent that low strength concrete results. By the time a strength problem is detected, much concrete may have been placed. Because of the probable significance of the structure and the concern for low strength concrete in it, the solution to the problem could be demolition. This is obviously a most undesirable solution, and avoiding it is worth the price of applying relatively severe specification limits. Low strength concrete can be justified much more easily in highway structures and pavements than in containment vessels."

A problem which has been encountered on a number of projects, but which was particularly difficult on one project, was with the percentage of material

passing the No. 200 sieve. The ASTM C33 limit for material finer than No. 200 sieve is 1.0%, with 1.5% being allowed in the case of crushed aggregate if the material finer than the No. 200 sieve consists of the dust of fracture. One of the projects in the study experienced a six week period of disrupted concrete production when the material finer than the No. 200 sieve exceeded this 1.5% limit. During this period a number of safety related concrete placements were considered nonconforming as a result of the aggregate which was used in them. As an interim measure during this period, coarse aggregate was washed prior to its use to achieve compliance with the specification requirements. After an extensive study, the individual limits for fines on sand and coarse aggregate were replaced by a single limit on total aggregate fines allowed in each batch of concrete. This "total fines" concept for aggregate was incorporated into the project specifications by revision. The specification revision established an equation for determining the acceptability of the aggregate based upon the total fines in the batch as determined by the weighted values of the aggregate components in the batch. The project specifications state:

> "If the results of any of the aggregate sizes exceeds the stated limits for fines, the aggregates shall be considered acceptable provided the following condition is met:
>
> $[(5.0 \times W1) + 1.5(W2 + W3)] \geq [(A \times W1) + (B \times W2) + (C \times W3)]$
>
> where A = Percentage of fines in sand as determined from test.
>
> B = Percentage of fines in 3/4" aggregate as determined from test.
>
> C = Percentage of fines in 1-1/2" aggregate as determined from test.
>
> W1 = Weight of sand in one cubic yard of concrete.
>
> W2 = Weight of 3/4" aggregate in one cubic yard of concrete.
>
> W3 = Weight of 1-1/2" aggregate in one cubic yard of concrete."

This "total fines" concept is something which should be considered for incorporation into other project specifications. The most recent issue of "Standard Specification for Concrete Aggregates", ANSI/ASTM C33-77 has

incorporated a "total fines" approach for the first time. Footnote d to Table 3 of C33 states:

> "[d]In the case of crushed aggregates, if the material finer than the No. 200 (75 μm) sieve consists of the dust of fracture, essentially free of clay or shale, this percentage may be increased to 1.5. A greater amount of dust of fracture passing the No. 200 sieve may be permitted provided the amount passing the No. 200 sieve in the fine aggregate (Table 1) is less than the specified maximum. In such case, the sum of the amounts finer than the No. 200 sieve from the separate fine and coarse aggregates shall not exceed the sum of the weighted maximum amounts permitted for the coarse plus fine aggregate."

Since this provision is included in an ANSI/ASTM standard, it would have to be considered acceptable for use in nuclear projects. Such a provision could make it possible to use an aggregate source closer to the project which might otherwise be unacceptable without the provision. In such a case, project costs could be reduced with no corresponding reduction in the quality of the concrete produced.

Material Storage. The storage conditions for aggregate on the projects studied varied widely. Some of the projects required paved stockpile areas with physical barriers separating the different classes of aggregate. On the other end of the spectrum was one project which did not require either a paved stockpile area or physical barriers between stockpiles. The ASME Boiler and Pressure Vessel Code requires that the aggregate be identified to show the size, source and controlling specification while it is in plant storage. ANSI N45.2.5 suggests inspections to verify that storage and handling techniques are not resulting in segregation or contamination with deleterious substances.

Care should be taken in the storage of aggregate because improper stockpiling practices can lead to problems with the aggregate. Problems associated with the stockpiling of aggregate include segregation, accumulation of fines, and variation in moisture content. ACI 304, "Recommended Practice for Measuring,

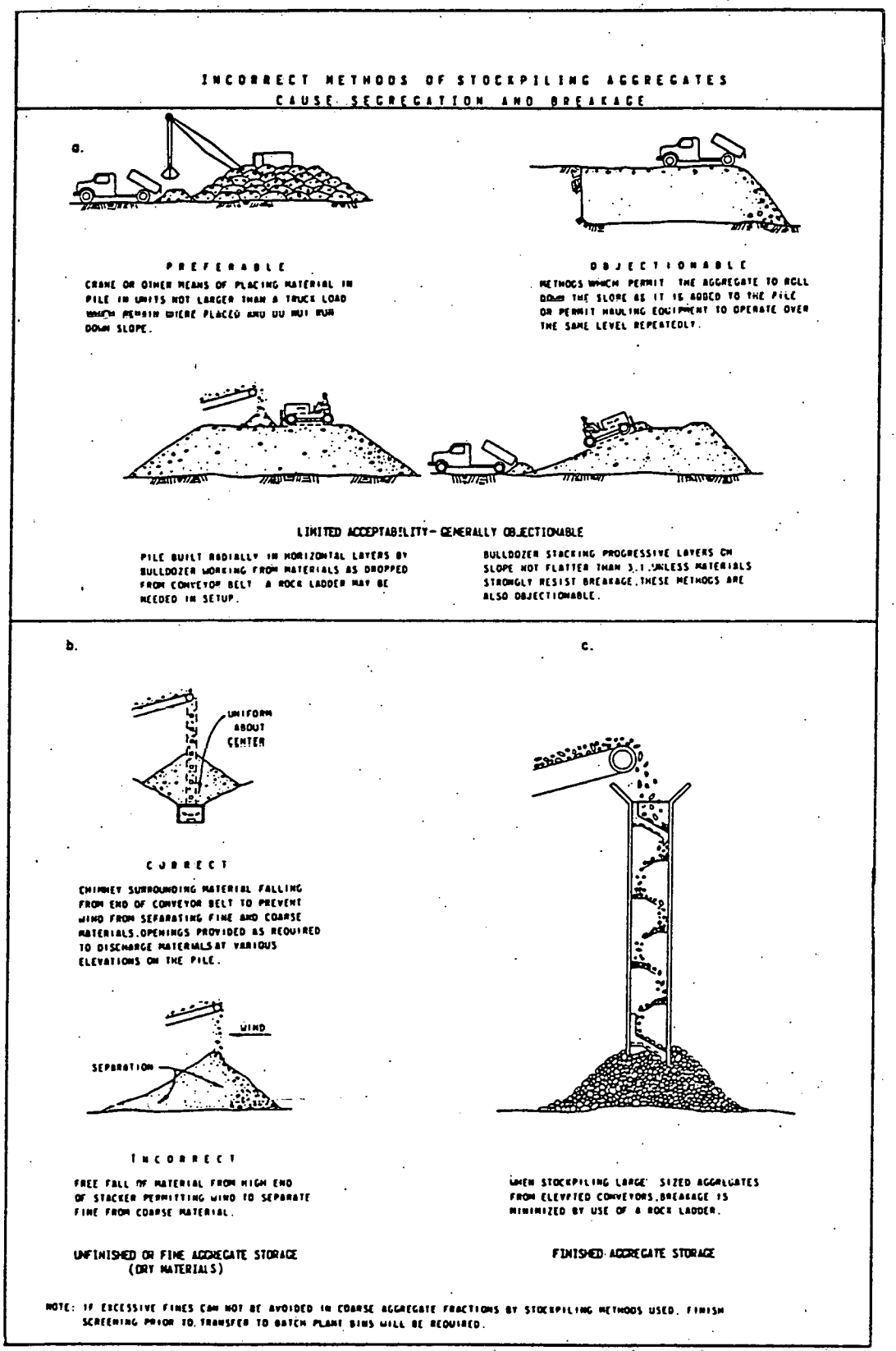


Figure 5.2.--Correct and Incorrect Methods of Handling and Storing Aggregates (Source ACI 304-73)

Mixing, Transporting, and Placing Concrete", includes techniques for handling and storing aggregates to minimize problems of segregation. ACI 304 indicates that use of incorrect stockpiling methods can cause segregation, aggregate breakage, and excessive variation in gradation. The recommended methods from ACI 304 are illustrated in Figure 5.2. It should be pointed out that none of the projects in the study used rock ladders for the stockpiling of aggregates. Failure to use these items, however, does not appear to have led to serious problems with segregation or aggregate breakage.

ACI 304 also states that stockpiling should be kept to a minimum "because even under ideal conditions fines tend to accumulate." This concern appears to be taken into account on the projects studied. All of the projects maintained relatively small stockpiles of aggregates at the project site considering the large volume of concrete that is required for the project. As mentioned previously, a number of sites did experience some problems with excess fines. Long periods of time in stockpile can increase the fines in the stockpile from aggregate breakage and from accumulation of dust raised during the project construction activities.

Another area which can lead to problems is in the area of moisture control in the stockpiles. One project in the study in particular experienced erratic slump results due to varying moisture contents in the aggregate stockpiles. ACI 304 states that the use of aggregates having varying amounts of free water is one of the most frequent causes for loss in control of concrete consistency as measured by slump. On the project just mentioned, it was determined that the source of the problem stemmed from inadequate stockpile size. The stockpiles were not large enough to allow time for the moisture content of the aggregate throughout the pile to stabilize. Adequate time for drainage of free water

from fine aggregate is of particular importance since fine aggregate can have a stable moisture content as high as 8 percent in some cases. Several of the project specifications address the problem of aggregate moisture content. Projects B, D, and G require that fine aggregate be stored on site for at least 24 hours to allow for drainage of free water. The ACI Manual of Concrete Inspection recommends that washed sand be allowed to drain 2 or 3 days to achieve a uniform moisture content (5.4). Two projects, D and E, place a limit on the amount of moisture variation which is allowable. Project D limits the moisture variation to $\pm$ 2 percent in 8 hours, whereas Project E allows a gradual change in moisture content of 1 percent in 4 hours or an abrupt change of 1/2 percent. The source of these requirements may be the Corps of Engineers which requires that moisture variation not exceed 2 percent in 8 hours or 1/2 percent in 1 hour (5.5).

The projects studied differ on the method of removing material from the stockpile. There are basically three methods for removing material from a stockpile: a clamshell, front end loader, or a conveyor belt operating in a tunnel below the pile. Two of the projects in the study, C and D, use the underground conveyor system. The remainder of the projects use an end loader to transport material from the stockpiles to the batch plant conveyor. Of the three methods mentioned, according to Waddell: "Use of an end-loader is the least desirable method, as this machine usually removes gravel from the periphery of the pile, near the bottom, causing the gravel to flow down the slope, with resulting segregation." (5.6) This potential segregation has not appeared to present any difficulties on the projects which were studied.

Water

Water initiates the chemical reactions that produce the binding properties of the portland cement. Generally speaking, water from any source of domestic

water supply may be used for mixing and curing concrete. Small amounts of impurities in the mixing water can be tolerated with no detrimental effects on concrete quality, however, impurities concentrated in sufficient quantities can have an appreciably harmful effect upon the strength or durability of the concrete in service (5.7). Certain other compounds may cause unattractive discoloration in concrete surfaces, efflorescence (movement of salts to the surface), and excessive corrosion of reinforcing steel. Due to these potential harmful effects, water for use in concrete on nuclear projects must be qualified and periodically tested just as are the other concrete components.

Material Qualification. The ACI Building Code Requirements for Reinforced Concrete, ACI 318, states that the water used in mixing concrete "shall be clean and free from injurious amounts of oils, acids, alkalis, salts, organic materials, or other substances that may be deleterious to concrete or steel." A statement similar to this appears in the specifications of each of the projects which were studied. ACI 318 also states that if nonpotable water is proposed for use, mortar test cubes made with the water should have 7-day and 28-day compressive strengths equal to at least 90 percent of the strengths of similar specimens made with potable water, when tested in accordance with ASTM C109. ACI 318 also states that for prestressed concrete or for concrete with aluminum embedments the mixing water should not contain deleterious amounts of chloride ion. The Commentary to ACI 318 suggests that chloride ion contents greater than 400 ppm might be considered dangerous.

The ASME Boiler and Pressure Vessel Code requires that water for mixing concrete should be clean with a total solids content of not more than 2000 ppm, and that the mixing water, including that contained as free water in aggregates, should contain not more than 250 ppm of chlorides. This figure can

be compared with the limits on the projects that were studied which are given in Table 5.6. As can be seen from the table, the earliest projects in the study, which had no outside guidance from a national code, established tighter limits than are given in ASME. These values that are required by ASME appear to be reasonable. The Bureau of Reclamation recommends a turbidity limit of 2000 ppm (5.1), and the Portland Cement Association indicates that water containing less than 2000 ppm of total dissolved solids is satisfactory for making concrete (5.2).

In addition to the chemical requirements stated above, ASME lists additional physical requirements. These additional requirements include:

> "Additional Requirements. A comparison of the proposed mixing water properties shall be made with distilled water by performing the following tests:
>
> (a) Soundness, in accordance with ASTM C 151, "Autoclave Expansion of Portland Cement"--The results obtained for the proposed mixing water shall not be more than +0.10 above those obtained for distilled water.
>
> (b) Time of Setting, in accordance with ASTM C 191, "Time of Setting Hydraulic Cement by Vicat Needle"--The results obtained for the proposed mixing water shall be within $\pm$ 10 min. for initial setting time and $\pm$ 1 hr. for final setting time of those obtained for distilled water.
>
> (c) Compressive Strength, in accordance with ASTM C 109, "Compressive Strength of Hydraulic Cement Mortars (Using 2 in. Cube Specimens)"--The results obtained for the proposed mixing water shall not be lower by more than 10% of those obtained for distilled water."

These requirements are more severe than those of ACI 318. ACI 318 mentions a comparison of proposed mixing water using only ASTM C109, whereas ASME requires ASTM C151 and ASTM C191 in addition to ASTM C109. Even in the requirement for ASTM C109 the two codes differ. ACI requires 90% of the compressive strength of specimens made with potable water, while ASME requires 90% of the compressive strength of specimens made with distilled water.

ANSI N45.2.5 also contains requirements for quality of mixing water used in concrete production. There are several differences between ANSI and ASME

Table 5.6.--Water and Ice Qualification and In-Process Tests

Project	A	B	C	D	E	F	G	H	I	ANSI	ASME
Water Source	Well	Municipal	Well	Well	River	Well	Well	Municipal	Municipal	-	-
Specification Reference	-	-	AASHO T26	AASHO T26-70	CRD-C400	-	AASHO T26-70	-	-	AASHO T26	-
Frequency of In-Process Testing	Water-Monthly Ice-Weekly	Monthly	3 Months	3 Months or 5000 CY	None	6 Months	6 Months or 5000 CY	None	6 Months	6 Months (Monthly)[e]	Monthly
Chemical Tests											
pH	-	-	4.5-8.5	4.5-8.5	✓[d]	✓	6.0-8.5	6.0-8.0	✓		
Chlorides (ppm)	100	100	-	250	✓	✓	250	250	✓	(250)	250
Sulphates (ppm)	-	300	-	1000	✓	✓	1000	250	✓		
Organic Solids (ppm)	-	-	✓	-	-	✓	500	-	✓		
Inorganic Solids (ppm)	-	-	-	-	-	✓	2000	-	✓		
Iron (ppm)	-	-	-	1	✓	✓	1	-	✓		
Total Solids (ppm)	-	2000	✓	-	-	✓	-	-	✓		
Nitrates (ppm)	100	100	-	-	-	✓	-	-	✓		
Sulphides (ppm)	100	100	-	-	-	-	-	-	-		
Turbidity	2000	-	-	-	-	-	-	-	-		
Calcium	-	-	-	-	✓	-	-	-	-		
Physical Tests											
Compressive Strength C109	-10%[b]	-10%[a]	-5%[a]	-5%[a]	CRD-C406	-10%[a]	-10%[a]	-10%[a]	-10%[a]	✓ (-10%[a])	-10%[a]
Setting Time C266	-	±25%[a]	±25%[a]	±25%[a]	-	-	±25%[a]	-	-		
Setting Time C191											
initial set	-	-	-	-	-	±10 min.[a]	-	±10 min.[a]	C150[c]	✓ (±10 min.[a])	±10 min.[a]
final set	-	-	-	-	-	±1 hr.[a]	-	±1 hr.[a]		(±1 hr.[a])	±1 hr.[a]
Soundness C151	-	-	-	-	-	+.10[a]	-	+.10[a]	C150[c]	✓ (+.10)	+.10[a]

[a] control specimens using distilled water

[b] control specimens using potable water

[c] Conformance to ASTM C150 i.e.: C191 initial set ≥ 45 min; final set < 8 hr.
C151 0.80% Maximum

[d] Indicates that test is required by project specifications but no limits are given

[e] Values in parentheses are from the proposed 1976 draft revision

in the area of requirements for mixing water. ANSI requires that proposed mixing water be tested by ASTM C109, ASTM C191, and ASTM C151, and also by AASHO T26. No additional chemical requirements are indicated. ANSI also recommends an in-process testing frequency for mixing water of every 6 months, whereas ASME requires monthly testing. It should be pointed out that the propsed 1976 revision to ANSI N45.2.5 would have changed the ANSI requirements to correspond to those of ASME, including the limits on physical tests, the chemical tests, and monthly testing frequency. These values are indicated in Table 5.6 by the values in parentheses under the ANSI column. Once again, as in the similar situation that occurred under aggregate in-process testing frequencies, one must wonder whether the ANSI committee proposed these changes because they felt they were necessary, or simply to be consistent with ASME.

Concerning the topic of testing frequencies, Table 5.6 indicates a broad range of in-process mixing water testing frequencies among the projects which were studied. The in-process testing frequencies vary from weekly, for ice on Project A, to not at all on projects E and H. Many of the projects, including E and H, call for retesting of the mixing water in the event that contamination is suspected. Monthly testing, as required by ASME, seems particularly unnecessary when a municipal water supply is used as the mixing water source. The approach employed on project E appears to be a sensible one. The project is only committed, by the specifications and PSAR, to retest water in the event that contamination is suspected. In reality, the mixing water is tested monthly for the purpose of process control. In this way, if the water quality is particularly good, and one or two monthly tests are omitted, problems do not arise for violating unnecessary PSAR commitments.

Mixing water testing requirements and frequencies for each of the projects

in the study are given in Table 5.6. A check mark indicates that the test is required in the specifications, but no limits are indicated. Projects F and H, which are among the later projects, follow exactly the ASME limits on the physical tests, whereas some of the earlier projects favor ASTM C266 for evaluation of the effect of the proposed mixing water on setting time. There is a very wide variation in the chemical tests which are required on the various projects. This in part stems from the various interpretations of qualitative statements which appear in the codes, such as "water shall be free from injurious amounts of oils, acids, alkalis, salts, organic materials, or other substances that may deleteriously affect concrete." A statement such as this places the burden on each individual specification writer to determine what limits are acceptable and unacceptable. This difficulty is, no doubt, an outgrowth of the fact that codes and standards are developed by committees, and it is inherently difficult to get a group of people to agree upon quantitative values. For purposes of comparison with project requirements, Table 5.7 is included. This table presents maximum allowable contents of various substances in concrete mixing water as recommended by the Portland Cement Association (5.2).

Most of the projects follow the ACI and ASME required limit of a maximum compressive strength reduction of 10% for samples made with the proposed mixing water as compared with control samples. Two of the projects, C and D, allow only a 5% strength reduction. It is probably questionable whether this more stringent requirement is justified in light of the fact that all of the codes are in agreement on the use of a value of 10%. This added requirement led to additional expenses on project D which were probably not necessary. The in-process test on an ice sample on this project resulted in a strength reduction of 8.8 percent. Thus, all of the concrete which had been placed since the

Table 5.7 Substances in Concrete Mixing Water
(Source: Principles of Quality Concrete-PCA)

	Maximum Content (ppm or ml/1)
Salts	
Sodium carbonate and bicarbonate	1,000
Calcium and magnesium carbonates	400
Magnesium sulfate and chloride	40,000
Sodium chloride	20,000
Sodium sulfate	10,000
Acids	10,000
Iron salts	40,000
Silt or suspended particles	2,000
Sea Water	35,000
Industrial Wastes	4,000
Sanitary Sewage	400
Sugar	500
Algae	1,000
Potassium and sodium hydroxide	0.5-1.0% (by weight of cement)
Oils	2.0% (by weight of cement)

previous test, 5000 CY, was written up as being in nonconformance with the specifications. The nonconformance could only be closed when the compressive strength results proved that the concrete in each placement met the strength requirements. This nonconformance proved to be very costly, yet, on any of the other projects, a strength reduction of 8.8% would have been within the specification limits.

Another aspect of water testing which was encountered on several of the projects was discussed previously in the section on aggregate gradation. This is the specification requirement that allows for retesting in the event that the initial sample fails. The specifications on these projects state that if the initial sample fails, then two additional samples shall be tested. If these samples are acceptable, then the water is considered acceptable. This practice should be considered questionable for the same reasons that were presented in the section on aggregate gradation.

Ice. All of the projects studied allow the use of crushed or flaked ice in the concrete mix in order to keep the concrete placing temperature down. This is particularly important during hot weather or for massive concrete placements where the heat of hydration is a factor of concern. The water for making ice is subject to the same testing requirements as is the regular mixing water. The testing frequencies for ice are the same as those for water on all of the projects but project A. On this project, ice is tested weekly, while water is tested monthly. Presumably, this is because the mixing water is supplied from on-site wells which are under the control of the contractor, whereas the ice is shipped in from outside the project. This arrangement of off-site ice production by outside parties was encountered on all of the projects but one. This project had an on-site ice plant. One area concerning the use of ice which was not clear in a number of the project specifications was the question

of how much ice could be used in the mix. ACI 305, "Recommended Practice for Hot Weather Concreting", states that "use of ice as part of the mixing water is highly effective in reducing concrete temperature," but places no limits on the amount of ice which may be substituted for mixing water. ACI 301, "Specifications for Structural Concrete for Buildings", allows the addition of well-crushed or flaked ice for "all or part of" the mixing water. Four of the projects studied indicated that ice could be used to replace up to 100 percent of the mixing water, while one project placed a 90 percent limit on the substitution of ice for water. The remaining project specifications were unclear, containing statements such as "a part of the mixing water may be replaced with crushed ice". With the concern over high heat of hydration temperatures in some of the massive concrete placements on nuclear power projects, it is probably advisable to clearly state in the specifications that 100% ice substitution is acceptable.

Admixtures

There are many different types of chemical admixtures currently being promoted and sold for inclusion into concrete. Admixtures are usually employed to modify the properties of concrete to make it more suitable for a particular application. Some of the reasons for which admixtures are used are: to increase workability, to reduce water-cement ratio (W/C), to accelerate or to retard setting time, to accelerate strength development, and to improve resistance to weathering. Admixtures which were encountered on the projects include air-entraining and water-reducing agents. In addition to these chemical admixtures, a number of projects used a pozzolan, fly ash, to replace a portion of the cement in the mix. Each of these items will be discussed in detail.

Air-Entraining Agents. Air-entraining admixtures are used on all of the projects in the study, except for project A. Air-entraining agents have been employed in the production of concrete for many years. There have been many advantages and disadvantages claimed concerning its use. Some of the advantages claimed for the use of air-entrainment are: increased workability, reduced bleeding and segregation, and increased durability. Among the disadvantages are reduced strength and inconsistency of the concrete mix. These advantages and disadvantages, along with their applications to nuclear projects, are discussed in this section.

Probably the most widely used argument for the use of air entrainment is the improved durability which it imparts to the concrete. This improved durability centers primarily around an improved resistance of air-entrained concrete to the action of freezing and thawing. Much research has been conducted which indicates that entrained air greatly increases the freeze-thaw resistance of concrete. In research conducted by PCA, the conclusion reached was that air entrainment is an important requirement of frost-resistant concrete and that adjustments in either the chemical composition of cement, fineness of grinding, or methods of manufacture have relatively little effect on increasing frost resistance of concrete as compared to air entrainment (5.2). The ACI Guide for Use of Admixtures in Concrete states that the primary purpose of air entrainment in concrete is to provide a high degree of resistance to the disruptive action of freezing and thawing and of de-icing chemicals (5.8). It would seem that this feature of entrained air would make the use of an air-entraining agent advisable for power plant construction, particularly in concrete which will be exposed to cycles of freezing and thawing.

On the other hand, it can be argued that the use of entrained air for increased freeze-thaw resistance is not necessary for power plant projects in

all cases. Tuthill (5.9) states that in mild climates, in unexposed portions of the structure in any climate, in exposed portions of structures not subject to saturation in any climate, and in portions of structures composed of such concrete with a W/C approaching 0.40, no air entrainment is required for the sake of durability.

ACI 211 has prepared a graded table which can be used for guidance when determining air content requirements (5.10). This table bases air content requirements on three exposure conditions: mild, moderate, and severe. These exposure conditions are defined as:

Mild exposure--When air entrainment is desired for a beneficial effect other than durability, such as to improve workability or cohesion or in low cement factor concrete to improve strength, air contents lower than those needed for durability can be used. This exposure includes indoor or outdoor service in a climate where concrete will not be exposed to freezing or to de-icing agents.

Moderate exposure--Service in a climate where freezing is expected but where the concrete will not be continually exposed to moisture or free water for long periods prior to freezing and will not be exposed to deicing agents or other aggressive chemicals. Examples include: exterior beams, columns, walls, girders, or slabs which are not in contact with wet soil and are so located that they will not receive direct applications of deicing salts.

Severe exposure--Concrete which is exposed to deicing chemicals or other aggressive agents or where the concrete may become highly saturated by continual contact with moisture or free water prior to freezing. Examples include: pavements, bridge decks, curbs, gutters, sidewalks, canal linings, or exterior water tanks or sumps.

A portion of the graded air content table from ACI 211 is included here

as Table 5.8. For most power plant applications, the concrete will probably fall in the moderate or mild exposure conditions. ACI 211 states that if a member is not continually wet and will not be exposed to de-icing salts, lower air content values such as those given for moderate exposure are appropriate even though the concrete is exposed to freezing and thawing temperatures (5.10).

Another advantage attributed to entrained air which would favor the use of air-entraining agents is an increase in the workability of the concrete. It has been estimated that the addition of 5 percent of air can increase the slump of a mix by 1/2 to 2 inches (5.11). However, Tuthill (5.9) observes that the concrete mixes commonly used in nuclear construction are usually rich, well sanded, and have relatively small maximum size aggregate. He goes on to state that for mixes such as these, purposeful air entrainment is not needed for the sake of workability.

A disadvantage of the use of air entrainment is the corresponding reduction in strength which can accompany its use. Since the entrained air increases workability, some of the water can be left out while maintaining, or actually improving, the workability. This decreased W/C helps to compensate for the strength loss associated with the entrained air. Investigations by Blanks and Cordon (5.11) show that in the cases in which the reduction which could be effected in the water content through air entrainment were small such as rich mixes, particularly where the maximum aggregate size was large, there was a reduction in both the flexural and compressive strength. Tuthill (5.9) states that in the rich mixes commonly used in nuclear construction, air entrainment is likely to reduce strength as much as 5 percent for each percent of entrained air. This reduction can result in increased cement contents to reach the required strength levels. This added cement can add to heat of

Table 5.8.--Approximate Air Content Requirements for Different Nominal Maximum Sizes of Aggregates (5.10)

	Nominal Maximum Size of Aggregate					
	3/8"	1/2"	3/4"	1"	1 1/2"	2"[a]
Recommended average[b] total air content, percent for level of exposure:						
--Mild exposure	4.5	4.0	3.5	3.0	2.5	2.0
--Moderate exposure	6.0	5.5	5.0	4.5	4.5	4.0
--Extreme exposure	7.5	7.0	6.0	6.0	5.5	5.0

[a]The slump values for concrete containing aggregate larger than 1 1/2 in. are based on slump tests made after removal of particles larger than 1 1/2 in. by wet-screening.

[b]Additional recommendations for air content and necessary tolerances on air content for control in the field are given in a number of ACI documents, including ACI 201, 345, 318, 301, and 302. ASTM C 94 for ready-mixed concrete also gives air content limits. The requirements in other documents may not always agree exactly, so in proportioning concrete consideration must be given to selecting an air content that will meet the needs of the job and also meet the applicable specifications.

hydration problems in massive sections. Tuthill goes on to state that the use of entrained air increases the problem of maintaining uniform slump and increases variation in the strength of test cylinders, because the percent of entrained air is sensitive to changes in temperature, in fines in aggregates, and in mixing, transporting, handling and placing operations. For these reasons, on one tunneling project which used water-reducing agents, air-entraining agents were not used and it was found that workability was sufficient and that 28-day strengths were increased by 17 percent (5.12).

Experiences of the projects in the study support the observations of Tuthill concerning the indiscriminate use of air entrainment. The specifications of the projects which were studied generally require across-the-board use of air entrainment in all concrete mix designs. Furthermore, the required air content of all classes of concrete is frequently the same value.

The required air content on the projects studied varied from a range of 2 to 6 percent to one of 4 to 8 percent. On project F, the specifications require that the air content of the first three loads of a mix batched on any day may be within ACI 301-Table 3.4.1 limits, but all others must be within 4 to 6 percent for mixes with #67 and #57 aggregates. The Table 3.4.1 air content limits for #67 and #57 aggregates are 4 to 8 percent and 3.5 to 6.5 percent, respectively. The concrete quality control consultant on this project felt that this requirement was restrictive and costly. These tighter limits increase the probability of rejecting concrete which is within acceptable ACI limits. On Project I, the air content requirements varied with the mix design. The requirements were all stated as $x \pm 1$ percent. Representatives of the engineer/constructor on the site expressed the opinion that these requirements were unnecessarily restrictive and that the ACI limits were more realistic.

Maintaining the air content of the concrete between the batch plant and the point of placement has proven to be a difficult task. Six of the projects studied have had to extablish complex and costly correlation test programs. Among other things, these programs attempt to predict the loss of air content between the batch plant and the point of placement of the concrete. One project in particular, Project G, experienced a great deal of variation in the air content of the concrete. On this project the specification limits were 3-6 percent, but air content tests were ranging from 2-10 percent. As a result of a study of the problem, it was determined that this wide variation in air content was due to the use of a flyash which was highly variable. Some other aspects of the air content requirements on this project are interesting. The specification limits on air content were widened to 2 to 6 percent, and the contractor recommended suspending the use of air entrainment since the plant was located in a climate which was not susceptible to freeze-thaw conditions. The owner, however, rejected this suggestion because it felt that air entrainment imparted other properties to the fresh concrete which justified its use. This raises an interesting point concerning the use of air entrainment on nuclear projects.

Due to the problems discussed above, and the fact that much concrete on nuclear projects is not subjected to freeze-thaw action, it must be questioned whether entrained air is necessary in all nuclear concrete. The unnecessary use of air-entraining agents adds another element of variability to the concrete production process. This increases the likelihood of rejecting concrete and also requires the added expense of additional testing. On one of the projects studied, nearly one-third of all concrete that has been rejected to date was due to the air content. Where air entrainment is necessary, guidance should be taken from the ACI recommendations. This will assure uniformity in

requirements and prevent unnecessarily restrictive specification limits which do little to improve the concrete quality. Air content requirements should be dictated by the exposure conditions of the concrete. ACI Committee 211 has recommended an approximate air content requirement of 2.5 percent for 1-1/2 inch maximum size aggregate concrete in mild exposure conditions. It may be possible to achieve air contents in this range without the use of an air-entraining agent. Widely used water-reducing agents contribute to workability and may add 1 or 2 percent air to the concrete. In view of this fact, and the fact that on many nuclear projects flyash and high cement mixes which improve workability are used, the use of air-entraining agents solely to improve workability may be a questionable practice.

Water-Reducing Admixtures. The addition of a water-reducing admixture to a concrete mix reduces the water requirements necessary to maintain the same workability. Water-reducing admixtures are classified as either (1) water-reducing, Type A, (2) water-reducing, set-retarding, Type D, and (3) water-reducing, set-accelerating, Type E. All of the projects in the study allowed water-reducing admixtures (Table 5.9). All of the projects allowed the first type of water-reducing admixtures except Project A. Project A used a water-reducing, set-retarding admixture, while the specifications of B, C, D, and G allow the use of both Type A and Type D water-reducers. All of the projects prohibit the use of Type E water-reducers. This is probably because many of these contain calcium chloride, and the chloride content is restricted in the concrete specifications of most of the projects. On the projects which allow both Type A and Type D admixtures the set-retarding type is used in hot weather, while the normal water-reducer is used in other conditions. The specifications for Project G call for the use of a Type A water-reducer when the ambient temperature is less than 80°F and a Type D water reducer when the ambient temperature is greater than 80°F.

Table 5.9. Use of Admixtures on the Projects Studied

Project	A	B	C	D	E	F	G	H	I
Admixture									
Air-entraining	-	✓	✓	✓	✓	✓	✓	✓	✓
Water-Reducing (Type A)		✓	✓	✓	✓	a	✓	✓	✓
Water-Reducing, Set-Retarding (Type D)	✓	✓	✓	✓			✓		
Water-Reducing, Set-Accelerating (Type E)	-	-	-	-	-	-	-	-	-
Pozzolan									
Flyash (Coal Fired Plant)	✓			✓	✓	✓[a]	✓[a]	✓	

[a]Use was discontinued.

Some of the original concrete mixes approved by the engineering firm for Project F contained either a water reducing agent by itself or in conjunction with flyash and air entraining admixtures. When the mixes were redesigned at the time that Project F stopped using flyash, trial mixes with and without water reducing admixtures were tested. With regard to the mixes which contained water reducing agents it was found that: (1) they did not perform sgnificantly better to justify their usage and (2) actual placements using some of these mixes were judged to produce excessive bleeding. These results prompted the engineering firm to discontinue the usage of water reducing admixtures for Project F.

This decision is particularly interesting because the widespread usage of water reducing agents in general construction, as well as on all of the other projects in the research study, appears to indicate that the benefits far outweigh any potential difficulties. In addition to reducing the water requirements for the concrete, water-reducing admixtures may reduce bleeding, increase workability at the same slump, and give increased strength in comparison to concrete without the admixture (5.8, 5.13).

Tests show that the slump loss of concrete containing water-reducing admixtures is usually slightly greater than for comparable concrete without the admixture (5.8). Hersey (5.14) has noted that water-reducing or set-retarding admixtures, when used with high or moderately high alkali cements, may cause a slump loss and false set of concrete when used in normal batching sequence. One of the projects in the study did experience an excessive slump loss early in the concreting operations which was attributed to the use of water-reducing admixtures. The trouble, however, was not caused by the admixture, but by a misunderstanding of its use on the part of the project personnel. The project was using a double dosage of the admixture because the ambient temperature was above 70°F. It was found that the double dosage requirement was

applicable only when the concrete temperature exceeded 70°F, not the ambient temperature. The use of the correct dosage of the admixture greatly diminished its influence on slump loss.

Most of the projects in the study use water-reducing agents in both concrete with and without air-entraining agents. As noted previously in the discussion on air-entraining admixtures, water-reducing admixtures may contribute to the air content of the concrete. Water reducers of the lignosulfonate variety usually produce some air-entrainment, whereas water reducers of the hydroxylated carboxylic acid type normally do not entrain air (5.8). In the amounts normally used, lignosulfonates may entrain 2 to 6 percent air in concrete (5.7). Due to the other potential benefits, the use of water-reducing agents in lieu of air entraining agents should be seriously considered. This elimination of the use of air-entrainment when possible should decrease the variability of the concrete production by eliminating a component of variability from the process

Superplasticizing or Super Water-Reducing Admixtures. One type of admixture which has not received wide use in this country, and which has received no use in the nuclear construction industry, is the so-called super-plasticizing admixture. One problem which is frequently encountered in the nuclear construction industry is the difficulty of placing concrete in heavily congested rebar areas. Several of the projects studied experienced problems with concrete voids in the areas of high rebar density. On Project A, the result of one concrete placement in the containment wall which contained voids was an extensive computer analysis to verify the integrity of the structure. The report of this study indicated that two of the reasons for the observed voids and honeycombing were: (1) the high density of steel reinforcement and its configuration, particularly around the hatches, which limited access to obtain proper consolidation, and (2) concrete pump failure resulted in some concrete

being placed with a low slump. The use of a superplasticizer could help to alleviate the concrete void problems.

Superplasticizing admixtures allow for the production of very high slump concrete without the very high water-cement ratio usually required to obtain such slumps. Concrete designed to have an initial slump of 3 inches can have its slump increased to in excess of 7 inches with the addition of a superplasticizer (5.15). This additional slump is achieved without the addition of water which could reduce the strength of the concrete. Research which has been done to date indicates that there is very little detrimental effects associated with the use of a superplasticizer. Research has indicated that superplasticizers have no significant effect on the strength, creep, durability, and drying shrinkage of the hardened concrete (5.15). While it is true that superplasticizers are very new in this country, they have been employed extensively in Japan since the late 1960's and Germany since 1972. Over seven million cubic yards of superplasticized concrete have been placed in Japan and Germany, including 13,000 cubic yards of 5800 psi and 7000 psi concrete placed at a nuclear power station and 20,000 cubic yards of 3600 psi concrete placed at a fossil station, both in Germany. The use of superplasticizers in nuclear concrete construction certainly warrants further research.

Pozzolans. A pozzolan is a siliceous material which will react in the presence of water with calcium hydroxide at ordinary temperatures to form compounds of low solubility possessing cementitious properties. Pozzolans may be either natural or artificial, with fly ash being the most common in the artificial category. Pozzolans have many properties which can make their use in concrete advantageous, particularly for mass concrete. Pozzolans are typically used to replace a portion of the cement in the concrete. Pozzolans are used to improve workability, to effect cost savings, or to reduce heat of hydration. Pozzolans have been used extensively

in the construction of concrete dams. The use of pozzolan as a separate cementing material to be added at the mixer in the ratio of one part pozzolan to two or three parts of Type II cement has become a regular practice by the Bureau of Reclamation and the Corps of Engineers (5.16). Six of the projects in the study use fly ash as a pozzolan (Table 5.9).

Fly ash is the residue from the combustion of pulverized coal collected by mechanical or electrostatic separators from the flue gases of coal-fired power plants. It constitutes about 75 percent of the total ash produced. Its properties vary widely, not only between different plants, but also from hour to hour within the same plant. Its composition depends upon the type of fuel burnt and on the variation of load on the boiler (5.11). Frequently, a utility which is constructing a nuclear power plant also owns and operates one or more coal fired plants. Such an occurrence provides the utility with a natural source of pozzolan for the nuclear concrete by utilizing the fly ash waste product from the coal fired plants. This approach is used by Projects A, E, and H in the study.

One of the advantages of the use of pozzolans which was mentioned previously, reduced heat of hydration, is of particular significance in nuclear construction where massive concrete placements are frequently encountered. This reduced, and delayed, heat of hydration is brought about by the fact that part of the cement is replaced by pozzolan. A rule of thumb which can be used for preliminary calculations is to assume that pozzolan gives off about 50 percent as much heat as the cement it replaces (5.16). As Tuthill (5.9) has noted, the use of pozzolans in proper amounts could reduce the maximum temperature rise by 15 percent. In addition to reducing heat of hydration, the use of pozzolans can reduce water requirements or improve workability. This can be particularly advantageous on projects where much of the concrete is placed by pump. The

reduction in water requirements and in the heat of hydration can help to reduce the likelihood of drying shrinkage and cracking, thus improving the overall quality of the concrete.

Some difficulties can be associated with the use of pozzolans, as evidenced by the fact that Projects F and G, which originally allowed fly ash, have discontinued its use. Some of the problems concerning the use of fly ash center around the high variability of the material and the difficulty in predicting how the fly ash will react with the other components in the concrete mix. These factors make it extremely difficult to write specifications for fly ash. Smith (5.17) notes that specifications will normally give limits for one property or another which a fly ash should or should not have in order to make good concrete in spite of the fact that "there is no property which can be shown to have any bearing on the quality of a concrete produced by any ash before it is actually used". This implies that an extensive program of trial mix evaluations should be performed on an ash before it is used for concrete production rather than to just specify limits on certain properties of the fly ash. Due to the large quantities of concrete used and to the potential benefits, such a preliminary evaluation would appear to be justified for nuclear power plant construction.

Smith (5.17) goes on to state that the ideal situation for the use of fly ash is a large batching plant where delivery of ash could be checked quickly for water requirement and specific gravity. These conditions are certainly present in the case of nuclear construction. It is important to note that the results of these tests must be employed to make adjustments in the weights of water, cement, and fly ash per cubic yard. This mix adjustment is necessary in order to maintain the concrete properties within acceptable limits. The two projects which have discontinued the use of fly ash have done so because of an inability or difficulty in maintaining the concrete properties within

specification limits.

The Project F concrete specification requires that the complete series of flyash tests cited in ASTM C618 (some of which require a long period of time to complete) be performed when the source of flyash is initially prequalified. The specification (before an April 1977 revision) also stated that certified test reports indicating the: (1) actual loss by ignition, (2) percentage passing the 325 mesh sieve and (3) Blaine fineness, be supplied for each lot which was shipped. ANSI N45.2.5 also requires additional in-process testing of the flyash.

Utility F's QA consultant for concrete, contrary to an interpretation by the engineering firm, felt that the statements in ANSI N45.2.5 required that each lot of flyash had to meet all of the tests in ASTM C618 before the flyash was shipped. Utility F's QC group, guided by this interpretation, therefore performed the full series of ASTM C618 tests on the flyash that was used during the early stages of the concrete production process. As a result, a large portion of the concrete which was placed over a 6 month period was identified as nonconforming because of flyash problems. Over this period a trend analysis of concrete batch plant nonconformances indicated that 40% (22 of 55) were written because the flyash did not meet the specification requirements.

In order to perform some of the long time period tests, the independent flyash supplier (i.e., not associated with one of Utility F's fossil plants) indicated that additional storage capacity would be required so that the flyash could be held until test results were available. The increased costs which Utility F would have incurred because of the additional storage

(based on a cost analysis by the engineering firm) was one of the factors which caused Utility F to reach a decision to discontinue the use of flyash on all future concrete placements.

Project G also experienced a great deal of difficulty with the fly ash which it used. The fly ash on this project was also obtained from a commercial supplier. The fly ash which was supplied to the project was of extremely high variability. This fact made it nearly impossible to maintain any degree of consistency in the slump and air content of the concrete. Air content values were extremely variable, ranging from 2 to 10 percent with very high loss of air content between the batch plant and the end of the pump line. The variability of the fly ash also influenced the water requirements and the slump of the concrete. The mixes were so erratic that adjustments in the mixing water were not possible. In some cases, all of the allowable water was necessary to produce adequate slump, while other times considerable water was not used. Early in the project, one of the specification requirements, that fly ash surface area be at least 6500 cm^2/cm^3, was deleted because the flyash which was being supplied failed to meet the requirement. Later, the engineer recommended that the fly ash supplier be changed and that the surface area requirement be reinstated because it was a vital characteristic of fly ash and should be required. The approach of changing the specifications to meet the materials, rather than finding materials that meet the specifications, should perhaps be reevaluated.

Project H has also experienced some problems associated with the use of fly ash. These problems have not been major ones and have not required that the use of fly ash be discontinued. Fly ash was not originally included in the project specifications, but was added at the insistence of the utility. The utility requested the use of fly ash to improve pumpability. Harsh sand used in the original concrete mix caused inadequate pumpability. The contractors

on the project then complained about slow setting time of fly ash mixes. Fly ash was then deleted, but its use was reinstated when pumpability problems again arose in the non-fly ash mixes. Another concern then expressed by the contractors was that the use of fly ash mixes caused a high liquid head. This led the contractors to complain about the associated additional formwork stability required by higher liquid head, even though the contractors were continually advised to design forms for full hydrostatic head, with or without fly ash mixed concrete.

In contrast to Projects F, G, and H, the other projects which use pozzolan, A, D, and E, have not experienced any significant problems associated with its use. Projects A and E use fly ash obtained from the respective utility's coal fired generating units. Such an approach provides the utility with a use for its fly ash and waste products, and facilitates communication and coordination between the fly ash supplier and the construction site personnel since the utility is involved in both of these areas. The utility which owns Project E makes extensive use of fly ash in all of its construction and has a general specification relating to its use in concrete. The requirements for fly ash that are included in this specification are listed in Table 5.10 along with the fly ash requirements from the other projects in the study. As can be seen from the table, the specifications for Project E divide fly ash into three separate classes, each with different specification limits. The general descriptions of these classes, as stated in the project specifications, are:

> "Class I--Fine Fly Ash--This provides the maximum strength contribution at all ages for given proportions of fly ash to cement. When properly proportioned, it is well suited for use in any class of concrete and is particularly suited to requirements for high concrete strength and for early concrete strength.

Table 5.10.—Fly Ash Requirements

Project	A	D	E	F	C	H	ASTM C618
Reference ASTM C618 in Specifications	Yes	Yes	No	Yes	Yes	Yes	
Testing Frequency							
—Carbon and Surface Area	Weekly	-	-	-	-	-	
—Fineness	-	-	Once Every 3 Trucks (60–75 Tons)	-	-	-	
—Chemical and Physical	Monthly	5000 CY	Periodically	200 Tons	200 Tons	200 Tons	400 Tons
Chemical Requirements							
—Silicon Dioxide + Aluminum Oxide + Iron Oxide, Min. %	✓[c]	✓	75	70	✓	✓	70
—Sulfur Trioxide, Max. %	✓	✓	4	5	✓	4	5
—Moisture Content, Max. %	✓	✓	3	3	✓	✓	3
—Loss on Ignition, Max. %	✓	6	6	6	✓	5	12
—Magnesium Oxide, Max. %	-	-	5	-	✓	5	5[a]
—Available Alkalies (as Na_2O), max. %	-	-	2	1.5	✓	✓	1.5[a]
Physical Requirements			Class				
Fineness:			I / II / III				
—Surface Area, cm^2/cm^3, min.	-	-	6500 / 5000 / 3500	6500	6500[b]	-	-
—Amount Retained when wet sieved on No. 325 sieve, Max. %	-	✓	12 / 22 / 32	34	✓	✓	34
—Sedimentation at end of 60 minutes, Max. in cc	-	-	35 / 45 / 55	-	-	-	-
Pozzolanic Activity Index:							
—With portalnd cement at 28 days, min. % of control	✓	✓	85 / 70 / 55	85	✓	75	75
—with lime at 7 days, min. psi	-	✓	1000 / 800 / 600	800	✓	✓	800
Water Requirement, max. % of control	✓	✓	- / - / -	105	-	✓	105
Autoclave expansion or contraction, max. %	-	✓	- / - / -	±0.5	-	±0.8	±0.8
Uniformity Requirement (individual samples may not vary from the average of preceding samples by more than:)							
—Specific Surface, Max. Variation, %	-	-	-	15	-	-	-
—Specific Gravity, Max. Variation, %	-	✓	-	5	-	-	5
—% Retained on No. 325 Max. Variaion percentage points	-	-	-	-	-	5	5
—For AE concrete, the AEA required to produce an air content of 18% by volume of mortar, max variation, percent	-	-	-	20	-	-	20[a]
Multiple Factor, Max. %	-	-	-	255	-	-	255[a]
Increase of drying shrinkage of Mortar Bars at 28 days, Max. %	✓	-	-	0.03	-	-	0.03[a]
Mortar Expansion at 14 days, Max. %	✓	-	-	0.02	-	-	0.02[a]

[a] Optional Requirement

[b] This requirement was discontinued because the fly ash being supplied could not meet this requirement.

[c] ✓ Indicates that test is required but limits are not stated in project specifications, merely that conformance to ASTM C618 is required.

Class II--Medium Fly Ash--This class provides good strength contribution at ages up to 28 days and very good strength contribution at 90 days or more for given proportions of fly ash to cement. When properly proportioned, it is well suited for use in any class of concrete.

Class III--Coarse Fly Ash--This class provides low strength contribution at ages up to 28 days and good strength contribution at 90 days or more for given proportions of fly ash to cement. Delivered cost must be low for economical use in 28-day strength concrete; however, when properly proportioned, it is well suited for concrete having strength requirements below 4000 psi at 90 days or more. Greater fluctuations in air content can be expected, requiring more frequent testing of air content for control with this class than required with the fine or medium dry ashes."

It should be noted that these specifications recognize that "greater fluctuations in air content can be expected" with Class III fly ash which is the coarsest of the three classes. Project G omitted the surface area requirement of 6500 cm^2/cm^3, which corresponds to Class I on Project E, and experienced extreme fluctuations in air content.

Another important aspect of the fly ash specifications for Project E is the fact that they recognize that mix adjustments must be made when the fly ash properties change from those of the fly ash which was used in the trial mixes. This provision recognizes the variability of the fly ash and the fact that changes in fly ash properties can influence the properties of the concrete mix. This project has a relatively high testing frequency for fly ash as compared with the other projects. The fly ash is sampled at the project site once for every three truckloads. These samples are tested for fineness only in order to identify the class of the fly ash. This frequent sampling helps to identify the class of fly ash so that mix adjustments can be made if necessary. Additional samples are taken periodically for complete physical examination.

Table 5.10 presents a comparison of the fly ash specification requirements of the projects in the study, along with the ASTM C618 requirements which govern the use of pozzolans. The ASTM requirements in the table are for Class F pozzolans which are fly ash from the burning of anthracite or bituminous

coal. Project E is the only one which breaks fly ash into different classes. Aside from Project E, the other projects follow ASTM requirements either exactly or very closely. Project F, which was one of the projects which experienced fly ash related problems, requires nearly all of the optional chemical and physical tests, along with the standard tests, that are required by ASTM. A check mark in the table indicates that the project specifications do not indicate a value for a specific requirement, but merely stipulate that conformance to ASTM C618 is required.

The use of fly ash as a replacement for a portion of the portland cement in the concrete is certainly not a universal practice in nuclear power plant construction. This practice does, however, have a proven record in the area of mass concrete construction such as dams. This proven record, along with the potential benefits in economy, workability, and heat of hydration makes the use of a pozzolan such as fly ash appear very attractive for the mass concrete pours encountered in nuclear construction. There are some potential disadvantages in the use of fly ash, such as its potential variability, which make it difficult to control certain concrete properties such as air content and slump. It should be pointed out, however, that three of the six projects which have used pozzolans have experienced little or no problems as a result, and on one project which did experience problems, the waiving of specification requirements could have contributed to the problems. In view of all the potential advantages associated with the use of pozzolans, their use should always be considered when developing the concrete mixes for a nuclear power plant project. As Smith noted: "It is probably true to say that once the addition to concrete of pozzolans such as fly ash becomes accepted practice, it will be difficult to envisage how good concrete was made without them." (5.17).

Summary

This chapter has presented a comparative analysis of the requirements of the projects in the study for procurement and testing of concrete components. It was pointed out that this process includes: the initial qualification of material sources, the receipt inspection of the materials at the construction site, and the periodic in-process tests which are performed on the various concrete components. These topics were discussed in Chapter 5 for each of the components which comprise the concrete. The contents of this chapter are summarized below according to the major concrete components.

Cement. The discussion regarding cement indicated that the cement requirements for the projects studied are all quite similar. This is because all of the projects stipulate that cement must meet the requirements of ASTM C150. It was pointed out that several of the projects place additional requirements on cement which are not included in ASTM C150. These requirements are in the area of the required strengths of mortar cube specimens made from the cement. One of the projects has a statistically based mortar cube strength requirement which includes a price adjustment provision. This is one of the few instances among the projects studied where statistical concepts were employed to allow for the natural variability which is associated with construction materials.

The procedure for receipt inspection of the cement at the project site was also discussed. All of the projects required certified copies of mill test reports on cement which is supplied. In addition to the mill test reports, the projects also require periodic in-process testing of cement. In addition to the normal testing frequencies, several of the projects require additional retesting for cement which has been in storage. Seven of the projects studied place a maximum limit on the delivery temperature of the cement. The limits range from 130°F to 170°F. In the discussion, it was pointed out that

aggregate and water temperature have a much greater effect on concrete temperature than does the cement temperature, and it was questioned whether an upper limit on cement delivery temperature is really needed, particularly during cold weather operations.

Aggregate. The discussion on aggregate indicated that the primary source of requirements for concrete aggregate is ASTM C33. All of the projects studied require conformance to this standard specification. It was indicated that there are two types of testing which must be carried out. These include the initial qualification of the aggregate source and the in-process tests which are performed during operations. A discussion of these testing requirements was presented in the chapter. It was noted that the primary sources for guidance in the area of testing frequencies are ANSI N45.2.5 and the ASME Boiler and Pressure Vessel Code. The later projects in the study tend to follow the ANSI guidelines either exactly or very closely, whereas the earlier projects in the study whose requirements were developed before ANSI was published tend to have some testing frequencies that are quite a bit higher than those in ANSI.

In the discussion it was noted that in the requirements for aggregate testing on the projects in the study, there was indicated a lack of application of statistical concepts for describing the natural variability of materials. Concepts such as random and multiple sampling which have been used for a number of years by state highway agencies were not employed on any of the projects which were studied.

It was also pointed out that on the projects studied, there are many in-process tests which are used as partial acceptance criteria for the concrete. This approach can result in a number of nonconformances which are ultimately closed by verifying that the cylinder strengths of the concrete in question exceed the required strength. Since ultimate acceptance is based on compressive strength, it was suggested that the in-process tests be used for process control

rather than for partial acceptance.

Water. A comparison of the mixing water requirements on the projects was presented along with the requirements of the applicable codes and standards. It was noted that there were some discrepancies among the codes in the test methods which are used in testing water acceptability. A broad range of in-process mixing water testing frequencies was encountered on the projects studied. It was also pointed out that there is a great deal of variation in the chemical tests which are performed and in the acceptance limits that are placed on these tests. This stems from the fact that the codes contain broad qualitative statements concerning mixing water requirements rather than specific testing requirements.

Concerning the use of crushed or flaked ice, it was stated that all of the projects allow their use in the concrete mix to keep the concrete placing temperature down. The testing requirements for ice were generally the same as for mixing water on all of the projects.

Admixtures. A discussion of the various types of admixtures which are used on the projects was presented. The need for the various types of admixtures for nuclear construction was also discussed.

The advantages and disadvantages of the use of air entraining agents were presented. In the discussion on air entraining agents, it was suggested that the use of entrained air for all nuclear concrete was not necessary and it was recommended that guidance be taken from ACI 211 concerning the use of air entrainment. ACI 211 has prepared a graded table which can be used when determining air content requirements.

The use of water-reducing admixtures on the projects was also discussed. It was noted that all of the projects prohibited the use of set-accelerating water reducers. Some projects allowed the use of both water-reducing and

water-reducing set-retarding admixtures, while others allowed only the use of water-reducing agents. The use of water-reducers in conjunction with air-entraining agents was also discussed, and it was noted that water-reducing agents may contribute to the air content of the concrete. A discussion of the use of superplasticizing (or super water-reducing) admixtures was also presented. It was suggested that the use of these admixtures for congested rebar areas be considered on nuclear projects.

It was noted that fly ash was used on six of the projects in the study. The potential advantages and disadvantages of the use of fly ash were presented. It was pointed out that two of the projects experienced difficulties with the use of fly ash and have discontinued its use. The specification requirements of the projects which use fly ash were presented and discussed in detail.

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CHAPTER 6

PRODUCTION AND EVALUATION OF FRESH CONCRETE

PRODUCTION OF CONCRETE

The very large volumes of concrete which are required on major projects such as dams and nuclear power plants have resulted in the development of very sophisticated equipment for the batching and mixing of concrete. Improved equipment for accurate and quick weighing and batching of portland cement concrete has been developed to keep pace with the high concrete demands associated with these projects. A typical nuclear construction project has an automated on-site batch plant capable of producing 200 or more cubic yards of concrete per hour. This section presents a comparison of the specification requirements for the batch plants on the projects in the study.

Batch Plant Requirements

The batch plant requirements on most of the projects are fairly similar. Most of the projects either reference or excerpt from ACI 301, ACI 304, and/or ASTM C94 in their specifications. The batch plants on every one of the projects are equipped for automated batching and automated recording of the batch weights of the various concrete components. All of the plants are equipped with moisture density probes and have the capability of automatically compensating for varying moisture contents in the fine aggregate. Most of the plants are operated by punch cards which automatically batch and record the weights of all components. In addition to this automatic recording, the batch plants also have a QC inspector who verifies that the scale readings agreed with the printed record. This function will be discussed below in the section on the Role of the Batch Plant Inspector. Most of the projects imposed additional requirements on the batch plant, particularly in the areas of production capacities. Five of the

projects have some form of back-up or emergency source of concrete in the event that the on-site batch plant breaks down during or before a placement. These additional requirements are presented below.

1. Project A has an automated batch plant with a rated production capacity of 240 cubic yards per hour, although the average rate of concrete production which has been experienced is 162 cubic yards per hour. On this project, there is no requirement for a back-up source of concrete in the event of a breakdown. In lieu of an alternate concrete source, a contingency plan has been developed which contains procedures and requirements for the establishment of a construction joint in the event of a failure of the batch plant during a concrete placement.

2. The specifications for Project B require an automated batch plant with a capacity of at least 120 cubic yards per hour. There is an additional requirement that material storage at the batch plant shall be sufficient to supply concrete at a minimum rate of 800 cubic yards per 8 hour shift for 5 consecutive shifts. There is no requirement for a back-up source. This project is nearing completion and the on-site batch plant has been removed and concrete that is needed is now being supplied from an off-site source. This off-site batch plant is still subject to all specification requirements and a QC inspector is stationed at the plant during production.

3. The specifications for Project C require an automated batch plant capable of operating at a maximum capacity of 250 cubic yards per hour. This is the highest hourly output which was specified among the projects in the study. There is no specification provision concerning the necessity for a back-up source, and none has been established for the project.

4. The specified production capacity of the batch plant on Project D is 200 cubic yards per hour. There is also an additional requirement for sustained production that specifies the plant be able to function at full capacity 24 hours per day for a minimum of 5 consecutive days. This would provide a sustained

output of 24,000 cubic yards. The concept of maintaining a sustained production rate for mass pours is certainly valid, but one must wonder how to verify that a proposed plant is capable of meeting this requirement without actually producing 24,000 cubic yards of concrete. It seems that this requirement is more of a paper exercise rather than something that can actually be verified in the field. This project does not have any requirement for a back-up source of concrete.

5. There is no specified production capacity for the batch plant on Project E. The automated batch plant which is at the project has a capacity of 100 cubic yards per hour. There is no formal specification requirement for a back-up concrete source, but there are two options available in the event of a breakdown during a placement. The first option which would normally be employed is the formation of a construction joint. Secondly, the cooling tower contractor has a dry-batch plant on site which could be employed in an emergency.

6. The specifications for Project F require an automated batch plant having a rated capacity of 150 cubic yards per hour. For concrete placed in safety related structures, or in cases where the amount of concrete between construction joints exceeds 300 cubic yards, in case of a breakdown an emergency source of concrete supply can be used for not more than 48 hours. The back-up plant is not required to have a central mixer nor automation, nor recordation. However, a QC inspector is required to observe batching and loading operations continually when the plant is being used. The back-up plant may be used to supplement the output of the main plant for the placement of the containment mat and other large placements with the approval of the engineer. The back-up source on the project is located 45-50 minutes from the project site. The use of this plant as an emergency source is questionable, since a QC inspector

would have to drive to the plant and the trucks would have to drive to the site, which could take nearly two hours. The back-up source has been used 4 or 5 times to produce about 50 to 75 cubic yards of concrete. These uses were not due to an emergency, but were all scheduled in advance.

7. The specifications for project G require that the batch plant and equipment be capable of a continuous production of 150 cubic yards per hour and a maximum production of 200 cubic yards per hour. This project has perhaps the ultimate requirement for a back-up source. The project has a second on-site batch plant identical to the primary plant in its requirements. While this plant has been used to supplement the primary plant on major placements at times, its primary function is to act as a back-up source of supply. In light of the fact that this is the only project with a second on-site plant, and the considerable expense involved in obtaining and maintaining a second fully automated batch plant, it is questioned whether this requirement is really necessary as a contingency measure to insure the continuity of concrete placements in the event of a shutdown condition on one of the plants.

8. The specifications for Project H require a fully automatic batch plant with a capacity of at least 250 cubic yards per hour. There is an additional capacity requirement that the plant must be capable of producing a minimum of 2000 cubic yards per 8 hour shift for 2 consecutive shifts. There is a back-up source located on-site. This is a dry-batch plant with a production rate of 60-80 cubic yards per hour. The dry-batch plant is normally used for the production of heavyweight concrete and shotcrete. In fact, all heavyweight concrete must be produced from this plant.

9. The specifications for Project I require a batch plant having an output of 125 cubic yards per hour. In case of a breakdown, an emergency source of concrete supply can be used for not more than 48 hours. Automatic batching and recordation are not required in the auxiliary plant. The back-up plant is required to be operational for all massive pours and all pours which cannot be properly stopped and jointed in the event of a failure of the primary plant.

Weighing and Batching

Scale accuracies and batching tolerances are specified on all of the projects studied. Some of the projects include these values directly in the specifications, whereas others incorporate tolerances into the specifications by reference to a code or standard. The primary source of guidance for concrete mixing plant requirements is ASTM C94, Standard Specification for Ready-Mixed Concrete. Among other things, this document establishes guidelines for measuring materials, batching plants, and mixing and delivering concrete. In addition to ASTM C94, ACI 301, Specifications for Structural Concrete for Buildings, and ACI 304, Recommended Practice for Measuring, Mixing, Transporting and Placing Concrete, also contain information on batching and weighing tolerances. In addition, the ASME Boiler and Pressure Vessel Code and ANSI N45.2.5 require that measuring and batching be in accordance with ACI 304.

Scale Accuracy.--ACI 301 requires that scales for weighing concrete ingredients be accurate within ± 0.4 percent of their total capacities. ASTM C94 also requires that scales should be accurate to ± 0.4 percent of the total capacity of the scale, and that scales conform to the National Bureau of Standards Handbook 44. Neither of these standards specify a calibration frequency for batch plant scales. This fact is evidenced by the very wide variation in the calibration frequencies on the projects which were studied. Calibration frequencies range from a high of once every week to a low of conceivably once

every six months. The required scale accuracies and calibration frequencies for the projects in the study are included in Table 6.1. As can be seen, several of the projects do not stipulate scale accuracies, but merely specify batching tolerances. Two of the projects, B and C, reference that scales should be calibrated in accordance with the National Bureau of Standards Handbook #44. This is the same document that is referenced in ASTM C94. Two projects, B and E, require that scales conform to the requirements of Federal Specification AAA-S-121d. Two of the projects require higher accuracies than do ACI and ASTM, while two other projects stipulate lower accuracies. It would appear that more uniformity in project specifications could be obtained if all projects would simply adopt the generally accepted standards of ASTM C94. Due to the very wide range in calibration frequencies that was encountered on the projects in the study, it is recommended that more specific guidance in this area be addressed by the ACI codes and ASTM standards.

Batching Tolerances.--Requirements for batching tolerances are given in ACI 301, ACI 304, and ASTM C94. The requirements of ACI 301 differ from those of ACI 304 and ASTM C94, which are identical. The batching tolerances stated in these codes are given in Tables 6.2a and 6.2b. As can be seen from the tables, ACI 301 employs a relatively simple approach in specifying batching tolerances, whereas ACI 304 takes into consideration individual versus cumulative batching and also considers the relative amount of material being weighed compared to the scale capacity. Both of these approaches were encountered on the projects which were studied. Once again, for the sake of uniformity of requirements, it is recommended that the tolerances of the generally accepted ASTM C94 (which are the same as ACI 304) be employed for nuclear projects. As was mentioned previously, ANSI and ASME both require batching in accordance with ACI 304. Five of the projects employ approaches that are the same or

Table 6.1.--Specification Requirements for Batch Plant Scale Accuracies and Calibration Frequencies

Project	Scale Accuracy	Calibration Frequency	Other Specification Requirements
ACI 301	±0.4% of total scale capacity	None Given	-
ASTM C94	±0.4% of total scale capacity	None Given	Scales to conform to National Bureau of Standards Handbook #44
A	±1% of true weight	Quarterly or every 40,000 CY	-
B	±0.4% of total scale capacity	Agg. & Cement-Monthly Water & Ice-Weekly	Comply with Federal Specification AAA-S-121d and National Bureau of Standards Handbook #44
C	±0.2% of total scale capacity	3 Months ± 1 Week	Scales calibrated in accordance with National Bureau of Standards Handbook #44
D	-	-	Comply with the requirements of ASTM C94-74
E	±1% of true weight	Monthly	Comply with Federal Specification AAA-121d.
F	±0.20% of total scale capacity (±0.25% for direct digital readout)	90 Working Days	-
G	-	6 Months or every 25,000 CY	Weighing scales shall be tested and sealed by the Bureau of Weights and Measures or an approved independent Testing Lab
H	-	State Agency-Yearly Testing Lab-90 days	Accuracy of the weighing equipment shall conform to the requirements of Section 8 of ASTM C94-73a
I	-	90 days	Scales shall be sealed by the Official Sealer of Weights and Measurements of the State

Table 6.2a.--Batching Tolerances from ACI 301

Component	Tolerance
Cement	±1 percent
Water	±1 percent
Aggregates	±2 percent
Admixtures	±3 percent

Table 6.2b.--Batching Tolerances from ACI 304 (same as ASTM C94)

Ingredient	Batch Weights Greater than 30 percent of scale capacity		Batch weights less than 30 percent of scale capacity	
	Individual Batching	Cumulative Batching	Individual Batching	Cumulative Batching
Cement and other cementitious materials	±1 percent or ±3 percent of scale capacity whichever is greater		Not less than required weight or 4 percent more than required weight	
Water (by volume or weight), percent	±1	Not Recommended	±1	Not Recommended
Aggregates, percent	±2	±1	±2	±0.3 percent of scale capacity or ±3 percent of required cumulative weight whichever is less
Admixtures (by volume or weight), %	±3	Not Recommended	±3	Not Recommended

similar to those of ACI 301. The requirements of these projects are indicated in Table 6.3.

One of the projects in the study has experienced significant difficulties in the area of batch tolerances. On this project, approximately 80 nonconformances, the largest number in the concrete area, have been written concerning batch weights outside of tolerances. The problem was caused by the failure to consider the least count of the scales when determining the batching tolerance requirements and the design weights for the concrete mixes. The least counts of the various scales on this project are:

Cement	8 lbs.
Pozzolan	8 lbs.
Aggregate	40 lbs.
Water	4 lbs.

A simple example will help to illustrate how the problem can arise. Assume that the cement weight is 544 pounds. The scale will either read 540 or 548, depending upon whether the actual weight is slightly above or below 544 pounds. If the design mix calls for 541 pounds of cement and the scale reads 548, then the allowable tolerance of 1% would be exceeded. Even though the actual batch weight was within tolerances, the concrete would be considered nonconforming due to the scale readings. The problem has been corrected by recognizing that tolerance above the scale tolerances is allowed by the National Ready Mixed Concrete Association. The quantity of concrete exceeding tolerances has had no discernable effect on the compressive strength of the concrete test cylinders. Even though this problem appears to have in no way affected quality, the dispositioning of the nonconformances required much time and expense which could have been avoided if the least count of the scales had been taken into account in the mix design process.

Table 6.3.--Batching Tolerance Requirements

for Projects B, E, F, H, I, and ACI 301

Project	B	E	F	H	I	ACI 301
Cement	±1%	±1%	±1%	±1%	±1%	±1%
Water	±1% (Added) ±3% (Total)	±1%	±1%	±1%	±1%	±1%
Aggregates	±2% (Individual) ±1% (Cumulative)	±2% (<1½") 3% (>1½")	±2%	±2%	±2%	±2%
Admixtures	±3%	±3%	±3%	±3%	±3%	±3%

Mixing Requirements

Mixing requirements are set forth in ACI 301, ACI 304, and ASTM C94. Several of the projects either reference these documents with respect to mixing requirements or include provisions from these documents in the project specifications. One area where there is a great deal of variation among the projects in the study is in the requirements for mixer uniformity tests. Concrete uniformity requirements are given in the Appendix of ASTM C94. Some of the code requirements for concrete mixing are discussed below along with the specification requirements from the projects in the study.

ACI 301 states that batches of 1 cubic yard or less shall be mixed for not less than 1 minute, and that the mixing time shall be increased by 15 seconds for each additional cubic yard or fraction thereof of capacity. The code goes on to state that this mixing time may be reduced if mixer uniformity tests in accordance with ASTM C94 indicate that the time is sufficient to produce uniform concrete. These requirements are both included exactly in the specifications for projects F and I, and indirectly by the project H specifications which reference the requirements of ACI 301-72. There are no specific mixing time requirements in the specifications for projects C and E, but both of these projects require conformance to the requirements of ASTM C94. Project B references ASTM C94 mixing requirements, but also stipulates an allowable mixing time range of 90-150 seconds. Project A requires mixing to continue for at least 90 seconds after all materials are in the mixer, and Project D specifies mixing time of 90±2 seconds. Project G does not specify mixing times, but requires that mixer uniformity tests be performed after the plant is set up to verify that the mixing is acceptable.

One area where there is a wide range of variation among the projects studied is the area of mixer uniformity tests. The ASME Boiler and Pressure

Vessel Code requires that mixer uniformity tests be performed after initial start-up of the plant and every 6 months thereafter. The specifications on Projects F and I require this same frequency. The same engineer is employed on both of these projects. It is interesting to note that the engineer's personnel on project F expressed the opinion that once every 6 months was not often enough, whereas the employees on Project I felt that once every 6 months was more often than was necessary. On Project A, a mixer uniformity test is only run at the request of the QC Structural Supervisor or the Utility. The specifications for Project C require that mixer uniformity tests be performed whenever the time of mixing is reduced, mixing equipment is altered or replaced, or whenever there is a major change made to the mix designs. Projects B and G require mixer uniformity tests after initial plant set-up, but make no statement concerning any additional test frequency. The specifications for Projects D and H do not specifically refer to mixer uniformity tests, although Project D references ASTM C94 and Project H references ACI 301-72, and both of these documents refer to mixer uniformity tests. Project E specifies that a mixer performance test be performed for every 20,000 cubic yards of concrete that are produced. This approach would appear to make sense because it ties the testing frequency into the concrete production rate. During heavy concrete production periods, the testing frequency would be more frequent than 6 months, whereas at other times it could be less frequent.

The projects which require mixer uniformity tests all require the results to conform to the limits stated in ASTM C94, with the exception of Project E. The mixer performance test requirements for Project E come from the Bureau of Reclamation's Concrete Manual (6.1). A comparison of these requirements with those of ASTM C94 is presented in Table 6.4. As can be seen from the table, ASTM C94 requirements are met by satisfactory results on five of six tests, whereas the Project E mixer performance test only has two requirements.

Table 6.4.--Comparison of Mixer Uniformity Requirements of Project E with those of ASTM C94

ASTM C94 Requirements	
Test	Requirement[a]
Weight per cubic foot calculated to an air-free basis	1.0 lb.
Air Content, percent by volume of concrete	1.0
Slump:	
--if average slump is 4 in. or less	1.0 in.
--if average slump is 4 in. to 6 in.	1.5 in.
Coarse Aggregate Content (%), portion by weight of each sample retained on #4 sieve	6.0
Unit Weight of air free mortar (%)	1.6
Average comp. strength @ 7 days for each sample (%), based on average strength of all comparative test specimens	7.5

[a]Expressed as a maximum permissible difference in results of tests of samples taken from two locations in the Concrete Batch.

Note: Test results conforming to the limits of five of the six tests listed shall indicate uniform concrete.

Project E (Bureau of Reclamation) Requirements

Mixer performance shall be such that, prior to discharge at the end of the prescribed mixing period, two samples, one taken at the front and one taken at the rear of the concrete surface with the mixer stopped, or taken from the first and last portions of the batch as discharged from the mixer, will not exceed the following limits of uniformity:

(1) Unit weights of air-free mortar from the two samples shall not vary more than 0.8 percent from the average of the two mortar weights.

(2) Unit weights of coarse aggregates retained on a No. 4 screen from the two samples shall not vary more than 5 percent from the average of the two weights of coarse aggregate.

Role of QC at the Batch Plant

The QC organizations of each of the projects studied are integrally involved in the inspection and operation of the concrete batch plants. Most of the projects have a QC Procedure which deals with batch plant inspection, and which outlines the functions of the batch plant inspector. The functions of the batch plant inspector on each of the projects in the study are described herein.

1. The QC Procedure for Batch Plant Inspection on Project A outlines the duties of the batch plant inspector and requires that he be in the batch plant while concrete is being produced. The batch plant inspector is responsible for inserting the properly punched control card into the batch control computer. The batch plant inspector visually observes the weight measurements of all materials on the scale indicators to check and confirm the automatic recording tapes. The batch plant inspector verifies the mix proportions of each batch of concrete and ascertains that samples are taken and tests are made of the concrete ingredients. The batch plant inspector verifies that the mixed proportions comply with those of the design mixes with the water content modified as required by measurement of surface moisture on the aggregates. The batch plant inspector is solely responsible for adjustments in water content of the mix. In addition to the above activities, the batch plant inspector is responsible for the preparation of a daily report, the Concrete Batch Plant Report, to document for each batch the following: mix number, mix cycle time, weight of each ingredient, and the batch number. A copy of this report form is shown in Appendix 6.A. The batch plant inspector is also responsible for preparing the truck batch tickets which show the batch number, mix number, truck number, date and time the truck is loaded, total amount of water in the batch, and the location of the placement. Note that the batch weights of each ingredient are automatically recorded on tape and a copy of this tape is attached to the Concrete Batch Plant Report.

2. On Project B, the batch plant inspector inspects the plant, including aggregate storage areas, weighing and measuring systems, stationary mixers and mixer trucks on a monthly basis for conformance to ASTM C94. The batch plant inspector samples and tests fine and coarse aggregate for gradation and moisture content prior to the first batch of concrete, and checks fine and coarse aggregate for moisture content at least every two hours during production. The batch plant inspector checks the mixing time of each cycle during mix operations to insure that it falls within the acceptable ranges, and will periodically check the cycle time with a stop watch. The batch plant inspector checks the batch card to assure that the proper mix is being batched and that the card is correctly punched. The inspector prepares batch tickets which show: date, time loaded, truck number, load number, initial number of revolutions on counter, batch code, concrete design strength, amount of concrete loaded, amount of each ingredient, including ice added, percent surface moisture of fine aggregate and coarse aggregate, total water content per cubic yard, amount of water allowed to be added at the pour site, amount of water in truck water tank, portion of the structure where used, mixing time, type of mix (central or transit), and signature of the batch plant inspector. In addition, the batch plant inspector checks the recording print out tapes for confirmation of the actual batch weights and forwards a copy to QC for permanent filing with batch ticket records.

3. On Project C, the batch plant inspector is required to verify on a daily basis that the scales and meters are in current calibration in accordance with the specified requirements. At least once per day, the inspector visually checks the master scale, slave scale, and digital recorder printout to verify that the individual readings are consistent. During the batching operation, the inspector is in the control room checking the amounts of materials that go into each batch. After he has verified that each component is batched within

specified limits, he then signs the delivery, or batch, ticket. This batch ticket includes the following information: batch number, date and time, class of concrete, number of cubic yards in the batch, batch weights of the various concrete ingredients, quantity of jogging water, percentage of moisture in the fine aggregate, and the mixer truck number. The batch plant inspector prepares a daily inspection report which indicates the items which have been inspected, whether the condition is satisfactory or unsatisfactory, and what corrective action may have been taken.

4. The QC Procedure for batch plant inspection on Project D requires that the measuring, batching and mixing of concrete be inspected by the batch plant inspector who must be present at all times concrete is being produced. The inspector advises the batch plant operator of the proper adjustment of the automatic moisture setting to assure proper adjustments of the water content are made. The inspector also checks the batch plant scales for zero reading and weighing accuracy before starting concrete batching and mixing. During batching operations, the batch plant inspector verifies the mixed proportions of each load batched by signing the batch delivery tickets, and assures that all material weights shown on the batching ticket comply with weight tolerances specified in the project specifications. The batch plant inspector is responsible for filling out a Daily Batch Plant Checklist and Daily Batch Plant Report. In addition to these forms, as a result of an audit by the utility, a number of other checklists and worksheets must also be filled out. This increased documentation has added to the already large amounts of paper generated at the testing lab. (The copy machine at the testing lab produces approximately 6,000 copies per month).

5. The Project E batch plant inspection QC Procedure states that no

concrete will be produced unless a certified inspector is present. The inspector makes a visual inspection of all components of the central mix plant before daily concrete operations begin. During batching operations, the mixing plant inspector reviews the automatic recorder to verify that its readings coincide with those of the scales, that the mix selector is set for the correct mix, and that air content, slump and temperature are within the acceptable ranges. For safety related structures, the mixing plant inspector prepares a concrete ticket which lists the truck number, mix, and date. The inspector is also responsible for filling out a Mixing Plant Report at the end of each shift. An example of this form is included in Appendix 6.A.

6. The responsibilities of the batch plant inspector for Project F are delineated in the Inspection Procedure for Concrete Batch Plant Inspection. This procedure requires that the batch plant inspector be present at the batch plant during concrete production. The batch plant inspector is responsible for verifying that concrete mix proportions are adjusted for moisture changes in aggregates, and that the batch weight of each ingredient is within specified tolerances. The inspector also checks the scales to assure that they are zeroed after each batching, and also checks the recorder printout system for reliability. The batch plant inspector is responsible for obtaining samples and performing in-process testing during production at the batch plant. The inspector is also responsible for filling out the daily Batch Plant Inspection Report, an example of which is included in Appendix 6.A.

7. On Project G, the specifications outline the responsibilities of the batch plant inspector. The specifications state that during concrete production, the measuring, batching, and mixing of all concrete shall be inspected by the batch plant inspector, who shall have the authority to reject improperly mixed batches. The inspector must be present at all times whenever concrete is

being produced. The batch plant inspector checks the scales for zero reading before batching, ensures that adjustment of the concrete mix is made for moisture changes in the aggregate, checks the plant scales during production to ensure the various ingredients conform to the mix design, and samples and tests the first batch of each class of concrete produced each day for temperature, slump, and air content. The batch plant inspector monitors the operation of the scales and certifies the concrete mix proportions of each batch delivered by signing each batch delivery truck ticket. He also enters on the face of each ticket the amount of water added by the jogging switch and the quantity of water that may be added to the batch without exceeding the total allowed by the mix design. For each shift the inspector submits a Concrete Mixer Report which shows the time the placement started, date, shift, location, section, elevation, time shift ended, concrete rejected or wasted, length of delays, and other pertinent information relating to the placement. An example of this form is included in Appendix 6.A.

8. The batch plant inspector on Project H must be present during the production of concrete. The inspector monitors the batching and mixing operations to ensure conformance to the specification requirements. The inspector verifies that the proper values are printed on the batch ticket by the automatic printer, and signs the ticket to verify that the mix is acceptable after monitoring all scale readings.

9. The batch plant inspector on Project I is present during concreting operations. The inspector checks the scales to be sure they have been calibrated, checks the batch weights of each ingredient to ensure they are within acceptable limits, monitors the automatic recording system to verify that all information is being recorded accurately, and checks timing devices with a stop watch to assure they do not allow batches to be discharged prior to the predetermined mixing time. The inspector also checks the supply of concrete materials to

assure there is enough on hand for each pour. The batch plant inspector indicates on the batch ticket the amount of water that may be added at the placement site.

As can be seen from the descriptions above, the requirements for batch plant inspection on all of the projects are quite similar. All of the projects require that the inspector monitors 100 percent of the concrete production operations. However, the degree of this monitoring process does vary from project to project. On some of the projects, the batch plant inspector must verify that every scale reading corresponds to the value printed out by the automatic recorder, whereas the requirements on Project C state that at least once per day, the inspector checks to verify the scale reading and the automatic printout. When one considers the sophistication of automated plants in use on the projects in the study, it would seem that the approach taken by Project C is quite sufficient. Checking each scale reading versus its corresponding printout reading seems to defeat the purpose of having automatic recordation.

Water Adjustment.--One thing which should be pointed out is the fact that on some of the projects, the batch plant inspector has so much responsibility that the plant operator becomes practically unnecessary. The batch plant inspector is typically responsible for all water adjustments at the batch plant. The specifications of Project A state that the batch plant inspector is solely responsible for adjustments in water content of the mix. Tuthill (6.2) addresses this point when he states:

> "... water is allowed to be changed only by the inspector after tests of aggregate and water content show a need for it to maintain a certain W/C. In the meantime the mixer operator, usually a conscientious individual who takes pride in the uniformity of his product, has no access to supplemental water to at least avoid discharge of dry batches that can cause delay and difficulty and sometimes imperfect placement. This is wrong whether it be a dam or for a nuclear power plant or whatever".

This raises an important point concerning the overall role of QC. If the batch plant inspector is given too much responsibility, then he is no longer the inspector, but the operator, of the batch plant. QC should be inspecting construction operations, and not directing them.

Batch Tickets--A comparison of the batch tickets on the various projects indicates a very wide range in the information which is recorded on these tickets. This range varies from 36 items which are recorded on the batch tickets on Project G to three items which are recorded on the batch tickets on Project E. Three different approaches were encountered on the projects in the study. The first approach, found mainly on the more recent projects, calls for very detailed information to be automatically printed on the batch tickets. An example of one of these detailed tickets, from Project G, along with instructions for filling out the ticket are shown in Exhibit 6.1. As can be seen, the amount of water which can be added at the placement is indicated on the batch ticket. The placement inspector indicates on the batch ticket how much water was added at the placement site. These tickets are then incorporated into the pour packet to form a record of the concrete production operation. The second approach is to provide less information on the batch ticket and to use an automatic printer tape to act as the permanent record. This is the approach which is employed on Project E, where only three items, date, mix number, and truck number, are recorded on the batch ticket. It is felt that it is not necessary that the placement inspector receive detailed information on the batch weights, but merely that he is assured that the proper mix is delivered to the placement. On this project, water cannot be added at the placement site, so there is no need to indicate water withheld on the ticket. An example of the batch Ticket used on Project E is included in Exhibit 6.2. A third approach which was encountered on one of the projects

Exhibit 6.1.--Description of Batch Plant Ticket for Project G

The items listed below, numbered 1 through 36, which coincides with the areas annotated on the copy of the Batch Plant Ticket included, must be checked for correct, complete, and uniform preparation.

1. Time concrete truck arrived at the job.
2. Time concrete truck left the job
3. Cubic yardage total
4. Placement number and location of placement
5. Batch number and date
6. Batch code
7. Number of cubic yards delivered this load
8. Free moisture in sand--water trim either adds or subtracts in gallons per yard from what is punched on the mix card.
9. Tare
10. 3/4 inch aggregate (wet weight in pounds)
11. 3/4 inch aggregate plus sand (accumulative wet weights in pounds)
12. 3/4 inch aggregate plus sand plus 1½ inch aggregate (accumulative wet weight in pounds)
13. Cement one and two designated bin number (pounds)
14. Fly ash plus cement (accumulative pounds)
15. Ice (pounds)
16. Ice plus water (accumulative pounds)
17. Air entraining admix (ounces)
18. Water reducing agent (ounces)
19. Concrete truck number
20. Time (military)
21. Tare
22. Water jogged (in gallons)
23. Amount of water (in gallons) allowed to be added in the field
24. Testing Lab batch plant inspector's signature or initials
25. Amount of water (in gallons) added in the field
26. Signature or initials of Testing Lab field receiving inspector if no water is added in the field. If water is added in the field, constructor's Quality Control representative signature will be required and he shall complete entry 25. This signature verifies that addition of water is in accordance with the specifications.

Exhibit 6.1--continued

27. Slump of concrete at the point of truck discharge or end of concrete pump line (test trucks only)
28. Temperature of concrete at the point of truck discharge or end of concrete pump line (test trucks only)
29. Revolutions of the truck counter upon arriving at the job.
30. Revolutions of the truck counter upon leaving the job.
31. Batch plant number
32. Number of yards placed from this load
33. Percent of air content
34. Code number for rejected concrete--The codes are as follows:
    1. high slump
    2. low slump
    3. high air
    4. low air
    5. temperature (high or low)
    6. incorrect agitation--low revs
    7. incorrect agitation--high revs
    8. 90-minute time limit (exceeded)
    9. 300 revs (exceeded)
    10. unauthorized addition of H_2O (constructor)
    11. unauthorized addition of H_2O (Batch Plant Contractor)
    12. incorrect mix design ordered for pour
    13. equipment malfunction (Batch Plant Contractor)
    14. rejected by Batch Plant Contractor
    15. water/cement ratio exceeded in field
    16. rejected by constructor--no test
    17. over-order
    18. other
35. Time of beginning of truck discharge
36. "Test load" when applicable

Exhibit 6.1.--continued

SOLD TO:_____ DATE (5) 19____

JOB NUMBER	ARRIVED JOB (1)	LEFT JOB (2)	UNIT (32)	CODE (34)	TOTAL YARDS INCLUDING THIS LOAD (3)

AGGREGATE N/A	(4) Placement No. _____ Location _____	A3 N/A
CEMENT N/A		A4 N/A
TIME (35)	(6) - BC	C1 N/A
DATE (5)	(7) - YD	C2 N/A
YEAR N/A	(8) - 3WA	ADI N/A
FORMULA NUMBER Mix	(9) - TA	AD2 N/A
BATCH CODE N/A	(10) - 2AG	AD3 N/A
YARDAGE N/A	(11) - 1AG	W N/A
MOISTURE COMPENSATION N/A	(12) - 3AG	ICE N/A
TRUCK NUMBER (36)	(13) - 1 or 2CM	FLY ASH N/A
A1 (27)	(14) - 3CM	OTHER AD (22)
A2 (28)	(15) - 2WA	OTHER INGREDIENTS (23)
(29)	(16) - 1WA	N/A
(30)	(17) - 1AD	N/A
(33)	(18) - 2AD	N/A
	(19) - TN	
	(20) - TI	
	(21) - TA	
	Show reason for rejection due to code no. 9 only	
	(31) 2	
	(24) John Doe	

READY MIX SYMBOLS

A = AGGREGATE	MC = MOISTURE COMPENSATION	AD1 = ADMIX
CM = CEMENT	TR = TRUCK NUMBER	AD2 = ADMIX
TI = TIME	A1 = AGGREGATE	AD3 = ADMIX
DT = DATE	A2 = AGGREGATE	WA = WATER
YR = YEAR	A3 = AGGREGATE	WF = ICE
F = FORMULA NUMBER	A4 = AGGREGATE	FLY ASH
BC = BATCH CODE	C1 = CEMENT	OTHER AD
YD = YARDAGE	C2 = CEMENT	OTHER INGREDIENTS

AUTHORIZED SIGNATURE

WATER ADDED (25) GALS. X (26) _____

	YES	NO		YES	NO		YES	NO
HEAT	☐	☐	COOLED	☐	☐	EXTRA COOLED	☐	☐

SIGNATURE X N/A

Exhibit 6.2.--Concrete Ticket for Project E

CONCRETE TICKET

MIX NO: _____

TRUCK NO: _____

DATE: _____

was a combination of the two previous methods. On Project B, the batch weights were automatically recorded on printer tape which was then kept as a record, but at the same time the batch plant inspector recorded very detailed information concerning batch weights on the ticket. This would appear to possibly be duplication of effort since this information was already recorded on the printed tape which was kept as a permanent record.

It is difficult to say which of these approaches is best. Each of them accomplishes the task of providing a record of the batching operations. On the detailed batch tickets, there is sometimes space provided to record the results of slump, air content, and temperature tests. In this manner, a great deal of information concerning the placement can be recorded on the same form, the batch ticket, and stored in the same location. This can be an advantage when it is necessary to trace the information for a given pour. On Project E, all of the information on concrete properties is recorded on separate forms, all of which are stored at the testing lab, with copies in the vault. All pertinent information concerning the placement can be traced, but the information must be retrieved from different locations.

Mix Design

The designing and proportioning of concrete mixes for a project takes place during the pre-construction, planning phase of the project. The mix designer uses information gathered on the properties of the ingredients that will be used in making the concrete; this information includes the results of mill tests of the cement, the physical and chemical properties of all admixtures, the type, size, and grading of both the coarse and fine aggregates, and the results of chemical tests of the water. One important attribute of the concrete that governs the mix design is of course the compressive strength, but there are many other characteristics that must also be considered when

designing a concrete mix. These characteristics include compatibility of the ingredients, placeability, consistency and durability of the concrete, mixing time and sequence required, etc. Established basic relationships and laboratory tests provide guides for optimum combinations. However, final proportions should be established by actual trial and adjustment in the field (6.1).

Design Criteria.--One important basic concept used in concrete mix design is the relationship between the water-cement ratio or cement content, and concrete strength. The Bureau of Reclamation (6.1) states that for best strength, durability, and other desirable properties, concrete should be placed with the minimum quantity of mixing water consistent with proper handling. The Bureau further states that, for a given water requirement, quality of concrete is proportional to cement content. While durability and strength of concrete are influenced by many variables, proportions should be selected to provide cement pastes of adequate quality to withstand expected exposures and ensure adequate strength. The water cement ratio is used in computing the estimated cement content of the mix.

ACI 211.1, Recommended Practice for Selecting Proportions for Normal Weight Concrete, states that strength requirements and factors such as durability and finishing properties play an important part in determining the required water-cement ratio. This code suggests that it is desirable to develop the relationship between strength and water-cement ratio for the materials actually to be used in the project. This practice was employed on the projects in the study. In fact, most of the projects reference ACI 211 (or its predecessor, ACI 613) in their specifications. Both ACI 301, Specifications for Structural Concrete for Buildings, and ACI 318, Building Code Requirements for Reinforced Concrete, state that the water-cement ratio shall be used to establish proportions for the concrete mixes. ACI 318, in particular, states that

laboratory trial mixes be used to determine the relationship between the water-cement ratio and compressive strength. When this is established, the maximum permissible water-cement ratio or minimum cement content is to be specified in the project documents.

Most of the projects in the study have provisions in the specifications that trial mixes based on laboratory tests be verified in the field using the actual site batch plant. For instance, the specifications on Project H call for such a verification program with adjustments to mix designs made as necessary. This type of a verification program is a good practice because it allows an opportunity to locate problems in the mix designs before actual concrete production gets under way. The Project E specifications require that control mixes be modified for field conditions and plant production as early as possible. In order to avoid wasting the concrete which is produced to verify the mix proportions, some projects allow this concrete to be used. Project E does not allow its use in a safety related location, whereas Project H does not allow this material to be used for structural concrete.

Eight of the nine projects in the study use the design mix water-cement ratio of the concrete to establish a limit on the amount of mixing water that may be used in the batching process. Three of these projects allow the addition of water at the placement site, but place a limit on the amount that may be added by requiring that the total water in the mix not exceed the maximum permissible water-cement ratio. The water-cement ratios that are stipulated on these projects have rigid limits established on their maximum values. This approach is also taken by ACI 211.1 and ACI 301, which provide tables of maximum allowable water-cement ratios.

This practice of placing rigid limits on water-cement ratio and not allowing these limits to ever be exceeded may not be the most desirable approach. Tuthill (6.2) states that by requiring that there be no change from the design

mix water content and water-cement ratio, the outcome of concrete operations can be seriously affected. The Bureau of Reclamation (6.1) gives values for water-cement ratios, but allows these ratios to vary by ±0.2 from the required values. This is not true on the projects in the study which have maximum limits on water-cement ratio which cannot be exceeded, even though the batch plant operator may feel that it is necessary in order to avoid discharging dry batches of concrete. This approach of not allowing the water-cement ratio to be exceeded has been termed the "locked water meter" by the ACI Manual of Concrete Inspection (6.3) which states:

> "Usually the consistency (of concrete) is regulated by varying the amount of water added at the mixer, based on observed consistency of previous batches. If aggregates are uniform in moisture content and grading, there will be small need for varying the amount of added water. Nevertheless, the water-measuring devices should not be locked at a fixed quantity, as unavoidable variations in moisture content of the aggregate would then result in variable consistency. The average moisture content of the aggregates and the average additional water requirements at the mixer will show whether the average mix conforms to specifications regarding water-cement ratio."

This approach of allowing the average mix to meet the specifications recognizes that, due to the natural variability of materials, individual batches can exceed the design water-cement ratio without adversely affecting the concrete quality. Tuthill (6.2) also states that once the job mix is established at an acceptable water-cement ratio and slump, the primary effort in mixing must be toward uniformity of slump and workability, allowing the water-cement ratio to vary slightly as necessary to attain it. Most of these variations will usually remain within the ±0.2 margin which is used by the Bureau of Reclamation and other specifications. It is suggested that this approach could be employed on nuclear power plant projects without adversely affecting quality, and may, in fact, improve quality by avoiding dry batches of concrete.

The approach of allowing the water content to vary to maintain uniform consistency was encountered on one of the projects in the study. On Project

E, the water-cement ratio is not specified for the purpose of limiting mixing water which can be added in the field. The concept of using the water-cement ratio as a field control measure was discarded by this designer in 1962. This organization employs fly ash extensively in its concrete mixes and states in the project PSAR:

> "...where fly ash is used, the same strength concrete is possible with many different combinations of cement, fly ash, and water such that the single water-cement ratio concept is meaningless. For batch-to-batch control of concrete in the field, water requirements must be controlled by controlling the slump of the concrete which can be easily measured. It is virtually impossible under normal production conditions to determine the exact water requirements of any single batch because of variations in the free moisture content of the aggregates."

Even though this approach is radically different from that employed by all of the other projects in the study, a number of both nuclear and fossil fueled power plants have been constructed using this approach by the organization now on Project E.

Number of Mixes.--The number of concrete mixes which were encountered on the projects range from 15 to 50, with most projects having more than 25. The pre-construction testing and approval of so many mixes can be a very time-consuming and expensive process. In addition to those mixes approved before construction begins, any mix adjustments that are made must also be approved before use.

It is easy to see how the number of mixes on a project as complex as a power plant can be quite large. There is a mix design associated with each strength class of concrete and usually a grout mix for each strength class also. In addition, there may be mixes with and without flyash or other admixtures, there may also be separate mixes for pumping within each strength

class. On one project, for each strength class of concrete there was a general purpose mix, a mix for improved workability, and a mix for pumping. It is certainly important to have a concrete mix approved for all applications which may be required on the project. On the other hand, due to the approval efforts which are required, some consideration should be given to keeping the number of mix designs to a minimum. This could help to reduce the number of in-process tests, since testing frequencies are applied to each concrete mix and not just to total concrete produced. A reduction in the number of mixes would also simplify the operation of the batch plant.

Mix Ingredients.--The individual concrete components were discussed in Chapter 5. This section presents some general observations concerning the mix designs that were encountered on the projects. In chapter 5, the widespread use of air-entrainment in concrete was discussed and it was recommended that its use be limited to cases where it was needed for concrete durability. On Project H, the specifications require that all structural concrete contain air entrainment because all structural concrete is considered to be subject to exposure. It does not seem realistic to assume that all structural concrete is subject to exposure, because this is certainly not the case. The concrete mixes encountered on the projects usually had very high cement contents and relatively small maximum size aggregates. Six of the projects at one time or another used fly ash as a substitute for a portion of the cement. This substitution can help to reduce the heat of hydration problems which are typically associated with high cement contents. These high cement contents seem to have been used to facilitate pumping and workability more so than to increase strength, since concrete compressive strengths for most of the mixes were well above the required strengths.

Design Strength.--Several of the projects required that trial mixes be proportioned

to produce an average strength at least 1200 psi greater than the specified strength fc'. The source of this requirement is ACI 301, Specifications for Structural Concrete for Buildings, which states that if a suitable record of strength test performance is not available, proportions should be selected to produce an average strength at least 1200 psi greater than the specified strength fc'. It should be remembered that this specification was written for building construction and not necessarily for the massive sections which are encountered in nuclear construction. Tuthill (6.4), in discussing high strength and high cement content requirements, states that for mass concrete in nuclear applications:

> "...the average strength fcr' required is unnecessarily set as far above the design strength fc' for this massive concrete as it clearly should be set for thin structural columns, beams, and slabs. A much lower average strength for massive sections is acceptable because of creep and stress adjustments, mixing of batches, water equalizing movement, and probability that lower-strength test cylinders do not fully mean low strength concrete in place."

Tuthill goes on to list a number of practices which lead to unnecessarily high cement requirements and corresponding high heat of hydration. These practices include:

1. Setting Strength requirements for 28 days although design loads can not possibly occur within a year.
2. Pozzolans are often not permitted, although their use in proper amounts could well reduce the maximum temperature rise by 15 percent.
3. Needlessly small maximum-sized aggregate is stipulated which requires more mortar in the concrete, including more cement.
4. Advantage is not taken of chipped ice in lieu of mixing water to mix and place the concrete at a low temperature which will require less water and less cement for the same water-cement ratio.

Tuthill closes by stating: "Despite all these possibilities for safely reducing the cement content, some arbitrary, too-high, amount is stipulated

because such an amount was used elsewhere for equally unacceptable reasons." These arguments of Tuthill make a strong case for specifying lower strength requirements, and correspondingly lower cement contents, for many nuclear concrete applications.

Mix Adjustments.--This section will concentrate on mix adjustments for purposes other than to change compressive strength. Mix adjustments to change concrete strengths will be discussed in detail in the section on Evaluation of Test Results. Mix adjustments can be made after concrete operations begin to facilitate pumping, improve workability, improve finishing characteristics, or for a number of other reasons. On the projects in the study, there appeared to be a tendency to solve problems by adding additional cement. On Project H, 98 percent of all concrete is placed by pump. In order to produce pumpable mixes, the designer's solution was to overdesign the mixes with excess cement. Due to the potential problem of high heat of hydration and shrinkage, the utility insisted that mixes be developed which used fly ash to reduce heat of hydration while maintaining pumpability. At the complaints of the contractors, the flyash use was discontinued and pumpability problems arose. The utility did not consider the contractors' complaint justified. The field attempted to solve these problems by increasing the cement content. This solution was not totally satisfactory and the use of flyash was subsequently reinstated.

Project C experienced a reduction in concrete strengths early in the concrete production phase. This strength reduction was caused by too great a reduction in cement content of the initial 5000 psi mix design and was also partially attributable to improper handling of field cast cylinders. Later

occurrences of reduction in strength were corrected by finer grinding by the cement supplier and changes in air-entrainment as well as by modification of the cement content.

These two cases indicate that the addition of more cement to the mix is not always an automatic solution to concrete problems. The entire mix design, including all ingredients (aggregate, cement, admixtures) should be taken into account when considering mix adjustments.

EVALUATION OF FRESH CONCRETE

Testing Requirements in General

In addition to the extensive testing which is performed on the individual concrete ingredients, a great deal of testing is performed on the freshly mixed concrete prior to its placement. The tests which are performed include: slump, air content, temperature, unit weight, and compressive strength. A number of different codes and standards address the area of what tests are required and their testing frequency. A discussion of the testing requirements of these codes and standards is presented, along with a comparison of the testing requirements of the various projects in the study.

Testing Frequencies.--As mentioned above, a number of different codes and standards include requirements dealing with the sampling and testing of fresh concrete. These codes and standards include: ACI 301, Specifications for Structural Concrete for Buildings; ACI 304, Recommended Practice for Measuring, Mixing, Transporting and Placing Concrete; ACI 318, Building Code Requirements for Reinforced Concrete; ACI 349, Code Requirements for Nuclear Safety Related Concrete Structures; ASTM C94, Specifications for Ready Mixed Concrete; ANSI N45.2; and the ASME Boiler and Pressure Vessel Code. These documents all list requirements for the evaluation of fresh concrete and include acceptance

criteria. A comparison and discussion of the requirements of these codes is presented.

ACI 301 requires that concrete compressive cylinders be taken for every 100 cubic yards, or fraction thereof for each mix design placed in any one day. This document requires that slump and air content of the concrete sample be determined for each strength test and whenever consistency of concrete appears to vary. On the other hand, ACI 304, ACI 318 and ASTM C94 all require strength tests for every 150 cubic yards. ANSI and ASME both require compressive cylinders for every 100 cubic yards. These documents also require that slump, air content, and temperature be determined for the first batch produced each day and for every 50 cubic yards placed. A comparison of the testing frequencies of these various documents is presented in Table 6.5. These testing frequencies will be discussed in detail in the sections dealing with each of the individual tests, but, in general, it can be said that the testing frequencies on nuclear projects are higher than those encountered on typical construction projects.

Location of Sampling and Testing.--The point of sampling and testing to determine concrete properties can be at various locations. For example, the sampling can either be performed at the point of discharge from the central mixer, point of discharge from the truck, or at the point of placement. The typical approach encountered on the projects in the study is to sample at the end of the pumpline when concrete is conveyed by pump and at the truck discharge when the concrete is to be conveyed by other means. Some problems can be associated with sampling and testing at the point of placement. Sampling and testing at the point of placement can sometimes lead to unnecessary delays in the placing operations while tests are performed and results obtained. Delays in placing operations can, at times, have detrimental effects on the quality of

Table 6.5.--Comparison of Testing Requirements

of Applicable Codes and Standards

Code/Standard	Compressive Strength Cylinder	Slump	Air Content	Temperature
ACI 301	100 CY	100 CY	100 CY	-
ACI 304	150 CY	-	-	-
ACI 318	150 CY	-	-	-
ACI 349	150 CY[a]	-	-	-
ASTM C94	150 CY	150 CY	150 CY	-
ANSI N45.2	100 CY	50 CY	50 CY	50 CY
ASME-B&PV	100 CY	50 CY	50 CY	50 CY

[a]When the standard deviation for 30 tests of a given class is less than 600 psi, the number of cubic yards representative of a single test may be increased by 50 cu. yd. for each 100 psi lower standard deviation except that the minimum testing rate shall not be less than one test for each shift when concrete is placed on more than one shift per day.

the concrete which is being placed. In addition, the reliability of the sampling and testing can be seriously impaired by performing these tasks at the point of placement. This can be particularly true for concrete which is placed by pumping.

Concrete is frequently pumped because the placement location is difficult to reach. In such circumstances, sampling and testing may have to be carried out high on a scaffold or in some other area where safety and congestion can be problems. More reliable and consistent sampling and testing can be performed in a simple facility set up for this at the point of discharge from the mixer (6.4). From the standpoint of sampling in a somewhat controlled environment necessary for consistent and accurate results, the end of the pump line location has many disadvantages when compared to other possible sampling points. The ACI Manual of Concrete Inspection (6.3) states that sampling for purposes of control of the quality of concrete as produced should be performed as the concrete is delivered from the final mixer, and that errors of sampling and test cylinder fabrication are least where the concrete is sampled from the mixer. This location is generally specified on the projects which were studied, except for the case of concrete which is pumped. This is due to the fact that the properties of the fresh concrete can be altered by pumping. This is closely related to the topic of correlation testing which is discussed in the next section.

Correlation Tests.--A number of the projects in the study have at one time established correlation programs to try to predict changes of material properties between the batch plant and the forms. On some projects, C and D for instance, there is a requirement in the specifications for an on-going correlation program during the course of the project. On other projects, A and H for instance, correlation studies were conducted to attempt to justify

a change in the sampling location. On some other projects, correlation studies were instituted in response to problems that were encountered.

The specifications for Project C include a requirement for correlation tests "in order to establish a correlation between concrete properties at the batch plant and at the point of pump discharge." These specifications require that pumped concrete be sampled at both locations to determine slump, air content, and concrete temperature. These correlation samples are taken from the same batch of concrete that is sampled for concrete cylinder strength tests at the central mixer plant and again from the same batch as it reaches the end of the pumpline. Samples for slump and temperature are taken from the first batch of each class of concrete produced per day and for every 200 cubic yards of each class of concrete produced thereafter. Samples for air content are taken for every 400 cubic yards of each class of concrete produced, with a minimum of once per day for each class of concrete produced. These frequencies are lower than those for the routine in-process control tests. The results of these correlation tests are transmitted monthly to the project engineering organization. The Project D specifications also have a requirement for correlation testing, although it is not as detailed. On this project samples for slump, air content and compressive cylinders are taken at the point of placement. The specifications require that a second set of cylinders taken at the batch plant to be used for correlation of concrete properties between the batch plant and the point of placement be made for each 500 cubic yards of concrete. This requirement seems rather vague since it does not refer to whether the concrete is placed by pump, conveyor, or bucket, and each of these could be responsible for different levels of change in concrete properties.

The specifications for Project H require that concrete for in-process tests be sampled at the discharge of the pump line. There is, however, a

provision in the specifications which states:

> "As an alternate to sampling pumped concrete where discharged, concrete may be sampled at the intake to the pump in accordance with a qualified procedure prepared by the site organization and approved the the engineer. That procedure shall identify a means for correlating the properties measured at the pump intake with those at the pump discharge. In addition, methods for establishing the significance of variations in the horizontal and vertical length of pump conduit, in the ambient temperature, in the diameter of the conduit, or in the type of pump on that correlation shall be described."

There are so many variables identified in this clause that it is difficult to visualize being able to correlate the effect that each has on changes in concrete properties. This is confirmed by the experiences at the project site. There has been an extensive correlation testing program under way on this project for some time. The exact details of the program (i.e., the time period over which tests have been performed, the amount of concrete subjected to correlation testing, the desired results, etc.) were not available to the authors; however, it was determined that the study is being performed for different pump line configurations, lengths, and lifts. The results of the study were submitted to the engineer, but were ruled to be inconclusive and the study is continuing. It should be pointed out that 160,000 cubic yards of concrete have been placed on this project and no significant correlations between variables have been identified. A great deal of time and money has been expended and sampling is still taking place at the end of the pumpline. It is questioned here whether it is really possible to correlate the change in properties due to pumping in light of the many variables which are involved.

On Project A, a correlation study was carried out to evaluate the slump loss for conveying concrete to a placement as compared with slump loss in mixing trucks. This study resulted from a visit to the project site by AEC personnel who raised a question concerning the validity of taking slump measurements at the batch plant rather than at the placement site, particularly in light of the fact that the concrete was being conveyed from the plant to

the placement by means of a long uncovered conveyor. A correlation study was run consisting of 310 pairs of slump tests run at the batch plant and the placement site. The results of this study indicated that there was no significant difference in slump measurement due to transportation by belt.

From what has been presented here, it would appear that it is very difficult to correlate changes in concrete properties when pumping is involved. The 1976 draft of ANSI N45.2.5 requires sampling at the point of placement unless correlation tests can establish a relation between the properties of the concrete at the point of placement and some other sampling point. This correlation is not difficult when concrete is transported by truck, conveyor, or bucket as is evidenced by the fact that most projects sample from the truck mixer when concrete is conveyed by these means. This correlation is extremely difficult when the concrete is placed by pump, as evidenced by the fact that several projects have attempted this correlation but still sample and test at the end of the pump line. Very little guidance is given in any of the codes concerning the conduct of correlation studies. Correlation studies are referred to, but no guidance concerning their implementation (what variables should be included, what level of significance should be used, etc.) is given. It would appear that the best approach to avoid sampling and testing at the point of placement is the one that is employed on Project E.

On Project E, sampling and testing is performed at the batch plant. This project is the only one in the study which uses rear dump trucks to transport concrete rather than agitator trucks. In this way, changes in concrete properties are kept to a minimum during transport from the batch plant to the placement site. In addition to this, very little concrete is placed by pump on this project. In contrast to some projects which pump a great deal of concrete, only about 5 to 10 percent of the concrete on Project E is placed by pump. In this way sampling and testing can be conducted under controlled conditions at the batch plant since

significant changes in properties do not occur between the batch plant and the forms. Testing at the batch plant can improve the reliability of the results and can also help to reduce costs since testing facilities do not have to be set up at the location of each concrete placement.

Compressive Strength

The primary acceptance criteria for concrete on all of the projects studied is concrete strength as determined from compressive cylinder tests. Whenever a nonconformance is written concerning concrete, the primary method of handling the nonconformance is to show that in spite of the nonconformance, the concrete strength is still acceptable. This is done be verifying that the cylinder strength equals or exceeds the required strength. The requirements for in-process control testing of concrete compressive strength on the various projects in the study are presented herein.

Testing Frequencies.--The compressive strength testing frequencies that are recommended by the various codes and standards are presented in Table 6.5. The source of the compressive strength cylinder frequency that is recommended by ASME and ANSI appears to be ACI 301. It should be noted, however, that this specification was written for ordinary building construction with smaller sections and usually smaller placements than are typically encountered on nuclear projects. The ACI Manual of Concrete Inspection (6.3) states that in general, relatively fewer tests need be performed for large-scale construction which is highly mechanized than for small jobs. With the tremendous amount of testing that is carried out on the concrete ingredients, the highly sophisticated automated batch plants, and the large placements which are associated with nuclear construction, it would seem that the testing frequencies of ACI 301, ANSI and ASME are higher than are necessary to control concrete production. Tuthill (6.4)

states that:

> "because it is nuclear, probably twice as many routine control tests are required at a frequency of once per 100 cubic yards placed, than are necessary for good, knowledgable control of such massive work where there are many hundreds of cubic yards in most concrete placements. But because it is nuclear, ACI 359 and ANSI N45.2.5 require this frequency."

Concerning the construction of dams and mass concrete in general, the ACI Manual of Concrete Inspection (6.3) indicates that it is common practice to take one or two sets of compressive strength cylinders per shift. The Bureau of Reclamation Concrete Manual (6.1) also indicates that, in general, one sample per shift is taken when large quantities of concrete are involved. Figure 6.1, taken from Wright (6.5), presents a comparison of results of regular daily tests over a period of time versus results of tests on consecutive batches during one shift. As can be seen, in six of the seven cases, there is very little difference between the ranges and coefficients of variation obtained from the two methods. In light of all that has been presented, it would seem that a shift to the requirements of ACI 318, ACI 349, and ASTM C94 of a test for each 150 cubic yards would easily provide the necessary control for nuclear projects. Note that ACI 349 has a provision for reducing this frequency (Table 6.5) when good process control is demonstrated by a low standard deviation. This would allow for a reduction in testing, and therefore costs, without affecting the quality of concrete.

The testing frequencies for concrete compressive strength for each of the projects in the study are presented in Table 6.6. As can be seen from the table, five of the projects employ the same 100 cubic yard frequency as is recommended in ACI 301, ANSI, and ASME. Three of the remaining four projects use this same 100 cubic yard frequency for safety related (Category I or "Q") placements, while requiring a different frequency on non-safety related placements. On Project G, non-safety related concrete is sampled for cylinders every 200

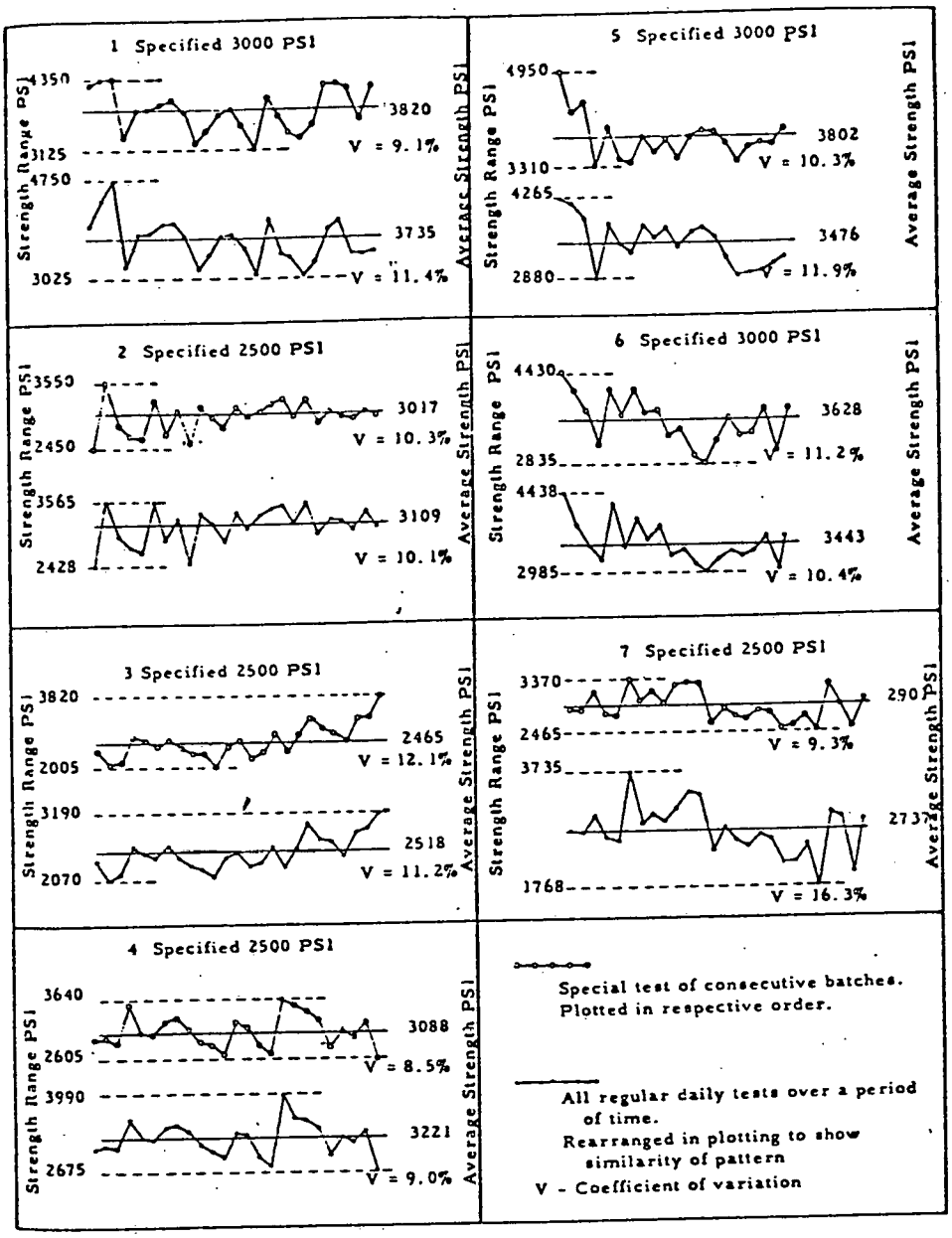


Figure 6.1.--Comparison of Strength Variations of Consecutive Batches During One Shift Compared to Variation Over a Concomitant Period

Table 6.6.--Concrete Compressive Strength Testing Requirements For the Projects Studied

Project	Testing Frequency	Acceptance Criteria Reference
A	100 CY	ACI 318 Sect. 4.3.3
B	100 CY	--for $\leq$ 3000 psi concrete: the average of any five consecutive strength tests must be $\geq$ f'c, and $\leq$ 20% of the strength tests are $\leq$ f'c. --for $\geq$ 3000 psi concrete: the average of any three consecutive strength tests must be $\geq$ f'c, and $\leq$ 10% of the strength tests are $\leq$ f'c. --Coefficient of variation $\leq$ 15%
C	100 CY	ACI 318 Sect. 4.3.3
D	100 CY	ACI 318
E	2000 psi-300 CY 3000 psi-200 CY 3000+ psi-150 CY	(See Table 6.8)
F	Safety Related-100 CY Non-Safety Related-250 CY	ACI 301 Chpt. 17; ACI 318 Chpt. 4
G	Safety Related-100 CY Non-Safety Related-200 CY	ACI 301
H	100 CY	ACI 301
I	Safety Related-100 CY Non-Safety Related-250 CY	ACI 301 Chpt. 17

cubic yards, whereas Projects F and I test non-safety related concrete every 250 cubic yards. On Project E a different approach is employed. On this project, the testing frequency is related to the required strength of the concrete. The highest testing frequency on this project, every 150 cubic yards for concrete with required strengths above 3000 psi, is still lower than the one recommended by ACI 301, ANSI, and ASME. These frequencies are more in line with those encountered in typical mass concreting practices.

Acceptance Criteria.--The acceptance criteria for concrete compressive strength that are recommended by the various codes and standards are presented in Table 6.7. As can be seen, there are two different criteria. The most common approach is based on the average of three consecutive strength test results. This approach is indicated by ACI 301, ACI 304, ACI 318, ACI 349, ASME, and ANSI. The acceptance criteria for concrete compresssive strength for the projects in the study are presented in Table 6.6. Seven of the projects studied reference that acceptance will be in accordance with either ACI 301 or ACI 318. These plants all have the same criteria since the requirements for acceptance of ACI 301 and ACI 318 are identical. Project B has acceptance criteria which are closely related to those of ASTM C94. The acceptance criteria for Project E are somewhat more involved than those on other projects. These requirements place limits on both the average strength of five consecutive tests and also on the maximum allowable standard deviation. These specifications also place requirements on cylinder strength at three days. (Table 6.8) This three-day strength is the estimated control strength necessary to attain the design mix strength.

This presentation of concrete strength requirements is really academic since the failure of a concrete cylinder to reach the required strength is a very rare occurrence on a nuclear project. For example, on Project F, 864 28-day breaks and 431 7-day breaks have been run and not a single result has

Table 6.7.--Acceptance Criteria of Various Codes and Standards for Concrete Compressive Strength

Code	Acceptance Criteria
ACI 301	17.2.--Acceptance of Concrete--The strength level of the concrete will be considered satisfactory if the averages of all sets of three consecutive strength test results equal or exceed the required fc' and no individual strength test result falls below the required fc' by more than 500 psi.
ACI 304	4.3.3--The strength level of the concrete will be considered satisfactory if the averages of all sets of three consecutive strength test results equal or exceed the required fc' and no individual strength test result falls below the required fc' by more than 500 psi.
ACI 318	4.3.1--The strength level of the concrete will be considered satisfactory if the averages of all sets of three consecutive strength test results equal or exceed the required fc' and no individual strength test result falls below the required fc' by more than 500 psi.
ACI 349	4.3.3--The strength level of the concrete will be considered satisfactory if the averages of all sets of three consecutive strength test results equal or exceed the required fc' and no individual strength test result falls below the required fc' by more than 500 psi.
ASTM C94	16.5.1--For concrete in structures designed by the working stress method and all construction other than that covered in 16.5.2, not more than 20 percent of the strength tests shall have values less than the specified strength, fc', and the average of any six consecutive strength tests shall be equal to or greater than the specified strength. 16.5.2--For concrete, in structures designed by the ultimate strength method and in prestressed structures, not more than 10 percent of the strength tests shall have values less than the specified strength, fc' and the average of any three consecutive strength tests shall be equal to or greater than the specified strength.
ANSI N45.2.5	6.2.1--Concrete quality and acceptance criteria shall conform to the requirements of ACI 318, Chapter 4.
ASME Boiler and Pressure Vessel Code	CC5234.2 (c)--The strength level of the concrete will be considered satisfactory if the averages of all sets of 3 consecutive strength tests at "a" days equal or exceed the specified strength and no individual strength test result falls below the specified strength test result by more than 500 psi.

Table 6.8.--Concrete Compressive Strength Acceptance Criteria for Project E

Required compressive strength (f'c), psi		2000		3000		4000	4500
Class of Concrete		C	B	B	A	A	A
Age for Required Strength, Days		180	90	90	28	28	28
Percent of tests allowed below required strength (f'c)		20	20	10	10	10	10
Maximum Size Aggregate	Strength and Deviation	Design Mix Strength and Allowable Deviation, PSI					
	f'c at 28	-	1650	2350	3700	4750	5300
3/4" & 1½"	σ at 28	-	380	440	540	600	630
	f'c at 3	-	450	750	1450	2000	2500
	τ at 3	-	±100	±140	±210	±275	±300
	f'c at 28	1100	1700	2400	3800	-	-
3"	σ at 28	320	420	480	610	-	-
	f'c at 3	300	460	750	1450	-	-
	τ at 3	±90	±110	±150	±240	-	-
6"	f'c at 28	1100	1750	2500	3900	-	-
	σ at 28	350	470	570	660	-	-
	f'c at 3	300	470	800	1500	-	-
	τ at 3	±100	±130	±180	±250	-	-

Notes:

f'c at 28 is design mix at 28 days.

σ at 28 is maximum standard deviation at 28 days.

f'c at 3 is estimated 3-day control strength necessary to attain design mix strength

τ at 3 is the allowable deviation of the moving average of five consecutive tests of 3-day strength above and below the 3-day control strength (as indicated by ±) before mix adjustments are required.

failed to reach the required strength. On Project H, 160,000 cubic yards of concrete have been placed and to date not a single test cylinder failure has been reported. This fact is related to the field adjustment of concrete mixes, which is discussed in a later section.

Number of Cylinders Cast.--The number of cylinders which are cast for each compressive strength sample on each of the projects studied is presented in Table 6.9. The number of cylinders cast per set ranges from a low of three on Project F to a high of ten on Project B. The requirements on Project B appear to be a bit extravagant when compared with those on the other projects and those recommended in the applicable codes and standards. ACI 301 requires that two specimens be tested at 28 days for acceptance and one at 7 days for information. Most of the projects cast and test more than the three cylinders which are required by ACI 301. Only Projects F, G, and I follow the ACI 301 requirements concerning the number of cylinders tested. However, on Project G there is a provision for testing two cylinders at 90 days if the first test at 28 days is low, and on Project I two additional cylinders are cast in the event that it becomes necessary to run additional tests. The requirements on these projects are presented in Table 6.9.

Evaluation of Test Results.--ACI 214, Recommended Practice for Evaluation of Compressive Test Results of Field Concrete, outlines statistical concepts for the evaluation of compressive strength results. A number of the projects in the study perform periodic statistical evaluations in accordance with this recommended practice. Four of the project specifications state that compressive cylinder test results will be evaluated in accordance with ACI 214. These statistical reports indicate that on many of the projects, compressive strengths are averaging values well in excess of the required strengths. ACI 318 and ACI 349 include provisions that allow mix designs to be adjusted in the event that high average strengths are obtained with low coefficients of variation. It does

Table 6.9.--Compressive Cylinder Testing Schedules

Project	Total Number of Cylinders Cast	Cylinders Tested 3 days	7 days	28 days	90 days
A	6	-	2	3	1 (if the 28 day break is low)
B	4000, 5000 psi 10	2	2	3	3
	3000 psi 8	2	2	2	2
C	5000 psi 6	-	2	2	2
	other 4	-	2	2	-
D	4	-	2	2	-
	with pozzolan 6	-	2	2	2
E	Class A 4	1	-	2	1
	Class B 4	1	-	2	1
	Class C 5	1	-	2	1 (1 at 180 days)
F	3	-	1	2	-
G	4	-	1	2(1)[a]	0(2)[a]
H	4000 psi 6	-	2	2	2
	3000 psi 4	-	2	2	-
I	5[b]	-	1	2	-

[a]If the first cylinder tested at 28 days is low, the second is held and two are tested at 90; if the first cylinder test is acceptable, then a second is tested at 28 days.

[b]One spare cylinder is cast, and one in the event of an aggregate failure.

not appear that this provision is being employed very frequently on the projects which were studied in spite of the high concrete strengths which are being obtained. Some examples of statistical evaluations of compressive strength test results from the projects in the study are included in Appendix 6.B. It should be noted that high cement contents are used on nuclear projects for their beneficial effects on other properties besides strength, such as workability and finishing. In spite of this fact, the occurrence of very high compressive strengths is so common that it would seem in some instances that mix adjustments could be made to reduce these strengths.

On one project, a study conducted by the constructor indicated that average compressive strength results far exceeded the design strength requirements. There was some disagreement concerning whether or not field adjustment of the mix designs should be allowed. Some people felt that a substantial amount of money could be saved by the reduction of cement. On the other hand, some people expressed the viewpoint that maintaining the high cylinder strengths was good insurance in the event that concrete problems develop in the future. The result of the study was the development by the constructor of a written procedure for the field adjustment of concrete mixes.

An example of one case where a concrete mix was adjusted due to high compressive strengths can be found in the statistical analysis from Project F which is presented in Appendix 6.B. This is an analysis of one of the most common 3000 psi mixes on the project. A total of 239 tests were made over a 17-month period. The cumulative 28-day average strength for all of these tests was 4677 psi with a coefficient of variation of 10.58 percent. After an analysis of the data by the engineer, a new mix design was developed with a targeted strength of 3700 psi. This re-design resulted in a reduction in cement content of 35 pounds per cubic yard. If similar mix adjustments were made on

other projects experiencing excessively high concrete strengths, potential savings in cement and costs could be recognized.

Slump Tests

The slump test denotes the fluidity of concrete and is also considered to be a measure of concrete consistency. The aim in controlling the slump is to control directly the consistency and the workability necessary for proper placement, and indirectly the water-cement ratio (6.1). The slump test is easily performed at the job site and is used very often in construction work. The requirements for slump tests on the projects studied are presented in this section.

Testing Frequencies.--The recommended frequencies for slump tests of various codes and standards are presented in Table 6.5. As can be seen, the frequency recommended by ANSI and ASME is higher than those recommended by ACI 301 or ASTM C94. ACI 301 and ASTM C94 both require that slump tests be performed when concrete compressive cylinders are taken. The ANSI and ASME frequencies appear to be higher than necessary for control of the process in light of the fact that they are two and three times higher than those of ACI 301 and ASTM C94. The purpose of sampling should be to verify that the process is under control and not to eliminate the need for observation and judgment on the part of the inspector. When discussing the requirement for a slump test every 50 cubic yards, Tuthill (6.4) states:

> "Mixer men and good Level II placing inspectors know when their concrete is of a suitable slump and when it is not. They need only occasional tests with the given mix to keep their eye in training. When the slump gets too low or too high, it is obvious and no testing is needed to know that or what, appropriate action should be taken. The slump taken with the routine random sampling and testing is sufficient for the record."

The testing frequencies for slump on the projects in the study are shown in Table 6.10. These frequencies on safety related structures vary from once every 20 CY on Project A to once every 150 cubic yards on Project E. The later

Table 6.10.—Slump Test Frequencies
For the Projects In the Study

Project	Testing Frequency
A	Every 20 CY
B	Every 50 CY after the first two Batches
C	Safety Related--every 35 CY Non-Safety Related--every 50 CY
D	Every 50 CY until production is uniform and then every 100 CY
E	2000 psi concrete--every 300 CY 3000 psi concrete--every 200 CY 3000+ psi concrete--every 150 CY
F	Safety Related--every 50 CY Non-Safety Related--every 250 CY
G	Every 30 CY
H	First two batches and every 48 CY
I	Safety Related--every 50 CY Non-Safety Related--every 250 CY

projects, F, G, H, and I, employ a 50 (or 48) cubic yard frequency which is in line with the ANSI requirements. Some of the earlier projects, A and C, whose specifications were developed before ANSI was published, have frequencies that are even higher than those in ANSI. Projects C, F and I have different frequencies for non-safety related placements. The approach on Project D has a great deal of merit. Testing is initially performed every 50 cubic yards until it is shown that production is uniform and then it is relaxed to every 100 cubic yards. This allows for higher testing frequencies initially to verify that the production process is under control.

Acceptance Criteria.--Of the codes and standards listed in Table 6.5, only ACI 301 and ASTM C94 include allowable tolerances for slump. ACI 301 contains the following requirements for slump in section 3.5:

> "Unless otherwise permitted or specified, the concrete shall be proportioned and produced to have a slump of 4 in. or less if consolidation is to be by vibration, and 5 in. or less if consolidation is to be by methods other than vibration. A tolerance of up to 1 in. above the indicated maximum shall be allowed for individual batches provided the average for all batches or the most recent 10 batches tested, whichever is fewer, does not exceed the maximum limit. Concrete of lower than usual slump may be used provided it is properly placed and consolidated. The slump shall be determined by the "Test for Slump of Portland Cement Concrete" (ASTM C143)."

ASTM C94 includes the following provisions for slump tolerances in Section 6:

> "6.1.1. When the project specifications for slump are written as a "maximum" or "not to exceed" requirement:

	Specified slump	
	If 3 in. (76 mm) or less	If more than 3 in. (76 mm)
Plus Tolerance:	0	0
Minus Tolerance:	1½ in. (38 mm)	2½ in. (63 mm)

> This option is to be used only if one addition of water is permitted on the job provided such addition does not increase the water-cement ratio above the maximum permitted by the specifications.

> 6.1.2. When the project specifications for slump are not written as a "maximum" or "not to exceed" requirement:

For Specified Slump of:	Tolerance
2 in. (51 mm) and less	±½ in. (13mm)
More than 2 through 4 in. (51 to 102 mm)	±1 in. (25mm)
More than 4 in. (102 mm)	±1½ in. (38 mm)

These two documents provide three different approaches to specifying slump requirements. ACI 301 specifies a maximum slump with an allowable tolerance of one inch above this value. It also provides that acceptance be based on a running average of ten tests. ASTM C94 presents two different approaches. One with a target value of slump with a specified tolerance above and below this value. The other approach establishes an absolute maximum value for slump and provides a tolerance range below this number.

Most of the projects in the study have developed their own sets of slump requirements rather than referencing a code or standard. Only Project H among those studied references ACI 301 and declares no exceptions or additions to its requirements. Several of the projects have rigid upper limits on slump similar to one of the approaches in ASTM C94. The slump requirements for Projects A, B, F, H and I are included in Table 6.11. With the exception of Project H, all of these projects place rigid upper limits on slump values.

Due to the natural variability of material, placing a strict upper limit on slump requires the average value of slump to be lower than the limit in order to prevent individual batches from exceeding the maximum limit. To avoid having batches exceed the maximum slump limit, the target slump value would have to be lower to account for material variation. The act of establishing a rigid upper limit, in effect, encourages the production of concrete that has lower slump than the maximum limit.

Two of these projects place a lower limit on slump values as well as an upper one. This is contradictory to the requirements of ACI 301. Chapter 14 of this specification states that concrete of lower than usual slump may be used provided it is properly placed and consolidated. Considering interpretation of code and specification requirements, Tuthill (6.2) states:

> "For instance, where a slump of 2 in. $\pm$ 1 in. was recommended to indicate a practical range of slump for massive concrete, overzealous inspectors rejected the better, drier concrete with a slump less than 1 in., even when with a little extra attention, it could often just as well have been used."

Table 6.11.--Slump Requirements for Projects A, B, F, H and I

Project	Class (psi)	Minimum (in.)	Maximum (in.)
A	all	--	4[a]
B	5000	1	3½
	3000	1	3
F	mass	-	3
	other	-	4
H	all		4[b]
I	mass	1	3
	other	-	4

[a]For certain congested areas, a mix with 5" slump is allowed, and in the highly congested containment wall, 6" and 7" slumps are permissible.

[b]A 1" tolerance is provided for as per ACI 301.

A different approach to specifying concrete slump is employed on Project E. This specification has incorporated provisions similar to those in ACI 301. These include use of an average value along with a tolerance above this value for individual batches. The slump requirements for this project are included in Table 6.12. This specification allows for variations in slump from batch to batch. It differs from ACI 301 in that the slump of any five consecutive batches is used to calculate the average slump, whereas ACI 301 uses an average based on ten consecutive tests. The second criterion in this specification limits the amount of concrete in any placement which exceeds an upper tolerance limit. The first criterion alone would permit an unlimited number of high slump batches provided there were enough low slump batches to hold the average down.

This method of specifying slump requirements seems to work well enough, but it does have some drawbacks. As with any moving average slump requirement, inspectors may tend to encourage lower than preferable slump at the start of the placement so as to have low values to average with any high ones which may appear later. One of the worst ways to start a placement is with low slump concrete. Proper consolidation of the concrete is difficult and delays may result which can reduce the slump of later batches. Concrete nearly wet enough to be rejected is preferable at the start of the placement, and subsequent upward water movement will bring its quality up to that of the average (6.2).

Another aspect of this specification that is somewhat less than desirable concerns the second criterion. It is easy to write that not more than 10 percent of the concrete placed in a pour shall have slump exceeding some value, but difficulties can be encountered in enforcing such a provision. In order to determine what this 10 percent limit will be for a particular placement, the concrete inspector must first find out the estimated amount of concrete in the placement and calculate 10 percent of this number. Then, during the placement,

Table 6.12.--Slump Requirements for Project E

Thickness of Concrete Section, Inches	Maximum Size of Aggregate, In.	Maximum Average[a] Slump, In.	Maximum[b] Slump, In.
	Walls, Columns, Beams, Girders		
Less than 12	3/4	3½	4½
12 to 24	1½	3	4
24 to 36	1½	2½	3¼
36 to 72	3	2	2½
Greater than 72	6	1½	2
	Slabs, Footings		
Less than 9	3/4	2½	3¼
9 to 12	1½	2½	3¼
12 to 18	3	2	2½
Greater than 18	6	1½	2

[a]The average slump of any five consecutive batches of concrete placed shall not exceed these limits.

[b]Not more than 10 percent of the concrete placed in a single lift or pour shall have slump exceeding these limits.

he must keep a running total of the number of cubic yards placed that have slumps exceeding the limits and reject all concrete with slump above the limit after the 10 percent amount has been reached. This task is quite cumbersome for the concrete inspector at the placement site.

Three projects in the study are using a different, fairly new approach to specifying slump requirements. The method used provides upper and lower working limits and also absolute rejection limits. There are no rejections when the working limit is exceeded unless the process is not brought back within limits in a reasonable time. The rejection limit allows a reasonable margin for occasional batches of concrete that exceed the working limit but do not measurably affect the strength of the concrete. This approach to slump requirements has been adopted on Proejcts C, D, and G. A typical example of this specification is shown in Table 6.13.

The slump must be less than or equal to the working limit but can occasionally exceed this limit by an allowable deviation called the "Inadvertency Margin". In each case, corrective action is required to bring the batching process under control. Each batch is sampled and tested until the proper slump control has been re-established.

This method seems to work quite well on the three projects. The working limit dictates the desired slump, the inadvertency margin allows slight deviations in the sample that are inevitable in the production of concrete, and there are no required averages to be met. This appears to be the best approach among the projects in the study and it is suggested that its use be considered on other projects.

Several of the projects have acceptance provisions which allow for retesting concrete which is initially out of the allowable slump limits. Projects B and F allow trucks with concrete having slumps that are too high to wait for 15

Table 6.13.--Method of Slump Requirement Specification on Projects C, D, and G

Type of Concrete	Working[a] Limit	Inadvertency[a] Margin	Rejection Limit
*	5	2	7
*	4	2	6
*	3	1½	4½
*	2½	1½	4
*	2	1½	3½
*	1½	1	2½
*	1	1	2
Tremie	6 to 8		

*Designate as required for parts of job such as walls, slabs, pavement, mass concrete, tunnel lining, thin sections, etc.

[a]The 'Working Limit' is the maximum slump for estimating the quantity of mixing water to be used in the concrete. The 'Inadvertency Margin' is the allowable deviation from the 'Working Limit' for such occasional batches of concrete as may inadvertently exceed the 'Working Limit'. Batches of concrete with slumps in the inadvertency margin will be rejected if the Contractor fails to comply promptly with instructions of the Engineer to reduce the slump of concrete to within the 'Working Limit'. Concrete of lower than usual slump may be used provided it is properly placed and consolidated. (6.4)

minutes with the drum revolving. The slump is then retested and if it is within allowable limits, the concrete is accepted. Projects D and F both have provisions which allow a second test to be performed in the event that the first test fails. On Project F, the inspector has the option of accepting the concrete even if the retest fails to meet the allowable limits. If the concrete is accepted a nonconformance report is written and compressive strength cylinders are cast from the batch to be used in evaluating and dispositioning the nonconformance.

Slump Adjustment-Addition of Water.--Prolonged mixing, excessive standby time, or elevated temperatures can cause high reductions in slump. This problem can be alleviated by improved planning and scheduling of the concrete operation and by properly modifying the concrete delivery systems to minimize the temperature gain of the fresh concrete. However, even when these precautions are taken, concrete can arrive at the placement with slump below that suitable for placing. The decision must be made whether or not to allow the addition of water to the mix to adjust the slump. There are two ways to deal with this addition of water: 1) small increments of retempering water can be added to mixed batches to obtain the desired slump, or 2) a partial amount of the initial mixing water can be withheld at the batch plant, then the mixture can be brought to the desired consistency by the addition of tempering water. Both ACI 301 and ACI 304 state that water may be added only if neither the maximum permissible water-cement ratio nor the maximum slump is exceeded.

Six of the nine projects in the study allow the addition of water to a batch of concrete. Project E uses rear dump trucks to transport the plastic concrete, and this precludes the addition of water on this site. Projects C and D, however, use agitator/mixer trucks but still do not allow the addition of water. Of the six projects which allow addition of water, two specify that water can be added only if some mixing water is withheld at the batch plant, three specify that the design water-cement ratio shall not be exceeded, and

two require that the addition of water take place within 45 minutes of the time of batching. Project G allows the addition of water to a batch of concrete but requires that the batch be tested for temperature, slump, air content, and compressive strength. Personnel on the project have decided that these tests cost more to perform than the load of concrete. Because of this, truckloads of concrete are rejected because of low slump rather than add water. The addition of water to a batch of concrete is therefore allowed in the specifications but not done because the costs of testing make it impractical.

Time Limit.--Many of the projects studied place a limit on the amount of time after mixing that the concrete can be placed. These projects require that concrete be placed within 90 minutes after the mixing water is added, and also that it be placed before the mixer drum has revolved 300 revolutions. This requirement is also included in ASTM C94. The difference between the specifications of the projects and ASTM C94 is that these time limits are rigidly enforced on the projects, whereas ASTM C94 allows that these limits be waived. ASTM C94 states that "these limitations may be waived by the purchaser if the concrete is of such slump after the 1½ hour time or 300 revolution limit has been reached that it can be placed, without the addition of water, to the batch." Placing an arbitrary time limit on the placing of concrete without regard to its consistency seems to be an unnecessarily restrictive requirement. The ACI Manual of Concrete Inspection (6.3) states:

> "Although some specifications limit the time after mixing that the concrete can be used, there is no reason to do so as long as the concrete can be properly placed and fully consolidated without the addition of water"

And Tuthill (6.4) states:

> "It has never been clear why some place a time limit on acceptability of concrete that can still be placed well and has had no added water. Such concrete has repeatedly been found to be of higher than average strength. Only the condition of the still plastic concrete and what can be done acceptably with it, not elapsed time, should be the criteria as to whether it should be used or rejected."

This is the approach which is used on Project E. On this project there is no arbitrary time limit on placing, but rather the judgment of the placing inspector determines whether or not the concrete may be placed. This is contrary to the general trend on the projects which was toward removing any judgment whatsoever from the inspectors and expressing everything in terms of absolute limits. Common sense and the judgment of a skilled inspector are assets that should not arbitrarily be eliminated simply because the project is nuclear.

Air Content

Air content limits are given in many codes and standards and are also included in the specifications of the various projects in the study. Potential advantages and disadvantages of various levels of air content were presented in Chapter 5 and, therefore, will not be discussed here. This section presents a comparison of the testing frequencies and specification limits for air content that are contained in the codes and standards and were encountered on the Projects which were studied.

Testing Frequencies.--The testing frequencies for air content which are recommended by the various codes and standards are presented in Table 6.5. ACI 301 and ASTM C94 require that air content be determined when compressive strength cylinders are cast. On the other hand, ANSI and ASME requirements call for testing slump, air content, and temperature twice as frequently as compressive strength. Over the course of the project, this can lead to a great deal of additional tests as compared with either ACI 301 or ASTM C94 requirements.

In light of the fact that both ACI 301, ASTM C94, and also the ACI Manual of Concrete Inspection (6.3) and the Bureau of Reclamation Concrete Manual (6.1) all recommend that air content be determined when cylinders are cast, the ANSI and ASME frequencies may be higher than necessary to maintain adequate control of the concrete operations.

The testing frequencies for air content on the projects studied are included in Table 6.14. These frequencies are either every 50 or 100 cubic yards for concrete which will be placed in safety related structures. Only three of the projects employ the higher ANSI and ASME frequencies, and one of these has a provision for decreasing this frequency after the concrete production process becomes uniform.

Acceptance Criteria.--Table 6.15 indicates air content requirements of various codes and standards which are applicable to nuclear construction projects. This can be compared with Table 6.14 which lists the air content requirements of the projects in the study. Several of the projects have provisions which allow the air content to occassionally exceed the specification limits without rejecting the concrete. Both projects C and D allow an "Inadvertency Margin" of $\pm$1% for occasional batches that are out of specification limits. Project G allows air contents below the lower specification limit provided corrective measures are taken within the following four batches. The other projects in the study have rigid limits on air content.

Project F has an air content requirement which was not found on any of the other projects that were studied. The specifications on this project require the air content of the first three loads of a mix batched on any day to be within the limits of ACI 301. All other batches produced must be within 4 to 6 percent for mixes with #67 and #57 aggregates. The concrete consultant on this project expressed the opinion that this requirement is restrictive and costly. Also, the specifications require mixes with #467 aggregate to have a maximum air content of 4%, whereas the ACI recommended limits are 3-6%. The concrete consultant stated that this requirement is unduly restrictive and increases costs and rejections.

Temperature

All of the projects studied have requirements for concrete temperatures.

Table 6.14.--Air Content Requirements for the Projects in the Study

Project	Testing Frequency	Acceptance Limits
A	Not Tested	None
B	Every 50 CY	4-6% Some Mixes 5-7% Some Mixes
C	Every 100 CY	3-6%[a]
D	Every 50 CY until production is uniform and then every 100 CY	3-6%[a]
E	2000 psi concrete--every 300 CY 3000 psi concrete--every 200 CY 3000+ psi concrete--every 150 CY	4-7%
F	Every 50 CY for safety related concrete, w/ cylinders for non safety related concrete	b
G	Every 100 CY	c
H	Every 100 CY	In accordance with ACI 301
I	Every 50 CY for safety related Every 250 CY for non-safety related	3-5% 4-7% 5-7% 6-8% } Various Mixes

[a]Where air entrained concrete is required, the total air content of the concrete, as measured at the point of placement, shall not be less than 3 percent nor more than 6 percent of the concrete by volume, with an "inadvertency margin" of one percent above or below these limits. This margin is the allowable deviation for the occasional batches that may inadvertently exceed the 3-6 percent range. Batches of concrete with air content in the "inadvertency margins" shall be rejected if instructions to bring the air content within the 3-6 percent range are not complied with promptly.

[b]The air content of the first three loads of a mix batched on any day may be within the limits specified in Table 3.4.1 of ACI 301 for the aggregate size being used. All subsequent tests shall show air contents conforming to those listed in prequalified and approved mixes. If at any time during concrete production, the air content does not conform to that shown in the approved mix but is within the limits of Table 3.4.1 of ACI 301, the admixture quantity shall be adjusted at once so that within the next three loads produced at the batch plant following notification the air content is brought within the tolerances of the approved mix.

[c]2-6%; Concrete below 2% will not be rejected until corrective action to raise the air content has failed in 4 successive batches.

Table 6.15.--Air Content Requirements of ACI 301, ACI 318, and ACI 349

Nominal Maximum Size of coarse aggregate, in.*	Size Number	Total Air Content, Percent by Volume
3/8	8	6-10
1/2	7	5-9
3/4	67	4-8
1	57	3.5-6.5
1½	467	3-6
2	357	2.5-5.5
3	-	1.5-5.5

The major sources of these requirements are ACI 305, Recommended Practice for Hot Weather Concreting, and ACI 306, Recommended Practice for Cold Weather Concreting. Placing temperature requirements will be discussed in detail in Chapter 7, so the presentation here will be limited to a discussion of the testing frequencies for concrete temperature on the projects in the study and those recommended by the applicable codes and standards.

The recommended testing frequencies for temperature of applicable codes and standards are presented in Table 6.5. These can be compared with the frequencies on the projects studied which are presented in Table 6.16. As in the case of air content, both ACI 301 and ASTM C94 require that temperature be determined when cylinders are cast, while ANSI and ASME require frequencies of once every 50 CY. The temperature determination is easy and relatively quick to perform, but if the operation is under control a frequency of every 50 CY seems to be higher than necessary. The temperature frequencies on the projects in the study generally conform to the slump test frequencies since most of the specifications require that temperature be determined when slump tests are taken.

SUMMARY

This chapter presented a comparison of the requirements for the production and testing of fresh concrete that were encountered on the projects in the study. These requirements were also compared with those of the applicable codes and standards.

Production of Concrete

The batch plant requirements on the projects were compared with each other and with those of ACI 301, ACI 304, and ASTM C94. It was noted that all of the

Table 6.16.--Temperature Determination Frequencies for the Projects in the Study

Project	Frequency
A	20 CY
B	50 CY
C	100 CY
D	100 CY
E	300 CY (2000 psi concrete) 200 CY (3000 psi concrete) 150 CY (3000+ psi concrete)
F	50 CY (safety related) with cylinders (non-safety related)
G	50 CY
H	48 CY
I	50 CY (safety related) with cylinders (non-safety related)

batch plants were equipped for automated batching, automated recording, and were capable of automatically compensating for varying moisture content in the aggregate. Most of the projects placed additional production requirements on their batch plants, and a comparison of these requirements was presented in the chapter.

The weighing and batching tolerances of the projects were discussed. It was noted that ACI 301 and ACI 304 have different requirements for batching tolerances and that five of the projects employ the simpler approach of ACI 301.

During the discussion on mixing requirements, it was pointed out that most of the projects studied require mixer uniformity tests in accordance with ASTM C94. There is a broad range, however, in the frequency with which this test is conducted on the various projects. It was also noted that one of the projects uses the fairly simple uniformity requirements recommended by the Bureau of Reclamation rather than the requirements of ASTM C94.

The role of the QC Inspector at the Batch Plant on each of the projects was discussed and it was noted that all of the projects require the inspector to be present at the batch plant at all times during concrete production. The level of responsibility of the batch plant inspector varies from project to project, and it was pointed out that on some projects the batch plant inspector has so much responsibility that the batch plant operator is practically unnecessary. It was suggested that the role of QC should be the inspection of construction operations rather than their direction.

The different requirements for concrete batch tickets were discussed. It was stated that there were two different approaches which could be employed in the use of batch tickets. The first is to provide very detailed information automatically printed on the tickets. The second approach is to provide less information on the batch tickets and to use an automatic printer tape to act as

a permanent record of concrete operations. An example of each of these approaches was presented.

A discussion of the concrete mix design requirements of the projects was also presented. It was indicated that eight of the projects use the design mix water/cement ratio of the concrete as a control measure. Several of the projects use this water/cement ratio to establish a limit on the maximum amount of water which may be used in the batch. It was suggested that this was not the best approach and it was pointed out that one of the projects states that "for batch-to-batch control of concrete in the field, water requirements must be controlled by controlling the slump of the concrete which can be easily measured".

In the discussion on strength requirements, it was suggested that concrete strengths are set higher than necessary for some of the mass concrete placements which are encountered on nuclear projects.

Evaluation of Fresh Concrete

A comparison of the testing requirements for plastic concrete on the projects in the study was presented. The testing frequencies on the projects were compared with those that are recommended in the applicable codes and standards.

The discussion of the location of sampling and testing indicated that, in general, sampling is performed at the point of placement when concrete is transported by pump, and at the truck discharge when the concrete is placed by other means. It was stated that sampling and testing can be impaired when performed at the point of placement rather than under controlled conditions at the batch plant. Several of the projects have at one time established correlation programs to try to predict changes of material properties between the batch plant and the forms. It was pointed out that such correlation was extremely

difficult for the case when concrete is placed by pumping.

In the discussion on compressive strength requirements, it was pointed out that the testing frequencies required by ACI 301, ANSI, and ASME are higher than those required by other codes and those normally employed in mass concreting operations. It was suggested that the use of the lower 150 cubic yard frequency of ACI 318, ACI 349, and ASTM C94 would be quite sufficient to provide adequate control of the concrete production operations.

The acceptance criteria for compressive cylinders on each of the projects was presented and compared with the requirements of the applicable codes and standards. It was pointed out that compressive cylinder test results generally far exceed required strengths. There were few occasions encountered on the projects where mix designs were adjusted to reduce these high strengths in accordance with the provisions of ACI 318 and ACI 349.

The required testing frequencies for other in-process tests on fresh concrete were presented. These in-process tests include slump, air content, and temperature. It was noted that ANSI and ASME stipulate frequencies that are quite a bit higher than those required by other codes and standards. The acceptance criteria employed on the projects for these tests were presented and compared with those in the codes and standards. A comparison of the different methods of specifying slump requirements was presented and it was recommended that the approach which is currently being used on three of the projects be considered on other projects. This approach stipulates a "working limit," but provides an "inadvertency margin" which is the allowable deviation from the "working limit" for occasional batches of concrete which may inadvertently exceed the "working limit".

Most of the projects in the study place a 90-minute time limit after which concrete cannot be placed. It was suggested that the condition of the plastic

concrete should determine its placeability, and not some arbitrary time limit. It was stated that there was a general trend on the projects toward removing any judgment whatsoever from the inspectors and expressing everything in terms of absolute limits. Common sense and the judgment of a skilled inspector are assets that should not arbitrarily be eliminated simply because the project is nuclear

LIST OF REFERENCES

6.1 U.S. Department of the Interior, Bureau of Reclamation, Concrete Manual, Eighth Edition, United States Government Printing Office, Washington, D.C., 1975.

6.2 Tuthill, Lewis H., Games People Play with Concrete, Journal of the American Concrete Institute, December 1976.

6.3 American Concrete Institute, Manual of Concrete Inspection (SP-2), Sixth Edition, Detroit, Michigan, 1975.

6.4 Tuthill, Lewis H., Quality Attainment and Common Sense in Nuclear Concrete Construction, Atomic Industrial Forum, Boston, Massachusetts, October 27, 1977.

6.5 Wright, R. Harlan, Discussion of "How Good is Good Enough?", Journal of the American Concrete Institute, Proceedings. V. 59, No. 9, September 1962.

APPENDIX 6.A

CONCRETE BATCH PLANT REPORTS

This appendix contains the following project documents and records:

1. Project A--Concrete Batch Plant Report

2. Project D--Daily Batch Plant Checklist
   Daily Batch Plant Report

3. Project E--Mixing Plant Report

4. Project F--Batch Plant Inspection Report (Front)
   Batch Plant Inspection Report (Back)

5. Project G--Concrete Mixer Report

6. Project I--Batch Plant Inspection Report (Front
   Batch Plant Inspection Report (Back)

CONCRETE BATCH PLANT REPORT--PROJECT A

Date _____ Time Start _____ Time Finish _____ Page _____ of _____

Location of Pours _____ Letter Designation _____ Mix No. _____ Class _____

_____ _____ _____ _____

_____ _____ _____ _____

Batch No.	Size	Mix Time	Cm-1 Cement	Cm-2 Fly Ash	Moisture (Percent) Sand	Moisture (Percent) Stone	AG-1 1"-#4 Stone	AG-2 Sand	AG-3 2"-1" Stone	AG-4 2"-1" Stone	Added Stone	Added Water	Water in Sand & Stone	Ice	Total

Signature of Batch Plant Inspector _____

DAILY BATCH PLANT CHECKLIST--PROJECT D

DAILY BATCH PLANT CHECKLIST

		YES	NO
1.	Have the aggregate tests been completed ~~prior to~~ during batching and do they conform?	✓	

	GRADATION	MOISTURE
1½"	✓	✓
3/4"	✓	✓
SAND: 1st	✓	✓
SAND: 2nd	✓	✓

2.	Have the organic impurities and flat and elongated tests been initiated?	✓	
3.	Have the temperatures been checked at the start of shift? Air 43 F. Concrete 58 F.	✓	
4.	Do the batch weights conform to Spec. 8856-C-7 & C-3 last rev? See attached forms EI 142, EI 143, EI 144 and EI 145.	✓	
5.	Have the proper adjustments been made to the moisture compensator?	✓	
6.	Have the proper adjustments been made to the mix water?	✓	
7.	Have the slave and master scales been checked for zero?	✓	
8.	Are the slave scales (control room) syncronized with the printer?	✓	
9.	Have the scales been checked for weighing accuracy? Date of last calibration 02-07-77.	✓	
10.	Are the slave scales sycronized with the master scales?	✓	

TICKET NO.	TICKET CODE	PRINT OUT	MASTER SCALE
30287	4AG	8640	8640
)	1AG	20120	20160
(	3AG	28040	28020
30286	1W4	1996	2000
)	1CH	4424	4424
(	2CH	5208	5208

11.	Cleanliness check: Central Mixer ✓ Truck No. All Tks. Used	✓	

REMARKS: Stock Pile #1 not in use

Batch Plant Inspector _____

Lab Chief _____

Reviewed by Constr. Q.C. _____

DAILY BATCH PLANT REPORT--PROJECT D

DAILY BATCH PLANT REPORT

Sheet 2 of 2

DATE 03-22-77 LOCATION CONTROL ROOM

SECTION 711-W-07 ELEVATION 753'0"/762'1½" @ Plug 769'10½" @ N.W.H.

START OF SHIFT 0800 END OF SHIFT 1630

START OF POUR 1036 END OF POUR 1737

MIX DESIGN DATA: CLASS 4000PSI CARD C2P

CEMENT	490 LBS.	AGGREGATE	
POZZOLAN	86 LBS.	SAND	1211 LBS.
AEA	— OZ.	3"	— LBS.
WRA	— OZ.	1½"	886 LBS.
WATER	294 LBS.	3/4"	960 LBS.

PLANNED CUBIC YARDS 203 ACTUAL CUBIC YARDS 204

REMARKS (Waste Report No., length of delays, etc.)

BATCH PLANT INSPECTOR _____

LAB CHIEF _____

REVIEWED BY CONSTR. Q.C. _____

MIXING PLANT REPORT--PROJECT E

DATE _____

Therm ∅ (Water Temp.) _____
Therm ∅ (Conc. Temp.) _____

	TOTAL BATCHES	BA. PER HOUR	4-YD. BATCHES PER HOUR	2-YD. BATCHES PER HOUR	1-YD. BATCHES PER HOUR	OTHER BA. PER HOUR	YARDS PER HOUR	WATER TEMP	CONCRETE TEMP
7:00 A - 8:00 A									
8:00 A - 9:00 A									
9:00 A - 10:00 A									
10:00 A - 11:00 A									
11:30 A - 12:30 P									
12:30 P - 1:30 P									
1:30 P - 2:30 P									
2:30 P - 3:30 P									
3:30 P - 4:30 P									
4:30 P - 5:30 P									
5:30 P - 6:30 P									
6:30 P - 7:00 P									

First truck arrived @ _____. Plant started @ _____. Plant stopped @ _____.

Recorder compared with scales ☐ MIXING WATER SOURCE _____

RECONCILED

	MIXED USED	BATCHES	
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			

NOTES _____

Inspector _____

MIX	AEA	GAL./YD.

Sample No.			
Cement			
Water			
Sand Corr.			
3/8 Corr.			
AEA			
Batch No.			

BATCH PLANT INSPECTION REPORT (FRONT)--PROJECT F

(FRONT)

SITE QUALITY CONTROL SECTION
BATCH PLANT INSPECTION REPORT

PROJECT NAME:

Report No.	Job Order No.: 12241	Date:

MIX NUMBERS	TOTAL CU. YDS.	PLACEMENT RELEASE CARD NUMBERS	

TIME BATCHING STARTED: _____ TIME BATCHNG COMPLETED: _____

WEATHER: _____

PLACEMENT LOCATION: _____

_____

BATCH PLANT DELAYS: _____

REMARKS: _____

_____

FOR INFORMATION ONLY

SQC INSPECTOR SIGNATURE: _____

BATCH PLANT INSPECTION REPORT (BACK)--PROJECT F

	CHECK (✓) APPLICABLE RATING (BACK)				
INSPECTION ITEMS	Excell	Good	Fair	Poor	See Remarks
Admix Storage Facilities					
Condition of Cement Silos					
Condition of Agrregate Stockpiles					
Condition of Delivery Trucks					
Reliability of Printout					
Hot/Cold Weather Provisions					
Overall Plant Performance					
Housekeeping					

TIME (See Note 1)	DELIVERY TICKET NUMBER (See Note 2)	Air Temp (°F)	Water Temp (°F)	Concrete Temp (°F)	Fine Agg. Moist. Lev. (%)	COARSE AGGREGATE MOISTURE LEVEL (%)				Allowable Water Lbs. Gal. (See Note 3)
						#4	#67	#57	#8	
AM PM										
AM PM										
AM PM										
AM PM										
AM PM										
AM PM										
AM PM										
AM PM										
AM PM										
AM PM										
AM PM										
AM PM										
AM PM										

FOR INFORMATION ONLY

NOTES:

1. Time sample taken for moisture test.
2. No. of first delivery ticket using information from this moisture test.
3. Total water allowable (from table) less ice added = "allowable water".

CONCRETE MIXER REPORT--PROJECT G

CONCRETE MIXER REPORT

Date _____

Project _____ Batch Plant No _____

Site _____ WP/IR Number _____

Spec. No. _____ Inspector _____

Location _____ Shift: From _____ To _____

Elevation _____ Weather _____

MIX NO.	CEMENT	POZZOLAN	SAND	AGGREGATE 3 4"	AGGREGATE 1½"	AGGREGATE 3"	WATER	AEA OZ.	WRA OZ	BATCH SIZE	NO. OF BATCHES	CU. YDS CONCRETE MIXED	CU. YDS WASTE	CU. YDS IN STRUCTURE

CEMENT	POUNDS	BARRELS
Mixed		
Waste		
In Structure		

ADMIXTURES	POZZOLAN TONS	WRA OZ.
Mixed		
Waste		
In Structure		

TOTALS

Heated _____ cu. yds

Cooled _____ cu. yds

Start of Pour:

End of Pour:

TEST DATA

Ticket Number	MIX NO.	CYL. NO.	UNIT WEIGHT	% AIR ENTR.	TEMPERATURE AIR	TEMPERATURE CONCRETE	BATCH PLANT TIME	BATCH PLANT SLUMP	TRUCK DISCHARGE TIME	TRUCK DISCHARGE SLUMP	FORM TIME	FORM SLUMP

Reason for Waste:

Plant Inspector (Initial) Contract. Rep. (Initial)

Delay: From To

Reason for Delay:

Plant Operator _____ Placing Inspector _____

BATCH PLANT INSPECTION REPORT (FRONT)--PROJECT I

QUALITY ASSURANCE DEPARTMENT
BATCH PLANT INSPECTION REPORT

PROJECT NAME:_____ REPORT NO._____

JOB ORDER NO._____ DATE:_____

MIX NUMBERS	TOTAL CU.YDS.	PLACEMENT RELEASE CARD NUMBERS	

REMARKS:

FQC INSPECTOR SIGNATURE:

BATCH PLANT INSPECTION REPORT (BACK)--PROJECT I

▲5040.113 (BACK)

INSPECTION ITEMS	CHECK (✓) APPLICABLE RATING				
	EXCELLENT	GOOD	FAIR	POOR	SEE REMARKS
CONDITION OF AGGREGATE STOCKPILES					
CONDITION OF DELIVERY TRUCKS					
RELIABILITY OF PRINTOUT					
HOT/COLD WEATHER PROVISIONS					
OVERALL PLANT PERFORMANCE					
HOUSEKEEPING					

TIME (SEE NOTE 1)	DELIVERY TICKET NUMBER (SEE NOTE 2)	AIR TEMP. (°F)	WATER TEMP. (°F)	CONCRETE TEMP. (°F)	FINE AGG. MOIST. LEV. (%)	COARSE AGGREGATE MOISTURE LEVEL (%)				ALLOWABLE WATER ☐ LBS. ☐ GALS. (SEE NOTE 3)
						#4	#67	#57	#8	
AM PM										
AM PM										
AM PM										
AM PM										
AM PM										
AM PM										
AM PM										
AM PM										
AM PM										
AM PM										
AM PM										
AM PM										
AM PM										
AM PM										
AM PM										

NOTES:
1. TIME SAMPLE TAKEN FOR MOISTURE TEST.
2. NO. OF FIRST DELIVERY TICKET USING INFORMATION FROM THIS MOISTURE TEST.
3. TOTAL WATER ALLOWABLE (FROM TABLE) LESS ICE ADDED = "ALLOWABLE WATER".

APPENDIX 6.B

STATISTICAL EVALUATIONS OF COMPRESSIVE STRENGTH CYLINDERS

This appendix contains the following project documents and records:

1. Project A--Cumulative Results of 28 Day Test Results for 3500 psi Concrete placed in the containment area.

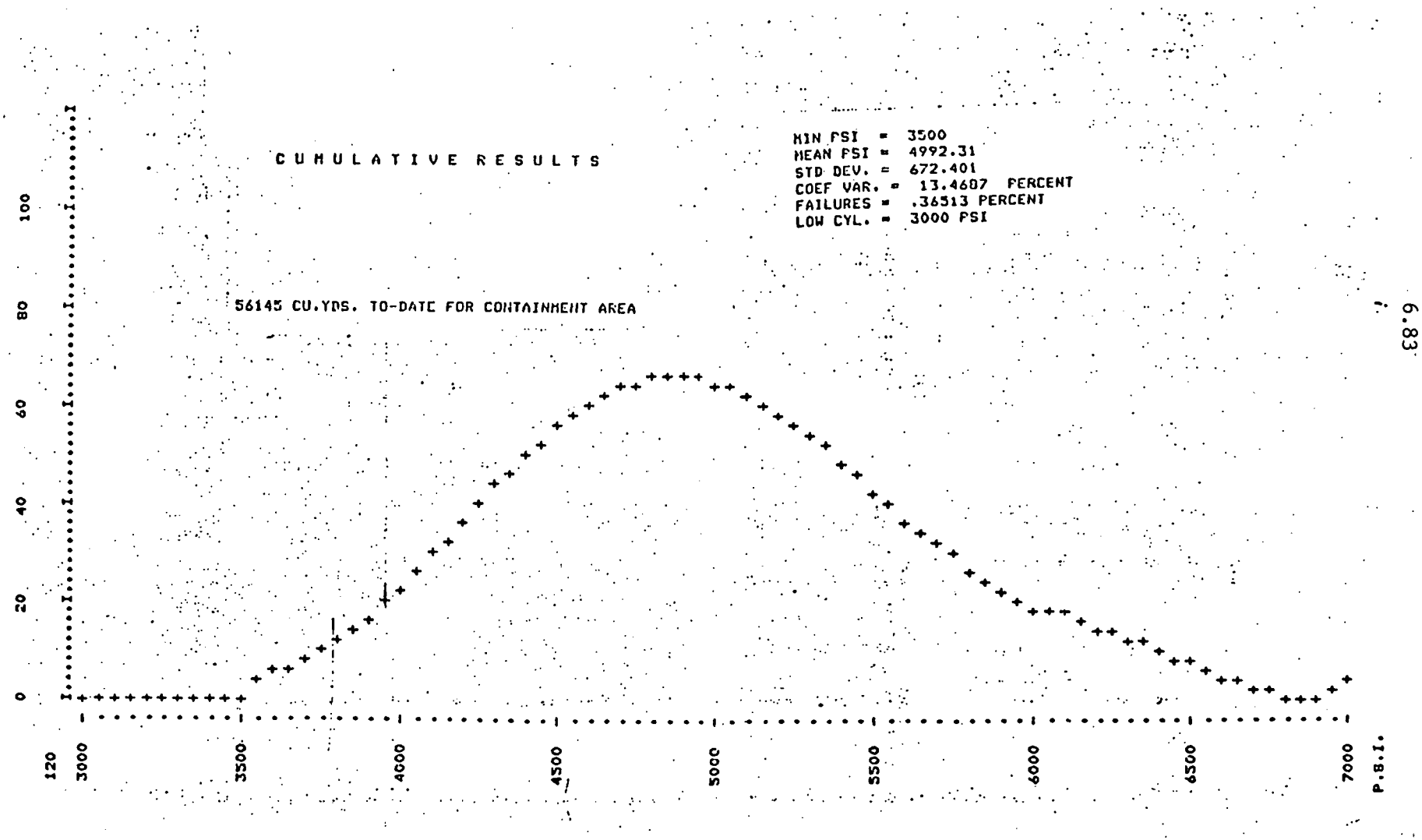
2. Project D--Monthly statistical evaluation of concrete for one 4000 psi mix design.

3. Project E--Monthly Concrete Test Results for one 3000 psi mix design

4. Project F--Analysis of Concrete Strength Results for one 3000 psi design mix

5. Project I--Evaluation of Concrete Strength for one 3000 psi mix design

PROJECT A



6.83

PROJECT D

MIX. No.
DESIGN 4000 PSI

Statistical Evaluation of Concrete Strength

CYLINDER NUMBERS	PLACEMENT NUMBER	PLACEMENT DATE	AVG. STRENGTH 2 CYLINDERS	RANGE psi	CYLINDER NUMBERS	PLACEMENT NUMBER	PLACEMENT DATE	AVG. STRENGTH 2 CYLINDERS	RANGE psi
3489	712-W-05	4-11-77	5565	130	3529	201-W-13	4-18-77	6140	20
3490	"	"	5450	180	3530	"	"	6385	270
3491	901-W-04A	"	5990	80	3532	604-S-01-02	4-19-77	5660	40
3493	463-S-01	4-12-77	4980	80	3535	"	"	6015	330
3494	676-S-08	"	4610	500	3537	"	"	6150	80
3495	463-S-01	"	5105	130	3539	903-W-23	"	6040	300
3497	676-S-08	"	5885	10	3541	604-S-01-02	"	6010	260
3508	903-W-35	4-14-77	6095	510	3547	182-W-10-1	4-20-77	5910	600
3522	676-S-04	4-18-77	6635	10	3551	"	"	5965	70
3523	676-S-12	"	6325	150	3556	"	"	6085	250
3524	201-W-13	"	6195	150	3558	676-S-11	4-21-77	6485	290
3526	676-S-12	"	6080	260	3562	"	"	6335	290
3527	676-S-04	"	5545	130	TOTAL				

n = number of cylinders tested
ΣX = sum of cylinder averages
$\bar{X}$ = average strength of all cylinders
σ = standard deviation $\sqrt{\Sigma X^2/n - \bar{X}^2}$
V = Coefficient of variation $\sigma/\bar{X} \times 100$
σ_1 = within test standard deviation $1/d^2 \times R$
R = range in cylinder strength per group
$1/d^2$ = see table 3
$\bar{R}$ = sum of R divided by n
V_1 = within test coefficient of variation $\sigma_1/\bar{X} \times 100$

TABLE 3—FACTORS FOR COMPUTING WITHIN-TEST STANDARD DEVIATION*

Number of specimens	d_2	$1/d_2$
2	1.128	0.8865
3	1.693	0.5907
4	2.059	0.4857
5	2.326	0.4299
6	2.534	0.3946
7	2.704	0.3698
8	2.847	0.3512
9	2.970	0.3367
10	3.078	0.3249

n = 25
ΣX = 147,640
$\bar{X}$ = 5905.6
σ = 468.9
V = 7.9
σ_1 = 181.6
$\bar{R}$ = 204.8
V_1 = 3.1

Lab. Chief: _____ Technician: _____ QC Review: _____

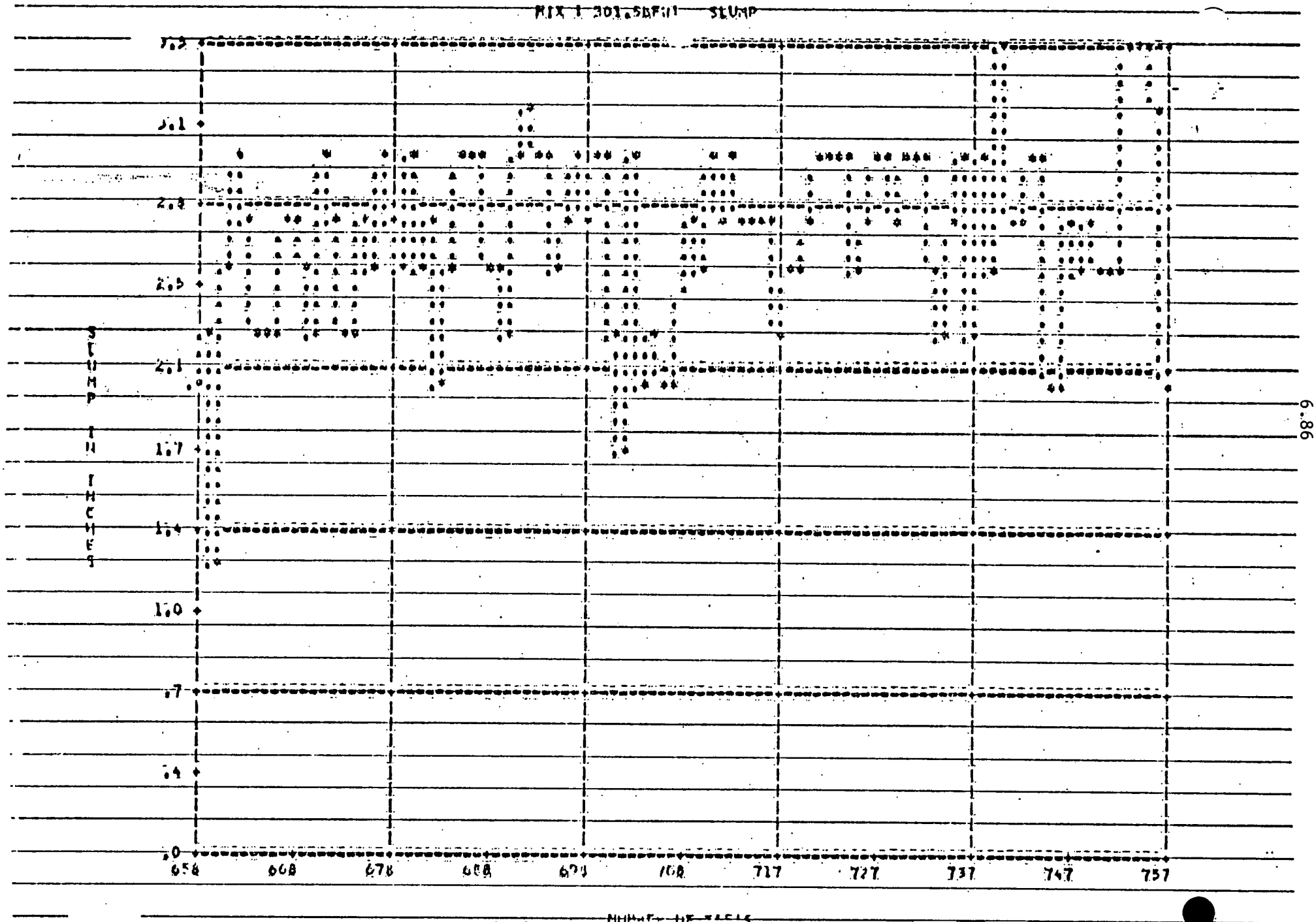
6.84

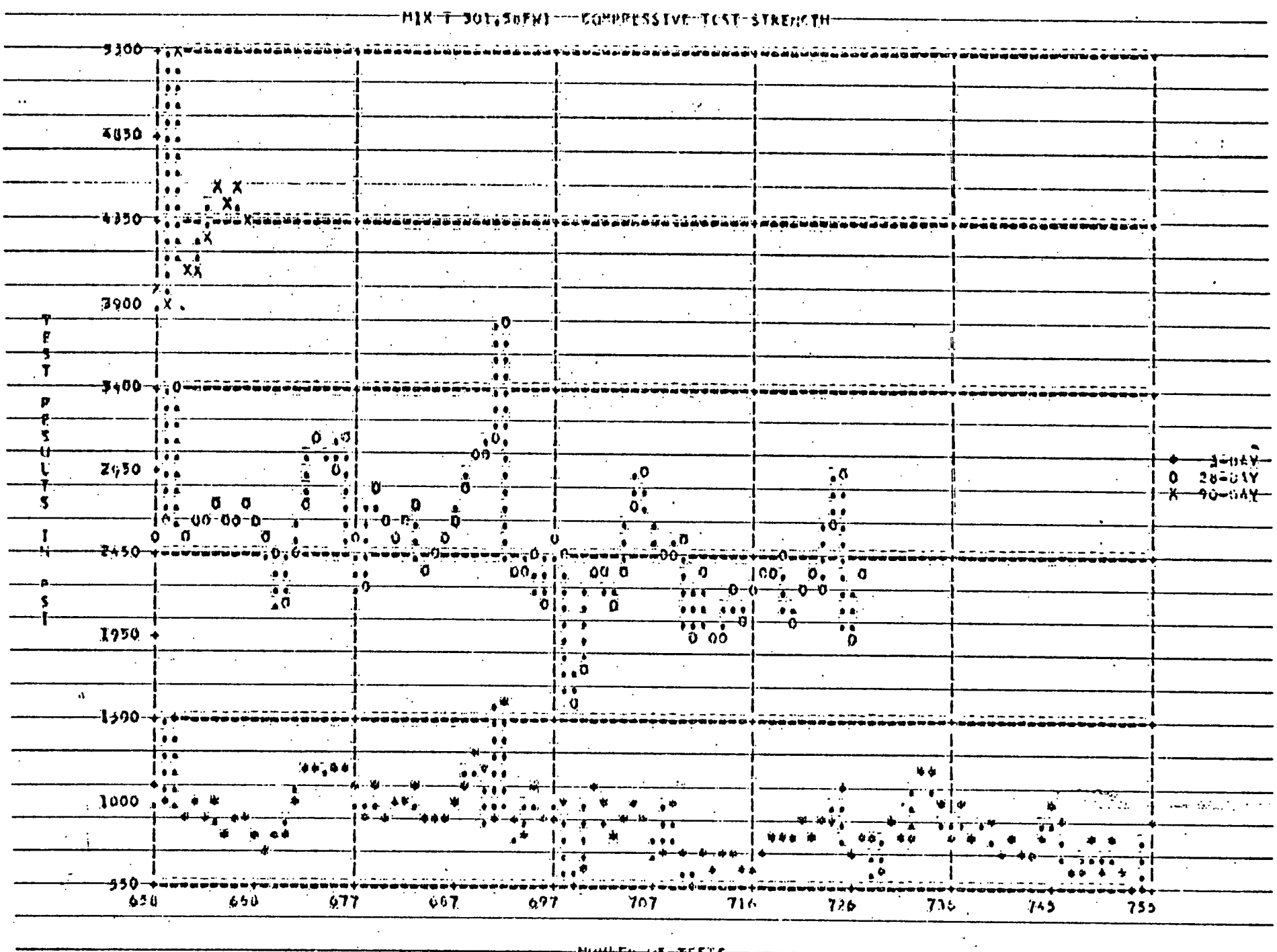
DATE 08/08/77 ********** CONCRETE TEST RESULTS ********** PAGE 148

MIX I 301.50PMT

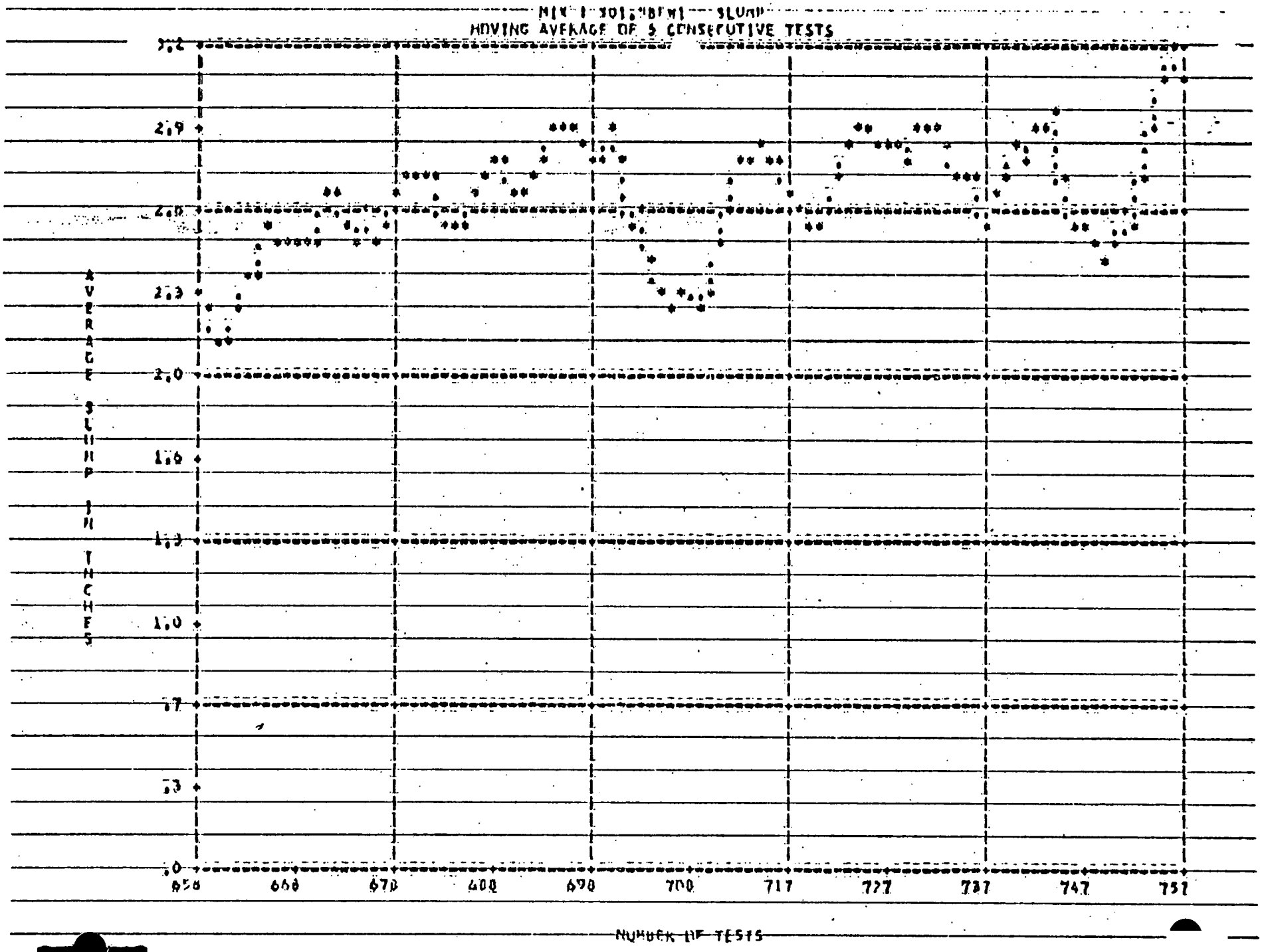
CYL NO.	TEST NO.	SLUMP (IN)	STRENGTH (PSI) 3-DAY	28-DAY	90-DAY	MOVING AVERAGE FOR 5 SLUMP (IN)	STRENGTH (PSI) 3-DAY	28-DAY	90-DAY
2724	729	2.75	940	0	0	2.80	826	2428	0
2725	730	3.00	880	0	0	2.90	778	2195	0
2726	731	3.00	780	0	0	2.95	786	2350	0
2730	732	3.00	780	0	0	2.95	772	0	0
2732	733	2.50	1230	0	0	2.85	862	0	0
2734	734	2.75	1220	0	0	2.75	976	0	0
2736	735	2.75	1040	0	0	2.70	1010	0	0
2742	736	3.00	780	0	0	2.70	1010	0	0
2745	737	2.75	990	0	0	2.55	1052	0	0
2752	738	3.00	930	0	0	2.65	972	0	0
2753	739	3.50	870	0	0	2.70	902	0	0
2762	740	3.50	760	0	0	2.95	946	0	0
2766	741	2.75	630	0	0	2.90	856	0	0
2777	742	2.75	740	0	0	2.90	806	0	0
2779	743	3.00	700	0	0	2.90	780	0	0
2781	744	3.00	800	0	0	3.00	786	0	0
2783	745	2.00	970	0	0	2.70	908	0	0
2786	746	2.00	870	0	0	2.55	816	0	0
2791	747	2.75	670	0	0	2.55	792	0	0
2794	748	2.50	670	0	0	2.45	786	0	0
2797	749	2.75	800	0	0	2.40	796	0	0
2798	750	2.50	650	0	0	2.50	722	0	0
2800	751	2.50	640	0	0	2.60	716	0	0
2804	752	2.50	840	0	0	2.55	720	0	0
2813	753	3.50	530	0	0	2.75	692	0	0
2814	754	3.00	570	0	0	2.90	646	0	0
2818	755	3.50	920	0	0	3.10	700	0	0
2822	756	3.25	0	0	0	3.25	663	0	0
2831	757	3.00	0	0	0	3.15	673	0	0
	AVERAGE =	2.84	972	2697	4345				
	STD DEV =	0.53	198	345	447				
	HIGH VALUE =	4.00	1710	3760	5770				
	LOW VALUE =	1.00	530	1595	3140				

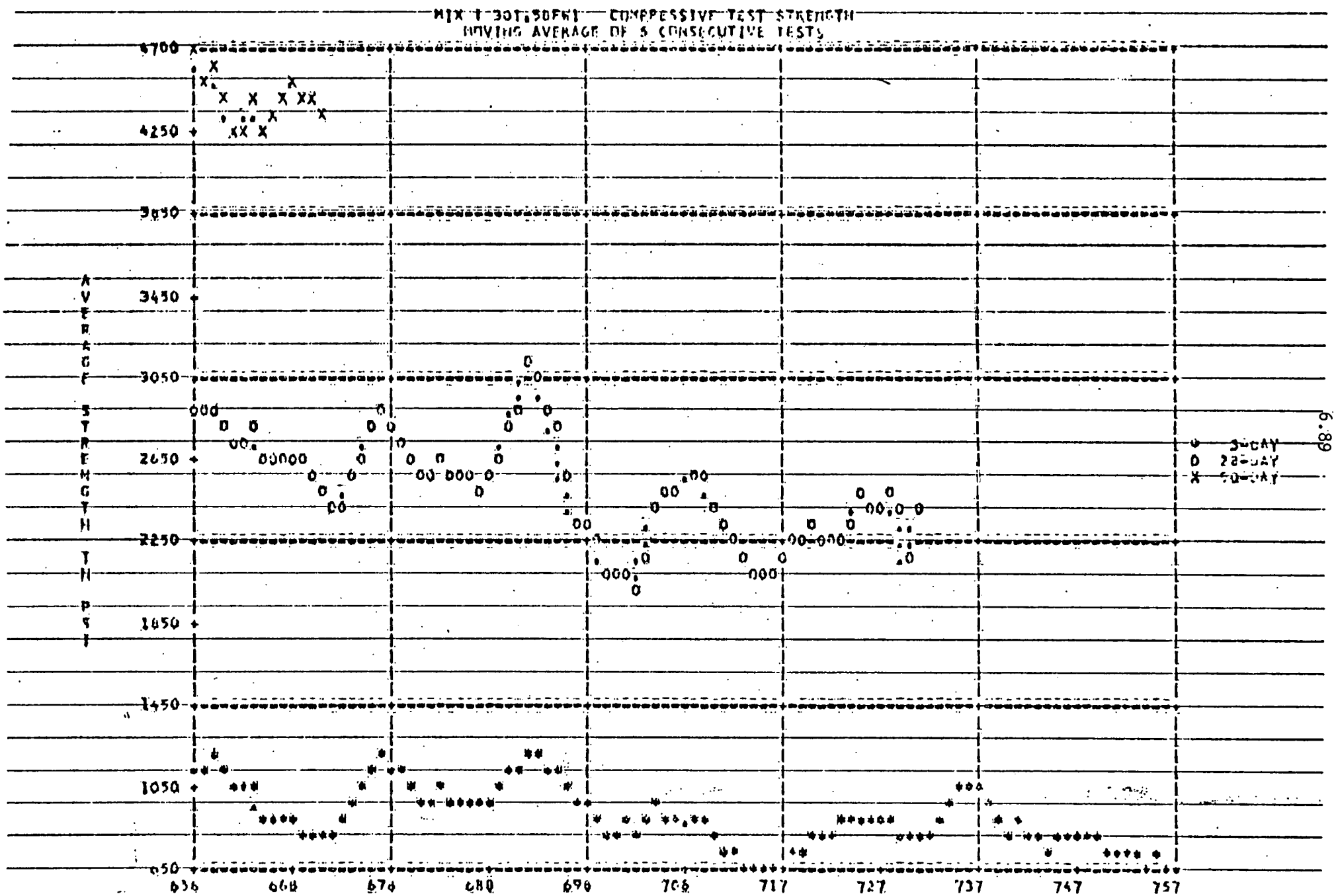
PROJECT E (CONT.)




MIX T 301.50FM1 COMPRESSIVE TEST STRENGTH
5300
4850
4350
3900
3400
2950
2450
1950
1500
1000
550
TEST RESULTS IN PSI
650
677
697
707
716
726
735
745
755
NUMBER OF TESTS
3-DAY
28-DAY
90-DAY

PROJECT E (CONT.)




MIX I 301.50FWI COMPRESSIVE TEST STRENGTH
MOVING AVERAGE OF 5 CONSECUTIVE TESTS
AVERAGE STRENGTH IN PSI
4700
4250
3850
3450
3050
2650
2250
1850
1450
1050
650
636
668
676
680
690
706
717
727
737
747
757
NUMBER OF TESTS
D 28-DAY
X 90-DAY
6.89

PROJECT E (CONT.)

DATE 08/09/77 ********** CONCRETE TEST RESULTS **********

NORMAL FREQUENCY DISTRIBUTION AT 28 DAYS

MIX (301.5DENI (25 TESTS)

RANGE (PSI)	NO. OCCURENCES	PERCENT OF TEST
2153 - 2455	1	4.0%
2455 - 2755	6	24.0%
2755 - 3055	8	32.0%
3055 - 3355	8	32.0%
3355 - 3655	2	8.0%
TOTAL = 25		100.0%

STANDARD DEVIATION = 287
COEFFICIENT VARIATION = 9.63%
AVERAGE = 2981PSI

Note: Required strength = 3000 psi at 90 days

6.90

PROJECT F

28 DAY BREAKS

MIX- 201-2

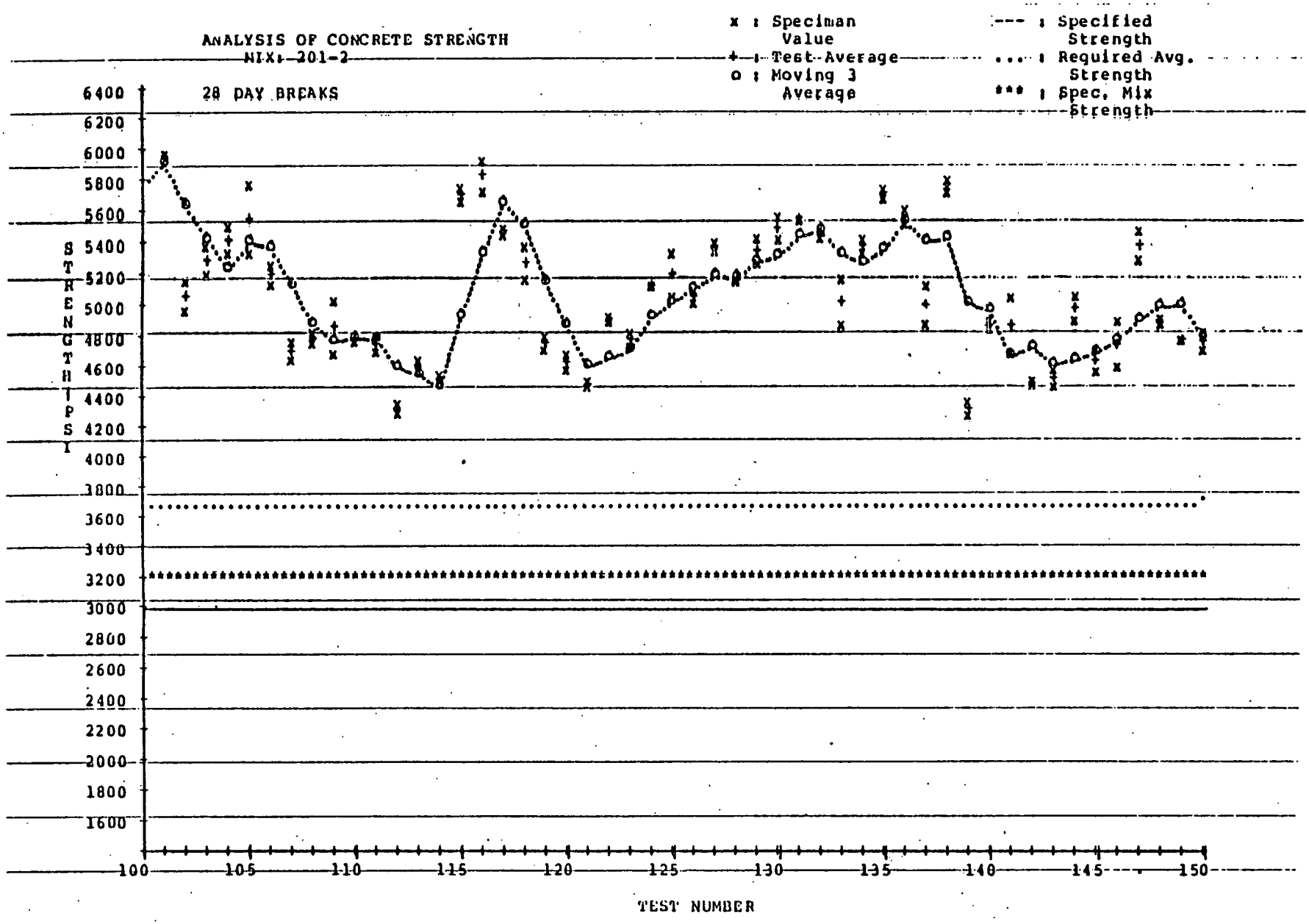
TEST NO.	POUR ID	DATE	SPECIMEN VALUES 1	2	3	TEST AVG	CUM AVG	MOVG 3AVG	COEF VAR	MOVNG 3 COEF VAR	RANGE	AVG RANGE	MOVG 10AVG RANGE	WITHN TEST VAR
1	manhole #19	3/18/76	4960	4870	0	4915	4915	0	0.00	0.00	90	90	0	1.62
2	manhole #5	4/1/76	4700	4600	0	4650	4783	0	3.92	0.00	100	95	0	1.76
3	manholes # 21,20,6	4/2/76	4590	4620	0	4605	4723	4723	3.55	3.55	30	73	0	1.38
4	manhole #19	4/7/76	4010	4400	0	4205	4594	4487	6.38	5.46	390	153	0	2.94
5	alt intake struct	4/8/76	5030	4860	0	4945	4664	4585	6.40	8.08	170	156	0	2.97
6	alt intke /m.h.#7,22	4/12/76	4720	4740	0	4730	4675	4627	5.74	8.23	20	133	0	2.53
7	manhole #18,6	4/15/76	4310	4250	0	4280	4619	4652	6.21	7.30	60	123	0	2.36
8	manhole #21	4/19/76	4910	4570	0	4740	4634	4583	5.81	5.73	340	150	0	2.87
9	manhole #5	4/22/76	3990	4220	0	4105	4575	4375	6.72	7.50	230	159	0	3.08
10	alt intake	4/23/76	4640	4710	0	4675	4585	4507	6.35	7.75	70	150	150	2.90
11	valve pit & alt intk	4/26/76	4880	4880	0	4880	4612	4553	6.30	8.82	0	136	141	2.62
12	manhole #19	4/27/76	4200	4000	0	4100	4569	4552	6.87	8.88	200	142	151	2.75
13	alt intake str	4/29/76	4710	4800	0	4755	4583	4578	6.65	9.15	90	138	157	2.66
14	manhole #18	5/4/76	4410	4500	0	4455	4574	4437	6.45	7.39	90	134	127	2.60
15	alt intake str	5/5/76	4320	4550	0	4435	4565	4548	6.27	3.94	230	141	133	2.73
16	manhole #21	5/5/76	4410	4550	0	4480	4560	4457	6.09	0.51	140	141	145	2.71
17	manholes #18,7,22	5/6/76	4590	4450	0	4520	4557	4478	5.90	0.95	140	141	153	2.73
18	valve pit a.i.s.	5/6/76	4330	4410	0	4370	4547	4457	5.82	1.74	80	137	127	2.68
19	alt int structure	5/7/76	4340	4410	0	4375	4538	4422	5.73	1.93	70	134	111	2.61
20	alt int structure	5/11/76	4430	4240	0	4335	4528	4360	5.68	0.50	190	137	123	2.67
21	contmt pump csg	5/12/76	5500	5180	0	5340	4566	4683	6.72	12.15	320	145	155	2.82
22	alt int structure	5/13/76	3990	4170	0	4080	4544	4585	6.98	14.53	180	147	153	2.86
23	contmt pump csg	5/14/76	4660	4780	0	4720	4552	4713	6.85	13.37	120	146	156	2.84
24	alt int structure	5/17/76	4800	4870	0	4835	4564	4545	6.80	8.95	70	143	154	2.77
25	manhole #8	5/17/76	4430	4300	0	4365	4556	4640	6.73	5.28	130	142	144	2.76
26	manhole strm sewer	5/18/76	5100	5100	0	5100	4577	4767	6.97	7.81	0	137	130	2.64
27	alt int structure	5/18/76	4220	3690	0	3955	4554	4473	7.35	12.97	530	151	169	2.94
28	m.h.#24 &2 plugs	5/20/76	4520	4310	0	4415	4549	4490	7.24	12.83	210	153	182	2.99
29	containm't pump	5/20/76	4970	4850	0	4910	4561	4427	7.24	10.79	120	152	187	2.96
30	Alt Intake Struct	5/21/76	4240	4300	0	4270	4552	4532	7.23	7.41	60	149	174	2.90
31	manhole #18	5/24/76	4460	4550	0	4505	4550	4562	7.11	7.10	90	147	151	2.87
32	strm swr m.h.#6	5/25/76	4810	5040	0	4925	4562	4567	7.13	7.27	230	150	156	2.91
33	manhole #18	5/24/76	4460	4550	0	4505	4560	4645	7.02	5.22	90	148	153	2.87
34	slab & diaphragm	5/27/76	4470	4760	0	4615	4562	4682	6.91	4.65	290	152	175	2.96
35	strm swr m.h.& #8,24	5/28/76	4560	4610	0	4585	4562	4568	6.81	1.24	50	149	167	2.90
36	diaph & m.h.#6,3A	6/25/76	4120	4220	0	4170	4551	4457	6.88	5.58	100	148	177	2.88
37	m.h.#2A,3 bsn #20	7/7/76	4410	4290	0	4350	4546	4368	6.03	4.76	120	147	136	2.87
38	bsn #20 m.h.#5	7/13/76	4150	4140	0	4145	4535	4222	6.91	2.65	10	143	116	2.80
39	bsn #20 m.h.#18,23	7/15/76	4100	4180	0	4140	4525	4212	6.97	2.85	80	142	112	2.78
40	manhole #21	7/16/76	3990	4030	0	4010	4512	4098	7.13	1.87	40	139	110	2.74
41	manhole #22	7/19/76	4160	4360	0	4260	4506	4137	7.11	3.02	200	141	121	2.77
42	manhole #6	7/22/76	3700	3460	0	3580	4484	3950	7.74	8.71	240	143	122	2.83
43	bsn #20 pipe enc#1	7/28/76	3650	3630	0	3640	4465	3827	8.21	9.84	20	140	115	2.78

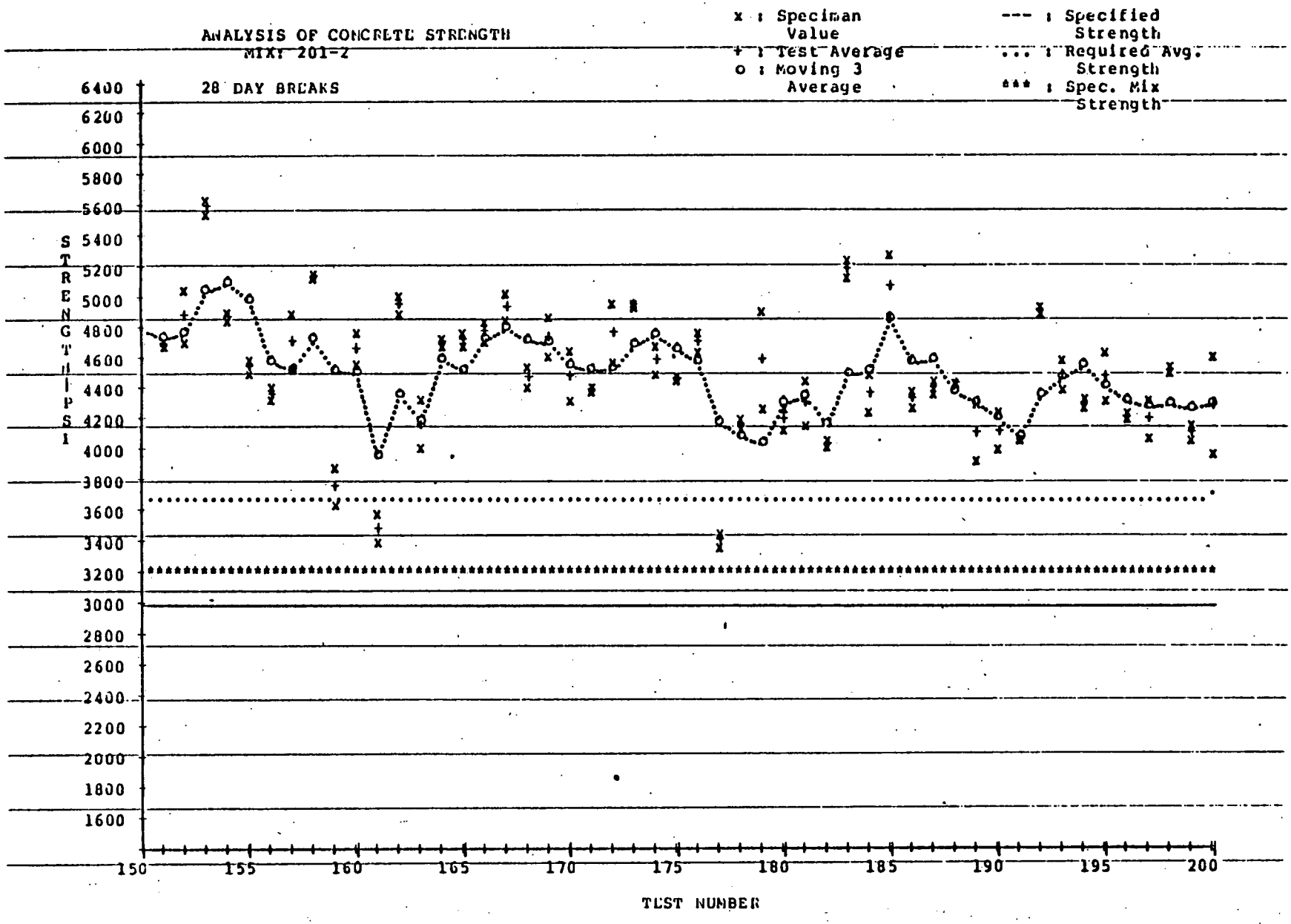
28 DAY BREAKS
MIX: 201-2

TEST NO.	POUR ID	DATE	SPECIMEN VALUES 1	2	3	TEST AVG	CUM AVG	MOVG 3AVG	COEF VAR	MOVNG 3 COEF VAR	RANGE	AVG RANGE	MOVG 10AVG RANGE	WITHIN TEST VAR
220	turbigrd bms/col	7/11/77	4300	4320	0	4310	4663	3965	10.65	14.74	20	142	95	2.70
221	turbigrd bms/col	7/11/77	4200	4150	0	4175	4661	3925	10.65	14.12	50	142	96	2.69
222	control room	7/13/77	4200	4060	0	4130	4658	4205	10.66	2.23	140	142	94	2.70
223	turb NW wall	7/13/77	5020	5020	0	5020	4660	4442	10.65	11.29	0	141	84	2.68
224	aux bldg md mt #6	7/14/77	4420	4510	0	4465	4659	4538	10.63	9.90	90	141	86	2.68
225	aux bldg md mt #6	7/14/77	4740	4340	0	4540	4658	4675	10.61	6.44	400	142	121	2.70
226	aux bldg md mt #6	7/14/77	4880	4900	0	4890	4659	4632	10.59	4.90	20	141	119	2.69
227	aux bldg md mt #6	7/14/77	4740	5170	0	4955	4661	4795	10.57	4.66	430	143	152	2.71
228	aux bldg md mt #6	7/14/77	5080	5380	0	5230	4663	5025	10.57	3.59	300	143	153	2.72
229	aux bldg md mt #6	7/14/77	5520	5040	0	5280	4666	5155	10.58	3.39	480	145	193	2.75
230	turb pedestals	7/15/77	5200	4990	0	5095	4668	5202	10.57	1.84	210	145	212	2.76
231	aux bldg fdtn #7	7/18/77	4640	4570	0	4605	4668	4993	10.55	6.99	70	145	214	2.75
232	aux bldg fdtn #7	7/18/77	4950	5080	0	5015	4669	4905	10.53	5.36	130	145	213	2.75
233	aux bldg fdtn #7	7/18/77	5680	5450	0	5565	4673	5062	10.58	9.52	230	145	236	2.75
234	aux bldg fdtn #7	7/18/77	5550	5820	0	5685	4677	5422	10.64	6.59	270	146	254	2.76
235	aux bldg fdtn #7	7/18/77	5600	5020	0	5310	4680	5520	10.64	3.47	580	147	272	2.79
236	turb supports	7/19/77	4460	4510	0	4485	4679	5160	10.63	11.90	50	147	275	2.79
237	turb mud mat	7/20/77	4320	4620	0	4470	4678	4755	10.61	10.11	300	148	262	2.80
238	turb p csg fill	7/21/77	4320	4370	0	4345	4677	4433	10.60	1.73	50	147	237	2.79
239	turb E ftg	7/22/77	4600	4730	0	4665	4677	4493	10.50	3.59	130	147	202	2.79

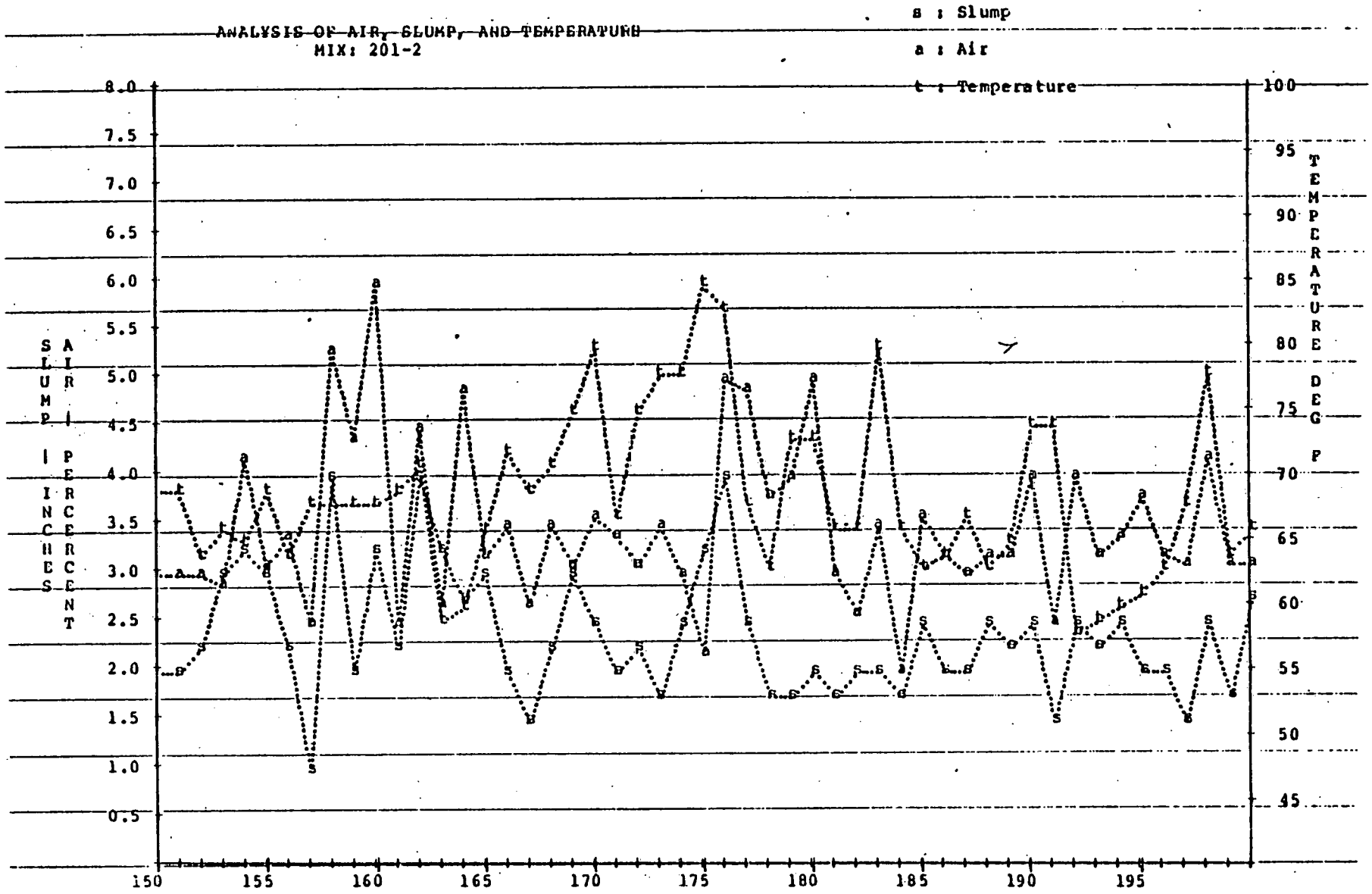
Note: Required strength = 3000 psi at 28 days

PROJECT F (CONT.)




ANALYSIS OF CONCRETE STRENGTH
MIX: 201-2
28 DAY BREAKS
x : Speciman Value
+ : Test Average
o : Moving 3 Average
--- : Specified Strength
... : Required Avg. Strength
*** : Spec. Mix Strength
STRENGTH IN PSI
6400
6200
6000
5800
5600
5400
5200
5000
4800
4600
4400
4200
4000
3800
3600
3400
3200
3000
2800
2600
2400
2200
2000
1800
1600
150
155
160
165
170
175
180
185
190
195
200
TEST NUMBER

PROJECT F (CONT.)



PROJECT I

EVALUATION OF CONCRETE STRENGTH

MIX NO. 301(3K57) MIX NAME(A-4)

CEMENT - TYPE II	450	LBS
SAND	1446	LBS
GRAVEL (NO 57)	1685	LBS
ADDITIVE - MBVR	5.5	OZ
WATER	36.7	GAL
W/C RATIO	7.05	GAL/
MAX SIZE AGGREGATE	1.0	IN
SLUMP	4	IN
AIR CONTENT	5	PCNT

6.96

PROJECT I (CONT.)

TEST NO.	DATE	TEST IDEN.	TEST VALUES 1	2	3	TEST AVG	CUM. AVG	MOVING 3AVG	CUM. C. OF V.	MOVING 3 C. OF V.	TEST RANGE	AVG. MOVING 10 RANGE	AVG. RANGE	WITHIN-TEST C. OF V.
1	60776	C722	3882	3904	0	3893	3893	0	0.0	0.0	22	22	0	0.50
2	60776	C722	3584	3584	0	3584	3739	0	5.84	0.0	0	11	0	0.26
3	60876	C720	3724	3707	0	3716	3731	3731	4.16	4.16	17	13	0	0.31
4	60876	C726	3421	3162	0	3292	3621	3530	7.00	6.15	259	74	0	1.81
5	60976	C723	3302	3250	0	3276	3552	3428	7.56	7.28	52	70	0	1.75
6	61076	C721	3425	3548	0	3487	3541	3351	6.82	3.50	123	78	0	1.95
7	61176	C734	3619	3804	0	3712	3565	3491	6.44	6.24	185	94	0	2.34
8	61476	C728	3952	4111	0	4032	3624	3743	7.42	7.32	159	102	0	2.50
9	61676	C739	3554	3636	0	3595	3621	3779	6.96	5.98	82	99	0	2.42
10	61676	C741	2967	3232	0	3100	3568	3575	8.10	13.04	265	116	116	2.88
11	61776	C738	3887	3729	0	3808	3590	3501	7.90	10.38	158	120	130	2.96
12	61876	C748	3554	3747	0	3651	3595	3519	7.53	10.57	193	126	149	3.11
13	62176	C755	3461	3339	0	3400	3580	3620	7.40	5.68	122	125	159	3.10
14	62376	C746	2775	3141	0	2958	3536	3336	6.60	10.51	366	143	170	3.59
15	62476	C750	3734	3752	0	3743	3550	3367	8.39	11.69	18	134	167	3.35
16	62876	C745	3712	3744	0	3728	3561	3476	8.19	12.91	32	128	158	3.19
17	62976	C749	4206	4206	0	4206	3599	3892	8.96	6.98	0	120	139	2.96
18	63076	C772	3747	3769	0	3758	3608	3897	8.73	6.87	22	115	125	2.83
19	63076	C773	3287	3305	0	3296	3591	3753	8.76	12.12	18	110	119	2.72
20	70176	C771	3525	3869	0	3697	3596	3504	8.53	7.00	344	121	127	2.90
21	70276	C775	3844	3734	0	3789	3606	3594	8.38	7.29	110	121	122	2.98
22	70276	C776	3630	3665	0	3648	3608	3711	8.18	1.93	35	117	106	2.88
23	70878	C784	3473	3502	0	3488	3602	3641	8.03	4.14	29	113	97	2.78
24	70976	C785	3869	3887	0	3878	3614	3671	7.98	5.35	18	109	62	2.67
25	71276	C796	3589	3642	0	3616	3614	3660	7.81	5.44	53	107	66	2.62
26	71376	C800	3677	3705	0	3691	3617	3728	7.66	3.62	28	104	65	2.55
27	71476	C780	3992	4216	0	4104	3635	3804	7.91	6.91	224	108	88	2.63
28	71676	C810	4118	4087	0	4103	3652	3966	8.09	6.00	31	105	89	2.55
29	71978	C818	3484	3537	0	3511	3647	3906	7.99	8.70	53	104	92	2.53
30	72076	C812	3612	3607	0	3610	3645	3741	7.86	8.48	5	100	50	2.43
31	72176	C824	4167	4255	0	4211	3664	3777	8.17	10.04	88	100	56	2.42
32	72276	C821	3717	3939	0	3828	3669	3883	8.07	7.04	222	104	75	2.51
33	72376	C822	3996	4097	0	4047	3680	4029	8.11	4.77	101	104	82	2.51
34	72676	C832	3502	3403	0	3453	3674	3776	8.08	7.96	99	103	90	2.49
35	72876	C840	4642	4552	0	4597	3700	4032	8.95	14.20	90	103	94	2.47
36	72876	C843	3106	3222	0	3164	3685	3738	9.19	20.20	116	103	102	2.48
37	73076	C849	3777	3525	0	3651	3684	3804	9.06	19.15	252	107	105	2.57
38	80376	C852	3061	3081	0	3071	3668	3295	9.38	9.45	20	105	104	2.54
39	80476	C850	3909	4014	0	3962	3676	3561	9.32	12.69	105	105	109	2.53
40	80576	C817	3652	3717	0	3685	3676	3572	9.20	12.76	65	104	115	2.51
41	80576	C861	3502	3368	0	3435	3670	3694	9.16	7.13	134	105	120	2.54
42	80676	C863	3409	3360	0	3389	3663	3503	9.14	4.54	41	103	102	2.49
43	81276	C858	3584	3648	0	3616	3662	3420	9.04	3.45	64	102	98	2.47
44	81276	C865	3734	3979	0	3857	3667	3620	8.96	6.46	245	106	113	2.56
45	81376	C872	3298	3152	0	3225	3657	3566	9.06	8.94	146	106	118	2.57
46	81776	C874	3443	3478	0	3461	3652	3514	9.00	9.08	35	105	110	2.55
47	81876	C876	3869	4044	0	3957	3659	3547	8.97	10.53	175	106	103	2.57
48	81076	C881	4520	4307	0	4414	3675	3940	9.32	12.69	213	109	122	2.63
49	82076	C883	4255	4146	0	4201	3685	4190	9.42	5.46	109	109	122	2.62
50	82076	C895	3787	4188	0	3988	3691	4201	9.38	5.07	401	114	156	2.74

TEST NO.	DATE	TEST IDEN.	TEST VALUES 1	2	3	TEST AVG.	CUM. AVG.	MOVING 3AVG.	CUM. C. OF V.	MOVING 3 C. OF V.	TEST RANGE	AVG. RANGE	MOVING 10 AVG.	RANGE	WITHIN-TEST C. OF V.
51	82376	C901	3869	3782	0	3826	3694	4005	9.29	4.70	87	114	151		2.74
52	82376	C903	4342	4412	0	4377	3707	4063	9.52	6.98	70	113	154		2.70
53	82376	C904	3560	3712	0	3636	3706	3946	9.43	9.76	152	114	163		2.73
54	82476	C909	4395	4237	0	4316	3717	4110	9.58	10.01	158	115	154		2.74
55	82576	C911	3572	3612	0	3592	3715	3948	9.51	10.55	40	113	144		2.70
56	82676	C907	3939	3852	0	3896	3718	3935	9.43	9.24	87	113	149		2.69
57	83076	C921	4317	4487	0	4402	3730	3963	9.53	10.33	170	114	140		2.71
58	83176	C924	3298	3414	0	3356	3724	3885	9.65	13.47	116	114	139		2.71
59	83176	C925	4188	4258	0	4223	3732	3994	9.70	14.01	70	113	135		2.68
60	90176	C928	4237	4202	0	4220	3740	3933	9.75	12.70	35	112	98		2.65
61	90276	C930	3141	3071	0	3106	3730	3850	9.93	15.73	70	111	96		2.64
62	90376	C933	3612	3403	0	3508	3726	3611	9.89	15.62	209	113	110		2.69
63	90976	C936	3162	2836	0	2999	3715	3204	10.15	8.37	326	116	128		2.77
64	91076	C939	3420	3630	0	3525	3712	3344	10.09	8.93	210	117	133		2.79
65	91376	C942	3992	3869	0	3931	3715	3485	10.03	13.40	123	117	141		2.79
66	91576	C946	3852	3922	0	3887	3718	3781	9.96	5.89	70	117	139		2.79
67	91676	C952	3752	3595	0	3674	3717	3830	9.89	3.59	157	117	138		2.79
68	92076	C955	3589	3362	0	3476	3713	3679	9.85	5.59	227	119	149		2.84
69	92176	C957	3852	3344	0	3598	3712	3582	9.80	2.79	508	125	193		2.99
70	92276	C950	3455	3420	0	3438	3708	3504	9.77	2.39	35	123	193		2.94
71	92276	C950	3752	3752	0	3752	3709	3596	9.70	4.37	0	122	186		2.92
72	92276	C950	3350	3449	0	3400	3704	3530	9.70	5.48	99	121	175		2.90
73	92276	C950	3584	3619	0	3602	3703	3584	9.64	4.93	35	120	146		2.87
74	92376	C967	3542	3665	0	3604	3701	3535	9.58	3.32	123	120	137		2.87
75	92476	C965	3529	3624	0	3575	3700	3593	9.53	0.45	99	120	135		2.88
76	92876	C977	3235	3263	0	3249	3694	3476	9.58	5.66	28	119	131		2.86
77	92976	C972	3913	3804	0	3859	3696	3561	9.53	8.57	109	118	126		2.83
78	93076	C983	3787	3687	0	3737	3697	3615	9.46	0.92	100	118	113		2.83
79	100176	C984	4149	3822	0	3986	3700	3860	9.44	3.22	327	121	95		2.90
80	100476	C989	3909	3992	0	3951	3703	3891	9.40	3.46	83	120	100		2.87
81	100576	C987	3652	3722	0	3687	3703	3874	9.34	4.21	70	120	107		2.87
82	100676	C998	3577	3542	0	3560	3701	3732	9.30	5.34	35	119	100		2.85
83	100776	C1000	4279	4014	0	4147	3707	3798	9.32	8.13	265	120	123		2.87
84	100876	C999	3572	3560	0	3566	3705	3757	9.28	8.97	12	119	112		2.85
85	101176	C1004	4412	4430	0	4421	3715	4045	9.44	10.79	18	118	104		2.82
86	101276	C1010	3734	3747	0	3741	3714	3909	9.36	11.56	13	117	103		2.79
87	101276	C1012	4500	4415	0	4458	3722	4208	9.55	9.60	85	118	100		2.76
88	101276	C1012	3922	3939	0	3931	3725	4043	9.50	9.19	17	115	92		2.74
89	101376	C995	4497	4479	0	4488	3733	4292	9.67	7.30	18	114	61		2.71
90	101476	C1005	4555	4363	0	4459	3741	4293	9.81	7.31	192	115	72		2.72
91	101576	C1017	3874	3792	0	3833	3742	4260	9.76	8.69	82	115	73		2.72
92	101576	C1019	4467	4485	0	4476	3750	4256	9.90	8.61	18	114	72		2.69
93	101976	C1021	4731	4520	0	4626	3760	4312	10.11	9.77	211	115	66		2.71
94	101976	C1021	4313	4275	0	4294	3765	4465	10.15	5.72	38	114	69		2.68
95	101976	C1021	4014	3861	0	3938	3767	4286	10.10	8.03	153	114	82		2.68
96	101976	C1021	4398	4572	0	4485	3775	4239	10.21	6.56	174	115	98		2.70
97	101976	C1021	3896	4031	0	3964	3777	4129	10.17	7.48	135	115	103		2.70
98	102076	C1023	4467	4398	0	4433	3783	4294	10.25	6.69	69	115	109		2.69
99	102176	C1026	4467	4450	0	4459	3790	4285	10.33	0.50	17	114	108		2.67
100	102276	C1025	4972	4729	0	4851	3801	4581	10.63	5.11	243	115	114		2.68

TEST NO.	DATE	TEST IDEN.	TEST VALUES 1	2	3	TEST AVG.	CUM. AVG.	MOVING 3AVG.	CUM. C. OF V.	MOVING 3 C. OF V.	TEST RANGE	AVG RANGE	MOVING 10 AVG.	RANGE	WITHIN-TEST C. OF V.
101	102576	C1028	3729	3769	0	3749	3800	4353	10.57	12.83	40	114	109		2.66
102	102776	C1046	3992	3852	0	3922	3801	4174	10.52	14.19	140	114	122		2.66
103	102876	C1045	4206	4171	0	4189	3805	3953	10.51	5.60	35	114	104		2.66
104	102976	C1050	4087	4209	0	4148	3808	4086	10.49	3.51	122	114	112		2.65
105	102976	C1054	4188	4153	0	4171	3812	4169	10.47	0.49	35	113	101		2.63
106	102[illegible]6	C1054	3974	3957	0	3966	3813	4095	10.42	2.75	17	112	85		2.60
107	110176	C1056	4377	4184	0	4281	3818	4139	10.43	3.60	193	113	91		2.62
108	110276	C1061	4258	4363	0	4311	3822	4186	10.44	4.57	105	113	94		2.62
109	110376	C1059	4188	4223	0	4206	3826	4266	10.43	1.27	35	112	96		2.60
110	110576	C1055	4118	4118	0	4118	3828	4211	10.40	2.29	0	111	72		2.57
111	110576	C1055	3752	3508	0	3630	3827	3985	10.37	7.70	244	112	92		2.59
112	110576	C1055	3682	3525	0	3604	3825	3784	10.34	7.66	157	112	94		2.60
113	111276	C1075	4535	4692	0	4614	3832	3949	10.45	14.58	157	113	106		2.61
114	111576	C1074	3857	4083	0	3970	3833	4062	10.41	12.59	226	114	116		2.64
115	111776	C1085	4188	4345	0	4267	3837	4283	10.41	7.52	157	114	129		2.63
116	112276	C1096	4202	4293	0	4248	3840	4161	10.40	3.99	91	114	136		2.63
117	112376	C1083	4762	4675	0	4719	3846	4311	10.55	6.04	87	114	125		2.63
118	112376	C1083	4272	4482	0	4377	3852	4448	10.57	5.41	210	115	136		2.65
119	112476	C1032	4307	3900	0	4104	3854	4400	10.53	7.00	407	117	173		2.69
120	120176	C1107	3887	3799	0	3843	3854	4108	10.49	6.50	88	117	182		2.69
121	120976	C1110	3922	4005	0	3964	3855	3970	10.45	3.28	83	117	166		2.69
122	121076	C1118	4487	4555	0	4521	3861	4109	10.51	8.80	68	116	157		2.66
123	121576	C1030	3665	3560	0	3613	3859	4032	10.46	11.35	105	116	152		2.67
124	121676	C1043	3922	3922	0	3922	3859	4019	10.44	11.49	0	115	129		2.64
125	121776	C1033	4325	4307	0	4316	3863	3950	10.44	8.93	18	114	115		2.62
126	122176	C1037	4128	3834	0	3981	3864	4073	10.40	5.22	294	116	136		2.66
127	122276	C1042	4171	4275	0	4223	3866	4173	10.39	4.14	104	116	137		2.66

CHAPTER 7

MAJOR ASPECTS RELATED TO CONCRETE CONSTRUCTION

INTRODUCTION

The discussion presented in the following three chapters will be directed towards preplacement, placement, and post placement activities performed by construction and quality control personnel. Chapter 7 will discuss several broad topics (e.g. control systems, mass concrete, and hot and cold weather requirements) which affect the overall concrete operation. Chapter 8 will present various aspects of preplacement and Chapter 9 will discuss placement and post placement activities.

PROJECT CONTROL SYSTEMS

Preplanning Requirements

The successful placement of quality concrete requires preplanning on the part of field engineering in order to insure that the proper documents are being used, adequate equipment and materials are available, and necessary coordination is done with all the parties involved. The actions taken to insure that adequate preplanning is accomplished vary from site to site. The discussion below will briefly describe the preplanning requirements for each of the projects. Also discussed will be the involvement of quality control in these activities. It will be pointed out that QC involvement varies considerably and reflects different reactions to the perceived requirements of 10 CFR 50, Appendix B. For a number of projects there is no available information regarding detailed work plans of the type that would be prepared for each individual concrete placement. It is recognized that such preplanning activities must be performed, however, these were not uncovered since their preparation and use is assumed to fall outside of the scope of the quality assurance program, per se. This is

evident by reviewing the inspection attributes established in the respective quality control procedures as will be pointed out below.

1. Project A is an early vintage plant and no information is available regarding detailed work or construction plans. There are field construction procedures, however, for special activities such as construction of the exterior reactor containment wall. These special procedures provide general guidance that can be used in the preplanning phase. The actual construction of these components is inspected and monitored against these procedures by quality control. For routine concrete placements, inspection and monitoring is made against the project specifications. The work plans should be differentiated from the field construction procedures. The erection of the containment wall for which the field construction procedure is prepared involves many placements and each of these requires a detailed work plan which would describe the measures to be taken in order to accomplish the work. Step-by-step instructions would be given as necessary. The detailed work plan would also describe applicable documents, material quantities, equipment needs, etc.

2. On Project B there are field construction procedures prepared for certain unique activities within a discipline, such as the construction of the containment wall or dome. Field construction procedures which govern concrete placements other than special structures may be used but are not considered to be part of the Quality Assurance Program. The QA Program requirements which are applied to general concrete placement activities include procedures for document control and pump conveying of concrete. The former procedure provides limited preplanning instructions and establishes mechanisms for ordering concrete and utilizing the concrete placement checkout record. Quality Control inspects and monitors against the field construction procedures for special structures and the project specifications for other placements. The necessary instructions for quality control personnel are provided in QC procedures which essentially

reflect the project specification requirements. There is no indication that QC reviews or approves construction preplanning documents or work plans.

3. Guidelines to construction superintendents and craft foremen on Project C is provided through field construction procedures (Job Rules) which address broad discipline oriented activities, such as concrete placement, installation of mechanical equipment, etc. On Project C many operations are done in accordance with a field procedure, which is part of the QA Program. This differs markedly from the system in existence on Projects A and B. Review and approval of these procedures by QC is required. The Project C field procedures are also presented in much greater detail than those for Projects A and B. The mechanism for ordering concrete and utilizing the concrete placement checkout record are presented along with a detailed description of those conditions which must be satisfied prior to acceptance by the responsible individual. Included are general guidelines covering placement and post placement activities, backfill concrete, and grouting. Also given is a contingency plan for placing a construction joint should a placement be interrupted. Quality Control inspects and monitors against its Quality Control Instruction which is compatable with the Job Rule.
A comparison of the quality control procedures between Projects B and C reveals one significant difference. On Project C the QC inspector is required to review the inspection and reference criteria for availability, familiarity, and correct approval and revision status. This includes the review of the latest applicable drawings, specifications, procedures, and vendor documents. Furthermore, he must review any open nonconformances which may affect the work operations. These activities have traditionally been labeled construction or field engineering responsibilities. The extension of QC responsibilities into planning activities on Project C seems to be somewhat limited, however, it will be pointed out later how this can lead to problems. It should be

pointed out that there is a requirement for quality control to review and approve the detailed construction Job Rules.

4. Project D is very similar in nature to Project C and therefore will not be discussed.

5. The organization and responsibilities for Project E are different from the other projects. As described in Chapter 3, the functions of field engineering and quality control are assigned to the discipline construction engineer, and it follows that each construction engineer is responsible for coordinating work activities as well as insuring that the quality aspects are satisfied. The advantages and disadvantages of this approach have been addressed in Chapter 3 however, there is one further advantage which should be highlighted. Since the quality and coordinating functions are performed in one organizational element, there is no necessity for separate field construction procedures and quality control procedures. On Project E all concrete placement operations are governed by a quality control procedure. The procedure outlines the duties of the responsible parties, including a concrete inspector who represents the materials engineer. Instructions on how the concrete placement checkout record is to be used is also provided. Finally, there are general instructions on how the concrete placement should be accomplished, including placement practices, consolidation attributes, and acceptance criteria for preliminary and placement verification. Because of this unique organizational structure, the function of reviewing and approving preplanning activities is accomplished simultaneously with the development of the work plans.

6. All construction activities on Project F must be performed in accordance with field construction procedures. The concrete placement field procedure describes the use of the concrete pour card and then outlines the important attributes to be observed during preplacement, placement, extreme weather, and

curing. The procedure restates many of the general requirements of the project specifications and is similar in scope to the field procedures for Projects C and D. No information is available regarding the preparation and use of detailed work plans.

7. The preparation of construction work plans on Project G is governed by a work plan procedure which serves to insure that adequate preplanning is done by field engineering and to establish general requirements for the preparation of the individual work plans. Exhibit 7.1 shows an example which delineates the minimum requirements of the work plan with regards to scope and detail. As can be seen, the sequence of operations necessary to successfully complete the concrete placement is provided. Unlike the field procedures for Projects C, D, and F, the procedure for Project G gives no description regarding how concrete is to be ordered since all concrete orders are made by the quality control representative. The QC representative relates to batch plant the location of the placement, quantity, mix design and other relevent information such as temperature and slump requirements. He also notifies the batch plant when the placement is released. The placement superintendent will notify the plant operator when the delivery is to commence if the placement is not scheduled to start immediately.

Among the important requirements established in the work plan procedure is the necessity for review and monitoring functions by quality control during preplacement, placement, and post placement phases. This involvement by QC is clearly evident in Exhibit 7.1. The work plan is not only used as a construction document but is also used as a convenient means of transmitting information to the field quality control department since their approval is required. The work plan also facilitates the identification of QC hold points. (It should be noted that on other projects, the concrete placement checkout record on pour card serves as a built-in hold point.) Quality Control must initial or sign the individual items on the work plan as they are satisfied, and thus the work plan is also a quality related record. The formalized

Exhibit 7.1.--Standard Work Plan and Inspection Record for Concrete Operations

REV	DATE	REVISION DESCRIPTION	RFE	SUP	QCE	REV	DATE	REVISION DESCRIPTION	RFE	SUP	QCE
0						2					
1						3					

ITEM NO.	WORK/INSPECTION ACTIVITY SEQUENCING REQUIRED YES ☐ NO ☐	INSTALLATION DOCUMENT #	REV	REV	HOLD PT	SUP'T	RFE	DATE	QCE	DATE	TYPE
	PREREQUISITES										
1	Estimated Concrete Quantity	NA				NA			NA		
2	Concrete Mix A B C D 1 2 PG					NA					
3	Grout Required Yes ☐ No ☐					NA					
4	Type of Finish					NA					
5	Type of Curing					NA					
6	Verify materials are available for installation	NA				NA	NA		NA		
7	Verify access to the work site is available, free of obstructions, adequate to accommodate the traffic and sequenced with other activities	NA				NA	NA		NA		
	CONCRETE OPERATIONS										
20	Prepare existing construction joints										
21	Verify joint surfaces (QCI 9.1-1)										I
30	Install waterproofing										
35	Install waterstop										
36	Verify waterstop (QCI 9.1-1)										I
40	Install reinforcing steel										
41	Verify rebar installation (QCI 9.1-1)										I

SIGNATURES	FOREMAN	DATE	SUPERINTENDENT	DATE	RFE	DATE	QCE	DATE

Exhibit 7.1.--continued

ITEM NO	WORK/INSPECTION ACTIVITY	INSTALLATION DOCUMENT #	REV	REV	HOLD PT	SUP'T	RFE	DATE	QCE	DATE	TYPE
42	Verify cadweld splices (QCI 9.1-1)										R
50	Install forms/blockouts										
51	Verify forms/blockouts (QCI 9.1-1)										I
60	Install const., control, expansion/contraction joints										
61	Verify const., control, expansion/contraction joints (QCI 9.1-1)										I
70	Install embeds other than reinforcing steel										
71	Verify civil embeds (QCI 9.1-1)										I
80	Verify structural steel complete (QCI 9.1-7)										R
81	Verify Mech/Pipe embedded items (QCI 9.1-)										
82	Verify electrical embedded items (QCI 9.1-)										
83	Verify I&C electrical items (QCI 9.1-)										
84	Verify embed welding and NDE complete (QCI 9.1-9)										
85	Verify leak testing complete (QCI 9.1-)										
90	Survey complete										
100	Liner Plate completed (QCI 11.1-5)										R
101	Verify liner plate welding and NDE complete										
110	Perform preplacement cleanup/preparation										
111	Verify receiving surfaces, and placement equipment (QCI 9.1-1)										I
112	Verify weather protection/conditions (QCI 9.1-1)										I
113	Verify testing preparations made; Lab notified (QCI 9.1-1)										I
114	Final preplacement hold point release (QCI 9.1-1)				QC						R

Exhibit 7.1.--continued

ITEM NO.	WORK/INSPECTION ACTIVITY	INSTALLATION DOCUMENT #	REV	REV	HOLD PT	SUP'T	RFE	DATE	QCE	DATE	TYPE
120	Place concrete										
121	Verify grout, mix, test results (QCI 9.1-1)				QC						R
122	Verify grade (QCI 9.1-1)										I
130	Finish concrete										
131	Verify finish (QCI 9.1-1)										I
140	Cure concrete										
141	Verify type of cure, starting time, temperature (QCI 9.1-1)										I
142	Verify curing duration (QCI 9.1-1)										R
150	Forms Loosening/Shoring Removal										
151	Loosen forms on:										
152	Verify forms loosened (QCI 9.1-1)										I
153	Verify concrete has reached _____ psi compressive strength prior to removing shoring (QCI 9.1-1)										R
	Determine method of concrete repair:										
160	Standard repair with grout ☐										
161	Verify preparation (QCI 9.1-1)										I
162	Verify finish (QCI 9.1-1)										I
163	Verify curing (QCI 9.1-1)										I
	-Or-										
170	Standard Repair with Concrete ☐ (See WP&IR #)										
171	Review WP&IR (QCI 9.1-1)										R
	-Or-										
180	Defer repair to later date ☐ (See WP&IR #)										
181	Review WP&IR (QCI 9.1-1)										R
190	Perform architectural finish, type:										
191	Verify finish (QCI 9.1-1)										I
200	Verify concrete placement complete (QCI 9.1-1)										R
210	Review completed WP&IR (QCI 9.1-1)										R

inspection effort on this project appears to be more extensive than on any of the other projects. As can be seen, there are 29 areas which could potentially require QC inspection. The verification philosophy on Project G is diametrically opposite the approach used on Project E.

8. As mentioned in Chapter 3, Project H is being constructed under the Construction Management mode and therefore, there are a number of contractors performing concrete work on the site. Each contractor has his own QA/QC program, and it is worthwhile to compare the approach taken by two of the contractors. It will be shown that each has reacted differently to the requirements imposed by the owner's quality assurance program.

Contractor H1 has reacted to the owner's requirements by preparing a quality control/work procedure which governs the preparation of the work plan. There are detailed procedures for all concrete related activities, including formwork, placement of reinforcing steel, concrete placement, etc. These procedures explain in detail how to satisfy the project specifications and include such details as the size tie wire to use and minimum allowable capacity of concrete pumps. The work plans are prepared using the information provided in the work procedures. Exhibit 7.2 shows the form which must be used in preparing the work plan. A list of applicable documents and procedures must be included along with a step-by step listing of each operation required to accomplish the work. The final step in the process is the completion of a quality control checklist. Quality Assurance must approve the work plan prior to its implementation, and as can be seen, the last page is a QC checklist. It includes several items which have traditionally been considered field engineering functions. This involvement by QC in the preparation of detailed work plans is more than that seen on Projects C and D., however it falls short of the involvement seen on Project G.

Exhibit 7.2.--Field Construction Procedure - Project H1

FIELD CONSTRUCTION PROCEDURE NO.

TITLE _____

CUSTOMER _____ CONTRACT NO. _____

APPLICABLE DOCUMENTS

DRAWINGS	REV	PROCEDURES	REV

	PREPARED BY:		APPROVED BY		
	F.P.C.	DATE	QAM	DATE	REMARKS
REV-0					
REV-1					
REV-2					
REV-3					

PAGE ____ OF ____

Exhibit 7.2.--Project H1-continued

SEQ.

List the sequence of operations in as many simple instructions as deemed necessary to provide a complete and clearly defined instruction for completing the work.

Rev. _____
Page ____ of ____

Exhibit 7.2.--Project H1-continued

Customer _____ Contract No. _____

Project _____ FCP No. _____

	Yes	No
1. Are all drawings listed on the FCP of the proper revision at the date of issue of the FCP?	_____	_____
2. Are all Procedures listed on the FCP of the proper revision at the date of issue of the FCP?	_____	_____
3. Have all the Quality Control forms referenced on the FCP been completely filled out and properly signed?	_____	_____
4. Does the FCP have the proper QCA Manager approval?	_____	_____
5. Have all sequences been properly initialled and dated?	_____	_____
6. Have all inspections been performed as designated?	_____	_____
7. Have all rejects or non-conformities been cleared?	_____	_____
8. Are the originals of all the referenced QC documents included in the FCP folder?	_____	_____
9. Have the data packages for all vendor supplied material and equipment been included in the FCP folder?	_____	_____

Additional Remarks: _____

Prepared By _____ QAE _____ Date

Approved By _____ FPC _____ Date

Approved By _____ Owner/Agent _____ Date

The perceived requirements of the owner were viewed differently by the second contractor H2. For the contractor H2 case, the field construction procedures and quality control procedures were prepared as separate documents. The field procedures list all the important attributes from the specifications. These may be expanded in some cases, but in general, they reference the applicable specification provision. Quality Control is not involved in the preparation of the work plans, and hence, no further information is available. The program is similar to the one used on Project F.

9. On Project I field construction procedures are prepared which provide a description of how to order concrete, the necessary construction documentation, and a detailed description on various activities such as joint preparation, consolidation, and cold and hot weather concreting. The field construction procedures are similar to those prepared for Project F, except that the Project I procedures are more detailed. There is no information available regarding detailed work plans.

As can be seen, the depth of involvement of Quality Control in construction preplanning activities varies considerably from project to project. In theory, an increase in the level of involvement of Quality Control should result in an increase in the quality of the end product. In reality, however, this may not necessarily be true. Indeed it has been found on at least one project that when construction operates under an agressive quality control environment, the construction supervisors and field engineers who normally are responsible for verification against the specifications have a tendency to relinquish this function to the Quality Control Inspector. On this project the Quality Control program may be creating field engineers and supervisors who do not feel total responsibility for quality (at least subconsciously) since they know QC will come along to

identify the nonconformances. It must be recognized that quality is built in and not inspected in, and no one is in a better position to insure quality than those who are involved with the work on a daily basis. Thus a serious paradox can potentially develop whereby a very active QC program may make high quality workmanship more difficult to obtain because of this subconscious delegation of responsibility. Every organizer and manager should be cognizant of this fact.

The above problem can be illustrated to a degree by reviewing a condition which was identified on one project where the quality control involvement in construction preplanning activities was particularly intensive. Quality Control was assigned the responsibility of verifying that the proper drawings and specifications were being used and that all documents had up-to-date revisions. Field engineering also had parallel responsibilities, and therefore it would be anticipated that this parallel effort would make it unlikely that the incorrect documents would be used. An audit of the work plans covering an eight month period revealed that out of 102 specifications that were listed, 81 had the incorrect revision. Obviously the system did not work as planned. It is recognized that there may have been many factors which contributed to this problem, however, it is valid to ask the question, did field engineering subconsciously pass on this responsibility to quality control because the prevailing environment was unusually QC intensive?

Even though on many projects QC is not involved with preplanning, it is essential that some coordination be done between the two departments. On most projects this is accomplished by the orderly control of concrete placement checkout sheets and pour cards as discussed below.

Concrete Order-Delivery Systems

There are two documents which are typically used to transmit information to the various parties, namely: 1) the concrete order form, and 2) the concrete placement checkout sheet or pour card.

The manner in which the ordering of concrete and timely dissemination of information to quality control is handled on the different projects may be divided into three groups. For the first group, no concrete order form is available. This group includes Projects A, B, E, F and I. Projects A and B utilize the placement checkout sheet to order concrete and alert quality control that a placement is being scheduled. These are prepared several weeks in advance and are distributed to the appropriate parties. For Projects F and I there is no information available regarding these coordination aspects. On Project E, the quality control aspects are performed by field engineering, and therefore, no coordinating effort is required. The second group includes Projects C, D. and H. On these projects a separate concrete order form is used as the coordinating mechanism and this is prepared two weeks in advance. The third group includes Project G which utilizes the work plan to coordinate with QC.

The concrete placement checkout sheet, sometimes referred to as the pour card, is a document used to identify when certain attributes of a placement have been accepted. The attributes are broad topic areas which fall under the supervision of a single craft supervisor, such as formwork, reinforcement, and cleanliness. The form is generally divided into two major areas for approval. The first part is where the individual attributes are approved, and this is usually signed at the time the activity is accepted. The second group of signatures indicate final approval. This section is not completed until the placement is scheduled to start. Table 7.1 shows the various signatures required for each of the

Table 7.1. Required Signatures on Concrete Placement Checkout Sheet

Title or Position	Project								
	A	B	C	D	E	F	G[a]	H	I
	Approval for Each Discipline/Craft								
Discipline/Craft Supervisor	X	X	X	X	X	X	X	X	X
Field Engineer		X	X	X	X		X		
Quality Control						X	X	X	
	Final Approval								
Quality Control	X	X	X[b]	X	X	X	X	X	X
Field/Area Engineer	X		X	X	X	X			X
Contract Administrator						X		X	
Area Superintendant				X					

[a]The work plan is used as the checkout sheet (see Exhibit 7.1)

[b]Review of QC is required even though the checkout sheet is not signed. QC assures that the pour card is signed by field engineers and superintendents prior to releasing the placement.

projects. Project G appears to have overreacted by requiring the approval of craft supervisors, field engineers, and quality control for each item. It should be pointed out that the work plan shown in Exhibit 7.1 is used as the checkout sheet, and therefore, there are more items than the five or six found on the other jobs. Another point of interest is that on Projects C and D the field engineer is required to sign each attribute as well as give final approval. Also the necessity for having the Area Superintendent give final approval on Project D is not clear. It is natural to suspect that the higher the position of responsibility the more likelihood there is that the checkout sheet is signed simply because all the other parties have approved. If the Area Superintendent must in fact inspect the placement, then this is merely another level of inspection and in all likelihood redundant.

MASS CONCRETE

Many of the placements on nuclear power plant projects are massive and require special attention. The principal technical problem peculiar to mass concrete is the probability of high tensile stresses resulting from heat generated by hydration of cement with subsequent differential cooling. It has been recognized throughout the industry that the ACI Code does not adequately address the subject of mass concrete where the members are heavily reinforced. The provisions of ACI 207, Mass Concrete for Dams and Other Massive Structures and ACI 301, Specifications for Structural Concrete for Buildings were developed as a result of experience gained from placing mass concrete on unreinforced gravity dams. As a result, many of the suggested practices are not applicable to nuclear construction. This is evident from the fact that the slump for mass concrete is limited to a maximum of 2 inches.

Also, aggregates as large as 6 inches are used in dam construction, however aggregates in excess of 1 1/2 inches are seldom used in nuclear construction. The materials and testing aspects were presented in Chapters 5 and 6 . The temperature and slump characteristics will be presented in this chapter, and Chapter 9 will discuss the applicable placement characteristics.

Mass concrete is defined in ACI 207 as "any large volume of cast-in-place concrete with dimensions large enough to require that measures be taken to cope with the generation of heat and attendant volume changes to minimize cracking." There are many factors which influence whether or not a structure may require special attention. These factors include weather conditions, the volume-surface ratio, rate of hydration, temperature and mass of surrounding materials, functional effect of surface cracking, and other factors. ACI 301 further states that "in general, the critical size may be more than 2 1/2 feet in the least dimension, but the requirements of each project should be evaluated on their own merits".

The practice of defining mass concrete by comparing the least dimension to a critical size limit is a satisfactory approach on a dam where the geometric configuration is "orderly". On a nuclear structure many of the placements are irregular in shape and have unique confinement characteristics. The establishment of a critical size limit may lead to problems since there may be large placements where non-mass practices should be employed. On the other hand, there may be small structures which should be characterized as mass concrete. The critical size limit can also lead to confusion and arguments between field engineering and quality control. These problems will be discussed later.

The approach of establishing a critical size for mass concrete is accepted on all projects, except Project E, however the definition of mass concrete varies

considerably. The project requirements are given below.

1. Five projects establish critical size limits. Projects A, B and C comply with ACI 301 by using a 36-inch limit. Project D uses 30 inches for its critical size. Project H has established 48 inches as the critical size, however fill concrete is not considered mass concrete.

2. On Project F mass concrete is defined as all slabs or footings greater than 36 inches, walls greater than 30 inches and columns with a least dimension exceeding 24 inches and having a cross-sectional area greater than 9 sq. ft.

3. Project G does not define mass concrete per se, however there are different placement temperature requirements when concrete exceeds 3 ft. and 6 ft. in the least dimension. Temperature aspects will be discussed later.

4. For Project I the mass concrete criteria is the same as for Project F except that the cross-sectional area provision has been deleted.

5. Project E does not define mass concrete as a structure whose least dimension exceeds a critical size. Rather, each placement is analyzed to determine if there will be problems with volume changes and dissipation of heat of hydration. This is a design function and the determination is recorded on the design drawings for each placement. Factors considered include the degree of confinement, rate of hydration, surface-volume characteristics, amount of reinforcement, and the functional requirements of the structure.

The establishment of a critical size is a simple approach to defining mass concrete, however it is not without problems. The use of the 36-inch limit is considered to be an example of quoting the code without giving adequate consideration to whether the provisions are applicable. Although there are many aspects discussed in ACI 207 which should be applied to nuclear construction, there are a number of features which separate nuclear construction from dam

construction. The difference in the size aggregate used and shape characteristics have been mentioned previously. Another characteristic important to mass concrete is the reinforcement and how it influences consolidation and temperature dissipation. Many of the questions regarding the behavior of mass concrete in heavily reinforced sections have not been answered, and it appears that the industry should further investigate this subject.

Most sites have experienced problems in defining mass concrete. For cases where nonconformances may have been written because of a misinterpretation in the definition of mass concrete, the quality of the structure may be jeopardized. Typical of the type of problem which can be encountered occurred on one particular project where part of a wall placement was 30 inches and the remainder of the wall was less than 24 inches. The entire wall was defined as mass concrete by quality control, after much debate with field engineering. Placement problems resulted since the maximum slump for mass concrete was 3 inches and non-mass was 4 inches. Thus the entire wall including the very narrow congested section had to be placed with the lower slump concrete. The problem was further worsened by the fact that the batch plant sent 2 inch slump concrete because the specifications allowed the addition of water at the point of discharge from the truck. The water, however, is rarely added on this project because it delays the pour, and the low slump concrete was placed into the heavily reinforced wall of 24 inch width or less. Under these conditions, the potential for voids is greatly increased, and hence adversely affects quality, because mass concrete is not adequately defined.

This problem is largely eliminated by the approach used on Project E. Each placement is analyzed and the results recorded on the project plans. Thus the determination of the important aspects of the placement is the sole responsibility of the design engineer. This requirement appears to be an

excellent approach which would not only enhance quality, but constructability as well.

The primary difference between concrete placed in a non-mass placement and mass concrete is the delivered temperature and slump requirements. These aspects will be discussed below.

ATTRIBUTES OF FRESH CONCRETE

There are three primary attributes of fresh concrete that are verified at the point of discharge or placement. These are slump, temperature, and air content. The amount of concrete rejected or wasted on each of the projects is given in Table 7.2. The totals rejected in each category on Project H were not available, however the major reasons for rejection in the order of frequency of occurrence were given as slump, time limit, air content and temperature, with slump having the highest rate of rejection. As can be seen, the detailed breakdown of quantities is not presented for several projects. Although this information is obtainable, it was not readily available and therefore is of little value to management. In Chapter 4 it was pointed out that a tremendous amount of data is collected and stored in vaults without ever being analyzed. The data in Table 7.2 represents such an example. Project management on Projects E and F can perform trend analyses (also discussed in Chapter 4) and correct detrimental situations as they are occurring, provided the data is current, however the other projects are probably able to identify the problem only after it has reached major proportions.

To illustrate this point, consider a problem which arose on a project where the data were not readily available. The slump and air content measurements fluctuated greatly over a period of 12-18 months. The problem was finally traced to variations in the quality of flyash. Had control charts been used or trend analyses performed on the air content measurements of the concrete and surface

Table 7.2. Total Cubic Yards of Structural Concrete Wasted

Project	A	B	C	D	E	F	G	H	I
Total cubic yards batched to date	548,154		222,039		350,000	32,217	315,000	130,000	68,552
Cubic yards rejected because of:									
--slump					612	347			
--temperature					0	57	2675		
--air content					0	255			
--time limit					197	150	4469[a]		
--equipment failure					195	7			
--other					474				
Total cubic yards rejected			2526		1478	816			
Overordered			2163		56	215			
Total cubic yards wasted	20,301		4689		1534	1031	7144	1100	3638
Percent wasted	3.7%		2.1%		0.4%	3.2%	2.3%	0.8%	5.3%

[a]Includes overordered concrete

area measurements of the flyash, the problem could have possibly been isolated and resolved before it became a serious one. According to figures prepared by the constructor's field engineering department, the air problems cost production over $200,000. Data collected from previous projects could have established the reasonably expected rate of fluctuation of each attribute thus facilitating the identification of the problem.

Slump

Prior to presenting how the various projects have specified slump requirements, it is worthwhile to paraphrase the ACI 301 provisions which allow a slump of 4 inches with a 1 inch tolerance for individual batches provided the average of the ten (or less) most recent batches tested is less than the 4 inch maximum. A maximum slump of 2 inches with the same allowable 1 inch tolerance is given for mass concrete. There is much disagreement among the industry regarding these slump limits as will be shown below, and of the nine projects studied, only one, Project H, accepts ACI 301 verbatim. It should be pointed out, however, that unlike ACI 301, there is no distinction between mass and non-mass concrete with regard to slump limits on this project.

Most specification writers recognize the inherent variability of slump measurements, and that occasional batches may exceed the slump limits without having a detrimental effect on quality. This knowledge is reflected in the 1-inch tolerance provided for in ACI 301. The underlying danger, however, in the Code approach is providing for an acceptance criterion based upon an average slump value. Although the concept is sound, it can have an adverse effect on quality by encouraging the placement to begin with batches having slumps on the low side of the preferable range, merely to provide low numbers which can be

averaged with higher values that may appear later. This is the worst way to begin a concrete placement (7.1). With dry, low slump first batches, consolidation is doubtful and more difficult, perhaps resulting in delays which may reduce the slump of later batches. Concrete almost wet enough to be rejected is preferable even after a suitable starter mix is used since the upward movement of water will bring its quality up to that of the average.

The production of low slump initial batches is further encouraged on Project H by requiring a slump measurement to be recorded for each of the first two batches. (The specification is unclear as to whether this means the first two batches produced during a shift or the first two batches of each placement). The situation is complicated because the initial batches are the most difficult to control. The batch plant operator does not know how long the first truck will have to wait before discharging, and the second and third trucks generally wait longer. The amp meter (slump indicator) on the batch plant mixer is continually changing during the first five or six batches, and frequently the moisture content test on the aggregate pile is not taken on a truly representative sample. Accordingly, some degree of flexibility is required during the early stages of a placement, however the ACI provision falls short of giving any guidance, presumably leaving this task to the engineer. Without any further guidance or clarification, the Project H Quality Control Inspectors have routinely rejected all batches, including the first few batches, which cause the average slump value to exceed 4 inches,and this is the very time when the higher slump values are desirable. The intention of the specification writer is to insure that the production process is quickly brought under control, however this can be accomplished quite well by the batch plant operator. Furthermore, the well-trained eye of a Level II inspector can easily detect when slump is out of control and

verbally communicate this information back to the batch plant operator.

While the intentions of the specification writer are good, the combination of the average slump approach and the requirement for early testing could lead to undesirable results. The concern for voids has been expressed by the Nuclear Regulatory Commission in Regulatory Guide 1.55 which states that "the presence of numerous concrete voids which have been detected at or near the surface of nuclear containment buildings raises concern about the density of portions of these and other concrete structures that cannot readily be inspected." Realistic slump requirements are certainly the first step towards achieving proper consolidation and hence reducing the potential for voids.

The slump requirements for four other projects are given in Table 7.3. It is evident that there is no recognition of the variability of slump measurements. This appears to be yet another approach which encourages the production of low slump concrete, and it is important to point out that this problem has been reported on Project F. Related to the problem of consolidation, it should also be noted that Projects F and I are the only two projects having separate requirements for mass concrete. The desire to have adequate consolidation in the heavily reinforced massive structures, such as the mat foundation, conflicts with the objective of controlling the heat of hydration. The various aspects of this problem have been discussed in Chapter 6. Project F did experience a problem concerning the definition of mass concrete and subsequently had consolidation difficulties because of the lower slump limit. This aspect was discussed briefly in the section on mass concrete.

The above problems can be overcome by providing upper and lower control limits on the allowable slump and absolute rejection limits which are different from the control limits. This concept has been adopted for Projects C, D, and G as shown in Table 7.4. Although each project has different design mixes, and

Table 7.3. Slump Requirements for Projects A, B, F, H and I

Project	Class (psi.)	Minimum (in.)	Maximum (in.)	Frequency of Testing
A	all	-	4[a]	Every 20 cubic yards.
B	5000	1	3 1/2	Every 50 cubic yards/class/day after initial first two batches.
	3000	1	3	
F	mass	-	3	Cat I-first batch and every 50 cubic yards thereafter
	other	-	4	Cat II-first batch and every 250 cubic yards thereafter
H	all		4[b]	First two batches and every 48 cubic yards thereafter
I	mass	1	3	Same as project F
	other	-	4	

[a] For certain congested areas, a mix with 5" slump is allowed, and in the highly congested containment wall, 6" and 7" slumps are permissible.

[b] A 1" tolerance is provided for as per ACI 301.

Table 7.4. Slump Requirements for Projects C, D and G

Class (psi) fc'	Maximum Aggregate Size (in.)	Working Limit (in.)	Inadvertency Margin (in.)	Rejection Limit (in.)
Design Mixes Containing Flyash				
3000	3/4	3	2	5
3000	1 1/2	3	2	5
4000	3/4	3	2	5
4000	1 1/2	2 1/2	2	4 1/2
5000	3/4	3	2	5
5000	1 1/2	2 1/2	2	4 1/2
Design Mixes Without Flyash				
4000	3/4	3	2	5
4000	1 1/2	2 1/2	2	4 1/2

hence slightly different slump requirements, the approach to slump requirements is the same. The slump must be less than or equal to the working limit, however the inadvertancy margin is the allowable deviation from the working limit for those occasional batches of concrete which inadvertantly exceed the working limit but are less than the rejection limit. In each case corrective action is required to bring the batching process under control. For Project G, this action must be accomplished by the fourth truck after corrective action is requested.

The concept of the inadvertancy margin appears to be a good approach towards recognizing the variability of slump. Adequate flexibility is provided while maintaining acceptable control measures over the process. Best of all, it does not overly encourage the production of low slump concrete.

Perhaps the best approach to slump requirements is the acceptance criteria based on Project E as shown in Table 7.5. The approach recognizes that slump requirements are not only a function of the design strength but also the size and type of member. The maximum average slump corresponds to the working limit presented in Table 7.4 and the maximum slump corresponds to the rejection limit. It is, however, recognized that there is a 10% probability that the maximum limit may be exceeded and yet the average may still be below the maximum average slump limit. Therefore, up to 10% of the placement may be greater than the maximum value. This concept is discussed in greater detail in Chapter 6. It should be stated however that this approach, as presented in Table 7.5, facilitates consolidation, recognizes inherent slump variability, and yet establishes definite control limits on the process. It should be recalled from Chapter 6 that all sampling on Project E is done at the batch plant and therefore the slump values in Table 7.5 should be adjusted downward by a factor of perhaps 1/2 inch before a direct comparison can be made with the values

Table 7.5 Slump Requirements for Project E

Thickness of Concrete Section (in.)	Maximum Size Aggregate (in.)	Minimum Average[a] Slump (in.)	Maximum Slump[b] (in.)
Walls, Columns, Beams, Girders (3000 psi)			
Less than 12	3/4	3 1/2	4 1/2
12 to 24	1 1/2	3	4
24 to 36	1 1/2	2 1/2	3 1/4
36 to 72	3	2	2 1/2
Greater than 72	6	1 1/2	2
Slabs, Footings (3000 psi)			
Less than 9	3/4	2 1/2	3 1/4
9 to 12	1 1/2	2 1/2	3 1/4
12 to 18	3	2	2 1/2
Greater than 18	6	1 1/2	2

[a] The average slump of any five batches placed shall not exceed these limits.

[b] Not more than 10% of the concrete placed in a single lift or pour shall have slump exceeding these limits, and if two consecutive tests exceed this limit, the batch shall be wasted.

presented in Tables 7.3 and 7.4.

With the exception of Projects B and I there is no lower limit on slump. The provisions comply with ACI 301 which states that low slump can be used provided it can be vibrated. One version of the specifications for Project C allowed concrete to be placed beyond the maximum time limit after completion of mixing provided the slump was sufficient to facilitate consolidation. A later version deleted the options and requires the concrete to be wasted. There are some within the industry that feel that slump and consolidation are the only acceptance criteria needed and such concrete should not be wasted.

One final point should be made regarding the attribute of slump. There is a provision in the specifications for Project B which allows a truck whose slump value exceeds the maximum limit to move aside and turn at agitating speed for not more than 15 minutes provided time and revolution limits are not exceeded. At the end of this time, the slump is retested and if it is within tolerances, the batch is accepted. This is perhaps, as mentioned above, an attempt to recognize slump variability. It may also be a convenient means of circumventing the specifications. Regardless of the purpose, it is considered by the authors to be a totally unacceptable approach. Slump values are a measure of consistency and workability. A batch whose slump is unacceptable is inconsistent with the other batches being produced, and no amount of agitation will make it more so. The material quantities are already established and the batch is either acceptable or unacceptable. From the standpoint of workability, if the batch is acceptable, then better workability will be obtained with the higher slump.

Temperature

Excluding hot and cold weather practices which will be discussed later, most project specification requirements comply with ACI 301 which establishes

a maximum placing temperature of 90°F for mass concrete. The problem with this provision is twofold. First, as has been discussed earlier, there is no clear definition of mass concrete. As was pointed out, arguments and delays can result which have little effect on quality, unless, or course, the delay occurs during the placement when the effect can be adverse. The second problem results from the fact that there is no provision for accepting perfectly good concrete which may inadvertently exceed the upper temperature limit by a few degrees.

Prior to presenting several solutions to the above stated problems, it is important to recognize that, as stated in ACI 306, concrete should always be placed at the lowest temperature possible since concrete placed at low temperatures receives long-time natural curing, develops higher ultimate strength, greater durability, and less thermal cracking than similar concrete placed at higher temperatures. This problem is particularly acute for massive structures. As stated in ACI 207, Mass Concrete for Dams and Other Massive Structures, it is almost standard practice in the United States to employ precooling for large dams to assure that the temperature of fresh concrete as it is deposited does not exceed 50°F. Considering the advantages of low temperatures it is questionable whether or not a lower temperature limit should be established, especially for massive structures. Several other factors must also be considered. First, large temperature gradients within a member should be avoided, and this could possibly be a justification for establishing a lower limit. Secondly, steel forms sprayed with water have been successfully employed as a means of dissipating internal concrete temperatures and thereby minimizing this temperature differential. This practice is probably not practical on a nuclear project, but it does raise the question of whether or not the reinforcing steel may serve a similar function. There are a number

of questions regarding placing temperatures which are unanswered, and it appears that more research needs to be done regarding temperature gradients in heavily reinforced, massive structures. One point, however, is clear: producers should be encouraged to batch and deliver concrete at the lowest possible temperature. This encouragement, except for a few isolated instances, appears to be absent in the projects studied. Concrete is rarely, if ever, rejected because the temperature is too low.

It is recognized that it is prudent to batch low temperature concrete only where there is an advantage to be gained with respect to quality. To do otherwise would needlessly add to concrete cost. A cost effective quality control program would therefore require the design engineer to evaluate each placement and select the appropriate mix design, slump, and temperature requirements based upon size of the placement, rebar congestion, degree of confinement which would limit expansion, and serviceability requirements. Certainly the use of ACI limits, although well suited to normal building construction, does not facilitate this approach. Of the nine projects studied, only Project E utilizes such a procedure. The maximum temperature limit is $85^{o}F$ and $65^{o}F$ on certain sections while the lower temperature limit is $50^{o}F$. The maximum placing temperature is determined by the designer and recorded on the plans as is suggested by ACI 349. There is no plus or minus deviation permissible; however, it should be noted from Table 7.2 that no concrete has been rejected on Project E for temperature reasons.

A different approach to establishing a range of allowable temperatures is used on Project H as seen in Table 7.6 and Figure 7.1. The acceptable range varies depending upon the ambient temperature, size of the section and degree of exposure. The dashed lines represent areas where the maximum or minimum limits are not clearly defined; however, the allowance of a 5^{o} deviation appears to provide the necessary flexibility. Project H experienced some difficulties with the initial version of the specification which did not have the 5^{o} tolerance

TABLE 7.6--Placing Temperature Requirements for Project H[a]

Exposed Concrete Face(s) Normal to the Thickness of the Placement		Limits for Concrete Temperature as Placed, °F		
		Thin Section	Moderately Massive Section	Massive Section
One Face Exposed		≤ 12"	12" to 48"	> 48"
Two Opposite Faces Exposed		≤ 18"	18" to 72"	> 72"
Temperature of Air Surrounding Concrete (Degrees F)	90	Max: 80	Max: 75	Max: 65
	80	Min: 45	Min: 45	Min: 45
	70	Max: 85	Max: 75	Max: 70
	60			
	50	Min: 45	Min: 45	Min: 45
	40	Max: 85	Max: 80	Max: 75
	30			
	20	Min: 55	Min: 50	Min: 45
	10	Max: 85	Max: 80	Max: 75
	0	Min: 60	Min: 55	Min: 50

[a]With the approval of the SITE ORGANIZATION Quality Control Administration, a tolerance of ±5°F may be applied to the maximum and minimum allowable temperatures listed. Concrete shall not be placed when the temperature of air surrounding the concrete is less than 0°F.

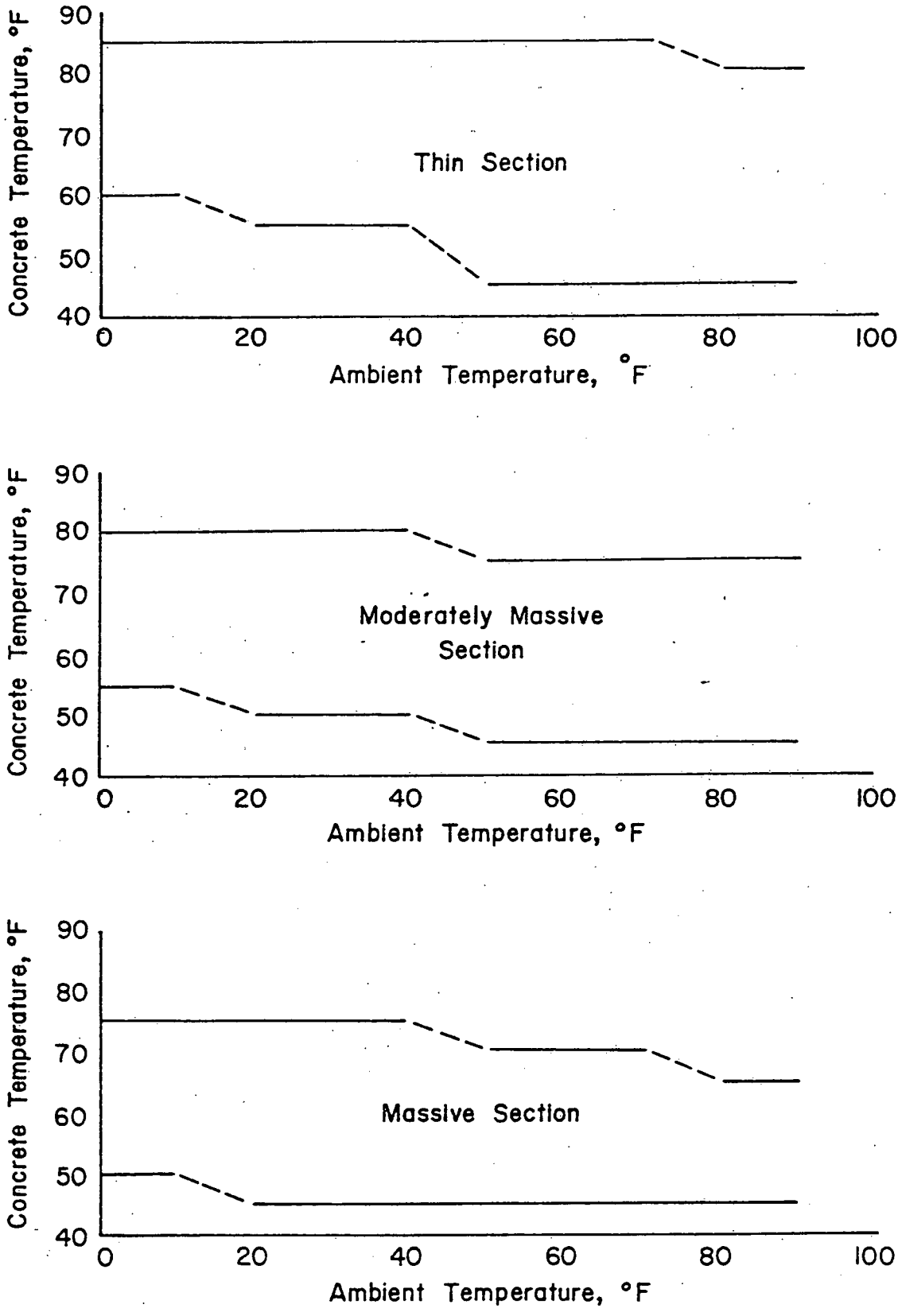


Figure 7.1. - Placing Temperatures for Project H

provision. A number of batches were wasted because they exceeded the temperature limits and subsequently the allowable tolerance was added. It should be pointed out, however, that there is a relatively wide margin between the upper and lower limits as shown in Figure 7.1. The batch plant operator is probably batching all concrete near the upper limit since this involves the least amount of ice and aggregate cooling. As mentioned previously, there is no encouragement to batch at lower temperatures.

Air Content

The project specification requirements for air entraining agents were discussed in Chapter 6, and it was pointed out that a number of projects have experienced problems with erratic results, particularly where used in a mix containing fly ash. Air content is relatively sensitive to how it is handled. Average losses of up to 1% can be anticipated if the process is under control, however the losses on many jobs have exceeded this figure by a considerable margin. On one project, the air content measurements ranged from 2 to 10 percent until the problem was identified as variability with fly ash. When the fly ash content was corrected, the average loss was reduced to approximately 0.8%. Use of air entraining admixtures also makes slump appreciably more difficult to control and of course reduces the concrete strength. Despite these disadvantages, air entrainment does improve workability, especially in very low slump concrete. The advantages and disadvantages of air entraining agents were discussed in greater detail in Chapter 6.

COLD WEATHER CONCRETING

Definition

The primary objective in cold weather concreting practices is to establish a procedure that will assure, despite freezing weather, that the concrete will

be amply strong and durable. This section will concentrate on how cold weather is defined and what temperature restrictions are placed on the fresh concrete. The cold weather protection requirements for adequate curing will be discussed in Chapter 9.

There is general agreement within the industry regarding when cold weather practices should be initiated. ACI 306, Recommended Practice for Cold Weather Concreting , suggests that cold weather be defined as when the mean daily temperatures are generally below 40°F. Under these conditions, concrete should be placed at the temperatures indicated in Table 7.7 (which is Table 1.4.1 in ACI 306). Most projects comply with this provision, except that on Project F and I, table 7.7 requirements are applicable when the temperature is expected to be below 40°F during placing or 24 hours thereafter. Project E, however, differs somewhat from the other projects. Cold weather practices are initiated when the ambient temperature falls below 40° as per ACI 306; however all of the ACI protection measures are not initiated immediately. The measures initiated include the use of blankets and suspension of water curing. It is felt by the Project Design Team that an ambient temperature as low as 20°F is not harmful and can be offset by the heat of hydration. Thus, even though the ambient temperature may be below freezing, the surface temperature of the concrete will be considerably higher. When the temperature has been or is predicted to fall below 20°F within 48 hours, more drastic measures, such as the use of artificial heat, are required.

Batching and Placing Temperature Requirements

The only difference between cold weather batching and placing and normal production on Project E is the protection requirements to prevent freezing. The lower placing temperature for all concrete year round is 50°F which is the same lower temperature requirement for Projects A and B. With respect to placing

TABLE 7.7.--EFFECT OF TEMPERATURE OF MATERIALS ON TEMPERATURE OF VARIOUS FRESHLY MIXED CONCRETES[a]

Line			Very thin sections				Thin sections				Moderately massive sections				Massive sections			
1	Approximate maximum size rock, in. (mm)		¾ (19)				1½ (38)				3 (76)				6 (152)			
2	Approximate percent sand		40				35				30				25			
3	Weight of sand for batch, lb (kg)		1200 (540)				1100 (480)				1000 (450)				900 (410)			
4	Weight of coarse aggregate for batch, lb (kg)		1800 (820)				2100 (950)				2400 (1090)				2700 (1220)			
5	Weight of water for batch (total), lb (kg)		300 (135)				250 (115)				200 (90)				150 (70)			
6	Weight of cement for batch, lb (kg)		600 (270)				500 (225)				400 (180)				300 (135)			
7	Minimum temperature fresh concrete as placed deg F (deg C)		55 (13)				50 (10)				45 (7)				40 (4.5)			
8	Minimum temperature fresh concrete as mixed, for weather,* deg F (deg C)	Above 30 F (−1 C)	60 (15.5)				55 (13)				50 (10)				45 (7)			
9		0 to 30 F (−18—1 C)	65 (18)				60 (15.5)				55 (13)				50 (10)			
10		Below 0 F (−18 C)	70 (21)				65 (18)				60 (15.5)				55 (13)			
11	Minimum temperature of materials to produce indicated temperature of freshly mixed concrete, deg F (deg C)	Cement†	35 (1.5)	15 (−9.5)	15 (−9.5)	−10 (−23.5)	35 (1.5)	15 (−9.5)	15 (−9.5)	−10 (−23.5)	35 (1.5)	15 (−9.5)	15 (−9.5)	−10 (−23.5)	35 (1.5)	15 (−9.5)	15 (−9.5)	−10 (−23.5)
12		Added water	140 (60)	140 (60)	140 (60)	140 (60)	140 (60)	140 (60)	140 (60)	140 (60)	140 (60)	140 (60)	140 (60)	140 (60)	140 (60)	140 (60)	140 (60)	140 (60)
13		Aggregate water‡	40 (4.5)	93 (34)	51 (10.5)	63 (17)	37 (3)	95 (35)	47 (8)	57 (14)	35 (1.5)	99 (35)	43 (6)	53 (12)	34 (1)	105 (40.5)	40 (4.5)	49 (9.5)
14	—	Sand	40 (4.5)	93 (34)	51 (10.5)	63 (17)	37 (3)	95 (35)	47 (8)	57 (14)	35 (1.5)	99 (35)	43 (6)	53 (12)	34 (1)	105 (40.5)	40 (4.5)	49 (9.5)
15	—	Coarse aggregate§	40 (4.5)	15 (−9.5)	51 (10.5)	63 (17)	37 (3)	15 (−9.5)	47 (8)	57 (14)	35 (1.5)	15 (−9.5)	43 (6)	53 (12)	34 (1)	15 (−9.5)	40 (4.5)	49 (9.5)
16	Temperature mixed concrete, deg F (deg C)		60 (15.5)	65 (18)	65 (18)	70 (21)	55 (13)	60 (15.5)	60 (15.5)	65 (18)	50 (10)	55 (13)	55 (13)	60 (15.5)	45 (8)	50 (10)	50 (10)	55 (13)
17	Maximum allowable gradual drop in temperature throughout first 24 hr after end of protection, deg F (deg C)		50 (28)				40 (22)				30 (17)				20 (11)			

*For colder weather a greater margin in temperature is provided between concrete as mixed and required minimum temperature of fresh concrete in place.

†Cement temperature has been taken as the same as that of average air and of unheated materials.

‡The amount of free water in the sand has been assumed equal to one-quarter the amount of the mixing water.

§Coarse aggregate is assumed to be surface dry and free of ice.

[a]Reproduced from ACI 306-66 Recommended Practice for Cold Weather Concreting

temperatures, only Projects F and I comply with the ACI 306 minimum temperature limits (line 7 of Table 7.7). The problem with complying with this provision again lies in the definition of very thin, thin, moderately massive, and massive sections, and each project has established different criteria which in effect changes the basis for comparison. Also, it should be noted that the design mixes presented as typical do not represent those mixes commonly found on nuclear projects. The maximum aggregate size for moderately massive and massive concrete ranges from 3-6 inches and contains 300-400 pounds of cement. The mixes used on nuclear projects have small aggregates and cement in typically the 500-600 pound range. Higher heat of hydration temperatures can be expected when the cement content is greater, and perhaps placing temperatures in the neighborhood of 40° F is advantageous for a wider variety of conditions than is indicated in ACI 306. This, of course, is not certain since the influence of reinforcing steel is not known; however, it does appear that there is still much to be learned regarding cold weather placing of heavily reinforced massive sections.

Projects C, D, and G address the question of minimum batching and placing temperatures by providing a sliding scale depending upon the ambient temperature. Figure 7.2 shows the minimum placing temperatures for Project G for massive or nonmassive sections. As can be seen, the regions around 0° and 30° can create problems unless the batch plant operator is batching concrete above the most restrictive limit. Projects C and G have a 5° tolerance limit provided corrective action is promptly initiated.

If there is no tolerance limit for occasional batches which may be below the minimum temperature limit, the batch plant operator is actually discouraged from producing concrete at the lowest possible temperature. As has been pointed out, this is not in the best interest when quality concrete is desired, and the opportunity provided by cold weather to readily do so should be taken.

One of the projects has been plagued by the 40°F demarcation point as well as an inadequate definition of hot weather conditions. The project shifts from ACI 305 requirements to ACI 306 and vice versa all winter long. Cold weather practices are occasionally employed when the ambient temperature is in the 70's or 80's and hot weather requirements may be in effect when the temperature is in the 20's and 30's. Clearly, such lack of flexibility could potentially affect the concrete quality adversely.

Table 7.7 (lines 8-10) suggests minimum temperatures of batched concrete such that, when placed, the temperature will not have fallen below those given on line 7 of Table 7.7. These are, of course, general guidelines and it must be recognized that ACI 306 represents generally acceptable approaches for all types of placements from sidewalks to apartment buildings. The conditions of each type of project are different. The change in temperature is dependent on many factors, including travel distance from the batch plant to the point of placement, duration of delays encountered at the discharge point, as well as the combined effect of temperature and wind. Thus, it appears that the batch plant operator should be given the freedom to deviate from the suggested batching temperatures in Table 7.7 in order to satisfy the placing temperature requirement. Most projects allow this flexibility, but, unfortunately, this is not the case on Project D. Figure 7.3 shows the required batching temperatures, and it should be readily obvious that similar problems with the discontinuous limits discussed in Figure 7.2 could also occur here. Not so obvious is the fact that in the region between 30 and 40 degrees, there is only a 10-degree range in which the concrete can be batched, and this must be delivered to the forms at a temperature not less than 50°. A 5° inadvertency margin is allowed. These limits appear to unnecessarily restrict the batch plant operator's ability to produce concrete at the desirable temperature, and it goes without saying

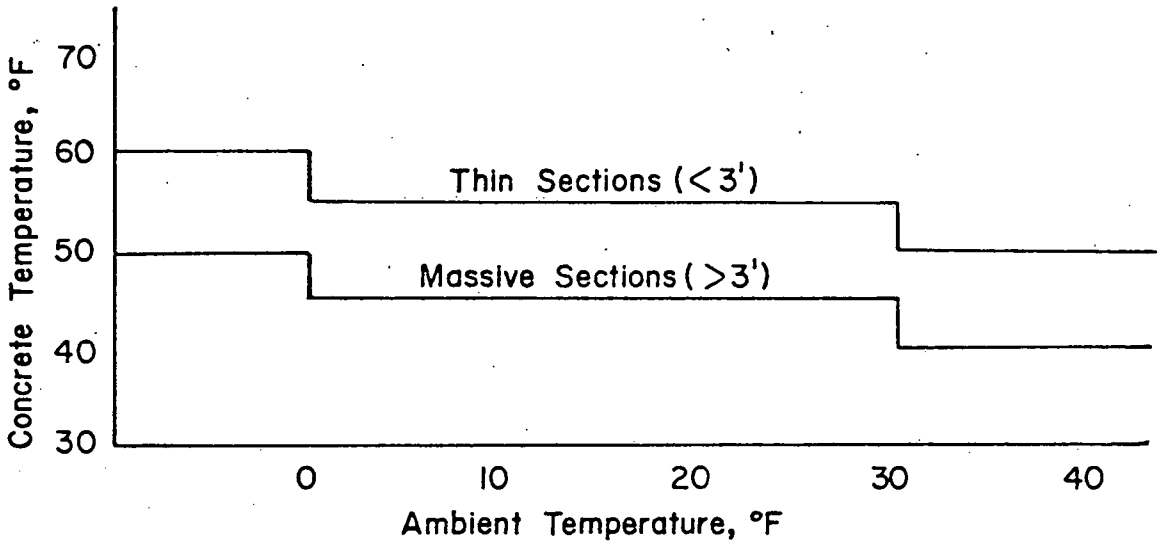


Figure 7.2. Minimum Placing Temperatures for Placing Concrete on Project G

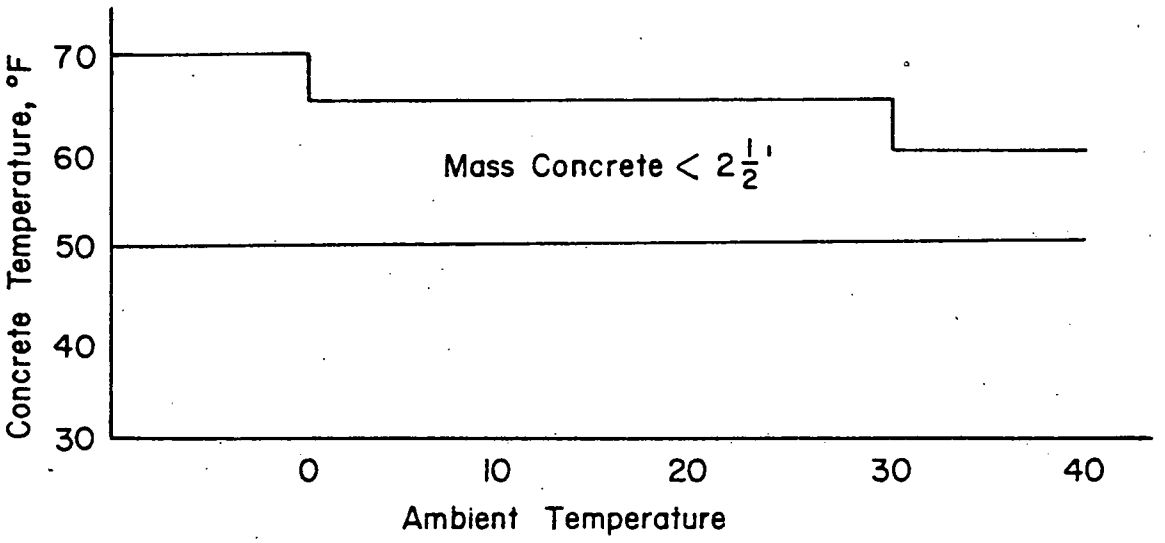


Figure 7.3. Range of Batching Temperatures for Placing Mass Concrete on Project D

that a significant amount of good quality concrete has been needlessly wasted on this project as a result of this provision.

Although Project C has similar lower limits, there is an upper limit of 70° on mass concrete and 85° on nonmass concrete. Batching temperatures on Project G are generally 5° higher than those shown in Figure 7.2; however, up to three consecutive batches with temperatures up to 5° less than those shown may be used. This allows time for corrective action to be taken. Project C allows a similar tolerance but with no reference to three consecutive batches. The temperature requirements for Project H were presented in Table 7.6 and Figure 7.1. There is no encouragement to produce at the lowest possible temperature.

General uncertainty with regard to the ACI 306 cold weather practices and their impact on the production effort led the constructor on Project C to conduct a number of studies to determine a) the temperature of concrete that could be expected when batching at low ambient temperatures, b) a commencement date for the start of warm weather procedures, and c) the weather protection to freshly placed concrete provided by pre-cast panels. There were several major changes in curing practices which resulted. The primary impact as it dealt with concrete temperatures was that the batch plant capacity was reduced to 163 cubic yards/hour because the heaters were insufficient to maintain the water temperature at a 100°F lower limit.

Delays at the point of placement can create difficulties in maintaining proper temperatures since the duration of the delay is highly unpredictable. On Projects C, D, and G there is an added dimension to this delay potential. On each of these projects, the specification writer has transformed a very general ACI provision into an unrealistic requirement. ACI 306 indicates that prior to placing concrete, the temperature of all surfaces to be in contact with the fresh concrete, such as reinforcement, forms, and embedments, should be

raised as close as may be practical to the temperature of the new concrete that is to be placed therein. For the projects mentioned, this is interpreted as 35° or greater. This represents another attempt at substituting a quantative value for a qualitative attribute. This is yet another item which must be inspected, and another potential source of a delay which will likely lead to the wasting of more good concrete. Although this might appear to be a way of minimizing low temperature problems, such provisions are not felt to be a part of a cost effective quality control program. There is no evidence to indicate that the quality of the final product is any different from concrete placed on projects where the batching temperature limits are more flexible and engineering judgement is used regarding the temperature of the forms and reinforcement.

HOT WEATHER CONCRETING

Definition

The primary concern during hot weather concreting is the rapid rate of evaporation of water from the concrete surface. If the rate of evaporation exceeds the rate at which water bleeds to the surface of the freshly placed concrete, then precautions must be taken to prevent plastic shrinkage cracks and subsequent drying of the concrete which can seriously impair its strength and durability. Unlike cold weather which affects concrete operations when the temperature approaches freezing, hot weather is difficult to define in terms of temperature alone. ACI 305, Recommended Practice for Hot Weather Concreting , defines hot weather as any combination of high air temperatures, low relative humidity, and wind velocity tending to impair concrete quality. Hence, hot weather conditions promote excessive evaporation and the ACI 305 Committee suggests that precautions should be taken when the

evaporation rate is expected to approach 0.2 pounds per square feet per hour. Figure 7.4 is reproduced from ACI 305 to illustrate how the rate of evaporation can be evaluated. One point should be readily obvious. The only factor over which there is any control is the placement temperature of the concrete. For the example calculation shown, an evaporation rate of 0.12 pounds per square foot per hour can be anticipated for the atmospheric conditions established and a concrete temperature of 60° F. If the concrete temperature rises 20° to 80°, the evaporation rate will triple.

Requirements

In general, the requirements for good quality concrete in hot weather are no different from the good practices employed during any other season except that the entire operation must be more closely controlled. The control of batched temperatures was mentioned above and every effort should be made to batch the concrete at the lowest temperature possible. Preparations must be made to transport, place, consolidate, and finish the concrete at the fastest rate possible. As stated in ACI 305, para 4.2.1.1, this means delivery must be scheduled to start promptly on arrival, particularly the first batch. As was pointed out in Chapters 6 and 7, sampling frequencies and congestion at the point of placement do not often facilitate rapid placement, and on many jobs, the quality of concrete could be jeopardized if concrete placement is continually interrupted or delayed. Certain specifications contribute to delays when retesting has to be performed. Inadvertency margins, as previously discussed, would contribute measurably to quality, especially during hot weather.

Another factor regarding delays during hot weather should be mentioned. On some jobs where concrete is being pumped, the placing operation must be stopped and the lines cleaned out when an attribute such as temperature, or

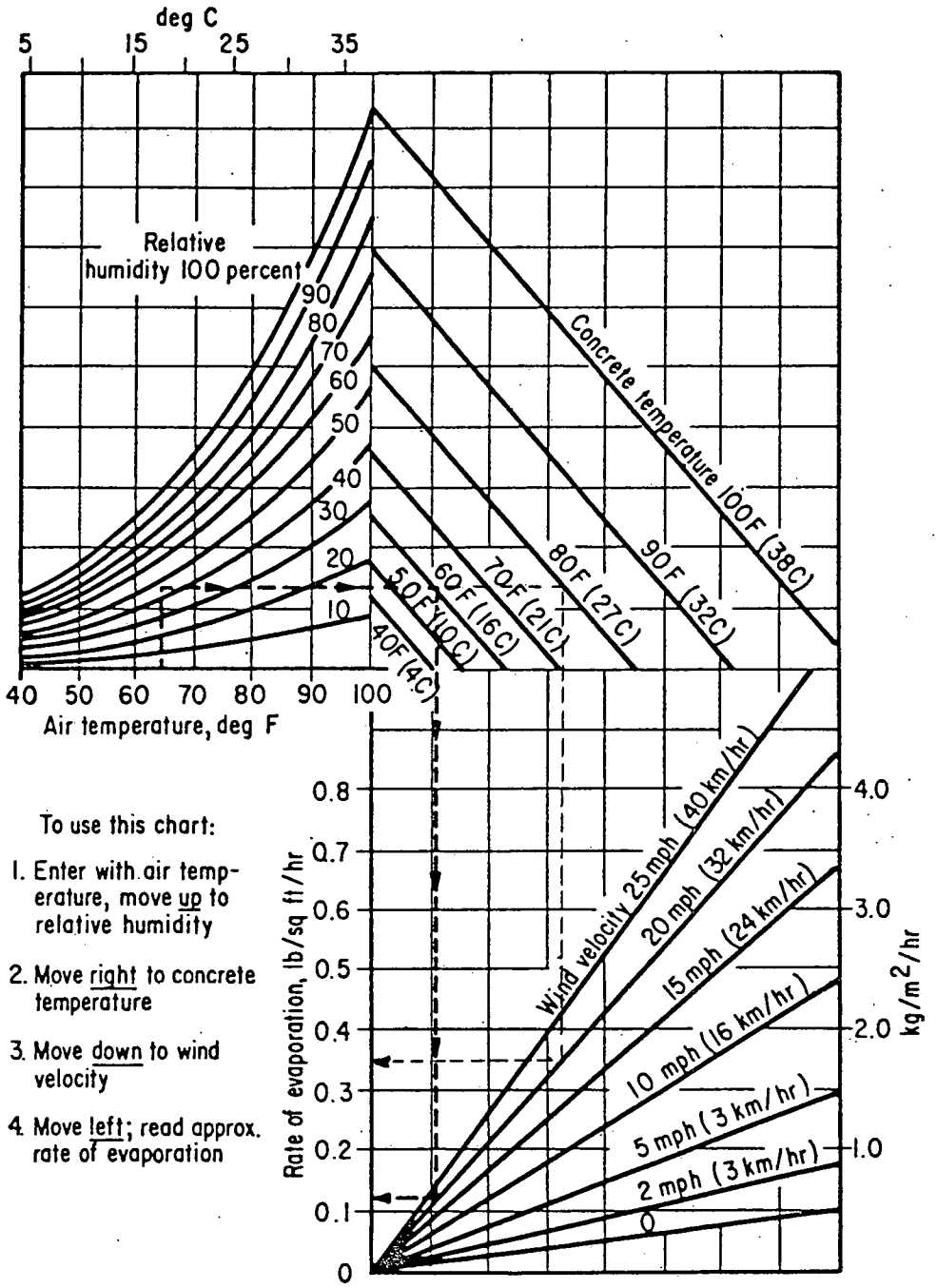


Figure 7.4.-- Effect of concrete and air temperatures, relative humidity, and wind velocity on the rate of evaporation of surface moisture from concrete. This chart provides a graphic method of estimating the loss of surface moisture for various weather conditions.

slump falls outside of the specification range. Except for extremely unusual cases, this is probably unnecessary. The delays which result can only impair quality. During the delay, trucks may wait in line if communications with the batch plant are not prompt. Subsequently, temperatures rise and slumps decrease as shown in Figure 7.5, thus increasing the potential for consolidation problems.

All projects except Project A comply with the ACI 305 with respect to the definition of hot weather conditions which requires that all concrete be delivered at a temperature of no more than 80°F for all placements. This exceeds the recommended 70° limit established in ACI 301, Chapter 14, and ACI 207. Based on field acquired information, it appears that for the concrete which was placed above 70°, no unacceptable cracks occurred. Other projects establish upper limits of 85-90° for nonmass concrete and 65-70° for mass concrete. The recognition that the necessity to control the temperature is a function of the size of the placement is carried further by Project H, as shown in Table 7.6.

One particular project has experienced a number of difficulties in defining hot weather requirements, and it is worthwhile to briefly trace how their specification has evolved to its present state. A brief summary is given below of several of the key features of the hot weather requirements.

1. Revision 0, dated 7-73
   a. Temperature limits are established as 70° for mass concrete and 90° for nonmass concrete. Mass concrete is defined as any member whose least dimension exceeds 2 1/2 feet.
   b. All concrete should be placed at a temperature as near to 50° as possible.

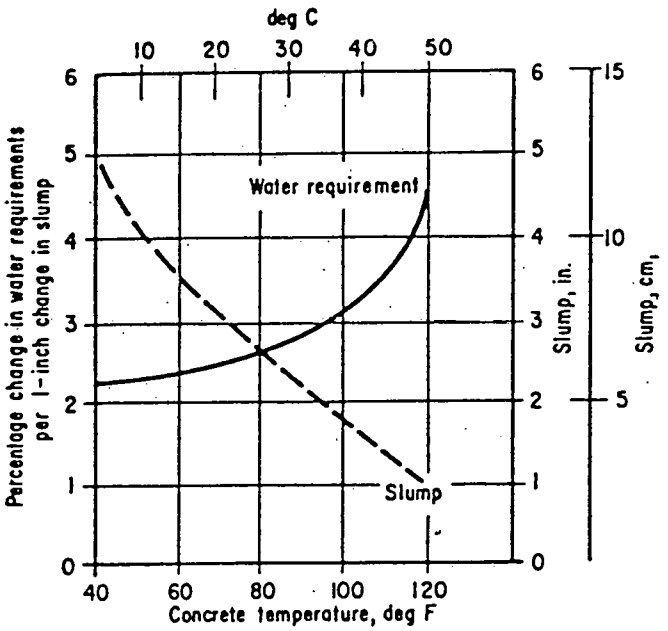


Fig. 7.5 — Effect of concrete temperature on slump and on water required to change slump. Cement content: 517 lb per cu yd (307 kg/m³); 4½ ± ½ percent air; maximum size of aggregate, 1½ in. (3.8 cm); average of data for Types I and II cements.

c. To control temperatures, the moisture content of sand should be limited to 5% whenever 100% ice is necessary.

2. Revision 2, dated 2-74

   a. No change

   b. Deleted

   c. Deleted

3. Revision 4, dated 9-75

   a. The temperature requirements are modified such that for mixes containing 85% cement and 15% fly ash, the temperature limits are 85° and 70° for nonmass and mass, respectively. For mixes containing 100° cement these limits are 75° and 60°.

   c. The 5% moisture provision which was deleted in revision 2 is added back.

   d. A new provision is added to state that members whose least dimension exceeds 6 feet should be placed as near as 65° as possible.

4. Revision 13, dated 3-77

   a. The temperature requirements are modified such that for all mass concrete the upper temperature limit is 75° and 85° for all non mass concrete. Furthermore, mass concrete is redefined as those members whose least dimension exceeds 3 feet.

   c. No change

   d. No change

The changes to the specifications indicate that there have been problems in establishing realistic temperature limits and/or satisfying these limits during actual production. Early in the project it was recognized that it was very costly to lower the concrete temperature to 50°. In the geographical region where the project is located, this would probably require refrigeration of aggregates, and the provision was subsequently deleted. Other approaches have been used to

cool the temperature. Among these is the necessity to limit the moisture content in the sand to 5%. It is questionable whether or not this provision would contribute significantly to lowering the temperature of the concrete. As pointed out in ACI 305, mixing water has the greatest effect per unit weight on the temperature of concrete of any of the ingredients. While it is recognized that reducing surface moisture would permit the use of more ice, it is not clear how this moisture would be controlled. It is not known why this provision was deleted on the second revision and reinstated on the fourth.

It should also be noted that there have been changes in the temperature limits as well as a redefinition of mass concrete. Changes of this nature are viewed as reactionary changes designed to alleviate field problems which were not anticipated. Problems of this nature are a common occurrence on the nine projects studied and cost an undetermined amount of money in terms of nonconformance reports and specification revisions. It would be unfair to say that the type of problem mentioned above was only found on one project. With few exceptions, these types of problems occur at all projects.

A number of measures are available to minimize the effect of hot weather. As has been mentioned, all projects use ice as a replacement for water, and in most cases 100% substitution is permissible. Projects E and G place concrete during the evening shift to take advantage of cooling temperatures. It is also advantageous to recognize that concrete placed in parts of the foundation are not as severely affected by ambient temperatures as other placements since the subgrade provides certain cooling or insulating properties. Recognizing this, Project F considers isolated footings, pedestals, and other shapes and structural backfill as non massive placements.

In light of the problems stated above, it would seem prudent to provide the

maximum flexibility in the specification by establishing placement temperatures that reflect the need for controlling shrinkage cracks. This, of course, is dependent on the individual character of each placement. The identification of fill concrete, isolated pedestals, etc. is certainly a step in this direction. Project E is the only project where each placement is analyzed to determine the required placing temperature, and it would appear that this approach would solve many of the problems mentioned previously.

SUMMARY

Presented in this chapter were a number of aspects which are not related specifically to preplacement, placement, or post placement activities. These aspects were a) Project Control Systems, b) Mass Concrete, c) Attributes of Fresh Concrete, and d) Cold and Hot Weather Concreting. These aspects are summarized below.

The Project Control System for each project was discussed. The primary emphasis was placed on the involvement of Quality Control in the preplanning phase as applied to the preparation of detailed work plans or construction plans for individual concrete placements. On a number of projects there was no indication that Quality Control was involved in the review or approval of detailed work plans, and thus it was theorized that the preplanning phase fell outside of the scope of the Quality Assurance Program for these projects. On several other projects, however, it was pointed out that QC was very actively involved in preplanning. These activities included reviewing documents for correctness and completeness and checking for open NCRs affecting the work. While one would anticipate improved quality with greater QC involvement, it was illustrated with two examples where such systems had not functioned as intended. The hypothesis was presented that increased involvement of QC beyond a certain intensity probably does not improve quality and in fact may have directly opposite effects.

Mass concrete was discussed with a major emphasis being placed on how mass placements were defined. It was pointed out that ACI 301 defines mass concrete as any member whose least dimension exceeds 2 1/2 feet; however many in the industry feel that ACI 301 does not apply to nuclear construction since the provision results from experiences gained on large gravity dam projects. Placements on such projects are usually orderly and members are not normally heavily reinforced. Since nuclear power plant construction is characterized

by complex heavily reinforced placements, the applicability of the Code is questioned. Eight out of nine projects use a critical dimension to define mass placements although the critical size varies from 30 to 48 inches. Occasionally exceptions will be made for fill concrete and isolated footings. One project evaluates each placement to determine if the heat of hydration will cause a problem, and, if so, a reduced concrete temperature will be required. It was pointed out that this procedure is recommended by ACI 349.

The attributes of fresh concrete were discussed. These include slump, temperature and air content. With regard to slump, the ACI 301 provisions requiring the computation of a running average were highlighted. It was shown that placements could get off to a bad start since the Code approach encouraged the production of low slump initial batches. An example was presented whereby initial batches of good quality concrete which fell between the maximum average limit and the rejection limit were wasted. One alternative was shown which utilized an inadvertency margin without the computation of a running average. A second alternative used the inadvertency margin and running average; however, up to 10% of the concrete sampled having slump measurements exceeding the rejection limit could be used.

The temperature requirements for each project were presented. It was indicated that there were some difficulties where ambient temperatures required a change in the maximim or minimum temperature limits. At these discontinuities in temperature requirements an inadvartency margin would minimize the wasting of concrete. Also discussed was the fact that on one project, when the ambient temperature fell between 30° and 40°F, there was only a 10° range within which to batch, deliver and place the concrete. This specification provision had led to the wasting of a significant amount of concrete which fell outside of the temperature limits.

The methods used to define hot and cold weather conditions on each project were presented. A number of projects reported some confusion and dissatisfaction with the ACI 306 provisions and in a few cases, studies have been conducted regarding when to initiate cold weather practices. The results of these studies were briefly discussed. Regarding hot weather practices, the specification revisions on one project were traced to illustrate the apparent confusion over the perceived requirements for hot weather concreting. It was suggested that the project engineering staff was searching for a set of workable provisions which provided a sufficient degree of flexibility.

REFERENCES

7.1 Tuthill, L. H., "Games People Play With Concrete," ACI Journal, Proceedings V. 73, No. 12, December 1976, pp. 671-678.

CHAPTER 8

PREPLACEMENT ACTIVITIES

INTRODUCTION

This chapter will discuss those activities which can collectively be defined as preplacement activities. The discussion will concentrate on four major areas, namely, (1) formwork, (2) reinforcement, (3) cadwelding, and (4) delivery systems. These topics will be preceded by an overview of the involvement of Quality Control in preplacement activities. In order to place each project in its proper perspective, Table 8.1 presents the amount of structural concrete required on each project and the percentage of concrete placed at the time the project was visited.

QUALITY CONTROL INVOLVEMENT

Quality Control Inspectors are generally involved in preplacement activities on a surveillance or monitoring basis and on a limited inspection basis. This involvement on each of the nine projects will be discussed below, and in doing so, reference will be made to concrete preplacement inspection documents which are presented in Appendix 8.A. Included for each project are preplacement checkout sheets and inspection attribute checklists. One exception is Project A. It should be recalled that Project A was an early vintage plant, and it does not appear that Quality Control was extensively involved in preplacement activities, except for the final inspection. The concrete checkout sheet is included in Appendix 8.A. This document serves as a pour card which was discussed in the previous chapter and must be signed by the Quality Control Inspector before the placement can commence. In performing the final inspection, work is verified against the Quality Control Procedure, however no checklist is available and there are no other documentation requirements. If the hypothesis is true that QC had limited preplacement duties, on Project A, then it would

Table 8.1.--Structural Concrete Placement Data

Project	Total Concrete Required (C.Y.)	Concrete Placed To Date (C.Y.)	Percent Placed (%)
A	527,853	527,853	100
B	170,000	170,000	100
C	400,000	217,350	54
D	235,300	165,000	70
E	475,000	348,466	73
F	145,018	31,186	22
G	376,612	307,856	82
H	450,000	128,900	29
I	164,000	64,914	40

partially explain why very few problems with formwork tolerances, rebar tolerances, etc. were identified or formally reported as nonconforming items on this project.

Project B, on the other hand, has a very detailed checklist which is shown in Appendix 8.A. The list is developed from the project specifications and the Quality Control Procedure. This inspection checklist is used during the final preplacement inspection. When all items have been checked to the satisfaction of the inspector, the Concrete Status Report is signed which denotes that the placement is ready to be started. The Concrete Status Report serves as the pour card.

The above two examples represent a single phase approach to quality control inspection. This phase is final acceptance, and even though it is recognized that Quality Control is probably involved to some extent with in-process surveillance, there are no documentation requirements. The Project C documents indicate that this project is in sharp contrast to Projects A and B, as well as several other projects which will be discussed later. Project C represents a two-phase approach where in-process surveillance activities, in addition to final acceptance functions, must be documented. The Quality Control Inspection Record (QCIR) is based on the QC Instruction and lists the required inspection activities. Also included in Appendix 8.A are Field Inspection Reports and In-Process Rework Notices which are generated as part of the in-process surveillance program. There is also a prerequisite section to the QC Inspection Report which requires the inspector to verify that the inspection and reference criteria has been reviewed and that there are no open NCR's affecting the work. Placing procedures and contingency plans, as denoted in item 3.6 of the QCIR, must be reviewed.

An integral part of the quality control system is the utilization of the Field Inspection Report and the In-Process Rework Notice. The Field Inspection Reports are used to define and document inspections not covered by QCI's/QCIR's.

The In-Process Rework Notices are transmitted to field engineering and are written to expedite and assure correction of major omissions or improper installations. They are not usually written for minor items but may include them when the Rework Notice is written as a "final punchlist" during final checkout of forms, rebar and embeds. Clearly some type of mechanism must exist on all projects whereby this type of information can be disseminated, between field engineering and quality control; however, it would appear that problems of a minor nature could be communicated verbally to the construction supervisor or field engineer. This is, in fact, done on a number of the projects studied. No other project has such a formalized system as Project C, and the most obvious disadvantage of this approach is the amount of paperwork generated. The inspection reports are generated for all Q-listed placements. Rework Notices are generated whenever deficiencies are identified regardless of the placement location.

The QCIR is used for discipline sign-offs to assure that all QC inspections have been completed and should be viewed in comparison with the other projects. As can be seen in item 3.4, the signatures of the structural, electrical, instrumentation, mechanical and piping Quality Control Engineers are required before the preplacement inspection is complete. On a number of other projects only one quality control signature is necessary; however, coordination is still necessary.

Project D is similar to Project C, and therefore will not be discussed.

The Project E approach to quality control and documentation is entirely opposite that of Project C. The field engineer does all in-process surveillance as part of his responsibilities for coordinating the construction effort. As the activities listed on the Concrete Pour Card are satisfactorily completed, the appropriate line is signed by the field engineer who verifies that the item is satisfactory from both an engineering and a quality standpoint. The final inspection is conducted by the shift engineer and a Quality Control Inspector representing the Materials Testing Unit (MTU). The MTU Representative

checks those items listed on the back of the Concrete Pour Card. This inspection is done in accordance with a Quality Control Procedure. As an additional requirement, the revision number of the QCP used must be entered on the Inspector's Record. This appears to be a very efficient system which takes full advantage of the delegation of authority and responsibility. The signature of the shift engineer and the materials lab representative have as much meaning as the multiple signatures on Projects C, D, and G since it all reduces to the level of confidence and trust placed in the individual performing the work.

Project F also utilizes a two-phase approach of in-process surveillance and final inspection. The Quality Control Inspection Report shown in Appendix 8. A is used for both phases of verification. This form is used as a convenient mechanism for transmitting information from QC to Construction. The contractor is notified verbally of the condition i during the course of in-process surveillance, the QC Inspector identifies unsatisfactory work being done. If the work can be corrected on the spot, then no further action is taken by QC. If the item cannot be corrected immediately, the Inspection Report is completed, with the attribute in question being identified as unsatisfactory, and forwarded to the contractor for disposition. The bottom part of the form is used by the contractor to indicate what corrective actions will be taken. If the item cannot be corrected, then a nonconformance report (N & D) is initiated.

During the final inspection, the same form is utilized, however it must be interfaced with the cadwelding and welding reports which are prepared by other inspectors. When all attributes are satisfactorily completed, the concrete pour card is signed, and the placement is started. The pour card appears to require a large number of signatures. It is not at all clear why this document must be signed by the field engineering, quality control, contractor supervision and again by quality control. It appears that the concept of delegating

responsibilities has not been fully utilized, and on several pour cards observed, the Quality Control Inspector signed in four different places since he also verified the forms and reinforcing. Thus the question should be raised: if the QC Inspector can sign for the QC Engineer, they why is the QC Engineer required to sign in the first place? It should be recognized that the delegation of responsibility and authority is fundamental to good and efficient management, and the opportunities afforded to take advantage of this principle should be readily taken. In this regard, the QC Inspection Report appears to be an efficient and flexible mechanism for communicating with construction as well as documenting results since the last column for SQC signatures is not being used.

Project G utilizes the Work Plan and Inspection Report which was discussed in detail in the previous chapter. In that discussion it was pointed out that this document did provide a means of communication between QC and Construction. The involvement of Quality Control is clearly evident in both the preliminary planning and in-process inspection phases. It should be noted that this Work Plan and Inspection Record must be reviewed and signed by Quality Control Engineering. This document takes the place of the QC Inspection Report and the Concrete Pour Card used on Project F.

To assist the QC Inspector, the Concrete Preplacement Inspection Checklist is provided in the applicable QC Instruction. This is similar to the checklist used on Project B except that the inspector must initial each line item rather than indicating acceptance with a check. It should also be noted that under reinforcing steel, there are appropriate places for signifying preliminary and final acceptance.

The preplacement checklists and inspection reports for three contractors on Project H are included in Appendix 8.A. For both Contractors H1 and H2, a single phase approach is being used whereby the primary involvement of Quality

Control is in the final acceptance phase. These documents are similar in nature to the checklists used on Projects B, C, D, and G except that inspection attributes have been grouped into fewer, broader categories.

The checklist used by Contractor H3 more closely resembles the Project B checklist since it lists many attributes which must be individually documented. Of special interest is the Quality Control Administrative Inspection Plan which indicates the level of inspection required during the final acceptance inspection. This is, of course, a very formalized approach to quality inspection. It was not perceived as necessary by Contractors H1 and H2.

Project I is similar to Project F in that attributes can be denoted as satisfactory and unsatisfactory. The attribute list is similar to the one used on Project B.

As can be seen, the major difference between projects is the method of recording objective evidence or documentation, rather then the items inspected. One approach is to provide the inspector with a detailed attribute list, and these attributes are initialled as the specific item is satisfactorily completed. Detailed attribute lists are provided on Projects B, G, H3, and I. Upon completion of all items, a separate concrete inspection report may be signed When all items on the inspection report are completed, the pour card discussed in Chapter 7, which represents the final preplacement acceptance, is signed. One obvious drawback is the volume of paper work generated, and as was discussed in Chapter 3, many sites have experienced paper management problems. This problem can be partially relieved by combining the attribute list and the inspection report into one form, as is the case with Projects C, D, F, H1 and H2. The size of the attribute list can also be reduced by establishing major categories which include a number of individual attributes. In such cases, more specific guidance must be provided in the quality control

procedure. This approach is exemplified on Projects E, H1, H2 and to some extent Projects C and D.

Although the attributes checked on each project are generally the same, there is considerable difference in the degree of guidance and the verification requirements given to the QC Inspector. This ranges from very limited documentation, as is the case with Project E, to very detailed instructions and attribute lists such as is done on Projects B and H3. The basic philosophy behind this latter approach seems to be that the inspector is unskilled or at best semiskilled and, of course, unmotivated and thus is not trusted to do a totally adequate job of inspection without the aid of a very detailed set of instructions. This approach works quite well when there is a minimal level of confidence in the capabilities of the inspection staff, but could have opposite effects on a highly trained staff. For skilled inspectors, a detailed checklist approach could stifle worker (i.e., inspector) productivity and motivation. In such cases, a thorough set of guidelines could be presented in the QC procedures with limited documentation requirements. This approach has been used effectively on Project E where it should be recalled that the field engineer performed quality control functions. On this project, the inspection staff is highly motivated and skilled and thus does not need to be given detailed instructions.

Another point should also be discussed regarding the mechanics of completing the preplacement inspection. A number of projects, including F, G, and H, require the inspector to sign or initial each line item. This requirement may be based on the following reasoning. The philosophy here is twofold. First, by requiring individual signatures, the inspector, in theory, feels accountable for each attribute, and hence the thoroughness and completeness of his work will be retained at a high level. In the initial phases of the job, this hypothesis may be true, but it seems unlikely that there would be more than just a short-term effect. Secondly, the multiple signature approach may be viewed as a means of guaranteeing

or documenting that all work was performed in accordance with the plans and specifications. Such is not necessarily the case since items could be overlooked and the documentation requirements completed at some later time. The interpretation of the signature is viewed by the authors as being directly related to the level of confidence and trust that is placed in the inspector, and in this regard the lone signature on Project E may mean more than the twenty-five identical signatures on Project F or G. Quality and thoroughness in inspection results from competent and motivated individuals. If the individual is poorly trained and unmotivated his work cannot be trusted, and requiring many signatures will not make it so. This fact appears to have been overlooked in the nuclear construction industry.

FORMWORK

Tolerances

One of the most important aspects of formwork, from the quality standpoint, is allowable tolerances. The principal standards which provide guidance regarding formwork tolerances are ACI 301, "Specifications for Structural Concrete Buildings", and ACI 347, "Recommended Practice for Concrete Formwork". The tolerances for building construction, as given in ACI 301, are presented in Table 8.2. ACI 347 agrees with ACI 301 for buildings; however, it does provide a certain degree of flexibility for special structures such as canal linings, bridges, mass structures and tunnel linings. The recommended tolerances for mass structures are also presented in Table 8.2, and it can be seen that for some elements, the tolerances are more restrictive and for others they are less restrictive.

Most projects comply with either ACI 301 or 347, except for special structures such as the dry well wall, etc. Projects A, B, D, and H reference ACI 301. Projects C, F, and I reference 347. For those referencing ACI 301,

Table 8.2.--Formwork Tolerances[a]

	ACI 301 & 347 Building Structures	Mass Structures	Project		
			D[b]	E	G
Vertical Surfaces and Control Joint Grooves					
Variation from plumb: in 10 feet	1/4	1/2	1/2	1/4	1/2
in 20 feet	1/4	3/4	1/2	3/8	1/2
40 ft. or more	1/2	1 1/4	1	1/2	1/2
but not more than	1		1 1/2	1	1
Horizontal Surfaces and Horizontal Grooves					
Variation from level: in 10 feet	1/4	1/4	1/2	1/4	1/2
(slab soffits, ceilings, and beam soffits) in 20 feet	3/8		5/8	3/8	5/8
40 ft. or more	3/4	1/2	1	1/2	1
(exposed lintels, sills, and horizontal grooves) in 20 feet	1/4	1/4	3/8	3/8	3/8
40 ft. or more	1/2	1/2	1	1/2	1
Position of Walls, Columns and Partitions					
Variation in location: in 20 feet	1/2	1/2	1/2	1/2	1/2
40 ft. or more	1	3/4	1	1	1
Buried Construction: in 20 feet				1	
40 ft. or more				2	
Floor and Wall Openings and Sleeves					
Variation in size: plus	1/4		1/2	1/4[c]	1/2
minus	1/4		1/4	1/4	1/4
Variation in location: plus	1/4		1/2	1/4	1/2
minus	1/4		1/4	1/4	1/2

(continued)

Table 8.2. (continued)

Dimension of Members						
ariation in cross-section of columns, beams; thickness of walls, slabs:	plus	1/2	1/2	1/2	1/2	1
	minus	1/4	1/4	1/4	1/4	1/4
If dimension exceeds two feet:	plus				1	
	minus				1/2	
Footings, Pits and Sumps						
Variation from dimensions:	plus	2	2	2	2	2
	minus	1/2	1/2	1/2	1/2	1/2
isplacement or eccentricity:	(%)	2[d]	2[d]	2[d]	2[d]	2[d]
Reduction in thickness:	(%)	5	5	5	5	5

[a]Dimensions in inches unless otherwise noted

[b]Proposed revision to project specifications

[c]But not to exceed 1/2 of 1 percent of opening dimension in direction of misplacement

[d]But not more than 2 inches

it does appear that some flexibility has been lost since these projects do not use the increased tolerances for mass structures. Project D references ACI 301 however a proposed revision would increase the tolerances to essentially those of Project G. These values generally double the limiting values of ACI 301. Project E does not reference ACI for form tolerances, but rather establishes tolerances based upon past experiences. These tolerances, along with those of Projects D and G, are presented in Table 8.2. The major difference between ACI and the specification requirements for these projects is the relaxation of tolerances on vertical and horizontal surfaces and grooves. There seems to be some justification for this which will be discussed in detail below. In a structure as complex as a nuclear power plant, flexibility in the specifications is essential if the quality control program is expected to operate in a cost effective manner. This flexibility appears to have been provided at Project E. The tolerances for walls, columns, and partitions have been doubled if it is buried construction. Also doubled are the allowable deviation for member dimensions when the dimension exceeds two feet. These provisions can, of course, be overridden by providing for different tolerances on the design drawings. Project E has not experienced any difficulties with these tolerances although it should be pointed out that to achieve these tolerances, considerable care and pre-planning is still essential.

Practically all projects have had some degree of difficulty meeting the ACI 347 tolerance requirements. Very few nonconformances (Project D--sixteen NCR's on formwork tolerances; Project F--five; Project H--less than ten) have been written, however this does not reflect the difficulty in meeting these requirements. Considerable construction manhours are expended in order to meet the precision specified by ACI. Those provisions which require the greatest effort are: (1) variation from plumbness of 1/4 inch per ten feet,

(2) variation in location of walls, columns, and partitions, and (3) variation in the cross-sectional dimension of columns and beams and thickness of walls and slabs. The variations from ACI 301 and 347 found in the specifications for Project G reflect the fact that a number of difficulties were encountered.

The need for communication and understanding between field engineering and the design engineer should be discussed. The formwork tolerances for Project G were not relaxed until approximately 75% of the concrete had already been placed. On Project D, approximately 50% of the concrete work is complete and the modifications have yet to be approved. Clearly something is wrong. Perhaps the design engineer has failed to anticipate these difficulties. Surely these problems have existed on previous jobs, and it could be that the management system has failed because it does not facilitate learning from past experiences. Perhaps the Construction Engineer has failed to adequately communicate field problems in a clear concise manner back to the design office. Conceivably, the communication system does not permit the sharing of problems and ideas. In some cases the owner may refuse to permit the relaxation of tolerance limits. Finally, the situation may be such that the ACI tolerances are necessary in order to achieve the degree of quality desired. Whatever the situation, it appears that much more thought should be given to determining appropriate formwork tolerance requirements. It seems realistic to expect that tolerances should differ depending upon the type and location of the placement. Perhaps these should be given on the design drawings for each placement.

Several projects resolve difficulties with formwork tolerances by requesting engineering design changes on a case-by-case basis. The frequency of occurrence, however, would tend to indicate that this practice is in reality merely a means of circumventing the specifications. The fact that many of these requests for changes do not result in specification changes has been

documented in Chapter 4 . The positive and negative aspects of this approach were also discussed. Where this mechanism is used with some degree of regularity, the implication would be that the specifications do not provide a sufficient degree of flexibility since the number of these instances is usually large.

There does appear to be some justification for relaxing the limits given in ACI 301 and 347. The Code establishes minimum requirements for ordinary commercial reinforced concrete structures. ACI Committee 318 has stated that for special structures, the provisions of the ACI Code shall govern where applicable. There are many within the industry that feel that nuclear power plants qualify as special structures and are only governed by applicable provisions of the Code rather than the Code in its entirety.

Considering the high degree of control over adverse variations in material strength and workmanship which is characteristic of the nuclear construction industry, it does appear that a relaxation of the tolerances, as has been done on Projects D, E, and G, will still result in an acceptable level of quality and strength as compared to the theoretical. In substantiating their position on relaxed tolerances, one project solicited the expertise of a well-known concrete expert and consultant, Mr. Lewis H. Tuthill. In his report which concurred with the relaxed tolerances, he presented the following comments:

> "Appropriate tolerances are often debated. Obviously the law of diminishing returns of refinements beyond a practical value or necessity applies."
>
> "Accordingly, tolerance values should be judged on their merit or necessity in each case. ACI 347 and ACI 301 are well considered guides but should not be mandatory if wider tolerances are adequate or narrower tolerances really worthwhile. It should be noted that ACI/ASME, Section III, Division 2 (ACI 359), CC4342, says, 'The tolerances for the placement of reinforcement shall be specified in the Construction Specifications'."

ACI 347 points out that in specifying tolerances, it should be remembered

that more exacting tolerances than needed may increase construction costs. Certainly there are locations within the nuclear structure where tolerances must be carefully controlled, however there are also many places where the tolerances are not as critical. In view of the fact that there are different levels of criticalness within the plant, perhaps each placement should be evaluated individually and the most stringent tolerances necessary for that placement recorded on the plans.

Another problem that has occurred on several projects is that of form bulging. This is of course a problem of insuring that the placing rate is compatable with the form design criteria, such as the spacing of walers and studs, etc. The reaction and subsequent solution to this problem on Project C is presented below and clearly illustrates how concerns over quality have, on occasion, resulted in seemingly ridiculous requirements.

Approximately six months after the construction permit was issued, the formwork for one particular wall pour bulged during the placement. (The walers indicated bent flanges at she-bolt locations). This was the first time that form problems had been experienced. The problem does not appear to have been serious and as stated in the project correspondence log, "Forms might have deflected but this is not obvious." Unfortunately the measures taken to prevent reoccurrence do not appear to be commensurate with the significance of the situation. The area formwork engineers are now required to inspect completed formwork of all wall placements and determine the capacity in pounds per square foot. The capacity is then converted into liquid head for normal weight concrete, and the placement rate is controlled so as not to exceed this allowable liquid head limit. The Quality Control Inspector determines the liquid head by using a 3/4" diameter rod which is pushed into the fresh concrete without mechanical assistance. Data for each placement is recorded

on Exhibit 8.1 to include liquid head permitted, rate of placement, and actual liquid head measurements. This approach is unprecedented since the placing rate, and hence form buldging, can be easily controlled by field engineering or quality control, and in any case, the forms should be designed for the maximum feasible placing rate (which is a function of the number and size of pumps and vibrators, etc). In the opinion of the authors, the project staff has reacted unnecessarily to what appears to be a minor problem by requiring the measurement and documentation of liquid head on all placements.

Cleanliness

Very little is said in ACI 347 regarding cleanliness of forms except that the forms should be thoroughly cleaned of all dirt, mortar, and foreign matter and coated with a release agent. Each project references ACI 347 and states that forms should be designed and engineered accordingly. The only other reference to form cleanliness is found in the project quality control procedures where phrases such as "properly cleaned" or "cleaned as completely as possible" are often used. To facilitate cleaning, inspection, and placement, access openings are permitted in columns and walls. The interpretation of cleanliness is a qualitative attribute and therefore is a matter of engineering judgment on the part of the inspector. In most cases, this responsibility has been administered satisfactorily since most projects have not experienced any difficulties with cleanliness. There have, however, been cases where the interpretation of cleanliness may have resulted in some difficulties.

On Project F, a trend analysis of approximately three hundred Concrete Inspection Reports (see Appendix 8.A) indicated that for the total concrete operation, including preplacement, placement, and post placement, approximately 230 out of a total of 5000 attributes were listed as unsatisfactory. (It should be noted from table 8.1, that approximately 31,000 cubic yards of

Exhibit 8.1.--Liquid Head Record, Project C

PLACEMENT #_____ DATE_____

DESCP. of FORMWORK_____

_____

_____

OVERALL DIMENSIONS: Length_____ Width_____ Thickness_____

LIQUID HEAD PERMITTED_____ DESIGNED CONC. QTY.:_____CU. YDS

PLACEMENT TIME: Start_____ Complete_____ Duration_____

NOTES: All readings of liquid head shall be recorded. Location shall be noted if varying head is observed. Direction and depth of each pass such as '18" north to south" etc. shall be noted. Any stoppage due to equipment or other reasons shall be noted and it's time. Include in description, type of heating, enclosure, if used.

TIME	DESCRIPTION	PLACEMENT HEIGHT	LIQUID HEAD READINGS				NOTES: Depth & Direction of passes. Delays, unusual conditions, etc.
			1	2	3	4	
	Start Placement	0'-0"					
	Liquid Head						

concrete have been placed to date). Table 8.3 summarizes those attributes that were listed as unsatisfactory more than three times and, as can be seen, formwork cleanliness was unsatisfacotry a total of sixty times. These unsatisfactory attributes were identified when the placement was supposedly ready for final acceptance and therefore represent potential problems that were corrected prior to the placement. The fact that the formwork was not clean to a satisfactory degree may not indicate that a problem exists since it is not unlikely the craft supervisors frequently test the system to determine what is acceptable to the inspector.

One case can be illustrated where the requirements for cleanliness were carried to the extreme. On Projects C and D, extensive use is being made of corregated metal decking, called Q-decking, as a bottom support for slab placements. The form cleanliness provisions of ACI 347 were interpreted to such a degree that an extensive vacuuming process utilizing a high pressure water jet had to be used to clean the debris from the fluted portions of the decking. Following this, a workman used a long rod with a magnet attached to the end to retrieve any nails or tie wire that may have been left behind. Needless to say, the cleaning costs on these two projects were very high. Subsequently, a study was initiated to determine the effect of debris on bond and structural integrity of the slab. The results indicated that the effect was negligible and the QC interpretation has been modified accordingly. On Project C the technical specifications have been modified as follows:

> "Tops of the Q-decking ridges to receive concrete shall be cleaned thoroughly to remove organic material such as paper, wood pieces, or sawdust. Scattered pieces of tie wire or nails, as determined by the Project Field Engineer, may be left on the top of Q-decking ridges to receive concrete."
>
> "The fluted portions of Q-decking to receive concrete may contain inorganic debris such as tie wire, nails, etc. Up to 1/2 inch of organic debris such as paper, wood pieces, sawdust, etc. may be present in the flutes of Q-decking to receive concrete. The level

Table 8.3.--Summary of Unsatisfactory Formwork Attributes, Project F[a]

Description of Attributes	Number of Occurrences[b]
Approved Founding Elevation	8
Orientation of Formwork	3
Location and Preparation of Construction Joints	3
Number and Location of Embedments	11
Cleanliness of Placement	60

[a]Results from trend analysis of 310 concrete inspection reports.

[b]A total of 230 out of 5000 attributes were listed as unsatisfactory.

of organic debris may be increased to 50 percent of the flute depth when approved by the Project Field Engineer."

This provision goes a long way towards clarifying an acceptable degree of cleanliness, but it still represents the substitution of a quantitative value for a qualitative attribute. Conceivably, the quality control inspector could be required to measure the depth of debris before each pour, however, it is not known if this has in fact occurred. Nevertheless, it does represent a workable, realistic solution.

Quality Control Activities

Initially, it appears that the inspection effort of quality control as it pertains to formwork, reinforcing steel, embedments, etc., varies considerably. For example, Project B inspects sixteen individual formwork items whereas Projects D and E inspect only two items. To fully understand what is included in each line item, however, it is necessary to study the related quality control procedures. A review of the QC procedures indicates that, in general, the same attributes are checked on each project. The primary difference is in the method of documenting the results. A comparison of the procedures and attribute lists also indicates that there are four major areas that are inspected on each project (excluding Project A). These are: (1) surface preparation and coating, (2) cleanliness, (3) joint tightness, and (4) alignment, grade, and tolerances.

Other areas are inspected less uniformly. Structural adequacy is one characteristic of quality which is viewed in a different perspective on each project and, of course, represents a different degree of reaction to perceived quality requirements. Such items as bracing, shoring, waler size and spacing, and wall tie spacing are evaluated as specific attributes on Projects B, H, and I and to a lesser degree on Projects C, D, and E. Projects F and G, however, are not involved in checking the structural adequacy of forms except in a

superficial manner. Inspection of formwork for structural adequacy on a very limited scope basis does appear to be prudent, but any evaluation on a more extensive scale would probably overlap with the responsibilities of field engineering which usually designs and checks all formwork. Certainly the inclusion of specific items on an attribute list enhances the potential for redundancy in inspection and is not viewed as contributing measurably to quality. The installation of chamfer strips is also included as a specific attribute to be inspected on Projects B, C, D, G, and I.

REINFORCEMENT

Storage and Control

The storage and control of reinforcement is an important aspect of the Quality Assurance Program and must satisfy ANSI N45.2.2 for receipt inspection and storage and N45.2.5 for in-process tests. All projects have a well-established program; however three distinct problem areas have been identified. These are concerned with the user tests, rust problems during storage, and control of nonconforming or rejected reinforcement. Each aspect will be discussed below.

On one particular project, samples representing 2800 tons of reinforcing steel were subjected to a tensile and/or yield strength in-process test. The test results indicated that sixteen out of approximately one hundred heats of the reinforcing bar failed the tensile and/or yield strength tests. Since mill test reports had originally indicated that all of the rebar was adequate, a new test procedure was developed to retest the sixteen heats in which the original deficiencies had been identified. The retest procedure was as follows:

> "If a test specimen fails to meet the tensile requirements of ASTM A615-72, two additional specimens from the same production rolling and heat and of the same bar size shall be tested. Should both of these specimens

> meet the tensile requirements of A614-72, all those bars from the same production rolling of the same size and heat as represented by the specimens are acceptable. Should either of the two specimens fail to meet the tensile requirements of A615-72, all bars from the production roll of the size and heat from which the specimens were obtained shall be rejected."

The results of the retest based on the revised acceptance criterion indicated that only eleven heats failed the tests. These were subsequently rejected and returned to the supplier.

This approach to material acceptance has no statistical merit or justification. At first glance it would appear that acceptance is based upon multiple sampling theory, however, this is not the case since two samples would not be tested in the event the first bar passed the test. If the first bar fails the test but the two retests are acceptable, then the heat is considered as complying with the specification. This would imply that acceptable results on two out of three tests would be sufficient grounds to accept the lot. If this is in fact the appropriate acceptance criterion, then problems arise when the first test is acceptable. Suppose that three samples are taken and that only one of these is acceptable. If the acceptable sample is tested first, then the two unacceptable samples will never be tested, and the lot will subsequently be accepted when it is in reality unacceptable. The concept of the retests does not have any statistical basis and appears to be just a convenient means of circumventing the specifications.

Long-term storage of reinforcing steel can cause problems when the cleanliness attribute is applied. Both ACI 301 and 318 specify that reinforcement should be free of mud, oil, or other materials which may adversely affect bond. Reinforcement with rust or mill scale is acceptable without cleaning or brushing provided weights and dimensions of a cleaned sample are not less than required by ASTM. It is further stated in the commentary to ACI 318 that research has shown that a normal amount of rust actually increases bond, and

normal rough handling generally removes rust which is loose enough to injure bond.

A problem of interpretation of ACI resulted on Project F. Shear assemblies which had been stored on site for two years had rusted, and construction and Quality Control were unable to agree on whether or not the assemblies had rusted to a degree that adversely affected the bond. An extensive testing program was initiated, and the results indicated that there were no detrimental effects.

It seems impractical to eliminate the problem of interpretation by establishing some quantitative value other than ASTM requirements as an acceptance standard. Indeed, this would probably result in the necessity for establishing an entirely new program for qualification and in-process testing. The conservative attitude of quality control does not appear to be justified in this case in light of the information presented in the Commentary to ACI 318. The effect of rust and scale on the bond characteristics of reinforcing bars has been studied previously (8.1). An experimental program was established to provide needed information on bond characteristics of ASTM A 432 bars with a broad range of scale and rust conditions. The principle parameter in the tests was the bar surface condition. It was concluded that the bond characteristics of deformed reinforcing bars with deformations meeting ASTM A305 specifications do not appear to be adversely affected by varying degrees or types of surface rust or mill scale, provided the weight of the bar meets the minimum ASTM requirements. The deformation dimensions appear to govern bond characteristics and the rusted bar should meet the ASTM requirements in this regard. The test data indicated that the current bond requirements of ACI 318 were quite conservative, especially with respect to smaller bars, and that concrete strength appears to control the overall bond behavior to a much greater extent than does the surface condition of the bar.

The problem of rust has also been studied by the Bureau of Reclamation (8.2) and Gilkey et. al. (8.3) and similar results were reported. The latter report states that two-year air rust samples which had a thick coating of rust lost less than 5 percent weight upon cleaning. Unless deliberate action is taken to produce a special surface, it appears that bars would have to rust in water or air for an extraordinarily long period before a cleaned sample of maximum overweight bar would be rejected on the basis of not passing a weight or deformation height test. In addition, it would be impossible to maintain these heavy coatings with normal handling on site, and any removal of this delicate surface would improve bond resistance significantly.

Several projects have implemented specification procedures to address the problem of rust on rebar. These provisions generally involve the description of a method of determining some quantitative number. The Project D specifications are typical and state:

> "Excess amounts of rust, mill scale, dirt, grease, or other foreign substances shall be defined as those which are visually determined to be in excess of 5 percent of the bar surface within any 5 foot segment. Heavy or flaked rust and loose mill scale is defined as that which may be removed by wiping the bar with a gunny sack. Any rust or mill scale remaining after such wiping is acceptable."

In view of the research data discussed above, it appears that the concerns over rust and mill scale on reinforcing steel as exemplified on Project D are unnecessary and should be reevaluated.

Although the control of both conforming and non-conforming items is generally good, one incident should be related since it does represent a management-type problem which could potentially happen elsewhere. On one project, non-conforming No. 18 reinforcing steel was inadvertently issued from the jobsite storage area and was installed in the containment base mat foundation. A contributing factor was that no one department had total responsibility for

the control of reinforcing bars. Quality Control performed receipt inspection, monitored storage, and approved warehouse withdrawal requisitions, which was supposed to assure that nonconforming items would not be issued to construction. The prime responsibility for the receiving, storing, and issuing of all materials remained with the field procurement organization. Thus two groups were sharing responsibilities for the control of reinforcing steel. The issuance of nonconforming rebar was a reportable deficiency under the provisions of 10 CFR 50.55 (e). The corrective action initiated assigned Quality Control the total responsibility for receiving, storing, and issuing of certain critical bulk materials that were identified as difficult to control. These items include reinforcing steel, pipe, and other miscellaneous metals.

From the viewpoint of the authors, the solution to the above problem raises several fundamental questions. It appears that there are now two autonomous groups doing field procurement responsibilities, one for difficult to control items and one for non-difficult to control items. It is also not clear why Quality Control has been assigned the responsibility for handling certain items. Field Procurement should logically have warehouse and document control specialists trained in material receipt and control. This action is viewed as another area where Quality Control has assumed an ever expanding role. It appears from the information available, that the original system did not fail because of incompetency on the part of field procurement services, but rather because the responsibilities were not clearly defined or because they overlapped. Regardless of whether or not the divided responsibility approach is the best, it does represent a solution to an organizational problem. Other projects should be very cognizant of the potential hazards of having organizations and departments sharing duties and responsibilities.

Tolerances

The ACI reinforcement tolerance requirements for fabricating, placing, and cover are generally followed by most of the projects as shown in Table 8.4. The tolerances listed are general, and in a number of special cases, additional guidance is provided. On most of the projects, the tolerances are indicated on the plans.

From the data in Table 8.4, it should be clear that it is necessary to reference both ACI 301 and 318 in order to fully address all tolerance conditions. A blanket endorsement to both documents, however, could lead to problems since there is a disagreement between the two documents regarding the location of top bars in slabs and beams. As can be seen, for thin members ACI 301 tolerances are more restrictive than those of 318. ACI 318 is more restrictive for massive members.

Fabrication tolerances and cover requirements for the various projects generally comply with ACI, however there are several significant deviations for placing tolerances. Project C has doubled the ACI 301 tolerances for clear distances to formed surfaces. On Project H, contractor No. 2 allows a one-inch tolerance on spacing between rebar. Other exceptions to ACI are in the top bars of beams and slabs and the longitudinal location of continuous ends and ends of bars.

One of the difficulties encountered with placing reinforcing steel is the problem with embedments. The Code, except for ACI 301 which allows bars to be moved a maximum of one bar diameter so long as the tolerance requirements are not exceeded, does not address the complexities around embedments. In most cases, the latter provision will govern. In order to deviate from the allowable tolerances, a design deviation request must be initiated. This results in a tremendous amount of paperwork which could perhaps be avoided if the

Table 8.4.--Partial Summary of Reinforcing Bar Tolerances[a]

	ACI		Projects								
	301	318	A[b]	B	C	D[c]	E	F	G	H2	I
Fabrication Tolerances											
Sheared Length	±1			±1	±1	±1	±1	±1	±1	±1	±1
Overall dimensions of stirrups, ties, and spirals	±½			±½	±½	±½	±½	±½	±½	±½	±½
Other bends	±1			±1	±1	±1	±1	±1	±1	±1	±1
Placement Tolerances											
Clear distances to formed surfaces	±¼			±¼	±½	±¼	±¼	±¼	±¼	±¼	±¼
Spacing between bars	-¼			-¼	-¼	-¼	-¼	-¼	-¼	±1[d]	-¼
Top bars in slabs and beams: members 8" deep or less	±¼	±⅜		±⅜	±⅜	±¼	±⅜	±¼	$\{^{+1\frac{1}{2}}_{-\frac{1}{4}}$	±⅜	±¼
Members 8" to 24" deep	±½	±½		±½	±½	±⅜	±½	±½	$\{^{+\frac{3}{4}}_{-\frac{3}{8}}$	±½	±½
Members greater than 24"	±1	±½		±½	±½	±½	±½	±1	$\{^{+1}_{-\frac{1}{2}}$	±1	±1
Crosswise of members	±2			±2	±2	±2	±2	±2	±2	±2	±2
Lengthwise of members	±2			±2	±2	±2	±2	±2	±2	±2	±2
Longitudinal location of bends and ends of bars		±2		±2	±3	±3	±2	±2	±3	±2	±2
discontinuous ends		±½		±½	±½	±½	±½	±½	±½	±½	±½
Minimum Cover Requirements											
Concrete placed against the ground	3	3		3	3	3	3	3	3	3	3
Exposed to weather: #6 bars or larger	2	2		2	2	2	2	2	2	2	2
#5 bars or smaller	1½	1½		1½	1½	2	1½	1½	1½	1½	1½

(continued)

Table 8.4. (continued)

Interior surfaces: beams, girders, columns	1½	1½		1½	1½	1½	1½	1½	1½	1½	1½
Slabs, walls, joists: #11 bars or smaller	¾	¾		¾	¾	¾	¾	¾	¾	¾	¾
#14 bars and #18 bars	1½	1½		1½	1½	1½	1½	1½	1½	1½	1½

[a]Units are in inches

[b]Information unavailable

[c]Proposed revision

[d]The spacing at embedments is increased to ±2 inches.

tolerances were relaxed. There are many in the industry who feel that ACI 301 was not written for complex nuclear structures and that special tolerance provisions should be considered. On Project H this has been done where the tolerances around embedments have been increased to two inches. This does appear to be a practical solution since most design deviation requests are usually approved. There are, of course, a number of other ways the impact of embedments on placing tolerances could be eased. A more detailed approach could be as follows:

"If the dimension of the embedded item that interferes with the bar is 12 inches or more, the bar arrangement shall be as shown. If the dimension of the embedded item that interferes with the bar is less than 12 inches, the bar arrangement shall be as follows:

1. For bar size #8 and larger: move entire bar
2. For bar size #7 and smaller: bend bar to an offset of 1:6 maximum with radius of bends in accordance with ACI 315 Section 2.9, or move entire bar."

This is a proposed revision to the Project D specifications, and does appear to be a workable solution.

Very detailed inspection of reinforcement by QC using the ACI guidelines can, of course, become very time consuming and costly, and a point of diminishing return could quickly be reached. Providing specific guidance is not always easy. One example of easing the burden on production and quality control (the paper management problem may also be relieved) was presented above. Another example is presented below from the Project G specifications which states that:

> "Where bars in walls and slabs are specified on design drawings at a uniform spacing (precise numbers are not specified), the number of bars shall equal the required number of bars within the tolerances given below, unless otherwise noted:

Number of Bars	Tolerance (percent)
Greater than required	10
Less than required	5

This requirement may be verified by measuring and totaling the sum of five or more contiguous bar spaces (where the theoretical sum is equal to or greater than 6 feet), and comparing the measured sum with the theoretical sum. Accept when the measured sum is within the allowable tolerance, in percent, of the theoretical sum. A visual comparison of adjacent areas of the same wall or slab is acceptable."

Provisions of the type mentioned above are necessary supplements to both ACI 301 and 318 and contribute significantly to the working relationship between Construction and Quality Control. It is unfortunate that such provisions were not part of the initial specification but rather are the outcome of many debates and arguments.

As was stated previously, many within the nuclear construction industry feel that the ACI tolerances are unrealistic. This thought is particularly strong with regard to #14 and #18 bars. Quality, however, is the first concern and the impact of relaxed tolerances on structural adequacy needs to be clearly understood. One constructor has conducted field studies directed toward the development of practical reinforcing tolerances. These studies involved observation of actual field problems and subsequent submittal of prospective solutions for engineering evaluation. The design methods, criteria, and assumptions were reviewed with respect to the effect of increased tolerances on the strength of structural elements, and the results showed that there would be no detrimental impact on member strength through the application of slightly wider tolerances.

If there is cause for concern over tolerances as it relates to structural integrity then perhaps a cost effective approach would be to increase the capacity factor during the design phase to account for increased allowable tolerances.

Formwork - Reinforcement Tolerance Relationship.

The relationship between formwork tolerances, reinforcing tolerances and concrete cover requirements adds another degree of complexity to nuclear concrete construction. On a number of projects it has been stated that reinforcement placing tolerances were difficult to achieve because of the fabrication tolerances allowed. Many of the areas are heavily congested, and there may be interferences with embedments. In such areas, the fabrication tolerances may use up all of the allowable placement tolerances. This is also related to formwork tolerances through the minimum cover requirements.

The need for flexibility in such areas is important, and placement in accordance with ACI does not provide this flexibility. Clearly specification writers need to pay more attention to this problem. The difficulties are generally resolved with design deviation requests before the actual placement. This is an expensive approach which could possibly be avoided except in areas where there is a genuine concern over structural adequacy. If the problem is not resolved prior to construction, then a non-conformance report is generated. Tables 8.5 and 8.6 summarize the unsatisfactory attributes and nonconformances related to reinforcement on two projects. It should be pointed out that the number of nonconformaces generated does not indicate the true magnitude of the problem.

CADWELDING

Cadwelding is one of the most important operations related to concrete construction and is observed very closely by Quality Control. The discussions below will present the crew qualification, quality control, and testing aspects of cadwelding. The primary documents governing cadwelding operations are the manufacturers' literature (8.4), which addresses the actual production procedure

Table 8.5.--Summary of Unsatisfactory Reinforcement Attributes, Project F[a]

Description of Attributes	Number of Occurences[b]
Number and Location of Reinforcing Bars	30
Bar Supports	11
Cleanliness of Reinforcement	7
Concrete Cover	14

[a]Results from trend analysis of 310 concrete inspection reports.

[b]A total of 230 out of 5000 attributes were listed as unsatisfactory.

Table 8.6.--Summary of Nonconformances on Reinforcement, Project D

Description of Nonconformance	Number of Occurences
Reinforcement Tolerance	8
Bars Mislocated or Misoriented	26
Inadequate Dowel Projection	9
Bars Omitted	8
Bar Cut Off	9
Design Change to Completed Work	10

and visual inspection characteristics, and Regulatory Guide 1.10, "Mechanical Splices in Reinforcing Bars of Category I Structures", which governs crew qualifications, inspection, and testing. Since the ASME Boiler and Pressure Vessel Code restates the Reg. Guide 1.10 requirements, the discussion below is applicable to both documents even though only the Reg. Guide is mentioned. The production aspects of cadwelding will not be addressed in this report. On all projects there is general compliance with Reg. Guide 1.10, however, compliance as will be pointed out later should not be construed as meaning agreement.

Reg. Guide 1.10 was published because in the late 60's and early 70's there were no well-established, acceptable standards governing cadwelding operations, and hence, the tensile test results indicated that the process was not being controlled to a statistically acceptable degree. Table 8.7 shows the available test data for each of the projects. Projects A and B pre-date the Reg. Guide, and it is evident that the degree of quality control has improved considerably in the latter projects. The discussion which follows will generally be organized into two categories, namely (1) the pre Reg. Guide group, and (2) the post Reg. Guide group.

Crew Qualifications

Regulatory Guide 1.10 requires each member of the cadweld crew to prepare two qualification splices in each of the horizontal, vertical, and diagonal positions. Each of these splices is inspected visually and then subjected to a tensile test. Each inspection and test must pass the acceptance criteria which will be discussed later.

For both pre-dated projects, the qualification requirements for crew members is different from the Reg. Guide. One project considers crew members

Table 8.7.--Cadweld Inspection and Test Results

Project	Total Mech. Splices	Total Visual Rejects	Percent Visual Rejects	No. Tensile Tests	No. Tensile Failures[a]	Percent Tensile Failures
A	62,453	766	1.23%	2632	201	7.6%
B	30,833	139	0.45%	1044	72[b]	6.9%
C	31,876	463	1.45%	2379	0	0.0%
D	18,646	227	1.22%	757	1[c]	0.1%
E	958	60	6.26%	61	3[c]	4.92%
F	3,954	53	1.34%	122	1[c]	0.8%
G	47,299	1840	3.89%	-	-	-
H	-	-	-	300	2	0.7%
I	4,013	28	0.70%	411	0	0.0%

[a]Failure to achieve 125% of minimum yield strength of the bar.

[b]Splice failures = 41, bar failures = 31.

[c]Bar failures.

to be qualified if the acceptance criteria is satisfied for the following bar conditions, numbers and positions:

a) three splices horizontal size to size,

b) three splices vertical size to size,

c) three splices horizontal reducing sizes,

d) three splices vertical reducing sizes.

If one bar fails to meet the acceptance criteria, then the crew member must prepare two additional splices of the same type, both of which must be satisfactory. If either of these specimens is unacceptable, then the crew member must undergo further training. This approach fails to recognize that the material components may be defective, but rather, it assumes that all splice failures result from deficiencies in workmanship.

For crew members to qualify on the second project, a single test splice for each bar size and position must be made and tested against the acceptance requirements. Any test splice which fails to meet these standards is then examined to determine if the failure resulted from a discrepancy in the procedure or improper workmanship. If the workmanship is at fault, then the crew member is not allowed to make splices on the project. Again, material component defects are not tested.

In the second category, which contains seven projects, there is general compliance with the Reg. Guide. Several projects have further clarified the intent of the regulation, and with respect to the position of the splice, two of the projects provide the following guidance:

a) horizontal, including 10^{o} to horizontal

b) diagonal, 45^{o} from horizontal, including 10^{o} to 80^{o} from horizontal

c) vertical, including 10^{o} to vertical except in the containment, where 20^{o} to vertical is acceptable.

The Reg. Guide does not address the question of what happens if the crew member fails the qualification test. Three projects provide further guidance in this area by stating that in the event that one of the specimens fails either the visual inspection or tensile test, two additional splices shall be made. Should either fail to meet the acceptance criteria, then the potential crew member must receive additional training (two projects stipulate a five-day training period) before a retest can be administered. The exact nature and scope of this training is not clear.

All projects studied recognize that during the course of production, a condition may arise whereby the competence of a crew member could be questionable. The recognition of this fact has been addressed in several ways. In the pre-Reg. Guide group, Project A was governed by the following provision from the Quality Control Procedure:

> "Failure of a tension test of a splice (test result less than 90,000 psi) will be cause for additional sampling required by the specification as follows:
>
> The splice made by that same splicer immediately preceding or following the sub-standard splice shall be cut out and tested. If the re-sample test result is over 90,000 psi, the process will be considered in control."
>
> "If this second test splice does not meet the requirements, all work by this splicer shall be stopped. Five adjacent splices made by the man shall be cut out and tested. Should any of these five splices not meet the requirements, the man who made the splice shall be required to requalify and from the results the Structural Engineer (owner) must be able to justify that this man is capable of performing further production splices."
>
> "Should the five splices meet the requirements, the reinforcing shall be re-spliced. Any one of the re-splices may be selected for a test."

Retesting in this manner could become very expensive, however, it should be recalled from Table 8.7 that the rate of tensile failures was approximately 7 1/2%.

On the second project in the pre-Reg. Guide group, a crew member is banned from making any further cadwelds on the structure if a tensile test failure results from his workmanship.

The Reg. Guide states that a crew member is subject to requalification if (a) the specific splice position (e.g. horizontal, vertical, diagonal) has not been used for a period of three months or more, (b) if completed splices fail to pass the visual inspection or tensile test, or if (c) there is any cause for questioning a crew member's ability. Only one of the seven plants in the Post Reg. Guide category restate these provisions. The other six attempt to clarify item (b) by giving a specific failure rate which would necessitate requalification. These rates are generally defined as when unsatisfactory visual inspections or tensile tests exceed one in fifteen consecutive splices. One project has relaxed this provision to two in fifteen for the visual inspection. These appear to be realistic rates since the test data from Table 8.7 indicates that for the later vintage plants, approximately one splice out of eighty is rejected during the visual inspection, and approximately one out of 1000 tested fails to pass the tensile test. For the one project that does not specify a specific rate when retesting should be done, presumably retesting is not done every time a splice fails since the specification states that the crew member "is subject to" requalification.

Acceptance Criteria

The primary concern during the visual inspection of completed splices is to insure that the splice is satisfactory with respect to: (1) longitudinal centering of the sleeve on the spliced ends, (2) allowable voids in the filler material, and (3) slag at the tap hole. The centering of the sleeve can be easily checked by observing the reference points marked on each bar, and the

extent of voids can be evaluated against the specifications of the manufacturer (8.4) in order to determine whether or not the splice is acceptable. With respect to slag in the tap hole, there is some room for judgment regarding the extent of slag which would indicate that the splice was unsatisfactory. The manufacturer's literature provides no guidance on this aspect except to state that a tap hole not completely filled with filler metal is not a cause for rejection. Presumably then, some slag in the tap hole would be acceptable. Seven of the projects allow slag to extend to, but not beyond, the inner face of the sleeve, whereas the remaining two, Projects B and H, do not allow slag in the tap hole. It is not known how this is interpreted by the QC Inspectors, and slag may well be allowed to the same extent as on the other projects. No correlation can be drawn between the stringent or liberal interpretation of allowable slag and the rates of rejection of visual splices in Table 8.7. Project G has the most liberal allowance from the standpoint of slag as well as one of the highest visual rejection rates.

The tensile test acceptance criteria on the seven later vintage projects agrees with Reg. Guide 1.10 which states that (a) the minimum tensile strength is 125 percent of the minimum yield strength as specified in ASTM, and (b) the average strength of each group of fifteen consecutive tests should exceed the guaranteed ultimate tensile strength of the bar. For the pre-dated Reg. Guide projects, both require that the strength of the splice must equal or exceed the minimum ultimate tensile strength of the bar. Even though the tensile failure rates in Table 8.7 cannot be compared directly, it is still felt that the data clearly indicates that the reliability of the cadwelding process has improved significantly.

The testing frequency on each project is summarized in Table 8.8. It can be seen that there is general compliance with the Reg. Guide for the

Table 8.8.--Cadweld Testing Frequency Requirements

	Reg. Guide 1.10	Projects								
		A	B	C	D	E	F	G	H	I
Production Splices Only										
1 prod. splice out of first 10 1 prod. splice out of next 90 2 prod. splices out of next and subsequent 100	X				X	X	X	X	X	X
4 prod. out of first 100 3 prod. out of next 100 2 prod. out of subsequent 100			X							
Combination of Production and Sister Splices										
1 prod. splice out of first 10 3 prod. and 1 sister splice out of next 90 3 splices (prod. or sister or comb.) out of subsequent lots of 100. Minimum of 1/4 must be prod. splices	X				X	X	X	X	X	X
1 sister splice out of first 10 3 sister splices out of next 100 2 sister splices out of each subsequent 100 splices 1 prod. splice out of every 100		X								
1 prod. and 2 sister splices out of every 75				X						
Sister Splices Only										
1 sister splice out of first 10 4 sister splices out of next 90 3 sister splices out of subsequent 100						X		X		X
3 sister splices out of every 75				X						

post Reg. Guide group. It should also be noted that the Reg. Guide does not provide testing frequency requirements for sister splice programs that are necessary for "B" series and curved "T" series splices. A further discussion of these frequencies is included later in this report.

Substandard Tensile Test Results

There is a definite necessity for establishing those measures which must be taken should cadweld splices fail the tensile test. It should be recalled that for the pre Reg. Guide projects, the only acceptance criterion was that the tensile strength must equal or exceed the ultimate tensile strength of the bar. The Project A provision for dealing with a failure was presented under the discussion on crew qualifications, and it can be seen that in the event of a failure, the splice immediately preceeding the defective one would be tested. Should this splice fail, five adjacent splices would be tested, and the failure of one of these would be cause for requiring the crew member to requalify. There is no requirement for evaluating the structural integrity of the reinforcing system, although presumably this would be done.

The Project B specifications state that when a cadweld splice fails to meet the tensile test requirements, the next previous or subsequent splice made by the source operator shall be tested. If this test exceeds the minimum value, then the process will be considered to be under control. If this splice fails, the responsible crew must discontinue cadwelding and an engineering evaluation will be made. Initially this provision does not appear to provide reactionary measures commensurate with the level of seriousness of the problem. By reviewing the acceptance criteria for pre- and post- Reg. Guide projects, however, there are many more opportunities for invoking the above provisions because the acceptance criteria for both Projects A and B does not recognize

the statistically inherent variability of the materials and testing methods. Hence the engineer is given the freedom to evaluate each incident on an individual basis by considering any unique circumstances. As indicated below, such flexibility is not provided for in Reg. Guide 1.10.

The requirements of the Reg. Guide state the following:

"(a) If any production or sister splice tested fails to meet the tensile strength specification of paragraph (a), and the observed rate of splices that fail the tensile test at that time does not exceed one for each fifteen consecutive test samples, the sampling procedure shall be started anew.

(b) If any production or sister splice used for testing fails to meet the tensile test specification in paragraph (a) above, and the observed rate of splices that fail the tensile test exceeds one for each fifteen consecutive test samples, mechanical splicing should be terminated. In addition, the adjacent production splices on each side of the last failed splice and four other splices distributed uniformly throughout the balance of the 100 production splices under investigation should be tested and an independent laboratory analysis should be made to identify the cause of all failures. The results of these tests should be evaluated by the designer of the structure and the licensee to determine the required corrective action. The designer and the licensee shall specify the extent of repairs necessary and the actions required to prevent further failures from the identified causes.

(c) If two or more splices from any of these six additional splice samples fail to meet the tensile test specification of paragraph (a) above, the balance of the 100 production splices under investigation should be rejected and replaced.

(d) When mechanical splicing is resumed, the sampling procedure should be started anew.

If the average tensile strength of the fifteen consecutive samples fails to meet the provisions of paragraph (b) above, the designer of the structure and the licensee should evaluate and assess the acceptability of the reduced average tensile strength with respect to the required strength at the location from which the samples were taken."

These measures appear to be drastic, since it seems unlikely that the process would be out of control for the length of time required to produce 100 cadweld splices. Furthermore, an engineering evaluation could be very

lengthy, and therefore, it is not clear why all cadwelding should be discontinued. One of the questions which must be addressed is the determination of the causes; are they due to material defects or crew member deficiencies? If the material is the cause, then the indicators would be surfaced sooner if there had been any significant usage of the defective material. Otherwise, use of the suspected material lots could be suspended until an evaluation was made. It does appear that some flexibility should be considered.

The individual projects have reacted differently to the need for contingency measures, particularly in the case of the later dated projects. Table 8.1 indicates the percent of concrete placed for each project, and the project provisions below are listed according to the percent complete of the concrete placement (older projects listed first).

1. Project G complies with Reg. Guide 1.10.
2. Project E complies with Reg. Guide 1.10.
3. Project D complies with Reg. Guide 1.10.
4. Project C when a splice fails to achieve 125% of the minimum tensile strength of the bar but the average tensile strength for each group of 15 consecutive samples exceeds the ultimate tensile strength of the bar, then the work of the crew will be stopped. Three splices representing a lot size of 25 will be tested. If all splices are satisfactory, then the lot is accepted and the crew may resume splicing. If one or more splices fails, then the entire lot is rejected and replaced.

If the average strength of 15 consecutive samples is below the guaranteed minimum ultimate strength of the bar, or if more than one sample in 15 fails to achieve 125% of the minimum tensile strength, cadwelding shall be stopped and an evaluation of completed splices shall be made by the Engineer.

The testing requirements on Project C are slightly more involved than those in the Reg. Guide when a single bar fails, however the lot size which could potentially be rejected is considerably smaller than the lot size suggested by the Reg. Guide.

5. Project I--The Reg. Guide provision is applicable for splices which fail to achieve 125% of the tensile strength of the bar and when the observed rate of failures at that time does not exceed one in 15 consecutive tests. When the failure rate exceeds one in 15 consecutive tests, splicing by the individual cadwelder shall be stopped and the complete set of test results shall be referred to the Engineer for an evaluation.

6. Project H--In the event a splice should fail the tensile test, the specimen shall be examined by the test lab, and if necessary, by the manufacturer's representative. Based on the results of the investigation, additional splices may be directed to be taken from the structure and tested. These shall include the one preceding and succeeding the splice that originally failed. All production work for the crew shall be halted until the exact cause of the failure has been determined.

7. Project F complies with Reg. Guide 1.10.

A number of engineers within the industry have expressed concern over the present requirements of Reg. Guide 1.10 and the ASME Boiler and Pressure Vessel Code since these documents do not address the qualification of material batch shipments to the jobsite by in-process, user testing. The present concept also neglects to require qualification tests on splice components to determine any defective shipments.

The data presented in Table 8.7 indicates that the visual inspection effectively identifies those splices containing defective workmanship that may be of inferior strength. The present testing program does not appear

to be identifying those batches of material that may be deficient.

Exhibit 8.2 is a suggested revision to the ASME Boiler and Pressure Vessel Code which would eliminate destructive production and sister splice testing in lieu of the visual inspection program. It would also establish a needed in-process user test program.

Preparation Requirements

The primary concern during the preparation of a cadweld splice is that the components (i.e., bar ends, pouring basins, crucible, sleeve) are properly cleaned and free of moisture. The manufacturer provides very general instructions with regard to drying and cleaning by stating the following:

> "Flame dry ends with oxy-acetylene torch to remove all moisture and/or burn away any other foreign matter. Flame should be soot-free and not leave any residue or deposits on bar ends. A rose bud torch tip is recommended.
>
> Remove all loose mill scale, rust, etc., with a power wire brush.
>
> Cleaned bar ends which must be left out overnight should be protected and must be redried and recleaned."

Projects E, G, H and I each restate these general requirements, however other projects have felt a necessity to further clarify the degree of preheating in the following manner:

1. Project A--Bar ends should be cleaned to bare metal and heated to a temperature between 200° and 300° F. Temperature measuring devices are to be used.

2. Project B--All molds should be heated to at least 212° F. Bar ends should be heated. If the temperature is below freezing, all materials and equipment should be pre-heated in place.

3. Project C--Pouring basins, crucibles and bar ends should be heated to a minimum of 212° F. Temperature measuring devices will be used.

Exhibit 8.2.--Suggested Revision to Cadweld Provisions of ASME Boiler and Pressure Vessel Code

SECTION III, DIVISION 2 — SUBSECTION CC

CC-2320 MATERIAL IDENTIFICATION

Reinforcing systems material shall be tagged or marked to ensure traceability to the Certified Material Test Report during production and while in transit and storage.

CC-2330 SPECIAL MATERIAL TESTING

CC-2331 Tensile Tests

CC-2331.1 Number of Tests Required. One full-diameter tensile test bar from each bar size shall be tested for each 50 tons or fraction thereof of reinforcing bars produced from each heat of steel. The tensile test procedures shall be in accordance with SA-370.

CC-2331.2 Acceptance Standards. The acceptance standards shall be in conformance with the tensile requirements of Table 2 of ASTM A 615. If a test specimen fails to meet the tensile requirements of ASTM A 615, two additional specimens from the same heat and of the same bar size shall be tested. If either of the two additional specimens fails to meet the tensile requirements, the material represented by the tests shall not be accepted.

CC-2332 Bend Tests

CC-2332.1 Number of Tests Required and Test Procedures

(a) Bend tests on bar sizes No. 3 through No. 11 shall be performed in accordance with ASTM A 615.

(b) If it is intended that bars of sizes No. 14 and No. 18 will be bent during construction, bend testing of bars from such heats of material shall be conducted at the rate of one test bar for each bar size from each heat. The bend tests shall be conducted at a temperature of at least 60 F. Full-section test bars shall be bent in the unmachined condition over a ten-bar-diameter pin through 90 deg.

CC-2332.2 Acceptance Standards

(a) The acceptance standards for bar sizes No. 3 through No. 11 shall be in conformance with the requirements of Section 8.1 of ASTM A 615.

(b) For bar sizes No. 14 and No. 18, the acceptance standards shall be an absence of cracks on the outside of the bend portion. Material from heats meeting this criterion may be bent during construction.

CC-2333 Chemical Analysis

(a) A ladle analysis of each heat of reinforcing bar shall be made and reported to the purchaser.

(b) The ladle analysis of reinforcing bar heats intended for arc-welding shall be as follows:

carbon: 0.30% maximum
manganese: 1.50% maximum
sulphur: 0.05% maximum
phosphorus: 0.05% maximum

An analysis for the following residual elements shall also be performed and reported: copper, nickel, chromium, molybdenum, and vanadium. The carbon equivalent of such bars shall comply with the 0.55 maximum as computed in CC-4334.6.

(c) Check analysis tolerances for carbon, manganese, phosphorus, and sulphur shall be in accordance with ASTM A 29.

CC-2340 SPLICE SLEEVES WITH FILLER METAL

CC-2341 Material

Specific material components for the splice assembly will be in accordance with the Manufacturer's Specifications and standard product line.

CC-2342 Splice Material Test Specimens

CC-2342.1 Cartridge Powder and Filler Metal. One bag of cartridge powder shall be selected at random from each lot of cartridge powder bags received during construction and a splice for the largest bar size to be used in the project shall be prepared and tensile tested in accordance with CC-2343.

CC-2342.2 Splice Sleeve. One splice sleeve for each size and series within a heat of steel shall be selected at random and a splice shall be prepared and tested in accordance with CC-2343.

CC-2342.3 Combined Test Specimens. Test specimens may be prepared from the combination of selected samples obtained from a lot of cartridge powder and a heat of splicing sleeves provided that if substandard tensile test results are obtained, the provisions of CC-2344 (d) shall be followed.

CC-2343 Tensile Testing

Splices prepared from samples of cartridge powder and sleeves shall be tensile tested using the loading rates set forth in SA-370. The tensile strength of each

Exhibit 8.2.--continued

CC-2343 Tensile Testing (cont.)

sample shall equal or exceed 125% of the specified yield strength as shown in Table CC-4333-1. If any sample tested fails to meet this provision, the requirements of CC-2344 shall be followed.

CC-2344 Substandard Test Results

(a) If a cartridge powder or sleeve splice sample used for testing fails to meet the strength requirement of CC-2343 and failure occurs in the bar, the cause of the bar break shall be investigated by the Constructor. Any necessary corrective action affecting splice samples shall be implemented prior to continuing the testing.

(b) If a splice sample used for testing cartridge powder fails by pull out of the bar from the sleeve and fails to meet the strength requirement of CC-2343, two additional splice samples shall be made by using bags of cartridge powder obtained from the same lot of powder bags from which the original sample was selected. If after testing, either of these two test samples fail to meet the strength requirement of CC-2343, the entire lot from which the samples of cartridge powder were selected shall be rejected and tagged for removal from the jobsite.

If any of the splice specimens used for testing cartridge powder fail by rupture of the steel sleeve below the strength requirements of CC-2343, an investigation shall be implemented prior to the preparation of another cartridge powder splice specimen from the same lot.

(c) If a splice sample used for testing steel sleeves fails at the splicing sleeve and fails to meet the strength requirement of CC-2343, two additional splice samples shall be made by using sleeves obtained from the same heat of steel from which the original failed sample was selected. If after testing, either of the two test samples fails to meet the strength requirement of CC-2343, the entire heat of sleeves from which the sample sleeves were selected shall be rejected and tagged for removal from the jobsite.

If any of the splice specimens used for testing steel sleeves fail by pull out of the reinforcing bar from the steel sleeve below the strength requirements of CC-2343, an investigation shall be implemented prior to the preparation of another steel sleeve splice specimen from the same heat.

(d) If a combined test specimen using samples from both a cartridge powder lot and a heat of sleeves fails to meet the strength requirement of CC-2343, the type of failure shall be determined by the Constructor and noted on the test report. Two additional test specimens shall be prepared for testing by selecting samples of cartridge powder and steel sleeves from the same lot and heat from which the original samples were selected. If either specimen fails, the type of failure shall be determined by the Constructor and noted on a test report. If the failures are indicative of filler metal failures (i.e., bar pullout from sleeve without bar failure), and the splice fails to meet the strength requirement of CC-2343, the entire lot from which the cartridge powder was selected shall be rejected and tagged for removal from the jobsite. If the failures are indicative of sleeve failures (i.e., the steel sleeve fails), and the splice fails to meet the strength requirement of CC-2343, the entire heat of sleeves from which the sample sleeves were selected shall be rejected and tagged for removal from the jobsite.

In the event the initial and the subsequent failures from the same lot of cartridge powder or heat of steel sleeves are not the same type of failure and the testing results are below the strength requirements of CC-2343, both the entire lot of powder and the entire heat of steel sleeves from which the samples were selected shall be rejected and tagged for removal from the jobsite.

CC-2345 Recording of Tensile Test Results

The results of all tensile tests obtained from the tests prescribed by CC-2342 and CC-2343, along with all other pertinent data, shall be recorded.

Exhibit 8.2.--continued

CC-4333 Sleeves with Filler Metal Splices

CC-4333.1 Qualifications, Records, and Identifying Stamps

CC-4333.1.1 Required Qualifications. Each Constructor is responsible for the splicing made by his organization and he shall conduct the tests required by this Subarticle in order to qualify the splicing procedure and the splicers.

CC-4333.1.2 Maintenance and Certification of Records. The Constructor shall maintain a record of the splicing procedure and the splicers qualified and employed by him, showing the date and results of tests, and the identification mark or marks assigned to each splicer. These records shall be reviewed, verified, and signed by an authorized individual assigned by the Constructor. The records shall be accessible to the Owner and to the Authorized Inspector.

CC-4333.1.3 Splicing Prior to Qualification. No splicing shall be undertaken until a splicer has been qualified. Only splicers who are qualified in accordance with CC-4333.2 shall be used.

CC-4333.2 Requirements for Splicing Procedures. All splicing shall be performed in accordance with a written procedure which shall include, as a minimum, the following information:

(a) bar end location tolerances
(b) permissible gap between reinforcing bar ends
(c) allowable voidage in the filler metal

CC-4333.3 Initial Qualification Tests. Each splicer shall prepare two qualification splices on the largest bar size for each of the splice positions (e.g., horizontal, vertical, diagonal) to be used. The qualification splices shall be made using reinforcing bar identical to that to be used in the structure. The completed qualification splices shall be tensile tested and the tensile results shall meet those specified in Table CC-4333-1.

CC-4333.4 Welding. Welding of splice sleeves to parts shall be performed using welding procedures and welders qualified in accordance with AWS D1.1-72 or Section IX. All welds shall be visually examined for the presence of undercuts, overlaps, and cracks. Unacceptable defects shall be removed or reduced to an acceptable limit.

4. Project D--The bar ends shall be heated to between 212° and 800° F and verified by temperature measuring devices.

5. Project E--Sleeves must be externally preheated in place when the temperature is below freezing and the relative humidity is greater than 65 percent.

6. Project F--The sleeve and bar ends shall be heated around the entire circumference to 400°F as verified by temperature measuring devices. Before the splice is fired, the sleeve and bars shall be allowed to cool to at least 200°F.

By reviewing the test data presented in Table 8.7, it appears that there is no correlation between the generality of requirements and the rate of visual rejections. Projects G and I have very general requirements similar to those suggested by the manufacturer and yet these projects have the second highest and lowest rates of visual rejections, respectively. One would conclude that the inclusion of very specific requirements with regard to cleaning and drying may be counter-productive. Quantitative values are being substituted for qualitative attributes, and this represents another item which must be measured and recorded. This appears to be unjustified since there is no evidence to suggest that formalized instructions have increased the level of quality of cadwelds.

The visual inspection appears to be the key aspect in the quality control program. As stated by the manufacturer, improperly cleaned and dried splices result in severe voids and blow-outs. Thus, it appears reasonable to expect that a quality control program consisting of (1) random surveillance of the operational procedures on an infrequent basis, and (2) a thorough visual inspection of the completed splice will identify virtually 100 percent of all defective splices, except where defective bars and sleeves

are the cause. The evidence clearly indicates this, and accordingly, most cadweld inspection programs appear to be overinspected, overtested, and over-documented.

Quality Control Involvement and Documentation

The surveillance and inspection activities of quality control can be divided into two categories, namely (a) in-process activities, and (b) final inspection. All projects require 100% visual inspection of completed splices against the acceptance criteria previously discussed. Therefore, the discussion below will concentrate on in-process aspects.

On the two pre Reg. Guide projects, as can be seen in Table 8.9, quality control hs heavily involved in the cadwelding process. Both projects require 100% inspection on a surveillance basis. All operations must be observed by the inspector using a cadweld checklist. A Quality Control Cadweld Report form for Project B which includes the checklist is shown in Appendix 8.B. As can be seen, the checklist is quite extensive and would likely require one cadweld inspector per cadweld crew in order not to hinder the production effort. This, of course, is based upon the assumption that the inspector must observe all phases of the operation. The paper management aspects mentioned in Chapter 3 should also be noted. It appears that there is considerable potential for consolidating the report since the required information on at least two pages is rather sparse.

One additional point should be addressed regarding the inspection requirements on Project B. The project specifications require heating of bar ends to remove moisture, grease, and paint. This is a general requirement and presumably provides sufficient direction to the cadwelder with regard to what is acceptable. One finds in the Quality Control Instruction presented in Appendix 8.B that there

Table 8.9.--Comparison of Cadweld Inspection and Surveillance Requirements[a]

Inspection and Surveillance Activities	Projects								
	A	B	C	D	E	F	G	H	I
Prerequisite Activities									
Inspection and reference criteria			R	R			RI		
Review performed on open NCR's			R	R					
Review maintenance and storage requirements		R	R	R					
In-Process Activities									
Personnel qualified		R	R	R		R		R	
Splice sleeves wrapped and traceable to lot no.			S	I					
Splice sleeves free of rust, moisture, foreign matter	I		S			RI	RI		
Equipment and material properly selected	I	I	S			RI	RI	RI	RI
Pouring basin and crucible pre-heated		I	S	I					
Pouring basin and crucible cleaned			S	I					
Rebar deformations full size, bar ends square	I		S	I		RI	RI		RI
Rebar ends have required gap					I	RI	RI	RI	
Rebar ends preheated	I	I	S	I		RI	RI	RI	RI
Rebar ends cleaned	I	I	S	I	I	RI	RI	RI	RI
Rebar marked for reference point	I		S	I		RI	RI	RI	RI
Sleeve correctly located	I	I	S	I	I		RI	RI	RI
Splice sleeves externally preheated	I		S	I					
Splices made as per manufacturer's instructions	I	I	S	I		RI	RI		
Protection during inclement weather				I					

[a]The following notation is used: Inspection-I; Random Inspection-RI; Review-R; Surveillance-S.

has been a further interpretation of the project specification requirements as amplified in item four of the referenced document. Although the exact sequence of events which led to this interpretation by QC is not known, it does appear that this decision is an engineering function and not one belonging to Quality Control. Regardless of where the responsibility lies for originating this provision, the transmittal of information and requirements to the job site should be done through the project specifications or field procedures, rather than in quality control directives. The emphasis here seems to be on the temperature of the elements instead of on the cleanliness of the bar, and this appears to be especially true when one considers that the bar must be reheated every five minutes until the splice is fired.

Projects C and D are very similar with respect to the functions required of the Quality Control Inspector, except that Project C utilizes the random surveillance mode whereas Project D verifies cadweld procedures on an inspection basis. A Quality Control Inspection Record for Project C is shown in Appendix 8.B. By using the inspection mode, Project D has, in effect, established built-in hold points in order to verify and document that the project specifications and manufacturer's instructions have been followed. This has also been done to a lesser degree on Project E. The documents required for Project E are included in Appendix 8.B, and offer yet another opportunity to point out proper management aspects. The inspection reports used on Projects C and D are required for each individual cadweld or group of cadwelds, whereas the records for 15 cadwelds can be recorded on the Project E inspection sheet. The approach used on Project E is the more favored one from the standpoint of production since there is only one interface with the cadweld crew prior to firing the cadweld. Verification of the bar cleanliness and gap can be accomplished simultaneously, and the sleeve location can be checked during the final inspection. The impact of the cadweld inspector on productivity on Project

D, however, is far greater since he must physically verify each step of the operation. If he is absent from his place of duty, then the cadweld crew must presumably stop work and wait for the inspector to return.

Projects F, G, H, and I perform inspections on a random basis. This approach differs somewhat from the other projects and reflects a general recognition that the final visual inspection identifies essentially all defective welds. This trend could also be interpreted as an indication that the Nuclear Regulatory Commission recognizes that the final visual inspection is probably the key activity in the acceptance process.

On Project F, Quality Control inspects splices for dryness and cleanliness using an acceptance lot size of six. The procedure included in Appendix 8.B shows that one cadweld out of six may be randomly selected, and that the six inspection attributes are also randomly determined. It should be noted that there is a probability of 0.50 that no cadwelds in the lot size of six will be inspected. This appears to be a well-conceived procedure which should readily identify improper methods and procedures without requiring continuous monitoring and inspection of crews. Other projects should consider such an approach.

The NRC considers the random inspection approach an acceptable method of insuring process control of cadwelding. An NRC Audit Report of Project F indicated that while the random inspection idea was valid, there needed to be a formal procedure to insure that the process was truly random, meaning that each weld should have an equal probability of being selected. Project F had no such procedure at the time of the NRC visit. Consequently, the procedure presented in Appendix 8B was developed. The background on why the procedure was prepared is presented because this type of reaction appears to have occurred on a number of projects. The NRC visits the site and identifies

a deficiency or perhaps only asks a question related to a certain operation, and the owner and his consultant act immediately to tighten requirements. All too often, these reactions are not well conceived and have very little justification, especially as they relate to improving quality. In this particular case, however, the owner felt that the NRC made a valuable contribution in identifying a deficiency in the sampling program and was instrumental in helping establish a sound statistical sampling procedure.

Project G randomly observes each cadweld crew instead of each cadweld. The inspector must witness at least one cadweld per week per crew "in-process" to insure that the specification requirements are being followed. The documents required are included in Appendix 8.B.

The Contractor Quality Control Inspector on Project H performs a daily, random, visual inspection of each cadweld operator to verify compliance to the items shown in Table 8.9. A 100% visual inspection is performed on each completed cadweld, and the Site Organization Quality Control Inspector will select approximately 20% of the completed welds to inspect.

The first level inspection of cadwelding on Project I is done by the cadwelders themselves. They inspect their own work and can also reject completed splices. In this manner the individual crew member is not charged with a bad splice and thus is not subject to requalification. Quality Control randomly inspects 20% of all in-process cadwelding as a minimum but performs a 100% visual inspection of completed welds.

SUMMARY

The chapter began with an overview of the involvement of Quality Control in preplacement activities for each project. It was shown that in the early vintage projects, QC had very few duties or documentation responsibilities except at the point of final inspection. It was also shown how the QC involvement has gradually increased. Along with this increased activity has come increased documentation requirements. This has led to the hypothesis that there has been an ever increasing emphasis on written communication as opposed to verbal communication. The documents were reviewed with respect to their role in paper management.

Formwork aspects were discussed, and it was pointed out that the number of nonconformance reports in no way indicated the number of manhours expended or the difficulties encountered in trying to achieve the tolerance limits established by ACI 301 and 347. The difficulties are particularly acute around embedments. Several projects have relaxed the ACI tolerances for vertical and horizontal surfaces and grooves. The justifications for doing so were presented. The method of getting relief from formwork tolerances on a case by case basis by requesting an engineering design change was discussed, and in several cases, the frequent use of this approach would indicate that the project site organization was using this as a convenient mechanism for avoiding certain specification requirements.

Formwork adequacy and cleanliness requirements were briefly discussed.

Reinforcing steel was discussed with respect to user tests, rust, and control of nonconforming or rejected items. The problem of rust was particularly troublesome, and it was pointed out and substantiated by research documents that the concerns over excessive rust as it applies to bond characteristics are generally unnecessary. Results of several research projects were briefly discussed as well as several of the provisions in the project specification.

Reinforcing bar tolerances were discussed, and it was pointed out that many of the difficulties encountered in formwork tolerances were also applicable to reinforcement. There is also a relationship between the formwork tolerances, rebar fabrication tolerances, rebar placement tolerances, and the cover requirements. Several projects have indicated that fabrication and placement tolerances take up most of the formwork tolerances, thus making the formwork erection process much more difficult.

Cadwelding aspects were organized into two groups, namely the pre Reg Guide 1.10 group and the post Reg Guide group. It was pointed out that the requirements for these two groups differed significantly in the areas of crew qualification tests, acceptance criteria, provisions for substandard test results and preparation requirements. The latter vintage plants generally comply with the Reg Guide provisions. With respect to testing it was suggested that the testing frequencies were excessive since the visual inspection and tensile test data indicates that virtually all the defective cadwelds were identified during the visual inspection. In light of this information it was also suggested that the industry should reevaluate the cadweld requirements. A proposed revision to the ASME Boiler and Pressure Vessel Code was discussed. The essential features were that the primary acceptance criterion is the visual test and that this would be supplemented by in-process tests for the powder and sleeves.

The preparation requirements were discussed and the primary concerns were to insure that the bar ends were properly cleaned and free of moisture. The project specification requirements for cleaning and heating the bars were presented, and it was shown that there was a great deal of variation between project specification requirements. Some projects go to great lengths to describe the temperature and cleanliness requirements whereas others merely state that the bars should be cleaned and free of moisture. It was pointed out that there was no correlation between the generality of requirements and the

rate of visual rejections.

The involvement of Quality Control was also discussed. The methods used to verify compliance to the specifications included surveillance, inspection, random surveillance, and random inspections. Considering the fact that the test data indicates that essentially all defective welds can be identified during the visual inspection of the completed weld and very exacting requirements for cleaning and heating do not appear to significantly reduce visual rejections, it seems that cadwelding is overtested and overinspected. There also seemed to be room for improvement in the paper management aspects.

REFERENCES

8.1. Kemp, E. L., Brezny, F. S., and Unterspan, J. A., "Effect of Rust and Scale on the Bond Characteristics of Deformed Reinforcing Bars," ACI Journal, Proceedings V. 65, No. 9, September 1968, pp. 743-756.

8.2. USBR, A Manual for the Control of Concrete Construction, U.S. Department of the Interior, Bureau of Reclamation (6th edition), 1956.

8.3. Gilkey, H. J., Chamgerlin, S. J., and Beal, R. W., "Bond Tests on Rusted Bars," Proceedings, Highway Research Board, V. 19, 1939, pp. 149-163.

8.4. ERICO PRODUCTS, INC., Cadweld Rebar Splicing, Bulletin Number RB5M-274.

APPENDIX 8.A

CONCRETE PREPLACEMENT INSPECTION DOCUMENTS AND ATTRIBUTE LISTS

This appendix contains the following project documents and records:

1. Project A--Concrete Placement Checkout Sheet

2. Project B--Concrete Status Report
   Inspector's Concrete Checkout Sheet

3. Project C--Quality Control Inspection Record
   Field Inspection Reports
   In-Process Rework Notices

4. Project D--Quality Control Inspection Record
   Concrete Placement Checklist

5. Project E--Concrete Pour Card
   Inspector's Record

6. Project F--Quality Control Inspection Report
   Concrete Pour Card

7. Project G--Work Plan and Inspection Report
   Concrete Preplacement Inspection Checklist

8. Project H--Concrete Preplacement Checklist (Contractor H1)
   Inspection Report for Concrete Placement (Contractor H2)
   QC Preplacement Checklist (Contractor H3)
   QC Administration Inspection Plan (Contractor H3)

9. Project I--Quality Assurance Inspection Report

CONCRETE PLACEMENT CHECKOUT SHEET--PROJECT A

DESCRIPTION _____

AREA _____

SPECIFIC LOCATION _____

_____

CONCRETE CLASS & MIX NO. _____ FINISH _____

ADDITIVES _____ CURING CONDITION _____

COMPUTED QUANTITY _____ DATE PLACED _____

	INITIALS	DATE	APPLICABLE DOCUMENTS
ELECTRICAL			
SURVEYING			
INSTRUMENTATION			
MECHANICAL			
PIPING			
STRUCTURAL			

REMARKS:

(CONTAINMENT RING PLACEMENTS)
COLD WEATHER CURING EQUIPMENT AVAILABLE?

	ISSUANCE APPROVAL	REISSUED	REISSUED
QUALITY CONTROL:			
PROJECT ENGINEER:			

CONCRETE STATUS REPORT--PROJECT B

Pour Area:

Location:

INSPECTION ITEMS	REMARKS
Concrete Schedules, Pour Sheets, Plans	
Subgrade	
Construction Joints	
Forms	
Blockouts	
Water Stops	
Embedded Items	
Reinforcing Steel	
Final Cleanup	
Miscellaneous	

Additional Comments

READY FOR PLACEMENT

Quality Control Inspector

INSPECTOR'S CONCRETE CHECKOUT SHEET--PROJECT B

A. CONCRETE SCHEDULES, POUR SHEETS, PLANS:
___1. Completeness
___2. Craft cert. of readiness
___3. Updated & avail. of designed plans

B. SUBGRADE:
___1. Compaction
___2. Vapor barriers installed
___3. Perimeter insulation
___4. Condition of materials used

C. CONSTRUCTION JOINTS:
___1. Laitance removed
___2. Proper location
___3. Expansion joint materials
___4. Contraction joints & filler
___5. Spalling

D. FORMS:
___1. Form surface
___2. Panel joints
___3. Bracing
___4. Tie spacing
___5. Make-up of ties
___6. Waler spacing & size
___7. Spreaders
___8. Grout leaks
___9. Form coating
___10. Chamfer where necessary
___11. Grade strip properly installed
___12. Plumb bob lines installed
___13. Horizontal form liner installed
___14. Horizontal & vertical alignment of forms
___15. Installation of keyways on previous concrete
___16. Metal lath bulkheads have 1" clearance from form surface

E. BLOCKOUTS:
___1. Proper size
___2. Proper location
___3. Internal bracing & shoring
___4. Vibrators holes top & bottom
___5. Grout tight

F. WATER STOPS:
___1. Proper location
___2. Joint welds
___3. Supported for concrete placement
___4. Water stop wedged into keyways
___5. Cleanliness

G. EMBEDDED ITEMS:
___1. Anchor bolts, inserts, pipe sleeves, pipe conduits, flashings, etc.
_____a. Proper projection

G. EMBEDDED ITEMS (CONTINUED)
_____b. Proper location
_____c. All threads wrapped
_____d. Secured for concrete placement
___2. Miscellaneous steel
_____a. Proper location
_____b. Secured or properly supported
_____c. Check drawings for type & number

H. REINFORCING STEEL:
___1. Proper spacing
___2. Number & size of bars
___3. Length of laps
___4. Length of dowels & alignment
___5. Cadwelds
___6. Ties
___7. Form cleanance
___8. Supports

I. FINAL CLEAN-UP:
___1. Check all forms & fixtures for displacement.
___2. Cleanliness of surfaces, ledges, f rebars, embedments, blockouts join subgrades, water stops, chutes, et
___3. Proper scaffolding
___4. Concrete chute arrangements
___5. Proper type & length of tremies

J. MISCELLANEOUS:
___1.

___2.

K. APPLICABLE EDR'S & ECM'S
___1.

___2.

L. (REACTOR POURS ONLY):
___1. Have tendons been tested and appro

Pour Area:_____

Location:_____

_____ _____
INSPECTOR DATE

QUALITY CONTROL INSPECTION RECORD--PROJECT C

1. INSPECTION RECORD FOR

3. POCI NO. _____ REV. ___ 4. Q.C.I.R. PAGE 1 OF 6?

ITEM/S: A) _____ B) _____

C) NOT APPLICABLE D) _____

6. SCOPE/LOCATION: R/B 1 CONTAINMENT DIAPHRAGM SLAB

7. REFERENCE CRITERIA: JRC-3 8, C-36 6, ADD 1.2, FA 11.35 ADDITIONS 1-27-76

REV DCN REV 2 DCN 1

8. RECORD PREPARED BY: C. Hayden 9. RECORD REVIEWED BY: D.E. Cuyler

10. A/T No.	11. DESCRIPTION	12. C	13. E	A	B	C	D
1.0	PREREQUISITES						
1.1	Inspection and reference criteria reviewed for availability, familiarity and correct approval and revision status.	R	*2	QV 1-30-76			
1.2	Review performed for open NCR's affecting work operations.	R					
2.0	IN-PROCESS INSPECTION ACTIVITIES						
2.1	Construction Joints a. Construction joints meet ACI 318-71 requirements. b. Horizontal joint max. spacing 16 feet. c. Construction joints clean (sandblast, green cut etc.) d. ~~Waterstops installed correctly.~~ NOT APPLICABLE C. Hayden 1-26-76	S	*1	QV 1-30-76			
2.2	Forms a. ~~Form workmanship and configuration correct.~~ b. ~~Successive placement forms aligned.~~ c. Forms for exposed concrete surfaces coated as specified. d. Temporary openings provided e. Form ties properly arranged. f. Chamfer strips provided ~~where required.~~ C. Hayden 1-26-76 NOT APPLICABLE C. Hayden 1-26-76	S					
2.3	Expansion and Contraction Joints a. ~~Expansion joints~~ formed per the drawings. b. Control/contraction ~~joints~~ per the drawings. C. Hayden 1-26-76 NOT APPLICABLE	S					
2.4	Reinforcement a. Rebar free on bond impairing coatings. b. Rebar placement, cover and spacing per the drawings. c. Rebar tolerances as specified. d. Rebar properly supported. e. Rebar cutting, welding, or bending only as specified.	S	*1 *3 *5	QV 1-26-76			
2.5	Embedded Items a. Civil embeds correct, securely fastened, properly located and space/separated. b. Other discipline embeds properly secured & spaced/separated. c. Metal embeds free of bond impairing coatings.	S S S	*2 *3 *4	QV 1-26-76			

FOR INFORMATION ONLY

QUALITY CONTROL INSPECTION RECORD (CONTINUED)—PROJECT C

10. A/T No.	11. DESCRIPTION	12. C	13. E	14. ITEM/C ACCEPTANCE A	B	C	D
3.0	FINAL INSPECTION ACTIVITIES						
3.1	Final inspection performed for activities defined under A/T 2.00 and results satisfactory: a. Construction joints b. ~~Forms~~ c. ~~Expansion and control joints~~ C. Vogelei 1-26-76 d. Reinforcement e. Civil embedments f. Other discipline embeds	I	#6	QV 1-30-76			
3.2	Placing equipment properly set-up	I		QV 1-30-76			
3.3	Non-QC inspected pipe hydrostatically tested. J Fuller 1-29-76	R					
3.4	Respective discipline embed installation complete. C-241 C-55 Structural QCE R Rutter 1-29-76 IR No. C-296, C-632, C-261-1 Electrical QCE [illegible] IR No. [illegible] Instrumentation QCE J Fuller IR No. [illegible] Mechanical QCE J M Estes 1-29-76 IR No. [illegible] Piping QCE J Fuller 1-29-76 IR No. [illegible]	R		QV 1-30-76			
3.5	Preliminary clean-up inspection to verify that no debris, mud, snow, ice, or frozen surfaces exist.	I		QV 1-30-76			
3.6	Placing procedures and contingency plans reviewed.	R		QV 1-30-76			
3.7	~~NCR listed by A/T 1.2 closed~~ Not Applicable C Vogelei 1-30-76 FOR INFORMATION ONLY	R					
4.0	SUPPLEMENTARY RECORDS						
	~~None required.~~ See Block 15 (Remarks) QC-G-1 In Process Inspections - Daily Record	R		QV 1-30-76			
5.0	EXCEPTIONS						
5.1 or 5.2	No exceptions noted. Indicated exceptions are described in remarks section.	R		QV 1-30-76			

15. REMARKS
#1 Rework Notice C-106
#2 Rework Notice C-127
#3 Rework Notice C-126
Rework Notice C-130
#5 QC-G-1 1st Layer Rebar
#6 Rework Notice C-132

Attached QC-G-1 for FCR & DCN Summary
Attached QC-G-1 for In-Process Inspection Daily Logs

16. COMPLETED INSPECTION RECORD REVIEWED AND ACCEPTED BY: C Vogelei DATE: 1-30-76

FIELD INSPECTION REPORT--PROJECT C

4. ITEM INSPECTED Rebar Installation

Attach to QCIR C-259-FS-J-1-1

5. LOCATION Unit 1 Diaphragm Slab

6. TYPE OF INSPECTION Surveillance of Installation of Main Reinforcement of Bottom Mat of Steel. Proper Number & Approximate Location as per Dwg C-259 & C-260

7. STANDARD / CODE / PROCEDURE / DRAWING / SPECIFICATION C-36 Ker 6 FA 11#35 Add 1#2 Addend → 12

8. INSPECTION EQUIPMENT USED None

FOR INFORMATION ONLY

9. RESULTS OF INSPECTION: SATISFACTORY ☑ UNSATISFACTORY ☐

10. ACTION TAKEN IF UNSATISFACTORY

12-17-75

Distribution:
White - QC Files
Canary - Originator

11. ENGINEER

FIELD INSPECTION REPORT--PROJECT C

4. ITEM INSPECTED In Process Inspection of Unit 1 Diaphragm Slab & ES-J-1

12-24-75 In-Process - Rebar & Various Items
1-5-76 " Various Items
1-6-76 " " " Area I Inserts
1-19-76 " " "
See Continuation Sheet

5. LOCATION Unit 1

6. TYPE OF INSPECTION Visual

7. STANDARD / CODE / PROCEDURE / DRAWING / SPECIFICATION N/A

8. INSPECTION EQUIPMENT USED Tape Measures

FOR INFORMATION ONLY

9. RESULTS OF INSPECTION: SATISFACTORY ☑ UNSATISFACTORY ☐

10. ACTION TAKEN IF UNSATISFACTORY

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Canary -- Originator

11. ENGINEER C. Vogel 1-30-76

CONTINUATION SHEET--PROJECT C

5. BLOCK CONT'D	6. FORM NO.	7. REPORT NAME
4	QC- 6-1	FS-J-1 DAILY IN PROCESS INSPECTIONS

8.

1-20-76 IN-PROCESS VARIOUS ITEMS DWG C-274

1-21-76 " " " " " "

1-22-76 " " " " " "
SWING SHEET, C-284 DWG INSPECTION COMPLETE

1-23-76 IN PROCESS - REBAR CLEARANCES @ DOWEL COVERS & ENDS. SWING SHEET = STUB INSPECTION

1-26-76 IN PROCESS - IMPOSSIBLE CARPENTERS, IRON WORKERS, BOILERMAKERS, + LABORERS WORKING. CONSTRUCTION JOINT TO BE PREPARED TONIGHT. MM

1-27-76 IN PROCESS FOR REBAR & CLEAN UP
DAY & SWING SHEET

1-28-76 " "

1-29-76 FINAL REBAR CHECK & CLEAN UP INSP.

1-30-76 PREFOUR FINAL INSPECTION FOR CLEAN UP AND FAIRWEAR CHECK OFF.

FOR INFORMATION ONLY

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Canary – Originator

9. ENGINEER

IN-PROCESS REWORK NOTICE--PROJECT C

Item Location / Area Bldg. (6)	Dwg. Part No. / Rev. (7)	Item Name (8)
Cont. 1 Diap. Slab	C-259 — C-260 —	Various (Rebar)

Inspection Criteria: Dwg. [✓] Spec [✓] Other [ ] Explain

Document Number & Title (9): Page 1 of 1

(10) No.	Description (List Serial Numbers where applicable) (11)
1	Congested Rebar - Shear Bar Hooks in Contact - Groups of 4.
2	#18 Clearances at Downcomers & Penetration.
3	#18's Parallel and Running Together Bottom Mat
4	Oil on C.J. @ RPV Pedestal from Welding Machinery.
*	Note - See Remarks

Originated By (12): C. Vogler

Receipt Acknowledged Date (13): [illegible] 12.16.

REMARKS: (14)

FOR INFORMATION ONLY

This is merely a preliminary check-out of major problem areas. Final Inspection to begin shortly.

DCN No's C247 for Clearance.

Item 4 - Shows on new Rework Notice.

Rework Completed (15)	Date	Reinspection Completed Date (16)
James L. Seymour	1/29/76.	C. Vogler 1-30-76

CONFIRMING TELECOPIER TRANSMISSION

FIGURE 1

IN-PROCESS REWORK NOTICE--PROJECT C

Item Location / Area Bldg. (6)	Dwg. Part No. / Rev. (7)	Item Name (8)
Diaphragm/Slab Unit 1-2	C-274 2 FCN-3, VCN-3	Studs - Embeds

Inspection Criteria: Dwg. ☑ Spec ☐ Other ☐ Explain

Document Number & Title (9)

(10) No.	Description (List Serial Numbers where applicable) (11)
1	Plan view shows Nelson Studs to begin 2'6" from ℄ of Pedestal Column. (Contrary to Spec C5.5 AWS D1.1-72 para 4.28.8 they have to be 1" from edge of Beam) Dwg 274 also shows studs starting side by side - which is contrary to Detail 3 of the same drawing.
2	Section C shows studs to be 3½" ± ½" apart - AJ Miller FDCN changed this, but drawing was not

Originated By (12): C. Kasch CV

Receipt Acknowledged Date (13): James L. Seymour 1/23/76

REMARKS: (14)

FCR C1209 Tolerance on Studs.

FCR C1202

FCR C957

FOR INFORMATION ONLY

Rework Completed (15): James L. Seymour Date: 1/28/76

Reinspection Completed Date (16): C Kasch

FIGURE 1

CONTINUATION SHEET--PROJECT C

5. BLOCK CONT'D	6. FORM NO.	7. REPORT NAME
10	QC- -	FS-J-1 Rework Notice C-127

8.

2- REVISED AS PER THIS FDCN

3- DETAIL 3 INDICATES STUDS TO BE SYMETRICAL ABOUT ℄ OF BEAM WHICH IS NOT THE WAY THEY WERE INSTALLED

4- NOTE 10 STATES " TWO ADDITIONAL STUDS WILL BE WELDED WHERE DISTANCE BETWEEN EDGE OF PLATE AND STUD EXCEED 12" BUT DETAILS 1 & 2 BOTH SHOW STUDS STARTING 15" FROM PLATE EDGES. STUDS ARE NOT AS PER NOTE.

FOR INFORMATION ONLY

Distribution:
White – QC Files
Canary – Originator

9.ENGINEER _____

IN-PROCESS REWORK NOTICE--PROJECT C

Item Location / Area Bldg. (6)	Dwg. Part No. / Rev. (7)	Item Name (8)
Diaphragm Slab Unit	C-274 / 2	Studs-Decking Repair

Inspection Criteria: Dwg. [✓] Spec [✓] Other [ ] Explain — Document Number & Title (9)

(10) No.	Description (List Serial Numbers where applicable) (11)
1	0° One Nelson Stud missing ~5' from RPV Pen.
2	120° One Nelson Stud head burned off ~5' " "
3 ct	150° Hole in "Q" decking ~5' from Column and 2' to the right of Electrical Box. Electrical Box at this point is also incomplete
4	180° Nelson Stud head burned off ~5' from ctr of Pen. Also hole in "Q" decking under

Originated By (12)	Receipt Acknowledged Date (13)	
C. Koch QC	J. L. Seymour 1/25/76	

REMARKS: (14) FOR INFORMATION ONLY

ctr Holes in deck repaired

ctr DCN No 5 C 247 Rev 7 Clearances.

ctr DCN No 4 C 247 Rev 7 5% studs may be omitted

Rework Completed (15)	Date	Reinspection Completed Date (16)	
J. L. Seymour	1/28/76.	C Koch	1/29/76

FIGURE 1

CONTINUATION SHEET--PROJECT C

5. BLOCK CONT'D	6. FORM NO.	7. REPORT NAME
10	QC- —	FS-V-1 Rework Notice C-128

8.

4- Electrical Box 3-4" from Column

5- 240° Hole in "D" Decking ~3" from RPV C.L.

6- ~195° Keak Behind Farthest Downcomer Resting on "D" Decking.

7- As Stated in Rework C-106, Downcomer & Penetration Clearance Problems exist in many Locations.

FOR INFORMATION ONLY

Distribution:
White – QC Files
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9. ENGINEER _____

IN-PROCESS REWORK NOTICE--PROJECT C

Item Location	Area Bldg. (6)	Dwg. Part No.	Rev. (7)	Item Name (8)
DIAPHRAGM SLAB	UNIT #1	C-274	2	STUDS

Inspection Criteria — Dwg. [✓] Spec [✓] Other [ ] Explain

Document Number & Title (9): DIAPHRAGM SLAB EMBEDS

(10) No.	Description (List Serial Numbers where applicable) (11)
1	15° Two Nelson studs burned off 11'± from RPV Pcd.
2	45° " " " " " 18'± " " "
3	105° S.E. stud missing end anchorage 13'± from RPV Pcd
4	195° One Nelson stud head burned off 8'± " " "
5	225° one half Nelson stud head burned off 7'± from RPV Pcd.
6	~~255° One Nelson stud missing South of Type III plate~~ OK CKord
7	285° Two Nelson studs missing 1' from RPV Pcd.

Originated By (12): CKord

Receipt Acknowledged Date (13): [illegible] 1/29/76

REMARKS: (14)

DCN #4 DWG. C-247 Rev. 2. ALLOWS DELEATING 5% OF NELSON STUDS. (ITEM 9 TO BE INCLUDED IN 5%)

FCR C1208F SPACING OF STUDS.

FCR C957 - ITEM 2 FOR INFORMATION ONLY

Rework Completed (15)	Date	Reinspection Completed Date (16)	
James L. Seymour	1/28/76	CKord	1/29/76

FIGURE 1

CONTINUATION SHEET--PROJECT C

5. BLOCK CONT'D	6. FORM NO.	7. REPORT NAME
10	QC- —	FS-J-1 REWORK NOTICE C-130

8. 315° Two Nelson studs missing 1' from RPV Ped.

9. 345° Nelson studs do not start 1'3" from center of first downcomer from R.P.V. Ped. (both sides)

10. 345° Stud bent more than 30° 10'± from RPV Ped

11. 345° Two Nelson studs missing 6'± from RPV Ped.

12. 15°, 45°, 75°, 105° 135°, 165° 195° 225°, 255° 285° 315° & 345° The two Nelson studs shown at each of these locations have been ~~rejected~~ relocated by moving 3' Rt. & ℄ need to know where.

FOR INFORMATION ONLY

Distribution:
White – QC Files
Canary – Originator

9. ENGINEER _____

IN-PROCESS REWORK NOTICE--PROJECT C

Item Location / Area Bldg. (6)	Dwg. Part No.	Rev. (7)	Item Name (8)
DIAPHRAM SLABS C-259 UNIT 1	C-259	3	REBAR ETC

Inspection Criteria — Dwg. [✓] Spec [✓] Other [ ] Explain

Document Number & Title (9)

(10) No.	Description (List Serial Numbers where applicable) (11)
1	S-3 EMBED LEVELING BOLTS & OTHER STEEL DECK
	FRAMING BOLTS - 1/4" CLEARANCE TO GRADE
2	2" BOLTS W/ PLATE 3/8" DIFF. IN GRADE TO
	S-3, 2¼" AWAY (example 265° - new Line)
3	TOP CRANE SUPPORT STEEL @ RPV CT - REMOVE
4	BOTTOM FLANGE @ ℄ FOR 4"ϕ PIPE NOT AS PER DWG
5	#18's AROUND 4"ϕ ℄ PIPE LITTLE OR NO CLEARANCE

Originated By (12) C. Voyles

Receipt Acknowledged Date (13) J. Seymour 1/29/76

REMARKS: (14)

1 & 2. FCR 1229 3/4 COVERAGE

3 - FCR 1215 LEAVE BARE

4 - FCR 1214 SIGHTING SLEEVE

5 - DCN'S DWG C247 Rev 7 CLEARANCE → Problem Corrected

6 - DOES NOT APPLY

7. REWORK COMPLETE

8. FCR 1227 ALLOW ±4D

9. FCR 1228

INFORMATION ONLY

Rework Completed (15)	Date	Reinspection Completed Date (16)	
James L Seymour	1/29/76	C. Voyles	1-30-76

FIGURE 1

CONTINUATION SHEET--PROJECT C

5. BLOCK CONT'D	6. FORM NO.	7. REPORT NAME
10	QC- —	F5-J-1 Diaphragm Slab R.W. C-132

8.

16- To prevent damage to downcomers (1/16" gouges) cover required.

17- Paint on rebar reinforcement - to be removed.

18- Hoop bars, measured from ℄ found out of tolerance, 7 locations when check @ ~ 65° & 270°.

19- Require copy of condensed survey notes for S-3 # bolts

FOR INFORMATION ONLY

Distribution:
White – QC Files
Canary – Originator

9. ENGINEER _____

CONTINUATION SHEET--PROJECT C

5. BLOCK CONT'D	6. FORM NO. QC-	7. REPORT NAME FS-T-1 DIAPHRAM SLAB UNIT 1
8.		
C-898	REVISED	C-261 ATTACHED
-957	"	C-274 ATTACHED
-1002	"	C-261 ATTACHED
-1130		— ATTACHED
-1131	"	C-294 ATTACHED
-1137	"	C-274 ATTACHED
-1142		— ATTACHED
-1171	"	C-294
-1175		— ATTACHED
-1177	"	C-294
-1178	"	C-294
-1179	"	C-294
-1184		— ATTACHED
-1186		— NOT ATTACHED - DRYWELL SECTION
-1187		— ~~NOT~~ ATTACHED - WELDING INSP.
-1191		— ATTACHED
-1195		— ATTACHED
-1197		— ~~NOT~~ ATTACHED - WELDING - INSP.
-1203	"	C-294 ATTACHED
-1205		C— ATTACHED
-1208		C-274 ATTACHED
-1200	"	C-652
-1202	"	C-274 ATTACHED
-1207	"	C-274 ATTACHED
-1209	"	C-259 ATTACHED
-1211	"	C-294 ATTACHED
1213		ATTACHED
1214	"	C-294 ATTACHED
1215		ATTACHED
1225	"	C-294 ATTACHED
1227	"	C 247
1228	"	C 294
1229		ATTACHED
1224		ATTACHED
966		ATTACHED
C-247 (7)	DCN 4	5% SHEAR STUDS MAY BE OMITTED
"	DCN 5	MIN. CLEARANCE MAY BE WAIVED P.A.E.

FOR INFORMATION ONLY

Distribution:
White – QC Files
Canary – Originator

9. ENGINEER C Joyce 1-30-76

QUALITY CONTROL INSPECTION RECORD--PROJECT D

5. ITEM/S: A) PLACEMENT No. 183-W-03 B) N/A 1/12/77 DAW
C) N/A 1/12/77 DAW D) N/A 1/12/77 DAW

6. SCOPE/LOCATION: Reactor Bldg., Unit #2, Area 33 & 34 exterior wall on "U" Line from elev. 716'-10" to 747'-4". See attached sketch for location.

7. REFERENCE CRITERIA:

8. PREPARED BY: DAW Walker DATE: 1/12/77 9. REVIEWED BY: T.A. McGinnis DATE: 1-12-77

10. ACT No.	11. DESCRIPTION	12. C	13. E	14. ITEM/S ACCEPTANCE A	B	C	D
1.0	PREREQUISITES						
1.1	Inspection and reference criteria reviewed for availability, familiarity, and correct approval and revision status.	R		DAW 1/21/77			
1.2	Review performed for open NCRs affecting work operations.	R		DAW 1/21/77			
2.0	IN-PROCESS INSPECTION ACTIVITIES						
2.1	Construction Joints	S		DAW 2/1/77			
	a. Construction joint spacing, size, location per drawings or as specified.						
	b. Construction joints cleaned.						
	~~c. Waterstops installed correctly.~~ NOT APPLICABLE 1/12/77 DAW						
2.2	Expansion, Contraction and Control Joints 1/12/77 DAW NOT APPLICABLE	S		DAW 2/1/77			
	~~a. Expansion joints located and formed per the drawings.~~						
	b. Contraction joints located per the drawings.						
	~~c. Control joints located per the drawings.~~ NOT APPLICABLE 1/12/77 DAW						
2.3	Forms	S		DAW 2/1/77			
	a. Formwork meets workmanship, configuration and gneral dimensional requirements; temporary openings provided. NOT APPLICABLE 1/12/77 DAW						
	~~b. Expanded metal forms used unless prohibited.~~						
	c. Chamfer strips, form coatings, and form ties checked.						
2.4	Reinforcement	S		DAW 2/1/77			
	a. Rebar free of bond impairing coatings.						
	b. Rebar size, location, spacing and tolerances correct.						
	c. Rebar properly supported and tied.						
	d. Rebar splices type as specified.						
	e. Rebar cutting or bending only as specified.						
	Embedded Items	S		DAW 2/1/77			
	a. Civil embeds correct type, securely fastened and properly located.						
	b. All disciplin: embeds properly secured and spaced/ separated.						
	c. Metal embeds f- - o bond impairing coatings.						

CONTINUATION FROM FRONT--PROJECT D

10 ACT No.	11. DESCRIPTION	12. C	13. E	14. ITEM/S ACCEPTANCE A	B	C	D
3.0	FINAL INSPECTION ACTIVITIES						
3.1	Time limitation for adjacent placements not exceeded.	R		DAW 2/2/77			
3.2	Final inspection performed for the following activities and results satisfactory: a. Construction joint location, spacing, cleanliness. b. ~~Expansion~~, contraction ~~and control~~ joint construction/ location. NOT APPLICABLE 1/12/77 DAW c. Form workmanship, configuration, ~~expanded metal~~. d. Reinforcement coatings; location, spacing, clearance, tolerances, support, cutting and bending. e. Embeds type, location, cleanliness, anchorage, space/ separation.	I		DAW 2/2/77			
3.3	Respective discipline embed ~~in~~stallation complete. 1-31-77 Civil/Struct. QCE [signature] 1-26-77 ~~IR~~ No. CCG-1-C2Y-1 Electrical QCE [signature] 1-26-77 IR No. EE-64-4-193W03 ~~Instrumentation QCE~~ 1/12/77 ~~IR~~ NOT APPLICABLE Mechanical QCE L. Worrell 1-13-77 IR No. APPLICABLE Piping QCE M. J. Gelb 1-13-77 IR No. APPLICABLE Welding QCE A. MacDonald 1-17-77 IR No. NOT APPLICABLE	R		DAW 2/2/77	—		
3.4	Preliminary clean-up inspection to verify that no debris, mud, snow, ice or frozen surfaces exist.	I		DAW 2/2/77			
3.5	Review Field Engineering Documents FP10A & FP10B	R		2/2/77 DAW			
4.0	SUPPLEMENTARY RECORDS						
	~~None required.~~ NOT APPLICABLE 1/12/77 DAW						
4.1	FP10A Concrete Call Out Sheet	R		DAW 2-2-77			
4.2	FP10B Concrete Check Sheet						
*43	O.C.C.I.-1 A. MacDonald 1-17-77 D.W 1-17-77						
5.0	EXCEPTIONS						
5.1	No exceptions noted.	R		DAW 2-4-77			
or							
5.2	Indicated exceptions are described in remarks section.	R					

15. REMARKS

* SEE ATTACHED F.I.R. A. MacDonald 1-17-77 D.W 1-17-77

16. COMPLETED INSPECTION RECORD REVIEWED AND ACCEPTED BY: [signature] DATE: 2-21-77

CONCRETE PLACEMENT CHECKLIST--PROJECT D

Concrete Mix C2-P 4000 PSI

Location RIB#2 AREA 33/34

Elevation 716'-10" TO 747'-4"

Date/Time Scheduled 1/13/77

180CY

CHECKLIST

ITEM	SUPERINTENDENT	FIELD ENGINEER
FORMS, LINE & GRADE	James Jarvis	C.J. Rapisil
JOINT PREP.	P. Moore	C.J. Rapisil
REBAR	M.H. Smith	C.J. Rapisil
ANCHOR BOLTS	James Jarvis	C.J. Rapisil
EMBEDDED STEEL	James Jarvis	C.J. Rapisil
ELECTRICAL	M.R. Hamilton	Earl Bray
MECHANICAL	P. Moore	Paul Davis
EMBEDDED PIPING	J. Eckerd	Vincent J. Libert
FINAL CLEANUP	P. Moore	C.J. Rapisil

Final Approval

Superintendent P. Moore DATE 2-1-77 P. Moore

Field Engineer C.J. Rapisil DATE 1-28-77

Quality Control Eng'r M.K. Walker DATE 2-1-77

2/2/77

CONCRETE POUR CARD--PROJECT E

POUR NO. _____ TO EL _____ DATE _____

LOCATION _____

CRAFTS	FOREMAN	ENGINEER	DATE	ACC. PER BNP-QCP
Carpenter				2.1 R
Boilermaker				
Mechanical				6.1 R
Electrical				3.1 R
Piping				6.1 R
Reinforcing				2.1 R
Struc. Steel				2.2 R
Sheet Metal				
Embedments Lines & Grades				2.1 R
Cleaning				5.3 R

FRONT

Remarks _____

Shift Engineer _____ Date _____ Time _____

INSPECTOR'S REPORT

INSPECTION	ACCEPTABLE
Surface Preparation and Cleanliness	☐
Form tightness	☐
Environmental conditions	☐
Condition of placing equipment	☐
Conveying and placing operations	
Deposit of concrete	☐
Layer thickness	☐
Concrete compaction	☐
Illumination	☐

Mix Number _____ Type finish _____

Conc. placing foreman _____

Date poured _____ Cu. yds. placed ___

Time: Started _____ Completed _____

Remarks _____

BACK

The above concrete placement and inspection was done in accordance with _____ and is acceptable.

The above repair poured with replacement concrete was done in accordance with _____ and is acceptable. Attachment D of BNP-QCP-5.4 has been completed and

above grout or drypack operation was done in accordance with BNP-QCP-5.5,R___ and is acceptable. Attachment A of _____ has been completed.

Representative _____ Date _____

QUALITY CONTROL INPSECTION RECORD - PROJECT F

Project F
INSPECTION REPORT

No. (I.D.)
Page 1 of
Initiator
Building/Area (BLDG) | Reference IP (I.D.)
Activity (BLDG) | (CHECK ONE) ☐ In Process ☐ Install ☐ Final
Location | CAT - ☐ I ☐ II ☐ III (CAT) | ASME III - Class ☐ 1 ☐ 2 ☐ 3
Drawing No. (DRWG) ☐ E/C ☐ Vendor | Issue No. | Spec. No. (SPEC)

No.	S	U	REWORK #1 S	REWORK #1 U	REWORK #2 S	REWORK #2 U	INSPECTION ATTRIBUTES	APPROVED DATE	APPROVED SQC SIGN.
S-51							Verify-Approved Founding Elevation		
S-68							Verify-Geotechnical Approval of Founding Elev.		
S-57							Verify-Location,Surface Prep.Construction Jts.		
S-58							Verify-Contraction Joints		
S-59							Verify-Expansion Joints		
S-54							Verify-Orientation Of Formwork		
S-55							Verify-Surface Preparation of Forms		
S-56							Verify-Tolerance of Formwork		
S-302							Verify-Current Approved Placement Drawings		
S-303							Verify-Grade of Reinforcing		
S-304							Verify-Cadweld Inspection		
S-305							Verify-Welding Inspection		
S-306							Verify-Lapped Splices		
S-308							Verify-Size of Rebars		
S-309							Verify-Number and Location of Rebars		

REMARKS:

RELATED DOCUMENTS

INSPECTION COMPLETE - UNSATS LISTED — Date — Inspector
INSPECTION COMPLETE - ALL ATTRIBUTES SAT — Date — Inspector
RELATED N & D | CLOSED DATE | APPROVED SIGNATURE

FOR PLANNING ONLY

Project F
INSPECTION REPORT SUPPLEMENT

No.
Page 2 of

No.	S	U	REWORK #1 S	REWORK #1 U	REWORK #2 S	REWORK #2 U	INSPECTION ATTRIBUTES	APPROVED DATE	APPROVED SQC SIGN.
S-310							Verify-Rebar Support		
S-311							Verify-Cleanliness of Rebars		
S-312							Verify-Placement of Tolerances		
S-313							Verify-Concrete Protection (Cover)		
S-314							Verify-Bending and/or Straightening		
S-60							Verify-Compressible Material (Rattle Spaces)		
S-61							Verify-Water Stops		
S-69							Verify-Anchor Bolts		
S-62							Verify-Embedments		
S-63							Verify-Inserts, Sleeves and Pipes		

FOR PLANNING ONLY

REWORK OF UNSAT ATTRIBUTES

REWORK #1 — ☐ Rework ☐ Engrg. Dispos. (N & D) — DISPOSITION WITHIN IP ☐ YES ☐ NO — Date — Contractor — CQCS
REWORK #2 — ☐ Rework ☐ Engrg. Dispos. (N & D) — DISPOSITION WITHIN IP ☐ YES ☐ NO — Date — Contractor — CQCS
N & D REQUIRED — ☐ Engrg. Dispos. (N & D) — DISPOSITION — Date — CQCS

8.81

CONCRETE POUR CARD--PROJECT F

Card Nº 137	Date
Concrete Mix	Strength
Identification of Pour	
Concrete Batching Record No.	

Ready For Pour	Signatures & Dates	
	Contractor	SQC
FORMS		
REINFORCING		
PIPING		
ELECTRICAL		
MECHANICAL		

Approved by E/C Rep.

Approved by QC Engr.

Pour Schedule

Date Time

Contractor Supervisor _____ Signature

QC Engineer _____ Signature

Pour Re-Scheduled

Date Time

Contractor Supervisor _____ Signature

QC Engineer _____ Signature

STANDARD WORK PLAN AND INSPECTION RECORD FOR CONCRETE OPERATIONS--PROJECT G

REV	DATE	REVISION DESCRIPTION	RFE	SUP	QCE	REV	DATE	REVISION DESCRIPTION	RFE	SUP	QCE
0						2					
1						3					

ITEM NO.	WORK/INSPECTION ACTIVITY SEQUENCING REQUIRED YES ☐ NO ☐	INSTALLATION DOCUMENT #	REV	REV	HOLD PT	SUP'T	RFE	DATE	QCE	DATE	TYPE
	PREREQUISITES										
1	Estimated Concrete Quantity	NA				NA			NA		
2	Concrete Mix A B C D 1 2 PG					NA					
3	Grout Required Yes ☐ No ☐					NA					
4	Type of Finish					NA					
5	Type of Curing					NA					
6	Verify materials are available for installation	NA				NA	NA		NA		
7	Verify access to the work site is available, free of obstructions, adequate to accommodate the traffic and sequenced with other activities	NA				NA	NA		NA		
	CONCRETE OPERATIONS										
20	Prepare existing construction joints										
21	Verify joint surfaces (QCI 9.1-1)										I
30	Install waterproofing										
35	Install waterstop										
36	Verify waterstop (QCI 9.1-1)										I
40	Install reinforcing steel										
41	Verify rebar installation (QCI 9.1-1)										I

SIGNATURES	FOREMAN	DATE	SUPERINTENDENT	DATE	RFE	DATE	QCE	DATE

8.83

WORK PLAN AND INSPECTION RECORD (CONTINUED)--PROJECT G

ITEM NO	WORK/INSPECTION ACTIVITY		INSTALLATION DOCUMENT #	REV	REV	HOLD PT	SUP'T	RFE	DATE	QCE	DATE	TYPE
42	Verify cadweld splices	(QCI 9.1-1)										R
50	Install forms/blockouts											
51	Verify forms/blockouts	(QCI 9.1-1)										I
60	Install const., control, expansion/contraction joints											
61	Verify const., control, expansion/contraction joints	(QCI 9.1-1)										I
70	Install embeds other than reinforcing steel											
71	Verify civil embeds	(QCI 9.1-1)										I
80	Verify structural steel complete	(QCI 9.1-7)										R
81	Verify Mech/Pipe embedded items	(QCI 9.1-)										
82	Verify electrical embedded items	(QCI 9.1-)										
83	Verify I&C electrical items	(QCI 9.1-)										
84	Verify embed welding and NDE complete	(QCI 9.1-9)										
85	Verify leak testing complete	(QCI 9.1-)										
90	Survey complete											
100	Liner Plate completed	(QCI 11.1-5)										R
101	Verify liner plate welding and NDE complete											
110	Perform preplacement cleanup/preparation											
111	Verify receiving surfaces, and placement equipment	(QCI 9.1-1)										I
112	Verify weather protection/conditions	(QCI 9.1-1)										I
113	Verify testing preparations made; Lab notified	(QCI 9.1-1)										I
114	Final preplacement hold point release	(QCI 9.1-1)				QC						R

8.84

WORK PLAN AND INSPECTION RECORD (CONTINUED)--PROJECT G

ITEM NO.	WORK/INSPECTION ACTIVITY	INSTALLATION DOCUMENT #	REV	REV	HOLD PT	SUP'T	RFE	DATE	QCE	DATE	TYPE
120	Place concrete										
121	Verify grout, mix, test results (QCI 9.1-1)				QC						R
122	Verify grade (QCI 9.1-1)										I
130	Finish concrete										
131	Verify finish (QCI 9.1-1)										I
140	Cure concrete										
141	Verify type of cure, starting time, temperature (QCI 9.1-1)										I
142	Verify curing duration (QCI 9.1-1)										R
150	Forms Loosening/Shoring Removal										
151	Loosen forms on:										
152	Verify forms loosened (QCI 9.1-1)										I
153	Verify concrete has reached _____ psi compressive strength prior to removing shoring (QCI 9.1-1)										R
	Determine method of concrete repair:										
160	Standard repair with grout ☐										
161	Verify preparation (QCI 9.1-1)										I
162	Verify finish (QCI 9.1-1)										I
163	Verify curing (QCI 9.1-1)										I
	-Or-										
170	Standard Repair with Concrete ☐ (See WP&IR #)										
171	Review WP&IR (QCI 9.1-1)										R
	-Or-										
180	Defer repair to later date ☐ (See WP&IR #)										
181	Review WP&IR (QCI 9.1-1)										R
190	Perform architectural finish, type:										
191	Verify finish (QCI 9.1-1)										I
200	Verify concrete placement complete (QCI 9.1-1)										R
210	Review completed WP&IR (QCI 9.1-1)										R

8.85

CONCRETE PLACEMENT INSPECTION CHECKLIST--PROJECT G

Inspection Item	Initial/Date PRELIMINARY INSPECTIONS		FINAL ACCEPTANCE
V. REINFORCING STEEL			
A. Size and number of rebars is per			
Dwg_____ Rev._____ DCN_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
B. Spacing is per			
Dwg_____ Rev._____ DCN_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
C. Rebar is tied and anchored	_____	_____	_____
D. Support spacing is satisfactory	_____	_____	_____
E. Splices are satisfactory	_____	_____	_____
F. Concrete cover is ok	_____	_____	_____
G. Field bending of rebar ok	_____	_____	_____
VI FINAL PREPLACEMENT CLEANUP	INITIALS	DATE	
A. Receiving surfaces are clean	_____	_____	
B. Embeds, joints, waterstop, forms are clean and surfaces to receive concrete are throughly wet	_____	_____	
C. Placement equipment is clean	_____	_____	

Reviewed by_____

Date_____

CONTINUATION--PROJECT G

Inspection Item	Initials	Date
I. CONSTRUCTION JOINTS		
A. Joints are located and spaced properly		
B. Joint surfaces have been cleaned properly		
C. Joints are made correctly		
II. FORMS		
A. Condition of forms is ok		
B. Chamfer strips are properly installed		
C. Forms are properly cleaned and coated		
D. Blockouts are per Dwg_____ Rev._____ DCN_____		
E. Control joints ok		
F. Expansion/contraction joints per Dwg_____ Rev._____DCN_____		
III WATERSTOP		
A. Size and location per Dwg_____Rev._____ DCN_____		
B. Joint materials ok		
C. Splices are made at change in direction		
D. Installation is per manufacturer's instructions		
IV EMBEDS OTHER THAN REINFORCING STEEL		
A. Embeds are oriented properly per Dwg_____ Rev._____DCN_____		
B. Embeds are supported and secured		
C. Consolidation access ok		

CONCRETE PREPLACEMENT CHECK LIST--PROJECT H1

Customer _____ P. O. # _____ Contract No. _____

Project Site _____ Pour No. _____

LOCATION: Elevation: Time: Date:

		CHECKED	N.A.
1. Forms: Checked:			
a. Snap Ties	a.		
b. Clamps and Shee Bolts	b.		
c. Form Joints Tight	c.		
d. Alighment and Grade	d.		
e. Bracing	e.		
f. Shoring	f.		
2. Embedded Items:			
a. Sleeves	a.		
b. Embedded Plate	b.		
c. Anchor Bolts	c.		
3. Reinforcing Steel: Checked:			
a. Tied 50%	a.		
b. Proper Size and Quantity — Visual ( ) Per Drawing ( )	b.		
c. Acceptable Spacing and Form Clearance — Per Drawing ( ) Per ACI 318-71 ( )	c.		
d. Cadwelds	d.		
4. Waterproof Membrane:			
5. Waterstop			
6. Stainless Steel Free of Carbon Steel			

Remarks: _____

_____

_____

_____ by _____ Date _____

CONCRETE PLACEMENT INSPECTION REPORT--PROJECT H2

CONCRETE PREPLACEMENT	DATE	APPV'D	REMARKS
1.0 Surface Preparation			
2.0 Forms			
3.0 Embedded Items			
4.0 Joints			
5.0 Line & Grade			
6.0			
REINFORCING STEEL PLACEMENT			
1.0 Cleanliness of Resteel			
2.0 Resteel Secured			
3.0 Placed for Drawings			
4.0 Field Cutting			
5.0 Concrete Cover			
6.0 Placing Tolerance			
7.0 Field Bending (When Req)			
8.0			
9.0			
CONCRETE PLACEMENT			
1.0 Correct Mix			
2.0 Final Preparation			
3.0 Working Conditions			
4.0 Placing Equipment			
5.0 Mix Appearance			
6.0 Placement Method			
7.0 Consolidation			
8.0 Finishing Surface			
9.0			
10.0			
DRAWINGS:			

CONCRETE PREPLACEMENT CHECKLIST--PROJECT H2

ITEM	REFERENCE
1.0 Surface Preparation	
1.1 Proper preparation of concrete surfaces to be poured against:	
a. Horizontal and vertical construction joints shall have keys unless otherwise noted on dwg.	SP-201, 1:09.1.4
b. The surface of the concrete at all joints shall be thoroughly cleaned and all laitance removed prior to placing adjoining concrete.	ACI 301-72; SP-201, 1:09.1.
c. Deleted	
1.2 Surface clean, clear of debris and organic material dirt, gravel, scale, loose fragments and other objectionable substances.	SP-201, 1:12.2
1.3 Vapor barrier, as required by drawings	SP-201, 1:20
2.0 Forms	
2.1 Wood or metal	SP-201, 1:07.2.1
2.2 Clean, smooth, good condition	SP-201, 1:07.2.4
2.3 Form ties shall terminate twice the dia. of tie or at least 3/4", from the formed face	SP-201, 1:07.3; ACI 301-72, 4.2.8
2.4 Forms, in contact with surfaces to receive Nuclear coatings will be I-P Black form or forms as specified in SP-201, 1:07.2 coated with "Nu-klad 108" or "Plastic Formcoat", or approved form release agent.	SP-201, 1:07.2.7a and b
2.5 Permanently exposed surfaces have 3/4" chamfer strip	SP-201, 1:07.1

CONTINUATION--PROJECT H2

2.6	Form appears sufficiently rigid and strong. Properly braced and tied.	SP-201, 1:07.2.1, and 2
2.7	Forms tight for good joint to prevent loss of mortar.	ACI 301-72, 4.2.4
2.8	Keyways for all const.jts. or as shown on drawing.	SP-201, 1:09.1.4
2.9	Blockouts adequately secured and located	SP-201, 1:11.4
2.10	Tolerance conforms to ACI 301, Table 4.3.1	SP-201, 1:07.5.1; ACI 301-72 Table 4.3.1

3.0 Embedded Items

3.1	Correct MK number	SP-201, 1:11.3
3.2	Secured to avoid displacement	SP-201, 1:11.2 and 4
3.3	Openings, if not on drawing, approved by engineer	SP-201, 1:11
3.4	Anchor bolts within specified tolerances	SP-201, 1:11.9.1, 2 and 3
3.5	Location of item per drawing	SP-201, 1:11.3
3.6	Tolerance of embedded item per dwg.	SP-201, 1:11.2, 1.11.9
3.7	Embedded items shall be protected	SP-201, 1:11.7

4.0 Joints

4.1	Construction Joints in accordance with drawing or approved by engineer.	SP-201, 1:09.1.4, 1:09.1.7
4.2	Max. spacing of 48' for vertical construction joint in walls	SP-201, 1:09.1.7
4.3	Max. spacing of 46' for construction joint in suspended slabs	SP-201, 1:09.1.8
4.4	Expansion joints placed as shown on drawings	SP-201, 1:09.2.1
4.5	Waterstop placed as shown on drawings and specified on the specifications	SP-201, 1:10.1; 1:10.2.3

5.0 Line & Grade

5.1	Embedded Items Checked	SP-201 1:11.8

When all items are acceptable, the item on the pour card may be signed off.

QUALITY CONTROL ADMINISTRATION INSPECTION PLAN--PROJECT H

RECEIVING [ ] CIVIL [X] ELECTRICAL [ ] PIPING [ ] INSTRUMENTATION [ ] TEST [ ] OTHER _____

CHG. NO. 462-046 48 LINE NO. _____ SPECIFICATION NO. SP-201 SAFETY RELATED [X]
Revision No. A B Revision No. 2
CODE _____ NONCONFORMANCE NO. QCA 120 NONSAFETY RELATED [ ]

BUILDING Auxiliary Buildings LOCATION AX1-N2-568.33 COMPONENT Structural Concrete Preplacement SUPPLIER/CONTRACTOR _____

CHECK LIST INSPECTION REQUIREMENT	INSPECTION INSTRUCTIONS	ACCEPTANCE STAMP & INITIALS *	DATE	HOLD POINT	REMARKS
I. Preplacement					
A. Base Preparation	Verify (10%)		2/24/77		Bush hammered. Sandblasted, sound surface
B. Formwork	Verify (100%)		2/24/77		Clean, release agent, 3/4" chamfer for exposed corners, slabs & walls
C. Reinforcing					
1. Placement					
a. Surface Condition	Verify (20%)		2/24/77		Free mud, oil, excessive rust, etc
b. Bar Count & Size	Verify (20%)		2/24/77		
c. Tolerance	Verify (20%)		2/24/77		Coverage and effective depth

* See Criteria of Acceptance List of the Same Numbers As Inspection Plan For Acceptance Criteria.

PREPARED BY [illegible] DATE 6-23-76 APPROVED BY [illegible] DATE 7-20-76
QCA ENGINEER QA

APPROVED BY [illegible] DATE 6-24-76 APPROVED FOR FILING [illegible] DATE 4/6/77
QCAM

8.92

QUALITY CONTROL ADMINSTRATION INSPECTION PLAN--PROJECT H

RECEIVING [ ] CIVIL [X] ELECTRICAL [ ] PIPING [ ] INSTRUMENTATION [ ] TEST [ ] OTHER _____

DWG. NO. _____ LINE NO. _____ SPECIFICATION NO. SP-201 SAFETY RELATED [X]
Revision No. _____ Revision No. 2
CODE _____ NONCONFORMANCE NO. _____ NONSAFETY RELATED [ ]

BUILDING Auxiliary Buildings #2 LOCATION AX2-N2-568.33 COMPONENT Structural Concrete Preplacement SUPPLIER/CONTRACTOR _____

CHECK LIST INSPECTION REQUIREMENT	INSPECTION INSTRUCTIONS	ACCEPTANCE STAMP & INITIALS *	DATE	HOLD POINT	REMARKS
d. Splicing					
(1) Lap	Verify (20%)	N/A			
(2) Cadweld		N/A			
(a) Postweld Inspection	Verify (20%)				Check taphole and measure void area
(b) Cadweld failures	Record (20%)				
(c) QCA detected Cadweld replacements	Record (20%)				
(d) Records	Verify (100%)				
e. Cadweld Tensile Test					
(1) Test splice samples					

8.93

See Criteria of Acceptance List of the Same Numbers As Inspection Plan For Acceptance Criteria.

PREPARED BY [signature] QCA ENGINEER DATE 6-23-76 APPROVED BY [signature] QA DATE 7-26-76

APPROVED BY [signature] DATE 6-24-76 APPROVED FOR FILING [signature] DATE 4/26/77

QUALITY CONTROL ADMINISTRATION INSPECTION PLAN--PROJECT H

RECEIVING [ ] CIVIL [X] ELECTRICAL [ ] PIPING [ ] INSTRUMENTATION [ ] TEST [ ] OTHER _____

DWG. NO. _____ LINE NO. _____ SPECIFICATION NO. SP-201 SAFETY RELATED [X]
REvision No. _____ Revision No. _____
CODE _____ NONCONFORMANCE NO. _____ NONSAFETY RELATED [ ]

BUILDING Auxiliary Building #2 LOCATION _____ COMPONENT Structural Concrete Preplacement SUPPLIER/CONTRACTOR _____

CHECK LIST INSPECTION REQUIREMENT	INSPECTION INSTRUCTIONS	ACCEPTANCE STAMP & INITIALS *	DATE	HOLD POINT	REMARKS
(a) Production splice	Record (100%)	N/A			
(b) Sister splice	Record (100%)				
(2) Test Results	Verify (100%)				
(3) Test failure	Record (100%)				
(4) Retest splice	Record (100%)				
(5) Test results	Verify (100%)				
D. Embedded items	Verify (25%)	[signature]	2/24/77		Location, number and type
E. Water stops (waterproofing)	Verify (25%)	[signature]	2/25/77		
F. Final clean-up	Verify (100%)	[signature]	2/25/77		No standing water clean of all debris, existing surfaces dampened See Rem 6.

* See Criteria of Acceptance List of the Same Numbers As Inspection Plan For Acceptance Criteria.

PREPARED BY [signature] QCA ENGINEER DATE 6-23-76 APPROVED BY [signature] QA DATE 7-20-76

APPROVED BY [signature] QCM DATE 6-24-76 APPROVED FOR FILING [signature] DATE 4/26/77

8.94

QUALITY CONTROL ADMINISTRATION INSPECTION PLAN--PROJECT H

RECEIVING [ ] CIVIL [X] ELECTRICAL [ ] PIPING [ ] INSTRUMENTATION [ ] TEST [ ] OTHER _____

DWG. NO. _____ LINE NO. _____ SPECIFICATION NO. SP-201 SAFETY RELATED [ ]
Revision No. _____ Revision No. 2
CODE _____ NONCONFORMANCE NO. _____ NONSAFETY RELATED [ ]

BUILDING Auxiliary Building #2 LOCATION AX2-M2-568.33 COMPONENT Structural Concrete Preplacement SUPPLIER/CONTRACTOR _____

CHECK LIST INSPECTION REQUIREMENT	INSPECTION INSTRUCTIONS	ACCEPTANCE STAMP & INITIALS *	DATE	HOLD POINT	REMARKS
G. Placement release	Record (100%)		2/21/77	X	Sign contractor's preplacement check-off record
					SIGNED OFF AT 7:50. W THERE WAS APPROX 3" OF WATER IN SHEAR
					KEY. CONTRACTOR WILL BE CONTINUE TO DUMP-OUT.
					THIS IS A CONDITIONAL RELEASE OF THAT THE SHEAR KEY IS
					DUMP-OUT BEFORE CONCRETE IS PLACED.

8.95

* See Criteria of Acceptance List of the Same Numbers As Inspection Plan For Acceptance Criteria.

PREPARED BY James R. Miller QCA ENGINEER DATE 6-23-76 APPROVED BY _____ QA DATE 7-20-76

APPROVED BY _____ QCM DATE 6-24-76 APPROVED FOR FILING _____ DATE 9/26/77

QUALITY CONTROL ADMINISTRATION INSPECTION PLAN--PROJECT H

RECEIVING [ ] CIVIL [X] ELECTRICAL [ ] PIPING [ ] INSTRUMENTATION [ ] TEST [ ] OTHER _____

DWG. NO. _____ LINE NO. _____ SPECIFICATION NO. SP-201 SAFETY RELATED [X]
Revision No. _____ Revision No. 2
CODE _____ NONCONFORMANCE NO. QCM-120 NONSAFETY RELATED [ ]

BUILDING Auxiliary Building #2 LOCATION AX2-M2-568.33 COMPONENT Structural Concrete Placement SUPPLIER/CONTRACTOR _____

CHECK LIST INSPECTION REQUIREMENT	INSPECTION INSTRUCTIONS	ACCEPTANCE STAMP & INITIALS*	DATE	HOLD POINT	REMARKS
I. Placement					
A. Joint preparation	Verify (25%)	[illegible]	2/25/77		Dampened, no standing water throughl covered with motar
B. Mix appearance	Verify (25%)	[illegible]	3/18/77		4" max slump non-massive (+1") ~~2" max slump massive (+1")~~ QCA 120
C. Placement method	Verify (25%)	[illegible]	2/25/77		Rate not to exceed 5' per hour 5' max for free drop
D. Consolidation method	Verify (25%)	NP			
E. Keys (construction joints	Verify (25%)	[illegible]	2/25/77		1/3 thickness of member for hort. joints, ½ the lateral dim. for vert. joint
F. Finishing method required	Verify (25%)	N/A			

* See Criteria of Acceptance Key of the same number as Inspection Plan for acceptance criteria.

PREPARED BY [illegible] QCA ENGINEER DATE 6-4-76 APPROVED BY [illegible] QA DATE 6-11-76

APPROVED BY [illegible] QCAM DATE 6-4-76 APPROVED FOR FILING [illegible] DATE 4/21/77

8.96

QUALITY CONTROL ADMINISTRATION INSPECTION PLAN--PROJECT H

RECEIVING [ ] CIVIL [X] ELECTRICAL [ ] PIPING [ ] INSTRUMENTATION [ ] TEST [ ] OTHER _____

DWG. NO. _____ LINE NO. _____ SPECIFICATION NO. SP-201 SAFETY RELATED [X]
Revision No. _____ Revision No. _____
CODE _____ NONCONFORMANCE NO. 120 NONSAFETY RELATED [ ]

BUILDING Auxiliary Building #2 LOCATION AX1-M2-568.33 COMPONENT Structural Concrete Post Placement SUPPLIER/CONTRACTOR _____

CHECK LIST INSPECTION REQUIREMENT	INSPECTION INSTRUCTIONS	ACCEPTANCE STAMP & INITIALS *	DATE	HOLD POINT	REMARKS
I. Post Placement					
A. Curing Method	Verify (25%)		2/28/77		2-25 2-26 2-28 2-27
B. Weather Protection	Verify (25%)		2-8-77		
C. Removal of Formwork	Witness (100%)		2/23 77		
D. Deficient Concrete	Exam (100%)	MA		X	No repairs without S.O. or Engineer approval
E. Contractor's Placement Documentation	Exam (100%)		1/26/77		

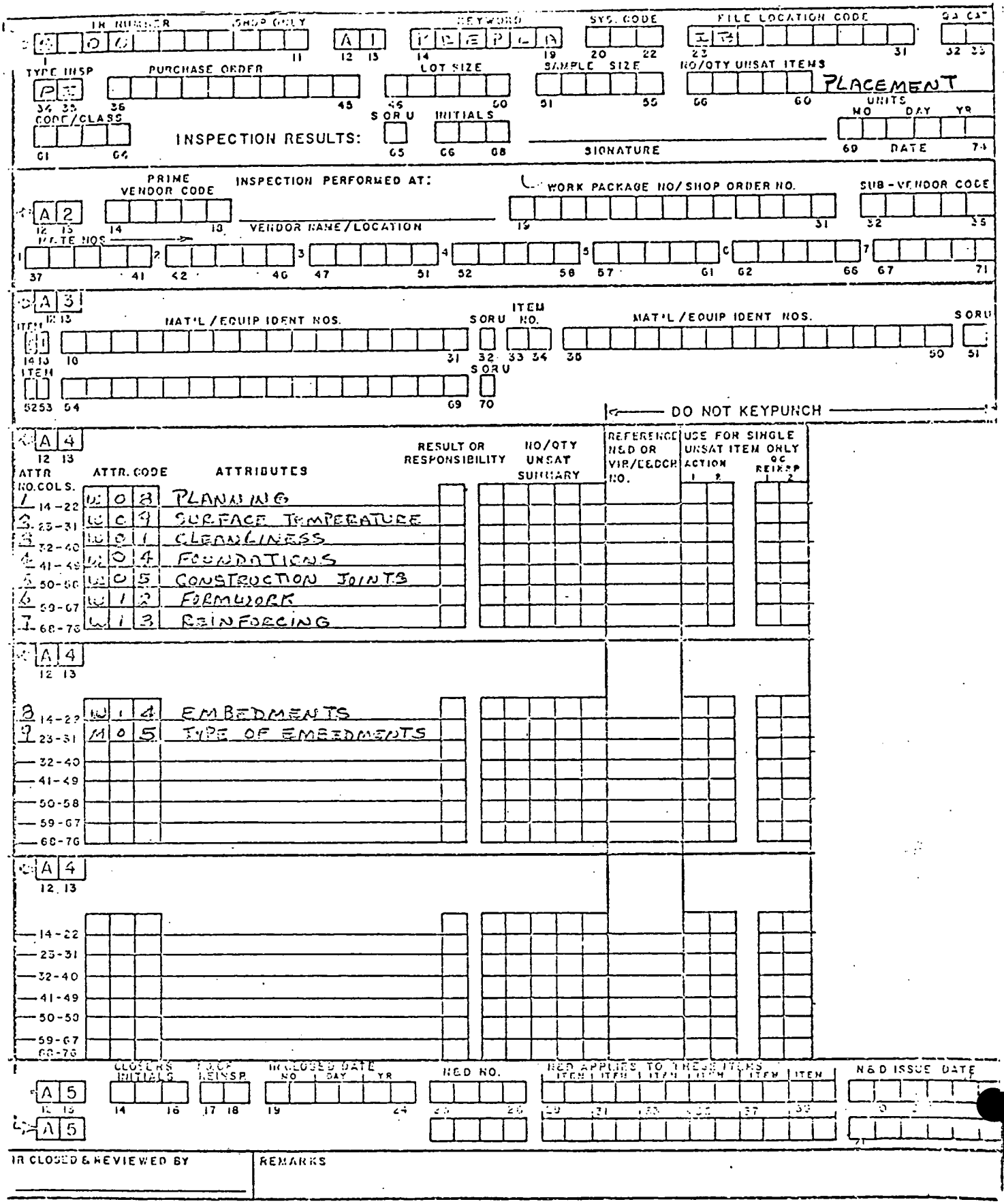
8.97

* See Criteria of Acceptance List of the Same Numbers As Inspection Plan For Acceptance Criteria.

PREPARED BY _____ QCA ENGINEER DATE 6-23-76 APPROVED BY _____ QA DATE 2-20-76

APPROVED BY _____ QCAM DATE 6-24-76 APPROVED FOR FILING _____ DATE 4/20/77

QUALITY ASSURANCE INSPECTION REPORT--PROJECT I



CONTINUATION--PROJECT I

ATTRIBUTES	RESULT OR RESPONSIBILITY IS
PLANNING	
(1) COMPLIANCE WITH DRAWINGS	
(2) ADEQUATE TOOLS & MEN FOR PLACING, COMPACTING, FINISHING AND CURING	
SURFACE TEMPERATURE	
(1) STEEL TEMPERATURE	
CLEANLINESS	
(1) SUBGRADE FREE OF DEBRIS	
(2) REBAR FREE OF CONC. & O.I., ETC.	
(3) EMBEDMENT(S) FREE OF FOREIGN MATERIAL	
(4) FORMWORK & CONST.-JOINTS CLEAN	
FOUNDATIONS	
(1) EXCAVATION COMPACTED (IF REQ'D)	
(2) SUBGRADE FREE OF FROZEN MATERIAL	
(3) STRUCTURAL STEEL ALIGNED	
CONSTRUCTION JOINTS	
(1) KEYWAY(S) COMPLY WITH DWG'S & SPEC.	
(2) LAITANCE REMOVED AND CLEAN, SHARP AGGR. EXPOSED	
(3) JOINTS COMPLY WITH DWG.'S	
FORMWORK	
(1) FORMS ARE TIED & BRACED	
(2) JOINTS ARE TIGHT	
(3) FORM SURFACES COMPLY WITH SPEC.	
(4) VERIFY DIMENSIONS FROM SURVEY NOTES	
(5) CHAMFER INSTALLED (IF REQ'D)	

ATTRIBUTES	RESULT OR RESPONSIBILITY IS
REINFORCING	
(1) MINIMUM CONCRETE COVER	
(2) SPLICES AND LAPS	
(3) SIZE, TYPE, LOCATION & NUMBER	
(4) TOLERANCES	
(5) REINFORCING EXTENSION	
(6) STABILITY AND SUPPORT	
(7) MILL MARKINGS (SPEC. CHEM.)	
EMBEDMENTS	
(1) PROPER PROJECTION	
(2) PROPER LOCATION & NUMBER	
(3) SECURED FOR PLACEMENT	
(4) CAT 1 TRACEABLE TO CONTROL NO.	
(5) PROPER MATERIAL	
(6) GROUT TIGHT	
TYPE OF EMBEDMENT (S)	
(1) ANCHOR BOLTS	
(2) WATERSTOP	
(3) PIPE SLEEVE (S)	
(4) PIPE CONDUIT (S)	
(5) STEEL INSERT (S)	
(6) FLASHING (S)	
(7) GROUNDING	
(8) BLOCKOUT (S)	

REMARKS:

APPENDIX 8.B

CADWELD SURVEILLANCE AND INSPECTION REPORTS

This appendix contains the following project documents and records:

1. Project A--Daily Log for Cadweld Crew
   Cadwelding Checklist

2. Project B--Cadweld Crew Summary
   Daily Log for Cadweld Crew
   Quality Control Checklist

3. Project C--Quality Control Inspection Record

4. Project D--Quality Control Inspection Record

5. Project E--Cadweld Splice Inspection Data
   Acceptability Test Report

6. Project F--Quality Control Inspection Report
   Cadwled Test Record
   Cadweld Control Report
   Cadweld Average Test Log
   Cadwelder Activity Record
   Procedure for Random In-Process Inspection of Cadwelds

7. Project G--Daily Summary Log of Cadweld Inspection
   Cadweld Test Frequency Log

8. Project H--Cadwelder Splice Test Report (Contractor 1)
   Cadwelder Splice Crew Record (Contractor 1)
   Cadweld Inspection Report (Contractor 2)

9. Project I--Cadweld Inspection Attribute List
   Quality Assurance Inspection Report

DAILY LOG FOR CADWELD CREW--PROJECT A

Daily Log for Crew No. _____ Date: _____

Inspector _____ Total Welds _____ Rejected Welds _____ Tested Welds _____

Weld No.	Time	Filler Ident.	Visual Inspection Ends A	Visual Inspection Ends B	Elev.	Location	Position	Steel Sleeve Lot Number	Remarks

CADWELDING CHECKLIST--PROJECT A

1. Check that proper equipment (sleeve, powder, pouring basin, crucible, wicking, etc.) is being used to perform the operation.

2. Check each splice sleeve prior to use for absence of rust and other foreign material on the inside surface.

3. Check that bar ends have been saw cut at right angles to the bar and have not been scarfed (deformations must be in the as-rolled condition).

4. Check that bar ends have been cleaned of all dirt, grease, moisture, rust and loose mill scale and power wire brushed to bare metal.

5. Check that bar ends have been preheated to approximately 200°F. to 300°F. immediately prior to assembly of the mold.

6. Check that bars have been marked by center punching or other suitable means, to provide method of assuring that ends are centered in the sleeve.

7. Check to ensure that the powder is thoroughly mixed prior to being placed in the crucible. The charge should be spread over the top of the powder, not just dumped on top.

8. When all packing materials, equipment and pouring basin are in position, check that the assembly has been preheated.

9. Note any unusual conditions during actual firing (slow burn, leakage, etc.) on the Cadweld Report.

QUALITY CONTROL REPORT--PROJECT A

QUALITY CONTROL

REPORT #_____

This report covers the visual and surveillance inspection of mechanical type splices made to join reinforcing bars by the "Cadweld" method.

All reinforcing bar ends were cleaned by heating and were wire brushed, and reheated if moisture was present. Centerpunch marks or other suitable markings were made 12" from the end of each bar to serve as reference points to check on the centering of the bars in the sleeve in the longitudinal direction.

The splices shown on the attached page were accepted in accordance with the provisions set forth in the Specification.

_____ _____

QC_____

DATE_____ _____

CADWELD CREW SUMMARY--PROJECT B

TOTAL IN STRUCTURE _____

DATE _____

TOTAL TESTS MADE _____

TOTAL WELDS MADE _____

TOTAL REJECTED _____

Last Weld No.	No. of Welds Made	No. of Welds Rej.	No. Removed for Test	Total in Structure	Last Test No.	Remarks

Temperature _____ Rain _____

Humidity _____ Time _____

Time _____

DAILY LOG FOR CADWELD CREW--PROJECT B

DAILY LOG FOR CREW NO._____ DATE_____

INSPECTOR_____ TOTAL WELDS_____ REJECTED WELDS_____ TESTED WELDS_____

WELD NO.	TIME	VISUAL INSP.	ELEV.	FILLER I.D.	LOCATION	BAR SIZE	REMARKS

8.105

QUALITY CONTROL CHECKLIST FOR SURVEILLANCE OF CADWELDING--PROJECT B

1. Verify all cadweld operators are qualified.

2. Verify storage of splice sleeves, powder and molds are stored in a clean, dry area with adequate protection from the elements to prevent absorption of moisture.

3. Check to ensure that proper equipment (sleeve, powder, pouring basin, crucible, wicking, etc.) is being used to perform the operation. NOTE: Check bar size transition splices for special cadweld splice kits manufactured for this purpose is used.

4. Verify bar ends to be spliced are properly cleaned to remove mill scale, rust, concrete and other foreign material. Prior to wire brushing, all water, grease and paint shall be removed by heating to 212°F minimum to 300°F maximum. NOTE: Any bar not fired within five (5) minutes of second heating shall be reheated to 212° minimum to 300°F maximum. Bars shall not be scarfed.

5. Verify molds are preheated to 212°F when necessary (new mold, below freezing temperature or change of shift) to drive off moisture.

6. Verify bars are marked by center-punching or other suitable means, so that assurance of centering ends within the sleeve may be made.

7. Check the alignment of sleeve on the bars. Check centering through filler hole in sleeve and around bar ends.

8. Verify during set-up that proper length asbestos wicking is used and that it <u>is not</u> forced into the sleeve at the time of packing, that there is no sleeve slippage (before and after cadwelding), that ceramic insert and guide tube are in place and the crucible and pouring basin are firmly attached to the sleeve.

9. Check to ensure the powder is thoroughly mixed prior to being placed in the crucible. The charge should be spread over the top of the powder, not just dumped on top.

10. Verify splices performed by each crew are tested by a random sampling procedure for each position, bar size and grade of bar. Tests shall be in accordance with the following schedule:

    Four (4) out of the first 100 splices
    Three (3) out of the next 100 splices
    Two (2) out of the next and subsequent 100 splice units.

CHECKLIST FOR SURVEILLANCE OF CADWELDING, CONTINUED--PROJECT B

Verify splice sleeves are visually examined prior to use to ensure the absence of rust and other foreign material on the inside surface.

12. Visual inspection will not be performed with evidence of wicking around cadweld sleeve. Perform 100% visual inspection of the cadweld as follows:

(A) Check for filler metal for the full 360 degrees; however, the splice sleeves need not be exactly concentric or axially aligned with the bars.

(B) Sound, nonpourous filler material shall be visible at both ends of the splice sleeve and at the tap hole in the center of the sleeve. Filler material may be released 1/4" from the end of the sleeve due to the packing material without being considered a poor fill. The allowable void limit shall be in accordance with Figure I of QC-1-2.

(C) Check riser for evidence of slag or porous metal; this is cause for rejection. A single shrinkage bubble is acceptable.

(D) Check to ensure sleeve did not slip during the cadweld operation by measuring from the permanent mark on the bar to the center of the sleeve.

NOTE: Any splice which, in the judgment of the inspector does not pass visual inspection, shall be cut out.

Check list items No. 1 to No. 11 shall be inspected on a surveillance basis by Quality Control. Check List item No. 12 shall be 100% visual inspection of the completed cadweld and visual acceptance annotated on Daily Cadweld Crew Breakdown form.

INSPECTOR _____ DATE _____

REMARKS:

QUALITY CONTROL INSPECTION RECORD--PROJECT C

5. ITEM/S: A)_____ B)_____

C)_____ D)_____

6. SCOPE/LOCATION:_____

7. REFERENCE CRITERIA:_____

8. PREPARED BY:_____ DATE:_____ 9. REVIEWED BY:_____ DATE:_____

10.ACT NO.	11. DESCRIPTION	12. C	13. E	14. ITEM/S ACCEPTANCE A	B	C	D
1.0	PREREQUISITES						
1.1	Inspection and reference criteria reviewed for availability, familiarity, correct approval and revision status.	R					
1.2	Review performed for open NCRs affecting work operations	R					
1.3	Review maintenance and storage requirements.	R					
2.0	IN-PROCESS INSPECTION ACTIVITIES						
2.1	Personnel qualified	R					
2.2	Work area acceptable, splice sleeves wrapped and traceable to lot number.	S					
2.3	Splice sleeves free of rust, moisture and foreign matter	S					
2.4	Equipment and material properly selected.	S					
2.5	Graphite parts preheated (min. 212 degrees F)	S					
2.6	Graphite parts cleaned.	S					
2.7	Rebar deformations full size and bar end square.	S					
2.8	Rebar ends preheated (min. 212 degrees F).	S					
2.9	Rebar ends cleaned after preheating.	S					
2.10	Rebar marked for reference point.	S					
2.11	Equipment positioned so the sleeve is correctly located.	S					
2.12	Splice sleeves externally preheated after material and equipment is in position.	S					

QUALITY CONTROL INSPECTION RECORD-CONTINUED--PROJECT C

10.ACT NO.	11. DESCRIPTION	12. C	13. E	14 ITEMS/ACCEPTANCE A	B	C	D
2.13	Splices made per Manual RB20M-173.	S					
3.0	FINAL INSPECTION ACTIVITIES						
3.1	Final inspection performed and Test Report Form is filled out accurately and completely and ID number recorded on record drawing only where required. (Primary Containment, Fuel Pool Girder) Damaged sleeves rejected as determined by the Project Field Engineer.	I					
3.2	Crew members requalified when required.	R					
3.3	Test frequency and sampling performed satisfactorily.	T					
3.4	Verify tests conform to the minimum and average tensile strengths.	R					
3.5	Verify conformance to substandard test procedures.	T					
4.0	REVIEW OF SUPPLEMENTARY RECORDS						
4.1	Cadweld inspection and test report form QC-FF-C-7 (attached).	R					
4.2	Splice Location Drawings(attached only where required.)	R					
4.3	Initial qualification, operator list QC-FF-C-1 (filed separately)	R					
4.4	Cadweld production worksheet QC-FF-C-2 (filed separately)	R					
4.5	Cadweld moving average report QC-FF-C-3 (filed separately).	R					
5.0	EXCEPTIONS						
5.1	No exceptions noted	R					
or 5.2	Indicated exceptions are described in remarks section.	R					

15. REMARKS

QUALITY CONTROL INSPECTION RECORD--PROJECT D

5. ITEM/S: A) _____ B) _____

C) _____ D) _____

6. SCOPE/LOCATION: _____

_____

7. REFERENCE CRITERIA: FP-C-3, C-20

Erico Products Bulletin RB20M-173

8. RECORD PREPARED BY: _____ 9. RECORD REVIEWED BY: _____

10. A/T No.	11. DESCRIPTION	12. C	13. E	14. ITEM/S ACCEPTANCE A	B	C	D
1.0	PREREQUISITES						
1.1	Inspection and reference criteria reviewed for availability, familiarity, correct approval & revision status.	R					
1.2	Review performed for open NCRs affecting work operations.	R					
1.3	Review field storage requirements.	R					
1.4	Review qualified cadweld operator's list.	R					
2.0	IN-PROCESS INSPECTION ACTIVITIES						
2.1	Splicing Equipment a. Graphite parts initial preheat. b. Graphite parts cleaned before reuse.	I					
2.2	Splice Sleeves Sleeves covered or sealed prior to use. Sleeve interior checked for rust or other foreign materials.	I					
2.3	Reinforcing Bars a. Deformations are full size and undamaged, and bar ends cut square. Each bar contains reference mark. b. Rebar preheated and cleaned to remove all foreign materials.	I					
2.4	Preheat Materials and equipment preheated as specified.	I					
2.5	Splice Preparation a. Splices made per manufacturer instructions. b. Material and equipment positioned correctly. c. Protection during inclement weather.	I					

REFERENCE COPY

QUALITY ASSURANCE INSPECTION RECORD-CONTINUED--PROJECT D

10. A/T No.	11. DESCRIPTION	12. C	13. E	14. ITEM/S ACCEPTANCE A	B	C	D
3.0	FINAL INSPECTION ACTIVITIES						
3.1	Verify quality verification inspections have been performed and QC Cadweld Inspection and Test Report Form is filled out accurately and completely.	I					
3.2	Crew members requalified when required.	R					
3.3	Test frequency and sampling performed satisfactorily.	T					
3.4	Verify tests conform to the minimum and average tensile strengths.	R					
3.5	Testing of additional samples performed when required.	T					
4.0	REVIEW OF SUPPLEMENTARY RECORDS						
4.1	Review QC Cadweld Inspection Test Report Form(s).	R					
4.2	Splice Location Drawings.	R					
5.0	EXCEPTIONS						
5.1 or 5.2	No exceptions noted / Indicated exceptions are described in remarks section.	R					

15. REMARKS

REFERENCE COPY

16. COMPLETED INSPECTION RECORD REVIEWED AND ACCEPTED BY: _____ DATE: _____

CADWELD SPLICE INSPECTION DATA SHEET--PROJECT E

Splice Number	Type (P or S)	Bar Size	Position (V or H)	Location	Splicer	Splicing Crew	Inspection				Tensile test*	Splice Acceptable?		Inspector	Date
							Cleanliness	Bar Gap	Sleeve Position	Filler Metal		Yes	No (Disposition - Failed visual inspection, tensile test, replaced, etc.)		

ACCEPTABILITY TESTS FOR CADWELDS--PROJECT E

Specimen No.	Bar Size No.	Tensile Area in^2	Description	Yield Stress, psi	Ultimate Stress, psi	Type of Failure

UNCONTROLLED

Date: _____ Signed _____

Singleton Materials Lab

QUALITY CONTROL INSPECTION REPORT--PROJECT F

QUALITY CONTROL INSPECTION REPORT Owner Site Quality Control Section	Date	Sheet 1 of	NO.
System/Structure Designation	Sub-System/Structure	Category	ASME III yes no
Location	P.O. No.	Reject Tag	Hold Tag
Drawing No. ☐ E/C ☐ Vendor	Issue No.	Spec. No.	Code	Reference SQC
In - Process	Pre - Install	Install	Final	Pretest	Initiator
Inspection Complete - All Attributes "Sat" Date Inspector		Inspection Complete - "Unsats" Listed Below Date Inspector			

No.	S	U	REWORK #1 S	REWORK #1 U	REWORK #2 S	REWORK #2 U	INSPECTION ATTRIBUTES IP-6.4 REVISION 5 8-1-77 Attach. 3.2	Quantitative Data	Date	SQC Sign
S-152							Cadwelder Qualification			
S-153							Random - Rebar End Prep			
S-154							Random - Witness Marks			
S-155							Random - Rebar End and Sleeve Cleanliness			
S-163							Verify - Unique Sleeve ID Number			
S-157							Random - Gap Between Rebars or Bottom			
S-156							Random - Rebar Ends & Sleeve Dryness			
S-158							Random - Proper Cadwelding Kit			
S-159							Random - Proper Installation Equipment			
S-160							Random - Filler Metal Remixed			
S-169							Verify - Proper Splice Staggering			
S-162							Measure - Sleeve Displacement			
S-161							Measure - Sleeve Ends & Tap Hole Voids			
S-168							Verify - No slag at tap hole			
S-164							Verify - Cadwelder ID Symbol			
S-166							Verify - Test Sample ID and Test Results			
S-170							Verify - Repair or removal and replacement of "B" Series Sleeves per IP 9.3S.			

CORRECTIVE ACTION PLANNED

☐ Rework ☐ Engrg. Dispos. (N&D) ☐ Scrap — Corrective Action Completed: Date _____ Contractor _____

Rework #1: ☐ Rework ☐ Engrg. Dispos. (N&D) ☐ Scrap — Disposition: Date _____ Contractor _____ QC Approval _____

Rework #2: ☐ Engrg. Dispos. (N&D) — Disposition: Date _____ QC Engineer _____

Remarks: (Measure/Test Device Identification No.)

FOR INFORMATION ONLY

Related N&D	Closed Date	Approved Signature

CADWELD TEST RECORD--PROJECT F

Cadwelder _____

ID No _____ Date Welded _____

Type Sample _____ prod _____ sister _____ qual

Position _____ horiz _____ vert _____ diag

Rebar Size _____ Grade _____

Contr. Sleeve ID No _____

Sleeve Series _____ Lot No _____

ID

Related IR No _____

Visual insp. of qualification splice (In accordance with IP 6.4)

_____ _____

Inspector Name Number

TENSILE TEST RESULTS

ID

Instrument No _____

Max. Load _____ Pounds

Max. Stress _____ PSI

TSG Operator _____ Name _____ Number

Date Tested _____

Type Break _____

SAT _____ UNSAT _____

(In accordance with TM 9.4)

NO

CADWELD CONTROL REPORT--PROJECT F

Building Code No. (ID)	Member (SUBJ)	Date Mo.	Date Day	Date Yr.	Inspect. I.D. No.	Inspect Initials	Bar Size	Position	Sleeve Series	Related I.R. No. (ID)	Transaction Code (Circle)		Page
											2 = Addition 5 = Change	2 5	
6-8	9-15	16-21			22-24		25	26	27-28			71	77-78

Sleeve Number No.	Sleeve Number *	Welder I.D. No	Cadweld Location Face	Cadweld Location Elevation	Cadweld Location Coordinates	Visual Sleeve Displacement	Visual No Slag	Void Area Lt. / Top	Void Area Rt. / Bot	Remarks	Seq.
1-6	7	10-13	36	37-41	42-51	52	53	54-55	56-57	58-68	79-80

8.116

*SPLICE NUMBER SUFFIX

P = Production Sample Replacement
R = Reject Splice Replacement
S = Sister Sample Taken
T = Indicates Tested Splice
Trace Samples, Rejects & Replacements in Remarks
REP = Replacement
PROD = Production
SIS = Sister Sample

S = Satisfactory
U = Unsatisfactory; Void Area, facing lot number

Data Reviewed by _____ Date _____

CADWELD AVERAGE TEST LOG--PROJECT F

	1) Cadweld Test Record No.	2) Tensile Stress PSI	3) Stress 15	4) Average of Fifteen Tests
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
21				
22				
23				
24				
25				
26				
27				

CADWELDER ACTIVITY RECORD--PROJECT F

ACTIVITY

Date	No. Splices this Date	Total to Date	No. Visual Rejects

TEST CYCLE

Qualification ___,___,___ ___,___,___

0-10 ___,___,___

10-100 ___,___,___ ___,___,___ ___,___,___ ___,___,___

100-200 ___,___,___ ___,___,___ ___,___,___

200-300 ___,___,___ ___,___,___ ___,___,___

300-400 ___,___,___ ___,___,___ ___,___,___

400-500 ___,___,___ ___,___,___ ___,___,___

500-600 ___,___,___ ___,___,___ ___,___,___

TYPICAL (1), (2), (3)

(1) Type Sample P, S, or Q

(2) Test Record Number

(3) Splice Number (number of splices since start of cycle)

PROCEDURE FOR RANDOM IN-PROCESS INSPECTION OF CADWELDS:

RESULT OF DICE THROWS--PROJECT F

Date: Related IR#

CREW	WHITE	GREEN	RED	RED

Red 1	S-153	-	Rebar End Preparation
Red 2	S-154	-	Witness Marks
Red 3	S-155	-	Rebar End Cleanliness
Red 4	S-156	-	Rebar Ends and Sleeve Dryness
Red 5	S-157	-	Gap Between Rebars
Red 6	S-163	-	Unique Sleeve ID

PROCEDURE FOR RANDOM IN-PROCESS INSPECTION OF CADWELDS BY THROWING DICE (CONTINUED)--PROJECT F

1. Set will consist of 1 white, 1 green and 2 red dice.

2. Inspector will throw dice for each Cadwelding crew at the beginning of each shift and after they have completed a set of six Cadwelds. The results of these throws will be recorded on the attached form.

3. Procedure

   A. The white die will determine whether an in-process inspection will be performed on any of the six Cadwelds in question. If the white number is odd an inspection will be made. If the white number is even an inspection will not be made.

      NOTE: This does not apply to the 100% final inspection of all Cadwelds.

   B. The green number will establish which of the six Cadwelds will be inspected.

   C. The red numbers will establish which attributes listed on the attached form are to be verified. If both red numbers are the same, all attributes shall be verified.

4. If any attribute verified by this procedure is less than satisfactory, the inspector shall perform 100% inspection on the next two Cadwelds produced by that crew.

5. Inspection results will be recorded on SQCF-640 (061077).

DAILY SUMMARY OF CADWELD INSPECTION--PROJECT G

(2) Splice Number	(3) Crew No.	(4) Bar Size	(5) Test	(6) Series T	(6) Series B	(7) Pro. or Sister	(8) Replacement	(9) Position V	(9) Position H	(9) Position D	(10) Plotted Dwg No.	(11) Ends	(12) Tap Hole	(13) Centering	(14) Rej.	(15) Prep. Inspections Yes	(15) Prep. Inspections No	(16) Sign. of Inspector	(17) Date Splice Made	(18) CCE	(19) Trans. to Frequency Log	(20) Remarks
SB-939	SB	7-7		X		PRO		X			Fsk-C 6997	S	S	S		X		D Strahan	1-27-77	JD	DSB	

CADWELD TEST FREQUENCY LOG--PROJECT G

CREW_____ POSITION_____ BAR SIZE_____ SERIES_____

No. of Splices Made by Crew	Splice Number	Test Splice	Sister or Production	Plotted on Dwg. No.	Date Splice Made	Lab Test Rep Number	Tensile Strength	Type Failure	Average Tensile	Pass	Fail

CADWELD SPLICE TEST REPORT--PROJECT H1

DATE _____

REPORT NO. _____

SPLICE NO.	CREW	BAR SIZE	SLEEVE LENGTH X OD	POSITION V/H/D(6)		TENSILE TEST LOAD LBS.	SPECIFIED LOAD (3) / 125% YIELD	TYPE(4) OF FRACTURE	PASS REJECT	REMARKS(5)

8.123

This form shall clearly indicate the sequence of testing. The specimen identification number shall contain the symbols "S" if the specimen is a sister splice or the symbol "P" if production splice.

Specified tensile load or 125% of yield based on ASTM Spec. A-615-68 Grade 40 and specified cross-sectional area of bar (in lbs.).

Types of Fractures:

a. Bar pull out

b. Bar pull out with shear of deformations

c. Sleeve break.

d. Bar break (inches from sleeve or grips).

(5) Remarks: Unusual splice appearance voids, excentricity, cocking, etc.

(6) Vertical/Horizontal/Diagonal.

TESTED BY _____

CADWELD SPLICE CREW REPORT--PROJECT H1

NO. _____ SPLICER _____

SPLICE NUMBER	ELEV.	POSITION	BAR SIZE	POWDER & SLEEVE BER. No.	DATE & TIME MADE	VISUAL OK BY	VISUAL INSP. DATE	SEQUENCE NO.	TENSILE TEST DATE	TEST PASS REJECT	SPLICE APPROVED BY	SPLICE APP. DATE

8.124

CONCRETE INSPECTION REPORT--PROJECT H2

POUR NO. _____

SLEEVE NO.	MATERIAL CERT. NUMBER		PRE-HEATING	CLEANING	WITNESS MARKS	ASSEMBLY	Voids		BAR CENTER	Slag	Filler Metal	Sleeve Type	Cadwelder	Date/ Inspector	REMARKS
	SLEEVE	POWDER													

8.125

X - When marked in box means item not witnessed
A - Acceptable
R - Unacceptable

FORM OP 10.3-1
REVISION 1

CADWELD INSPECTION ATTRIBUTE LIST--PROJECT I

ORIGINATOR: ☒ QSD ☐ SITE	PROJECT/UNIT N/A	LIST NUMBER	DATE

ATT NO.	ATTRIBUTE DESCRIPTION	INSPECTION TYPE										REFERENCE SOURCE(S)	PAR. REF.
		SHOP	REC. INSP.	PRE-INSTALL	IN-PROCESS	COMP'T TEST	FINAL	REL. TO TEST	SYS. TEST	QUAL.			
1	Preheating				X					X		Ref. 2.3	5.2.1
2	Cleaning				X					X		Ref. 2.3	5.2.2
3	Witness Marks				X					X		Ref. 2.3	5.2.3
4	Set-Up				X					X		Ref. 2.3	5.2.4
5	Filler Metal				X					X		Ref. 2.3	5.2.5
6	Sleeve Type				X		X			X		Ref. 2.3	5.2.6
7	Identification						X			X		Ref. 2.3	5.2.7
8	Bar Centering Marks						X			X		Ref. 2.2	5.2.8
9	Voids and Slag						X			X		Ref. 2.2	5.2.9
10	Location						X					Ref. 2.2	5.2.10
11	Ends Square Cut				X					X		Ref. 2.2	5.2.11
12	Splice Test Results						X			X		Ref. 2.2	5.2.12

QUALITY ASSURANCE INSPECTION REPORT--PROJECT I

ITEM DESCRIPTION: CADWELDING

IR NUMBER: S00 | SHOP ONLY: A1 | KEYWORD: CADWELD | SYS. CODE | FILE LOCATION CODE: IC | QA. CAT.

TYPE INSP: IN PROCESS | PURCHASE ORDER | LOT SIZE | SAMPLE SIZE | NO/QTY UNSAT ITEMS | SET-UPS

CODE/CLASS | S OR U | INITIALS | INSPECTION RESULTS: | SIGNATURE | UNITS | DATE: MO DAY YR

A2: N/A PRIME VENDOR CODE | INSPECTION PERFORMED AT: | VENDOR NAME/LOCATION | WORK PACKAGE NO/SHOP ORDER NO. | SUB-VENDOR CODE

M&TE NOS: 1 | 2 | 3 | 4 | 5 | 6 | 7

A3: ITEM 01 | MAT'L/EQUIP IDENT NOS. | S OR U | ITEM NO. | MAT'L/EQUIP IDENT NOS. | S OR U

ITEM | MAT'L/EQUIP IDENT NOS. | S OR U

DO NOT KEYPUNCH

A4:

ATTR NO. COLS.	ATTR. CODE	ATTRIBUTES	RESULT OR RESPONSIBILITY	NO/QTY UNSAT SUMMARY	REFERENCE N&D OR VIR/E&DCR NO.	USE FOR SINGLE UNSAT ITEM ONLY ACTION 1 2	QC REINSP 1 2
1 14-22	W09	PREHEATING					
2 23-31	W01	CLEANING					
3 32-40	W06	WITNESS MARKS					
1-49	W03	SET-UP					
50-58	M06	FILLER METAL					
6 59-67	M05	SLEEVE TYPE					
7 68-76	W07	ENDS SQUARE CUT					

ACTION ASSIGNED
1.
SIG/INITIALS DATE
2.
ACTION COMPLETED
1.
SIG/INITIALS DATE
2.

A4:

14-22	
23-31	
32-40	
41-49	
50-58	
59-67	
68-76	

QC REINSPECTION ALL ITEMS SAT
SIG/INITIALS DATE
JOB ORDER NO. 12179
DWG. NO/REV.

A4:

14-22	
23-31	
32-40	
41-49	
50-58	
59-67	
68-76	

SPEC. NO/ADD NO/REV. 2199.142-999 DATE 4-28-77 Add B Rev-1
PO. CHANGE NO. (PQC ONLY) N/A
ATTR. LIST NO/IPS NO. D-9.2-1-1066

A5: CLOSERS INITIALS | NO. OF REINSP. | IR CLOSED DATE MO DAY YR | N&D NO. | N&D APPLIES TO THESE ITEMS ITEM ITEM ITEM ITEM ITEM ITEM | N&D ISSUE DATE MO DAY YR

IR CLOSED & REVIEWED BY

REMARKS

QUALITY ASSURANCE INSPECTION REPORT--PROJECT I

ITEM DESCRIPTION: CADWELDING

IR NUMBER: S00 | SHOP ONLY: A1 | KEYWORD: CADWELD | SYS. CODE | FILE LOCATION CODE: IC | QA. CAT.

TYPE INSP: FINAL | PURCHASE ORDER | LOT SIZE | SAMPLE SIZE | NO/QTY UNSAT ITEMS | UNITS: CADWELDS

CODE/CLASS | INSPECTION RESULTS: | S OR U | INITIALS | SIGNATURE | DATE: MO DAY YR

A2: N/A PRIME VENDOR CODE | INSPECTION PERFORMED AT: | VENDOR NAME/LOCATION | WORK PACKAGE NO/SHOP ORDER NO. | SUB-VENDOR CODE

M&TE NOS: 1 | 2 | 3 | 4 | 5 | 6 | 7

A3: ITEM 01 | MAT'L/EQUIP IDENT NOS. | S OR U | ITEM NO. | MAT'L/EQUIP IDENT NOS. | S OR U

ITEM | MAT'L/EQUIP IDENT NOS. | S OR U

DO NOT KEYPUNCH

A4: ATTR NO. COLS. | ATTR. CODE | ATTRIBUTES | RESULT OR RESPONSIBILITY | NO/QTY UNSAT SUMMARY | REFERENCE N&D OR VIR/E&DCR NO. | USE FOR SINGLE UNSAT ITEM ONLY ACTION 1 2 | QC REINSP 1 2 | ACTION ASSIGNED

ATTR NO. COLS.	ATTR. CODE	ATTRIBUTES
1 14-22	M05	SLEEVE TYPE
2 23-31	B01	IDENTIFICATION
32-40	W06	BAR CENTERING MARK
41-49	W05	VOIDS & SLAG
5 50-58	W27	LOCATION
59-67		
68-76		

1. SIG/INITIALS DATE
2. ACTION COMPLETED
1. SIG/INITIALS DATE
2.

A4: 14-22 | 23-31 | 32-40 | 41-49 | 50-58 | 59-67 | 68-76

QC REINSPECTION ALL ITEMS SAT

SIG/INITIALS DATE

JOB ORDER NO. 12179

DWG. NO/REV.

A4: 14-22 | 23-31 | 32-40 | 41-49 | 50-58 | 59-67 | 68-76

SPEC. NO/ADD NO/REV. 2199.142-999 DATE 4-28-77

Add B REV-1

PO. CHANGE NO. (PQC ONLY) N/A

ATTR. LIST NO/IPS NO. D-9.2-1-1066

A5: CLOSERS INITIALS | NO. OF REINSP. | IR CLOSED DATE NO DAY YR | N&D NO. | N&D APPLIES TO THESE ITEMS ITEM ITEM ITEM ITEM ITEM ITEM | N&D ISSUE DATE MO DAY YR

A5

IR CLOSED & REVIEWED BY

REMARKS

CHAPTER 9

PLACEMENT AND POST PLACEMENT ACTIVITIES

INTRODUCTION

This chapter will discuss those aspects relating to placement and post placement activities. In a number of cases the emphasis will be on time delays and how these interruptions affect the quality of the structure. Prior to discussing these various aspects, the involvement of Quality Control in these activities will be presented.

QUALITY CONTROL INVOLVEMENT IN PLACEMENT ACTIVITIES

Quality Control personnel are generally involved in placement activities on a surveillance or random inspection basis. This is the approach taken on all nine projects. As was pointed out for preplacement activities in Chapter 8, one major difference between projects is the manner in which the objective evidence or documentation is recorded. This aspect is also true of placement activities and will be discussed below.

The Quality Control Inspector on Project A is required to document preliminary as well as in-process placement activities. This can be seen by reviewing the Concrete Pour Site Inspector's Report shown in Appendix 9.A. The preliminary aspects include the verification of the mix design, the condition of the forms and joints, and the proper application of grout. In addition, the QC Inspector is also required to check the conveying equipment to insure that it is functioning properly and verify that the number of vibrators at the placement location is adequate. The placement aspects which must be observed are the vertical drop, lateral flow, and consolidation of the concrete. Any delays or equipment failures must also be documented.

As was the case with the preplacement activities for Project A, discussed in Chapter 8, Quality Control is not deeply involved in placement activities. It should be pointed out, however that the observation of those activities

which could potentially have the greatest affect on quality, e.g., condition of surfaces, placing techniques, consolidation, segregation, etc., is an intergral part of the QC Program. This approach however leaves much of the judgement process up to the individual inspector since there are no specific requirements or guidelines in the Quality Control Procedure. On Project A all verification is made against the project specifications which establishes certain requirements such as "The vibrator should be inserted and withdrawn at many points from 18 to 30 inches apart, for short periods about 5 to 15 seconds." Neither the specifications nor the QC Procedures provide a list of sub-attributes which should be observed under the heading "proper consolidation," and in doing so, it appears that the inspector is being asked to evaluate the overall consolidation method rather than the individual parts. This would lead to the conclusion that if the vibrator was occasionally left inserted for more than 15 seconds, the inspector would be justified in not being overly concerned since the overall affect on the concrete quality would be negligible. This represents a low profile approach towards inspection and would, of course, require a reasonably well trained staff of inspectors. On Project A the planning and preliminary activities have been left to the field engineering and construction group.

The essential quality control features identified for Project A are also included on the Report of Concrete Placement for Project B (see Appendix 9.A). Several additional aspects require documentation, including the lift depth and direction of pour. These documentation requirements seem to be superfluous, especially if the inspector is being observant. The degree of responsibility for interpretation by the inspector is similar to that on Project A. The Project B inspector must refer to the Quality Control Procedure for guidance. With respect to concrete placement, the QCP states the following: "Also check that concrete is properly vibrated, consolidated, and finished as

specified on the drawings using appropriate equipment." Again considerable discretion is required of the inspector, however it does appear that a value judgement is being requested from the inspector regarding the placement practices as a whole, instead of individual activities. It should be pointed out that the adequacy of forms and reinforcing support must be observed. These attributes were also included as a part of the preplacement inspection function which was discussed in Chapter 8. A Quality Control Checklist for the Pump Placement of Concrete is part of the documentation package, and it is evident that the QC involvement in checking the condition of equipment, especially concrete pumps, is greater than that on Project A.

Project C is in sharp contrast to Projects A and B with respect to the level of QC involvement. A number of prerequisite items must be reviewed, including the revision status of plans and specifications, open NCR's affecting the work, and the document number of the Preplacement Inspection Record which was discussed in Chapter 8. This review of the prerequisites covers all of those prerequisite items checked in the preplacement inspection and, hence, appears to be somewhat redundant. The Quality Control Instruction provides additional guidance regarding which items should be checked. The level of detail provided in the QCI is illustrated below for items 1.5, 1.7, and 2.4.

1.5 Check that spare vibrators are available in the ratio of not less than one spare vibrator to each three vibrators required for satisfactory vibration of the concrete.

1.7 Perform a final inspection of all surfaces that are to receive concrete just prior to releasing placement.

a. No debris, mud, snow, ice or frozen surfaces exist.

b. Check the temperature inside the forms to assure that the temperature is as close as may be practical to the temperature of the new concrete (Cold Weather Concrete ACI 306-66).

c. All surfaces shall be thoroughly wetted (all excessive water shall be removed and surface shall be moist).

2.4 Visually observe the work operations to verify that concrete consolidation activities are in accordance with the following:

a. Vibrators are to be operated in the near vertical position, except when consolidating inaccesible concrete such as that located under embeds. Vibrators shall be inserted and withdrawn at many points, from 18 to 30 inches apart. At each insertion, the duration shall be sufficient to consolidate the concrete but not sufficient to cause segregation, generally from 5 to 15 second duration. (ACI 301-66, para. 803 (d)).

b. Vibrators and spares are to meet or exceed the minimum frequency requirement of 7000 cycles per minute, record the calibration device number and calibration due date on the IR.

c. Surface vibrators or manual jitterbugs are not to be used to consolidate slabs greater than 8 inches in thickness.

As can be seen, (with item 1.7b for instance) there is still considerable room for interpretation. The CQP is, however, much more explicit than those found on Projects A and B.

Project C inspectors closely observe those placement practices which are scrutinized on Projects A and B. However, other items such as moisture condition, screed boards, and pre-finishing operations must be inspected and documented. The vibrator serial number and calibration date must also be noted. It is not suggested that these items are not observed on the other projects, but rather, the QC Program on Project C requires that this information be documented and hence is felt to be more formalized. There are several disadvantages to a very formalized program. By preparing a detailed list of items which must be checked, the inspector is required to address each one on a micro scale

rather than observing the placement on a macro scale. The inspector could become so overly concerned with insuring that the vibrator is operated in a near vertical position that he could lose sight of the fact that difficulties with consolidation were being encountered around embeds or that the concrete mix was too stiff. It would appear that the macro approach (which minimizes documentation requirements) would provide a better opportunity for identifying consolidation problems, however, the merits of both approaches should be carefully weighted.

Project D is very similar to Project C and therefore will not be discussed.

The low profile approach used on Projects A and B is also used on Project E. The condition of the placing equipment and environmental conditions and requirements are reviewed by the inspector, but this represents a very limited involvement on the part of Quality Control in the review of prerequisite requirements. It should be recalled that the field engineer performs a similar function as part of his construction/quality responsibilities, and as stated in the Quality Control Procedure covering concrete placement:

> "The Civil Engineering Unit shall be responsible for insuring all prerequisite requirements for placing of concrete are complete and that concrete is placed in the correct pour."

This represents a sharp contrast to most of the other projects, especially Projects C and D. The advantages and disadvantages of the Project E approach have been discussed throughout this report. A Quality Control Procedure on Project E provides the more detailed guidelines on how the placement inspection is to be conducted. It is written in general terms and appears to emphasize the broader aspects of the placement practices. On Project E the revision number of the CQP must be entered on the pour card.

Project G utilizes the Work Plan and Inspection Record to document when an attribute has been satisfactorily completed. Several preliminary items must be checked including the receiving surfaces, placement equipment and weather protection. The inspection of the in-process placement is done in accordance

with a Quality Control Instruction. Included in this QCI is a checklist (see Appendix 9.A) and a detailed explanation of the items listed. The guidance provided on several items, such as consolidation is somewhat detailed. As can be seen in Appendix 9.A, the inspector is required to verify the equipment, vibrator insertion, duration of insertion, and the lateral flow of concrete. The QCI clarification or amplification of the consolidation attributes which provides detailed guidance for the inspector on Project G is given below along with Exhibit 9.1.

a. Consolidation equipment is OK - consolidation is being performed by internal vibrating mechanical devices (vibrators) aided by hand spading or tamping as needed. Vibrators are checked periodically for vibration frequency. Consolidation equipment is clean. Backup equipment is available.

b. Vibrator insertion is satisfactory - vibrator is placed in a near vertical position and allowed to descend by gravity. Penetration into lower lift (if applicable) is sufficient. Spacing of vibrator insertions is satisfactory (spacing is determined by radius of action, see Exhibit 9.1).

c. Duration of insertion is satisfactory - duration of vibrator insertion is sufficient to produce acceptable consolidation. Guidelines are as follows: concrete is generally level, no stacking; large aggregate is embedded; escape bubbles at the surface have nearly stopped.

d. Consolidation does not spread concrete - vibrator action is not spreading or moving the concrete.

This approach is viewed as a micro approach and as mentioned under the discussion of Project C, this is probably not the most ideal method for conveying instructions. In addition to placing and consolidation practices, the weather conditions, batch tickets, delivery times, and delivery pipes must be inspected.

Both contractors on Project H appear to have taken a low profile approach to QC inspection. The emphasis appears to be on those broad attributes such as the

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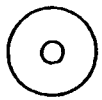
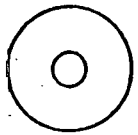
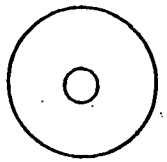
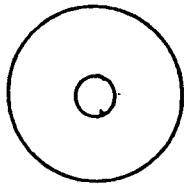
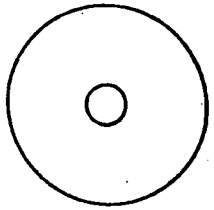
				
Radius of action 4"-6" in 4" to 6" slump concrete.	Radius of action 12" to 16" in 2" to 3" slump concrete.	Radius of action 14" to 18" in 3" to 4" slump concrete.	Radius of action 20" to 25" in 2" to 3" slump concrete.	Radius of action 22" to 28" in 3" to 4" slump concrete.
Useful in very thin areas or as a supplement to larger vibrators where severe congestion occurs. Normally capable of consolidating 1 to 5 cu. yds. per hour.	Used in normal construction and may be needed for supplementary work where larger vibrators are used. Normally capable of consolidating 7 to 15 cu. yds. per hour.		Used in general construction where accessibility is not a problem. Normally capable of consolidating 12 to 20 cu. yds. per hour.	

Exhibit 9.1.--Consolidation of Concrete, Project G

consolidation or placement method, rather than on the specific details of each major activity. The QC Procedures for both contractors provide additional guidance and in most cases this guidance refers to ACI standards or the project specifications.

Contractor H1 has incorporated the construction procedures and the quality control procedures into one document thereby eliminating any conflicts which could arise in the procedures written separately. The provisions are written in general terms except where specific items have been restated from the project specifications.

Contractor H2 has separate quality procedures and construction procedures and inspection is facilitated by the checklist included in Appendix 9.A. As can be seen, this approach. This approach, except for the preliminary revisions and level of documentation, is similar to the formalized program found on several earlier projects. One interesting item should be highlighted. For consolidation the construction procedure states the following:

> "Care should be taken to vibrate close to the form surface and around the reinforcing steel."

This aspect is also emphasized in the QC procedure which states that care should be exercised to insure consolidation in the corners. These guidelines would appear to place the priority on consolidating difficult-to-reach locations. Several other projects however have chosen to stress the fact that the vibrator should not touch the forms or rebar. This is, of course, an integral part of proper consolidation techniques, but it does seem that on these projects the things not to do are emphasized whereas Contractor H2 has chosen to emphasize the things that should be done. This latter approach would appear to be favored.

Projects F and I are similar in that both utilize an attribute list to facilitate placement inspection. The attributes are broad categories, i.e., placing equipment, access to areas, time limit, etc., and therefore the inspector must refer to a Quality Control Procedure for Project F or a Quality Assurance

Directive for Project I for more detailed instructions. The QAD however does not provide guidance which is sufficiently detailed and therefore much is left to the judgement of the inspector. The Inspection Report on Project I is organized to facilitate keypunching the status of attributes onto computer records. Once the records are stored on a computer it becomes quite easy to perform a trend analysis. Thus Project I utilizes the attribute approach during inspection to partially satisfy 10 CFR 50 Appendix B, Criterion XVI, Corrective Action, which requires a mechanism for the prompt identification and correction of deficiencies. On the other projects, the trend analysis is either done by hand or not done at all.

The various approaches to concrete placement inspection appear to be quite similar, except for two aspects. These are 1) the involvement in pre-requisite activities and 2) the amount of documentation. Each project begins with some form of checklist which identifies major categories which should be satisfactorily completed. A QC Procedure supplements this checklist by describing what aspects should be verified for each attribute. In some cases, these QCP's refer to the project specifications or ACI Standards; in other cases, the applicable provisions are restated.

There appear to be two basic types of programs. The first is characterized by the QC Inspector assuming a low profile where his responsibilities for verifying or reviewing prerequisite activities and documents is superficial. The placement checklist contain broad catagories encompassing a number of activities, and the QC Procedures or related documents are presented in general terms. Hence the emphasis in these programs would appear to be on the evaluation of the placement operation as a whole rather than on specific details. Documentation requirements tend to be minimal. Projects A, E, H, and to a certain extent F and I exemplify this approach.

The Quality Control Program of Projects C, D, and G depict the formalized approach. The checklists are comprehensive and include a number of prerequisite activities such as document reviews and equipment checks. The QC directives provide general guidelines which may be restated from the specifications, however, in a number of cases the inspection attributes are stated in detail. The emphasis in such areas tends to be directed towards the evaluation of details and thus is opposite the low profile approach discussed above. Documentation requirements tend to be extensive.

One final point should be made regarding the information contained in the QA procedures and checklists. It appears that several checklist and procedures stress the importance of activities which should not be done rather than those things which should be done. An example related to consolidation was given. In doing so the attention of the inspector may be drawn to specific details rather than the overall operation. This is not to imply that the detail aspects of an operation are not important but their importance should be evaluated in relation to the overall activity. In preparing QC and construction procedures which are very detailed, this perspective seems to be distorted.

DELIVERY SYSTEMS

The delivery of concrete from the batch plant to the forms may be considered a two phase system. Initially the concrete is transported by trucks from the batch plant to some convenient discharge point, and then it is conveyed to the forms by means of buckets, conveyors, creter cranes or pumps.

The principal aspect that will be emphasized throughout the discussion regarding delivery systems, as well as other placement activities, is that the concrete should be delivered, conveyed, and placed as rapidly as possible. In this respect, the addition of water at the point of discharge from the truck, point of sampling, and frequency of testing are all important. These activities have the greatest impact when the method of conveying is by pumping, and

therefore the discussion in this section will be directed towards this mode. The transporting of concrete from the batch plant to the point of discharge is done primarily by two types of trucks, namely 1) the end dump truck and 2) agitator trucks. The type of truck affects the testing aspects, and was discussed in Chapter 6.

Sampling Aspect of Pumping Concrete

The design of mixes which are pumpable is a major concern (9.1). Consideration must be given to the maximum size aggregate and the proportioning of the mortar components, and in this regard the aggregate gradations are very important. The principal aspects of the mix design and quality control of the components have been presented in earlier chapters and therefore will not be restated herein. The concern of most specification writers is over the change in properties of plastic concrete from the point of discharge from the truck to the end of the pump line.

The property changes resulting from pumping concrete are loss of slump and air content. There are several reasons for these losses. Some of these are variations in setting time of cement due to physical or chemical properties, variations in ambient air temperature, concrete temperature during mixing and pumping, variations in the temperature of the material components, behavior of air entraining agents, mix design characteristics, and absorptive capacities of the aggregates. All of these factors are generally recognized even though the interrelationships are not necessarily understood to the degree that slump and air losses can be accurately predicted. This point will be further illustrated in the discussion on correlation testing programs.

ACI 304 (9.1) states that a high degree of quality control for assurance of uniformity must be maintained. Presumably this refers to the control of material quality and adequacy of batching procedures. This concern for quality expressed by the ACI 304 Committee is carried further, however, since most

pumps have a mixing system in conjunction with the receiving chamber and discharge. Therefore, the pump is also considered as a stationary mixer. ASTM C 172-68 has established procedures for sampling at the point of discharge of a stationary mixer, and thus the ACI 304 Committee recommends that sampling be performed at both the truck discharge and point of final placement in order to establish any changes in mix characteristics as well as to assess the quality of the concrete being placed in the structure.

All projects, with the exception of Project E, have required that sampling be done at the point of discharge from the pump line, although some have relaxed this requirement after the completion of correlation programs. Because of the large placements which are scheduled on all projects (placement rates often exceed 150 cubic yards per hour) and the testing frequencies presented in an earlier chapter, the testing effort can become an almost continuous process. This has caused interruptions and delays to varying degrees on all projects (excluding Project E) which interfere with the smooth continuity of the placement and such delays are actually adverse to the objective of producing and placing quality concrete (9.2). Such delays have a definite affect on slump values and make it more difficult for the batch plant to produce batches with consistent slump measurements. The problem of delays is particularly acute under hot weather conditions. This fact is emphasized in ACI 306 (9.4) which states:

> "Cement hydration, temperature rise, slump loss, aggregate grinding, and loss of air all increase with passage of time; thus, the period between mixing and delivery should be kept to an absolute minimum."

There are many undesirable effects which may result if concrete delivery and placement are not expedited.

These include:

1) Increased water demand for desired consistency

2) Difficulty in controlling entrained air

3) Rapid evaporation of mixing water

4) Rapid slump loss

5) Accelerated set

6) Difficulties with normal handling, finishing and curing

7) Greater dimensional change on cooling of hardened concrete

8) Increased potential for plastic shrinkage

9) Reduced durability from increased water demand, air loss, and cracking

10) Possible "cold joints"

11) Increased permeability

The potential for delays resulting from the practice of sampling and testing at the end of the pump line (point of placement) was mentioned above, and it is important to note that on practically every project studied, concern over this problem was expressed. The situation is further compounded when a test parameter is out of the specification range and requires a retest or the cleaning out of the pump line. The former measure occurs fairly often (even though not required by the specifications), especially if the slump fails by only a small amount. Fortunately, cleaning of the pump line is required on only one project. This requirement appears to be totally unjustified, except for extremely rare occasions, since the pump line contains such a small amount of concrete. The delay incurred will almost surely be more adverse to the structure than the placing of one or two cubic yards of concrete whose slump exceeds the specification limit by a fraction of an inch. The role of practical slump limits, similar to those presented in Table 7.5, in relieving the potential for delays should be obvious. In addition, the quality and reliability of control sampling and testing is seriously affected by the congestion at the point of placement. This fact is recognized in the ACI Manual of Concrete Inspection, SP-2 (9.3) which recommends that routine control sampling and testing be done at a facility located at the batch plant.

When a delay does occur it is important to have direct communication with the batch plant to stop the batching process. Adequate communication systems do exist on all projects, however several projects noted that despite the availability of this mechanism, trucks still back up because most contractors are slow to respond to a breakdown or delay. On one project a 37 minute delay resulted in the concrete in the pump line achieving initial set. In this case the entire pumping system had to be dismantled.

Correlation Testing Programs

Six out of the nine projects studied have conducted some form of correlation program in order to evaluate the loss of slump and air content from the batch plant or truck discharge to the point of placement. The necessity for conducting such studies was discussed in Chapter 6. It was pointed out that, aside from direct cost and the interference with the placing operation, conclusive results may be difficult to obtain. Furthermore, the necessity for these programs has been questioned by Tuthill (9.5) who states:

> "Requirements that samples for such tests be taken and the tests made after conveyance of the concrete to the forms may be thought to be useful on occasion to measure correlation relationships between this and the point of first delivery of mixed concrete. Actually these relationships are not important because unless water is being added to the concrete somewhere in route, which would be readily visible to inspection, all other conditions such as evaporation, loss of air and slump, etc., tend to improve strength, not decrease it . . . Except for this infrequent possibility (addition of water), results of sampling as delivered from mixing or agitating equipment would be conservative; concrete in place would statistically be superior. End-of-conveying system sampling and testing will unnecessarily interrupt and delay the work and impair more than improve the probable quality of the placement aside from strength."

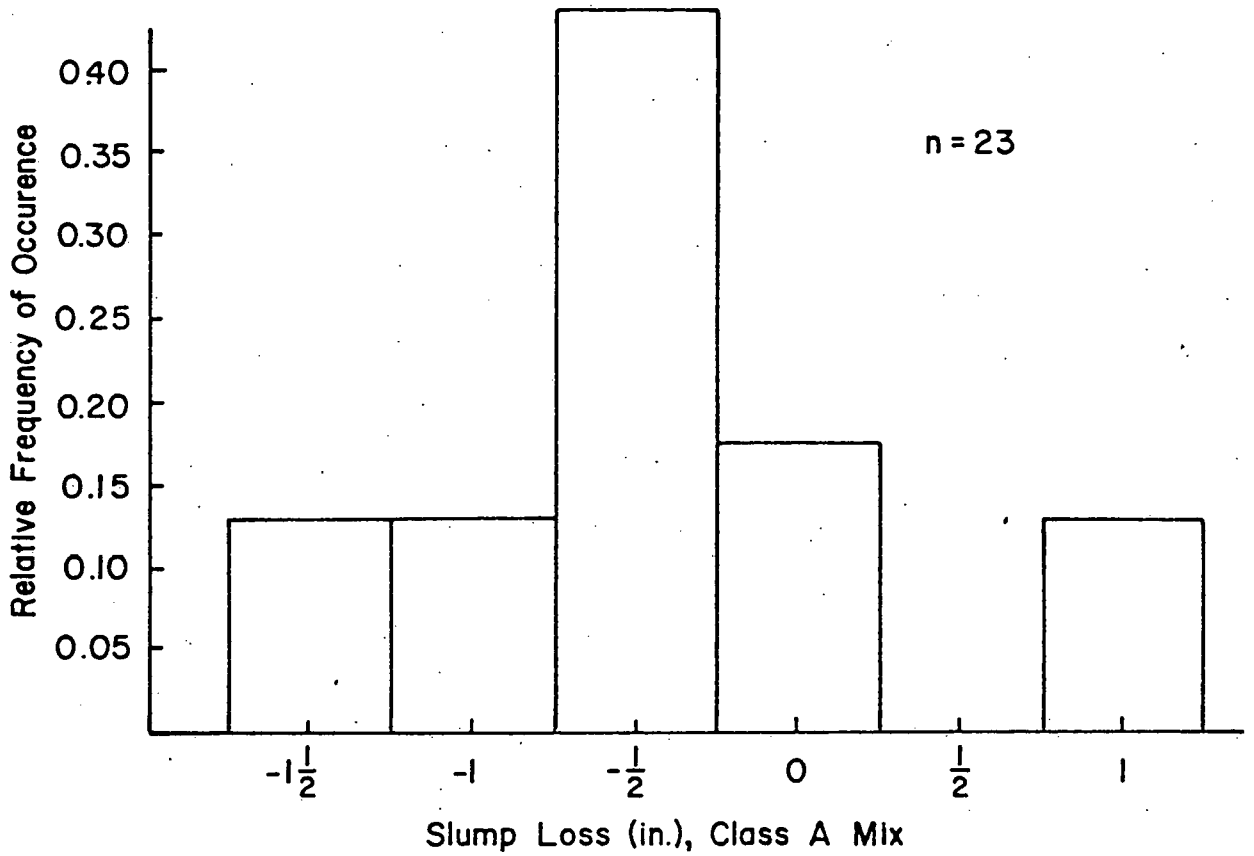
One motivation for correlation testing is the belief that all concrete should contain the amount of air entrainment that is required for severe, wet, freezing and thawing exposure. It was also pointed out in Chapter 6 that this is not always true and to include the maximum amount of air entrainment frequently causes more problems than it solves.

To establish a level of confidence in the concrete delivery process a correlation testing program may be necessary. (On at least one occasion, a correlation testing program was needed in order to satisfy an NRC inquiry.) When initiated, the testing program should be well planned using appropriate statistical concepts. The major contributing factors should be identified, and the sampling procedures and techniques should insure that statistically representative samples are obtained. Unfortunately, some of the correlation programs studied appeared to be performed in a haphazard manner. The belief is that if many samples are taken then the data will be satisfactory to identify all the major factors. Such a methodology has no statistical foundation. Clearly, this is not the way to implement a well conceived and planned program.

The results of three correlation studies are shown in Figures 9.1, 9.2, and 9.3. The unique features of each study are presented below.

1. Project C - Slump data was collected at the truck discharge and in the forms after discharge from a conveyor. The changes in slump and air content are shown in Figure 9.1. Data was also collected for concrete temperature, conveyor length, concrete mix class, relative humidity, and ambient temperature. The study lasted for one year, and during this time a total of 63 samples were collected. Two samples were deleted since their values were considered to be erroneous. Plots of each variable versus the loss and gain in slump were observed for any trends. As a result of this analysis, it was concluded that no apparent correlation exists between any of the variables and the loss of slump.

2. Project F - Slump and air content data was collected at the mixer truck discharge and pumpline discharge. Data was also collected for the amount of air entraining agent, time delay between batching and testing, concrete temperature, ambient temperature, type of pump used, pump pressure, and the



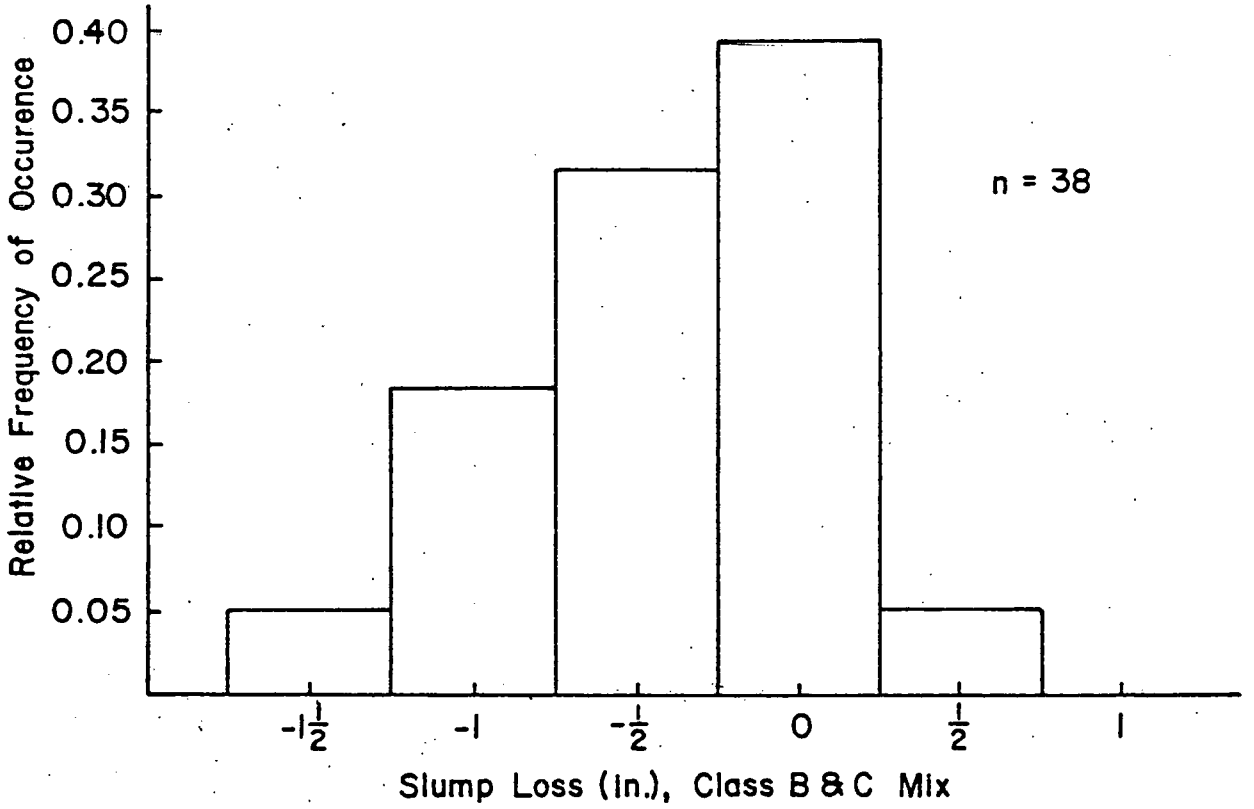
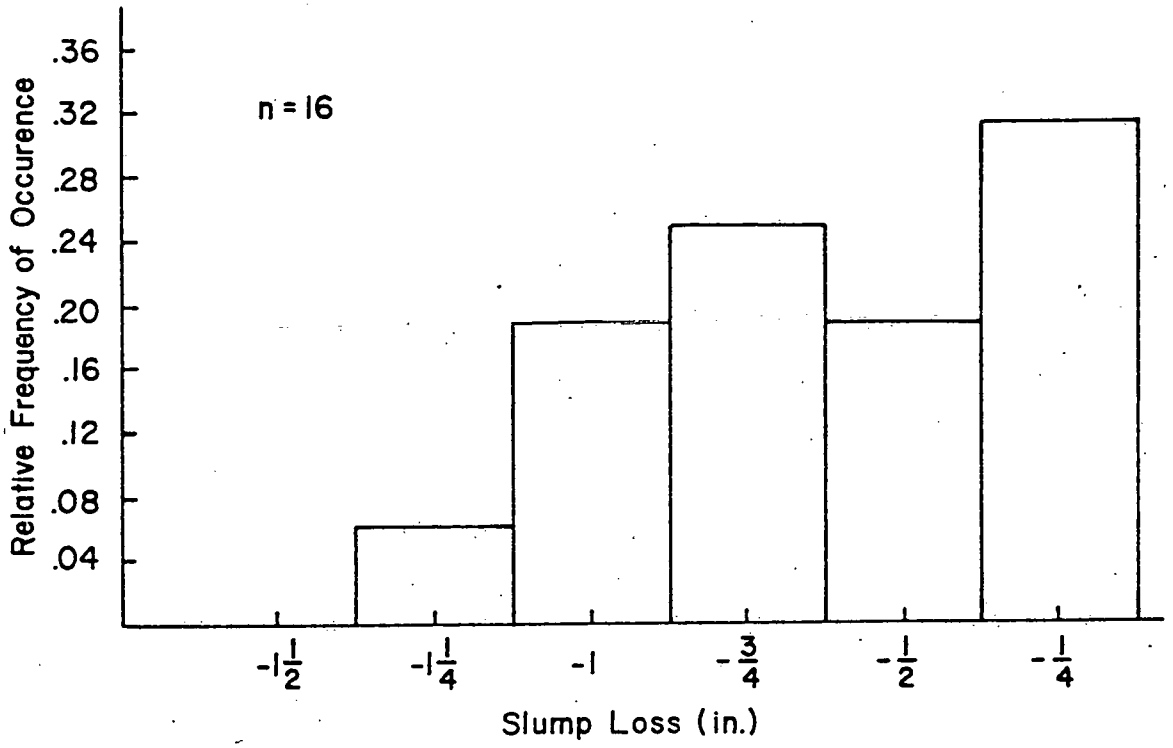


Figure 9.1. Correlation Study Results, Project C



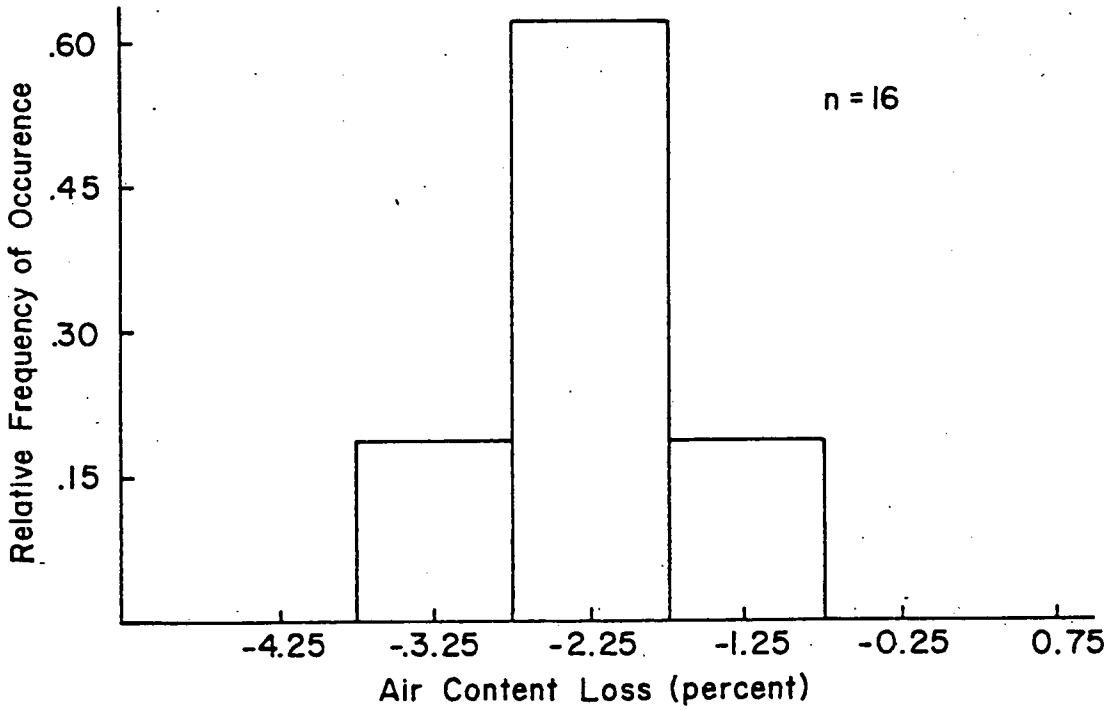
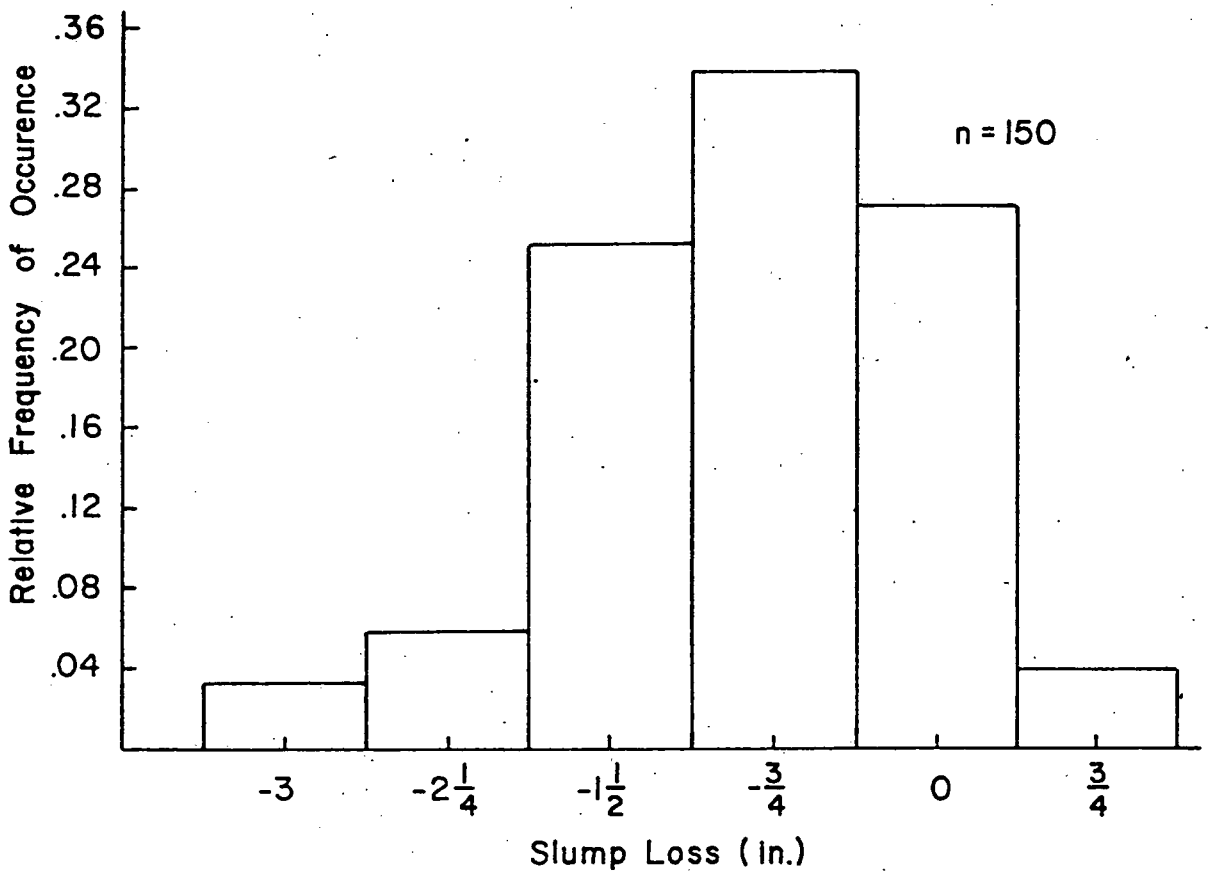


Figure 9.2. Correlation Study Results, Project F



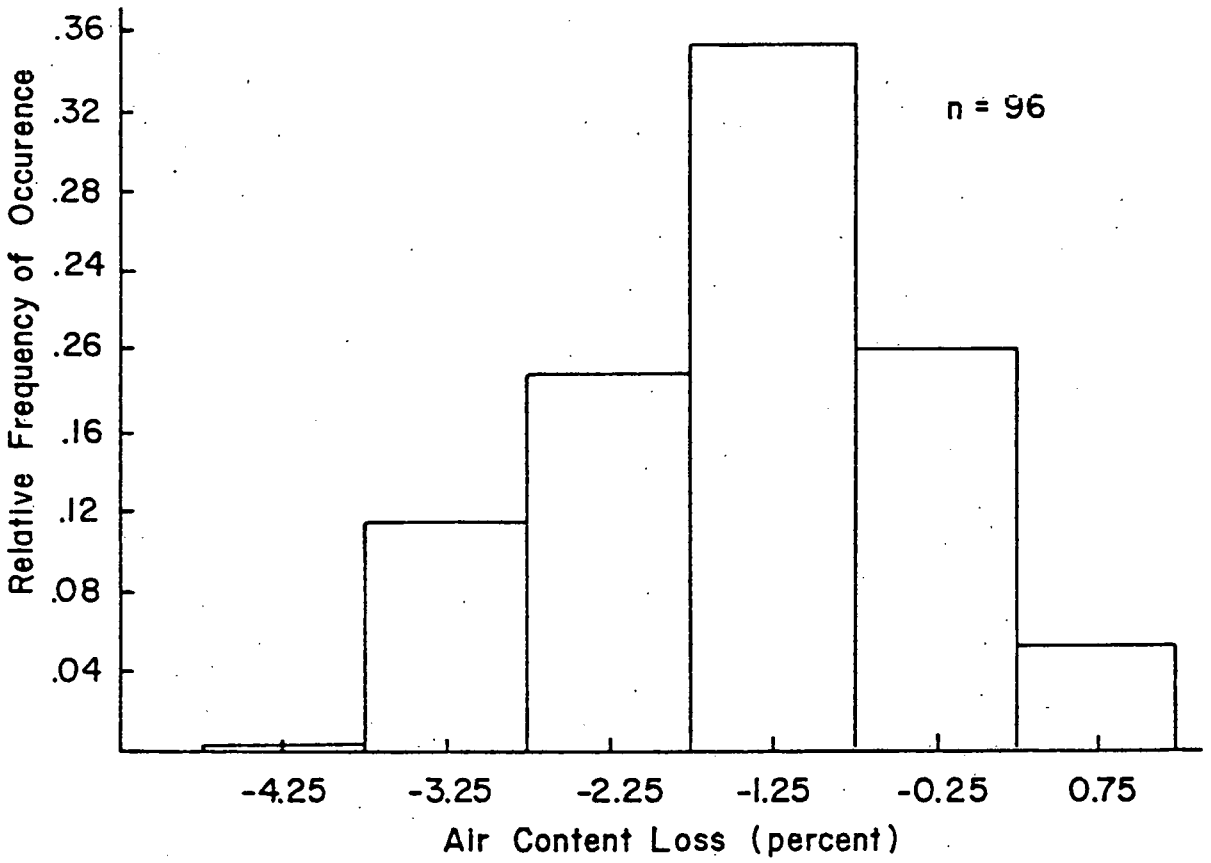


Figure 9.3. Correlation Study Results, Project H

configuration of the pump system. The data in Figure 9.2 represents sixteen samples which were collected during one day of production. This represents only a small portion of an extensive program conducted to determine how much air entraining agent should be added at the batch plant such that the air content at the point of placement would be within specification limits.

3. Project H - Slump and air content data was collected at the truck discharge and at the pump line discharge. Data was also collected for the ambient temperature, time lapse since batching, number of agitator truck revolutions, concrete temperature, concrete strength, and configuration of the pumping system. The data shown in Figure 9.3 was collected over a five month period. The initial test data was analyzed by the design engineer to determine correlation coefficients, significance of coefficients of correlation and regression equations to quantitatively define relations between variables. In those analyses, the only significant factor affecting slump loss seemed to be the initial slump itself. Because no other reasonable correlations existed and there was a perceived need to obtain conclusive data with which to respond to probable NRC inquiries, the correlation program continued, in accordance with instructions from the engineer defining those specific variables for which data was required. The preliminary analysis of this data again indicated little relation between the variables; and hence the program is still in progress.

The studies discussed above are only a small sampling of an industry wide effort which includes many ongoing programs. Each has its own unique features, objectives, and in many cases, statistical deficiencies. The data collection methodology, more often that not, is to gather as many samples as possible, i.e. the principle of safety in numbers, and the data analysis phase usually involves brief review of the tabulated information to see if it is reasonable. No evidence was found on any project to indicate that the data was analyzed statistically. In view of the expense and time involved and the apparent lack

of direction on some testing programs, it appears that a study should be initiated to establish a methodology to be used in a statistically based correlation program. The completion of such a program could establish the justification for performing routine control sampling at the batch plant and only random, infrequent sampling at the point of placement.

ADDITION OF WATER

The addition of supplemental water to the mix is handled in a variety of ways. In no case, however, is retempering of the mix permitted. The individual project requirements are summarized below.

1. Project A - When necessary, water can be added to truck delivered concrete in order to adjust the slump. The total amount of water added may not exceed by more than 1 gal/yd the amount required to produce the maximum slump limit. The maximum allowable slump, however, may not be exceeded. The QC Procedure does not require a slump measurement. The mixer must rotate at least 30 revolutions (at agitating speed) after the addition of water, and no addition of water is permitted if the elapsed time after batching has exceeded 45 minutes.

The origin or rationale for the 45 minute time limit is not known. Since the rate of slump loss increases with time, it would appear that the necessity for slump adjustment would be greatest as the total elapsed time approaches the maximum limit of 90 minutes.

2. Project B. - The addition of water is permitted up to the limits shown in the approved design mix relative to maximum slump, water, and water-cement ratio. Mixing agitating time and temperature must not be exceeded. Water may be added only once provided the following time limits are not exceeded:

Ambient Temperature	Max Elapsed Time
Over 90°F	30 minutes
75° to 90°F	45 minutes
less than 75°F	60 minutes

The mixer must rotate at least 30 revolutions at mixing speed after the addition of water. No slump measurement is required.

3. Project C - The addition of water is not permitted.

4. Project D - The addition of water is not permitted. During an NRC audit in the early stages of the project, it was discovered that there were no procedures governing the addition of water after the mixer left the batch plant. The owner subsequently chose to prohibit this practice. At a later date the constructor requested that the addition of water be permitted, however this request was denied. In clarifying the refusal, the owner stated that the practice would be permissible provided all of the following conditions were met:

a. The amount of water must be accurately measured and recorded.

b. The water/cement ratio shall not be exceeded

c. The total mixing time allowed by ASTM C 94 shall not be exceeded

d. The mixer shall be turned an additional 30 revolutions after the water is introduced

e. This procedure shall be limited to a maximum of one truckload of concrete in every 20 produced.

f. Concrete cylinders shall be cast and tested for each truckload of concrete in which the water content is adjusted.

Provision (a) seems to be reasonable only if the degree of accuracy is realistic and does not require special measuring equipment or unnecessary calibration needs. Provisions (e) and (f) do not appear to be reasonable and probably are the reason why a procedure for adding water has not been initiated.

5. Project E - End-dump concrete trucks are used, and therefore the addition of water would not be appropriate.

6. Project F - Up to 15% of the water may be withheld at the batch plant and any portion of this may be added at the point of truck discharge. The water-cement ratio must not be exceeded. Once the truck has started to dis-

charge concrete, no water may be added. The mixer must rotate at least 30 revolutions, and a slump test must be taken before the concrete is discharged.

7. Project G - The water cement ratio must not be exceeded and no water may be added after the truck has begun to discharge the concrete. Concrete may be discharged for the purpose of taking the slump test, however discharge must be in a suitable container and the concrete returned to the truck after the test has been taken. After the addition of water and the proper mixing has been achieved, the following tests must be taken, a) slump, b) temperature, c) air content, and d) compressive strength cylinders. The project organization has decided not to add any water because of these testing requirements.

8. Project H - The permissible quantity of water which may be added for an entire truckload is written on the batch ticket, and if a portion of a load is placed prior to the addition of water, the quantity of water is proportioned downward. If the cubic yards remaining in the truck cannot be closely estimated by the QA Administrator, then no water adjustment is attempted. In no case is the maximum water cement ratio to be exceeded. All additional water must be added within 45 minutes after the load has been batched, and the truck mixer drum is turned at least 30 revolutions at the mixing speed. Water may not be added after the mixing cycle is complete. Slump measurements must be made for each batch to which water is added. If the slump is high, additional revolutions may be made to bring the slump down, provided the 300 total revolution limit is not exceeded.

This last provision would appear to be unacceptable. Since the slump is a measure of consistency it would seem that the batch should be rejected. This aspect was discussed in more detail in Chapter 7.

9. Project I - Water may not be added once the truck has begun discharging concrete, however water may be added more than once. Up to 5 gal/yd may be added provided the water-cement ratio is not exceeded. The drum must be turned for 30

revolutions at the mixing speed. Neither the specifications nor the quality directives indicate that a slump test must be taken.

There are two opposing views regarding the addition of supplemental water. The first view is that the controlled addition of water should be allowed. To not do so would result in either good concrete being needlessly rejected or the consolidation process being jeopardized if the slump was too low. The practice of adding water is permitted by ACI 301 provided neither the maximum permissible water-cement ratio nor the maximum slump is exceeded.

Others oppose the addition of supplemental water for two reasons. The first reason is over the concern that adding water cannot be adequately controlled, and that once an addition is made, the concrete properties have changed and hence are unknown. This viewpoint is exemplified by Projects D and G. The second reason can be summarized by Tuthill (9.5).

> "Many jobs are set up for central mixing in order to minimize the variability that is inherent in truck mixing, but fail to prohibit addition of water prior to delivery, should someone think it necessary. Many who play this little game of water-as-you-please are horrified with the idea of this restriction. But it works, perhaps with a little encouraging firmness at first. Concreting organizations soon learn to operate accordingly which means they are motivated to expedite deliveries and to have arrangements and equipment in such good condition that there is a minimum of delays. Further, they should be assured that they are free to use the concrete regardless of time after mixing or its lower slump, provided it can be and is properly placed and consolidated. This is the only criteria. It has never been clear why some place a time limit on acceptability of concrete that can still be placed well and has had no added water. Such concrete has repeatedly been found to be of higher than average strength. Only the condition of the still plastic concrete and what can be done acceptably with it, not elapsed time, should be the criteria as to whether it should be used or should be rejected."

The two most effective means of reducing slump loss are 1) to cut down substantially the time between mixing and placing and avoid delays to the greatest degree possible and 2) reduce the temperature of the concrete as mixed by using chipped ice. The latter factor was illustrated in Chapter 7,

Figure 7.5. The elimination of delays can be facilitated in several ways. These include using the communication system to immediately shut off the concrete mixing and supply when a problem or delay is encountered. This aspect has been discussed previously, and it was pointed out that contractors are reluctant to exercise this option. Thus, the trucks line up and wait and add to the slump loss problem. Also related to delays is the impact of the correlation testing program. The necessity of such a program has been discussed and any reduction in this effort would minimize congestion problems and delays. A third factor which may be overlooked is the role and flexibility of the slump requirements. When the specification limits fail to include an inadvertency margin, then the batch plant operator is discouraged from producing concrete having average slumps at or near the desired upper limit. This aspect is further compounded if the addition of supplemental water is permitted. This problem has occurred on Project F in particular and perhaps on others as well. The batch plant consistently batches low slump concrete since the operator knows that water can be added if necessary. At the placement, however, water is not added because of the time delay involved and the extra testing that is required. Thus low slump concrete is consistently placed in areas where there is congestion due to rebar and embeds.

In view of some of the difficulties encountered on several projects, the practice of allowing the addition of supplemental water probably should not be permitted. Such a deletion must however be accompanied by realistic specification limits that encourage the mixing of concrete with slump that can be easily consolidated, rapid shut off of concrete supply when a problem is encountered, and reduction or elimination of correlation testing programs with subsequent sampling and testing at the batch plant.

CONSTRUCTION JOINTS

The quality of a construction joint depends on many factors including the quality of the concrete and the cleaning of the joint surface. Roughness alone will not assure a well-bonded joint. In fact, roughness as well as protruding pieces of large aggregate and depressed keys interfere with the accomplishment of good cleanup. Such features also make it difficult to completely remove free water, which if not done, will prevent good bond even though the surface has been properly cleaned (9.3, 9.6).

Industry Codes and Standards

ACI 301 provides very limited guidance on the preparation of construction joints, except to say that proper bond may be obtained with an approved adhesive or by exposing the clean aggregate bonding surface. This may be done by an air-water jet shortly after the concrete placement or by sandblasting the surface shortly before the next placement is scheduled to begin. A more detailed description of the latter two approaches is provided in the Bureau of Reclamation, Concrete Manual (9.6), ACI Manual of Concrete Inspection (9.3), and ACI 304 (9.7).

As pointed out in the Concrete Manual, Bureau of Reclamation and ACI 304, a high quality of bond is most likely when the concrete, especially that in the upper portion of the lift, has the least slump that will permit adequate consolidation. Wet mixes should be avoided since there is a tendency towards segregation and bleeding. These result in a weak layer of concrete and a heavy layer of laitance which is very difficult to clean. This is perhaps another justification for not permitting the addition of water at the point of truck discharge. It also appears that the ACI 301 slump requirements discussed in Chapter 7 may not contribute fully to attaining the desired quality level. As was pointed out, the running average approach encourages low slump initial batches which may be followed by higher slump batches towards the end of the placement. In this manner the average slump value always remains below the

maximum allowed value. Thus the fallacy of the running average number system should be evident. The inspector should be very aware of and insist on high slump initial batches followed by low slump batches towards the end of the placement. This of course would mean that the running average may not fall below the desired average limit until the placement is well under way. Thus in the full interest of quality, the competence and importance of the QC Inspector assumes a much greater role than a series of numerical measurements.

The so called "green cutting" method of cleaning joint surfaces by means of an air-water jet consists of removing the surface layer and exposing a clean surface of sound concrete. It must be done within 4 to 12 hours after placement, depending on the rate of hardening. A set retarder may be applied to slow the hardening process. If the cutting is done too early, the aggregate will become loosened, and too much good material will be removed. The surface should then be kept damp with a 2 inch layer of wet sand or by flushing with water, however the treated surface almost inevitably becomes contaminated to the point where it must be sandblasted before concreting can resume. For this reason, green cutting is not an approved method by the Bureau of Reclamation.

Standard Bureau practice for placement of mass concrete and structural concrete where watertight joints are required is wet sandblasting followed by wet washing (9.6). Experience and investigations have shown that this is the superior method. It is characterized by 1) simplicity, since there is no repetition of treatment, 2) dependability and uniformity of results and 3) economy. The disadvantage to this approach to this method is the associated mess and interference with other trades working in the area. In cleaning the joint surface, it is only necessary to remove the laitance film from the mortar covering. Tests have shown that no advantage is gained by cutting the joint surface to a depth necessary to expose underlying coarse aggregate. On the contrary, the joint may be weakened when the surface is cut so deep as to imperil

anchorage of the larger aggregate.

The use of mortar on the joint surface just prior to the placement of concrete is a subject of some debate. ACI 304 states that in some cases a 1/4 to 3/8 inch layer of soft mortar having the same proportions as that in the concrete can be used. This should be scrubbed into the surface of the joint with wire brooms. This is of course impractical in heavily congested areas, column forms and deep narrow forms. Here it is preferable to start the placement with several inches of mortar (starter mix). The Manual of Concrete Inspection makes the general assessment that the starter mix approach is the preferred method. It states that:

> "This procedure is coming to be recognized as superior to starting with mortar as is sometimes specified. It is just as effective in bonding if the joint surface is clean, and it avoids possible concentrations of mortar and interruptions of the concreting operation."

The above practice applies to horizontal joints. For vertical joints the following is stated:

> "At vertical or steeply inclined surfaces, the concrete itself should have ample mortar, and if bond is desired the surface of the old concrete should be sandblasted and scrubbed with a neat-cement mortar just ahead of the new concrete. The mortar or grout coating must not be placed so far in advance of the concrete that it becomes set or dried. The concrete being placed should be well worked at the joint to bring out the mortar and eliminate rock pockets."

The Bureau of Reclamation suggests that for surfaces of formed construction joints to which concrete is to be bonded should be sandblasted, washed completely, and surface dried. This practice appears to differ from that recommended by the Manual of Concrete Inspection which states that mortar should be applied to the joint after it has been continuously moist for several hours.

The fact that mortar or grout may be unnecessary has been identified by the ACI 207 Committee (9.8) as explained below:

> "Tests conducted by the U.S.Army Engineer Waterways Experiment Station failed to establish superiority of bond or water tightness by use or exclusion of a mortar coat.... To insure a tight invisible joint (as shown by drill cores), it is imperative that the first layer of concrete

be very thoroughly and systematically vibrated to full depth and that any rock clusters at batch perimeters where buckets are dumped, are vibrated."

Project Specification Requirements

Table 9.1 summarizes the major specification requirements for each project related to construction joints. These unique features along with the impact of quality control are described below.

1. Project A - The construction joint surfaces are cleaned by the "green cutting" method. A set retarder may be used. Laitance is removed within 24 hours after placing to produce a clean exposed aggregate bonding surface. After cleaning, the surfaces are washed and rinsed. There is no indication that subsequent protection such as wet sand is required. Before placing the next lift, the surfaces of all joints are throughly cleaned and wetted, and all excess water is removed. Horizontal joints are covered with a minimum of 1/4 inch sand/cement grout that has a water-cement ratio no greater than that of the concrete. Vertical joints are slushed with a coat of neat grout immediately prior to placing the next lift. A chemical adhesive may be used where grouting is infeasible.

As can be seen in Appendix 8.A and 9A, construction joints are checked during the preplacement inspection primarily to insure that all laitance is removed. The placement inspection concentrates on the application of mortar and grout. No guidance is provided in the Quality Control Procedure, and hence, such qualitative attributes as the removal of laitance is left up to the judgement of the QC Inspector.

2. Project B - The concrete joints must be throughly roughened and cleaned of laitance, foreign matter, and loose particles by sandblasting until the concrete aggregate is exposed. The surface is then washed thoroughly. The joints are coated with a neat cement grout just prior to placement. Whether or not the joint must be wetted is never addressed in the specifications or procedures.

Table 9.1 Specification Requirements for Construction Joints

Project	ACI Reference code;section	CLEANING			PREPARATION			TREATMENT	
		Water or Sand blast	(Green cut)	Set Retarder	wetted	keyed	Surface amplitude	Mortar Grout or Starter Mix	Bonding Compound
(A)	301;6.1.4.2		X	X	X			H: Mortar V: Grout	X
(B)		X	Approved by Engineer				½" Maximum	Grout	
(C)	318;6.4	X	X		2 hrs min. prior to pour			1/2"Grout (broomed) 3/4"starter	
(D)	318;6.4	X	X		2 hrs min. prior to pour			1/4"(broomed) starter mix	
(E)		X	X	X	No water 12 hrs prior to placement				Vertical only
(F)	301;6.1	X	X	X	X	as designated	1/4"	H: 1/2"Starter V: Cement Grout	
(G)	318;6.4	X	X		Saturated surface dry			1/4"Grout	
(H)	301;6.1.4.3 301;8.5.3	X			X	as designated	1/4"		
(I)	301;6.1 318;6.4	X	X	X	X	as designated	1/4"	H: 1/4"Grout V:Cement Grout	

"Green cutting" is permitted in lieu of sandblasting and was used on the containment shell structure. The Construction Procedure states that the cutting procedure should not unravel the surface in excess of 1/2 inch in depth. Thus it would appear that excess material may have been removed. This is certainly not in line with the Bureau of Reclamation practice where tests have shown this degree of removal to be unnecessary and potentially harmful. The Construction Procedure also states that where "green cutting" is unsuccessful, sandblasting or bush hammering will be done.

The QC Inspector must check the joint prior to placement, however no guidance is provided in the QC Procedure. The grouting operation must be observed during the placement.

3. Project C - Construction joints are cleaned by waterblasting, sandblasting, or bush hammering. The surface must be cleaned of all unsatisfactory concrete, laitance, coating or debris. The surface is then throughly cleaned. The horizontal surfaces may be prepared by green cutting. A suggested method for preventing accumulation of laitance after green cutting is to periodically flush the concrete with water. If laitance accumulates, sandblasting, etc. will be necessary to reclean the joint prior to placement of the next lift.

Joint surfaces shall be wetted and all excess moisture removed. The surfaces however must be moist. Horizontal joints receive 1/2 inch of grout mix thoroughly broomed into the surface. If congestion causes a problem, the layer of grout is increased to 1 inch. A 3/4 inch starter mix is allowed as a substitute by the specifications and is used extensively. Vertical joints do not receive a coating of grout.

The joints are inspected during the preplacement phase for removal of laitance and general cleanliness. Only general guidelines are provided in the QCI.

4. Project D - The joint preparation procedures are very similar to those used on Project C. Both sandblasting and "green cutting" are permitted. All surfaces to receive concrete must be free of surface water but will be saturated for a minimum of two hours prior to placing concrete. The intent is to produce a saturated surface dry condition. Approximately 1/4 inch of mortar is thoroughly broomed into the horizontal surface just prior to placement. A starter mix may be substituted for the grout application, and generally should be placed in a 4-6 inch layer. The layer depth may not exceed 8 inches. Vertical joints do not receive a grout treatment.

The QCI provides no specific guidance to the Inspector except that starter mixes are not permitted in members less than 2 1/2 feet deep.

5. Project E - Joint cleaning may be accomplished by sandblasting or "green cutting". The surface treatment should expose a sufficient amount of coarse aggregate to determine that the concrete at the surface is sound and representative of the entire lift. The coarse aggregate should not be undercut or loosened. It is only necessary to remove laitance and expose sound mortar.

With regard to wetting the joint, the specifications state that superior bonding is obtained if the surface is dry. Therefore, water-curing of the surface is terminated 12 hours before placing new concrete. This is followed by sandblasting, etc. and subsequent cleaning so the joints may be damp when the placement begins although this is not necessarily true. This approach would appear to solve several problems; first the problem of surface water would be greatly reduced as compared with projects where the time limit for wetting is two hours before the placement (Projects C & D). It has been pointed out that failure to remove free water will prevent adequate bond from being achieved (9.3, 9.6). Secondly, delays have occurred on several projects because the two hour time interval has not been fully reached or the free surface water has not been completely removed. The latter problem is

compounded on those projects where keying is required or there is some specified surface amplitude for the exposed aggregate. Thus delays may occur, slump in waiting trucks drops, quality may be impaired and costs soar. The Project E approach would appear to overcome this problem. The concern by the Engineer in using this approach may be over excessive moisture from the fresh concrete being absorbed into the dry joint surface. Three factors, however, appear to minimize this concern. First, there is moisture already present in the hardened concrete. If there is any doubt, the surface is wetted the day before. Secondly, if the mortar, grout, or starter mix is properly designed then the water content will be sufficient to overcome any absorption which takes place. Finally, if the quality of the concrete is satisfactory, the absorption rate into the hardened concrete should be minimal. No grout, mortar, or special mix (starter mix) is used on the joints on Project E.

6. Project F - Construction joints are prepared in accordance with ACI 301, para. 6.1. Cleaning may be done by sandblasting or "green cutting". In the latter case a set-retarder may be used to facilitate cutting of the surface for a full 1/4 inch. Retarded mortar must be removed within 24 hours. Joints with keys need not be treated to exposed aggregate unless specified by the Engineer, but other surfaces must be thoroughly cleaned to provide a rough surface having a full amplitude of at least 1/4 inch from surface to base. This provision does not appear to be in the best interest of producing quality joints as recommended by the Bureau of Reclamation and the ACI Manual of Concrete Inspection since there is a risk of loosening aggregate. Cleaning and removal of free water is also more difficult. The practice would also appear to be unnecessarily costly since tests have shown that such exposure of aggregate does not improve the water-tightness of joints. Thus, a reevaluation by the Engineer seems to be justified.

Concrete surfaces must be thoroughly wetted and care taken to remove excess water not absorbed by the concrete. Horizontal joints are covered by a minimum of 1/2 inch thick layer of grout and vertical joints are coated with a thick-bodied cement water paste.

The QC Inspector is provided with general guidelines in the QC Inspection Plan.

7. Project G - Joints are cleaned by sandblasting, water-blasting or light bush hammering which is continued until all unsatisfactory concrete, laitance, coatings, stains or debris are removed. "Green cutting" is permitted in lieu of sandblasting but must be supplemented by wet sand-blasting, bush hammering or water-blasting immediately before placing the next lift. Set retarders are not permitted. The surface must be cut to expose clean, sound aggregate, but must not undercut the edges of the large particles of aggregate.

All surfaces to receive new concrete shall be free of surface water but must be in a saturated, surface-dry condition. All horizontal surfaces are covered with 1/4 inch of grout thoroughly broomed into the surface.

8. Project H - The horizontal and vertical construction joints are to be prepared in accordance with ACI 301 except that grout is not applied to joint surfaces. The joint surfaces must be roughened so as to exhibit a full amplitude of approximately ¼ inch. Hence the condition discussed under Project F could also occur on Project H. In no case is "green cutting" permitted. All joint surfaces must be dampened prior to the placement.

All joints, unless otherwise specified on the drawings, must have keys with a minimum depth of 1 1/2 inches and a width equal to one-third of the width of the joint.

9. Project I - The construction joint requirements on Project I are essentially identical to those discussed for Project F, and therefore will not be restated.

There appear to be several modifications of construction joint practices which could improve production and not reduce the quality of joints. In a few of these circumstances the quality may actually be improved. First keys in joints should be used only when absolutely necessary since they introduce difficulties in cleaning. In cleaning, the "green cutting" method should be carefully evaluated for its necessity, since it is less favorable than sand-blasting. It is no longer accepted as standard practice by the Bureau of Reclamation, and the nuclear industry should reflect on the Bureau's experience and review their own position. In cleaning, the exposure of aggregate to a specified amplitude does not appear to be necessary and in fact could jeopardize joint quality. Tests have shown that such exposure offers no increased advantage in watertightness or bonding and hence should be abandoned. Projects should consider accepting the Project E practice of not wetting the joints for 12 hours prior to the placement. The practice of grouting joints, particularly horizontal joints, should be reviewed in favor of using starter mixes. In this regard, the requirement of brooming the grout into the joint surface appears to be superfluous. Finally recognition should be given to the fact that water-tight joints may not be needed throughout the plant and perhaps consideration should be given to having a less rigorous procedure for these joints.

PLACEMENT PRACTICES

General Requirements

As stated in the ACI Manual of Concrete Inspection, the placement stage of the work is the key point of the entire concreting operation. Proper methods of placing will not only prevent segregation, honeycombing, and voids but will also avoid displacement of forms and reinforcement, secure a firm bond between layers, minimize shrinkage cracking, and produce a

good appearance (9.3, 9.6). There are many important aspects to this phase, but only the following items will be discussed, 1) vertical drop, 2) horizontal movement, and 3) lift thickness. Consolidation will be presented in the next section.

To avoid segregation concrete should be deposited vertically as near as practical to its final position. Particular attention should be paid to operations where concrete crews are using sectional drop chutes to distribute concrete by pushing or pulling the lower sections in various directions at a considerable angle. The concrete should be dropped in such a manner so as not to strike reinforcement or the form sides above the level of the placement. Any method of placing concrete is acceptable as long as it places concrete close to its final position without objectionable separation of coarse aggregate. As long as groups and clusters of separated aggregate are not produced, unconfined fall should be permitted, and the height of fall should not be limited (9.5, 9.6). Lateral movement of concrete for more than a short distance should not be allowed. If there is lateral movement, as in dumping at an angle or depositing continuously at one point and allowing the concrete to flow, the coarse aggregate and mortar tend to separate. The Manual of Concrete Inspection establishes 2 or 3 feet as a reasonable lateral distance which concrete should be permitted to flow (9.3).

Table 9.2 summarizes the specification requirements for each of the projects. As can be seen, the vertical drop is generally limited to 5 or 6 feet with the exception of Projects A and E where it does appear that there is some flexibility provided. The owner of Project E has had considerable experience in placing concrete and the allowance of up to 10 feet reflects the fact that tests have shown that segregation does not occur in a free fall of this height. This view is shared by the Bureau of Reclamation as was previously pointed out. In this regard the limitation of 3 feet for exposed work on Project B seems to be an unnecessary restriction.

Five projects establish a five foot limit on lateral flow and four attempt to minimize lateral flow. For those five projects, it would appear that too much emphasis is being placed on some quantitative value rather than on the real problem of segregation. This is particularly true for Project D where an exception has been made for the containment drywell wall. One must also wonder how this lateral flow is actually measured, and in this respect it should be pointed out that several projects have experienced delays in the form of confrontations with Quality Control over the measured values of free fall and lateral flow. Such events serve no useful purpose and can only reduce the quality of the concrete by creating a delay. The emphasis should be on minimizing segregation instead of some arbitrarily established measured quantity.

Lift thicknesses have been established by ACI 301, 304, and 309. ACI 304 suggests a lift thickness of between 1 1/2 to 2 feet whereas ACI 309 recommends that concrete should be deposited in 12 to 18 inch layers. ACI 301 states that mass concrete should be placed in approximately 18 inch layers. On the other hand, the Bureau of Reclamation suggests that practical depths of layers for mass concrete are 15 to 24 inches and for structural concrete are 12 to 20 inches. As can be seen in Table 9.2, most projects have adopted an 18 inch layer thickness which seems to be reasonable. On all projects the placement rate is controlled by visual observation. On Project C however, the rate is also controlled by taking liquid head measurements. This aspect was discussed in the section on formwork in the previous chapter, in the author's opinion it appears to be unnecessary.

Weather Protection

All projects require adequate protection against inclement weather, particularly showers and thunderstorms. The detrimental effects of not doing so are obvious. The only problem area which has surfaced during the study of the nine projects is how to define the term adequate. A major milestone placement of 250 cubic yards on the fuel pool liner slab

Table 9.2. - Summary of Concrete Placement Practices

Project	Vertical Drop (ft)	Lateral Flow (ft)	Lift Thickness (in.)
A	As low as possible	5	Not specified
B	5[a]	minimum	18
C	6	5	18
D	6	5[b]	24
E	5[c]	minimum	18[d] Vibrated mass conc. 12 Hand compacted mass 10 Reinforced concrete
F	6	minimum	18
G	6	5	24
H	5	5	18
I	5	minimum	18

[a] This distance is reduced to 3 feet in exposed work.
[b] This distance is increased to 6 feet, 6 inches in the containment drywell wall.
[c] Vertical drop limit is generally 5 feet with a maximum free fall of 10 feet.
[d] In general, thickness of layers is as stated but in no case shall it exceed 24 inches.

of one particular project was delayed because disagreements arose between field engineering and quality control over the meaning of adequate protection. This incident prompted the constructor to build a temporary shelter which could be lifted above future placements by a crane and held in place as long as necessary. Other projects should also consider such a contingency measure.

Consolidation

There are a number of important aspects related to consolidation of fresh concrete. These will be discussed below, and those related to project practices will be highlighted.

The objective of vibrating concrete is to eliminate, so far as practical, voids within the concrete. Well-consolidated concrete is free of rock pockets, entrapped air and is in close contact with forms, reinforcement, and embedded items. To achieve proper consolidation, the concrete must be worked well around reinforcement, embedments and forms. For nuclear construction this is a particularly challenging task because of the reinforcement density and the number of embedded items.

The construction and quality control procedures can be of great value in conveying to inspectors, as well as to craft supervision, which aspects related to consolidation Engineering and Management feel should be stressed. Table 9.3 indicates those attributes which are included in the various project specifications, construction procedures or quality procedures. These aspects may also be supplemented by ACI 304 or ACI 309 which is used as a reference source. Only three projects stress in the project documents (e.g., specifications, construction procedures) that care should be taken to vibrate close to the form surface and around reinforcing steel and embedments. For these projects, this emphasis is further strengthened through the quality procedures. Consolidation in heavily congested areas is a very important aspect in nuclear construction. It appears that it should be emphasized more strongly by the other projects. Unfortunately most projects documents do not, and some actually stress the

opposite role of not touching the forms or reinforcing steel. It would seem that the greatest likelihood of achieving proper consolidation would result from operations performed under the influence of projects documents which stress the proper practices which should be followed rather than those practices which should not be followed. It should be pointed out however that there was no indication that the latter case has in fact occurred.

Five of nine projects stress that the vibrator head should be inserted vertically to the full depth of the layer being placed, and should not be dragged through the concrete. This is, of course, a good practice and rightfully should be observed; however this aspect should also be accompanied by a provision which allows for some deviation from the vertical position around embedments or other complex areas. Clearly the inspector should permit such variations to take place without special instructions, and in essentially all other forms of construction this would automatically happen. Such is not necessarily the case on nuclear construction projects. The rigid enforcement of the specifications, which is typical of nuclear work, could potentially be detrimental to concrete quality unless extra caution is taken in these areas. This potential would appear to be greatest on those projects where it is also stressed that the reinforcement, etc. should not be touched. Three projects have special provisions in the specifications related to consolidation around embedments and complex areas. The Project F specifications appear to have adequately addressed the condition as follows:

> "In no case shall vibrators be used to transport concrete inside the forms. However, for filling under embedments, blockouts, or surface obstacles that prevent placing concrete in its final location, concrete may be piled at one side of the embedded item and vibrators inserted into the pile, vertically or at angles, necessary to move the concrete into place. Vibrators may be inserted horizontally or at angles to consolidate concrete. Ample vibration time shall be provided to fill the space and to consolidate the concrete so long as segregation of the mix does not occur."

Concern over revibration is evident in the specifications for Projects B and F where it is stated that vibrators should not be inserted into layers that have begun to gain initial set. This appears to be contrary to good standards of practice since it has been pointed out by the Manual of Concrete Inspection (9.3) that revibration of concrete is beneficial as long after placing as the concrete will respond to the vibrator and again become plastic. Vibrators should penetrate deeply into lower layers as new layers are vibrated, and upper and final layers should be revibrated deeply as late as the running vibrator will sink of its own weight. This will improve the strength and appearance of the upper concrete and increase the bond with reinforcing steel and construction joints. Any vibration of steel or forms during placement is more likely to be beneficial than harmful (9.5). This fact is further stressed by the Bureau of Reclamation as follows:

> "Revibration is beneficial rather than detrimental, provided the concrete is again brought to a plastic condition. Revibration may be accomplished by immersion-type vibrators, by form vibration, or by transmittal of vibration through the reinforcement system. Apprehension as to use of the last method appears unfounded as extensive observation has disclosed no instance in which damage to the concrete could be attributed to this cause. Revibration could well be more widely practiced to eliminate settlement cracks and the internal effects of bleeding and also as an aid in making tight concrete repairs in walls and other structures.
>
> There should be no difficulty from cold joints if full advantage is taken of vibration and revibration. If the underlying concrete will still respond to revibration, the vibrator should be allowed to penetrate it deeply at each insertion in the new concrete. If this procedure is followed at close systematic spacing, the concrete at the joint will become monolithic. If the underlying concrete is too hard for revibrating and it is still very green concrete, thorough vibration close to the contact area will result in a good bond. Drill-core specimens have shown that the strength of such joints is equal to that of other portions of the specimens."

It appears that the industry, as amplified in the specifications and procedures, has not taken the best approach towards achieving proper consolidation. By stressing those aspects which should not be done, the industry could possibly be developing timid vibrator operators. Thus it seems the positive aspects should be emphasized.

Table 9.3.—Consolidation Attributes Emphasized in the Project Specifications, Construction or Quality Procedures

Attribute List	Projects								
	A	B	C	D	E	F	G	H	I
Consolidation in corners, around rebar, embeds	x							x	x
Do not touch forms or rebar					x	x			x
Special provisions for consolidation around embeds		x	x			x	x		
Virbrator head should be inserted vertically			x	x	x		x	x	
Spacing of insertions should be systematic	x				x		x		
Vibrator should not be inserted into layers that have begun to set		x				x			
Revibration allowed				x	x		x		
Form Vibrators permitted			yes[b]	yes[b]	yes[b]	yes[b]	yes[b]		yes[b]
Spare Vibrator(s) Required			1:3[c]	1:3[c]	x		1:3[c]	x	
Vibrator Speed (cycles/minute)			7000	8000	7000	8000	as per ACI 309	8000	8000
Calibration Required			x	x		x	x	x	
Duration of insertion (sec)	5-15				5-15	5-15	5-15	5-15	5-15
Spacing of insertions (in.)	18-30				18-30	18[d]	1 1/2[e]	18	15-25
Withdrawal rate of 3 in./sec.						x			x

[a] Vibrator shall not strike the face of the form
[b] When approved by the Project Engineer or authorized represencative
[c] A ratio of one spare to every three operating vibrators
[d] Maximum distance
[e] Spacing is 1 1/2 times the radius of action of vibrator

QUALITY CONTROL INVOLVEMENT IN POST PLACEMENT ACTIVITIES

Quality Control is involved in post placement activities, on both a surveillance and inspection basis. The areas observed include finishing, form removal, curing and repair of defects. The discussion below will present a general description of the project documentation requirements with particular attention to formwork removal and curing requirements. The post placement inspection documents are included in Appendix 9.B.

1. Project A - There is very little evidence to indicate that there are any QC responsibilities in post placement activities. There is no inspection record which must be completed. The inspector must however indicate the curing method used on the Concrete Pour Site Inspector's Report shown in Appendix 9.A.

2. Project B - Quality Control performs daily inspections of the curing process to assure compliance with the specifications. The temperature of the concrete and date is recorded on the Daily Concrete Curing Record included in Appendix 9.B. Information regarding form removal, curing, compounds, wetting and temperature control are observed but not documented unless these aspects are found to be unsatisfactory.

3. Project C - The involvement in post placement functions by QC is quite extensive as evidenced by the formalized documentation requirements included in Appendix 9.B. The inspector must perform surveillance activities on slab finishing, form removal, curing and loading. He is required to inspect for major defects and subsequent repairs. Verification of proper curing is also required. A separate post placement report is completed for finishing, form removal and repairs as well as the daily curing record. In conjunction with the curing record, there is also a temperature record, and it should be noted that the concrete temperature within the protection enclosure as well as the outside temperature must be recorded on an average of once every three hours. It should be pointed out that the curing period for the placement shown in Appendix

9.B was extended for two extra days because the curing practices were found to be unsatisfactory.

The inspector is provided guidance through a quality control procedure which is rather extensive and detailed. It is important to note that the QC Instruction Procedure has undergone 13 revisions. While most of these are the result of revisions to the project specifications or changes requested by the owner, and could therefore be interpreted as good communication and cooperation between the contractor and the owner, it does seem that 13 revisions in 22 months could also indicate that some type of organization, management, or communication problem exists on this project.

4. Project D - Essentially the same items observed by the Project C inspector must also be observed on Project D. The scope of the surveillance and inspection activities are very similar, however, the record of Finishing, Form Remocal, and Repairs, Daily Cure Record, and Temperature Record have been consolidated into one form, namely, the Concrete Postplacement Record. A comparison between the two projects shows that with two exceptions essentially the same information is required by both projects. First, the Field Engineer is required to sign the Concrete Postplacement Record on Project D, and second, the temperature of the concrete and the ambient temperature must be documented only once daily on Project D compared with eight times daily on Project C.

5. Project E - The field engineer must inspect the concrete during the postplacement period to insure that 1) the proper temperature was maintained, 2) the surfaces are protected from excessive moisture loss, and 3) the forms and supports remain for the proper length of time. This information is documented on the Form and Support Removal form shown in Appendix 9.B. As can be seen, the documentation requirements are very limited and are in sharp contrast to those requirements seen for Projects C and D.

6. Project F - Inspection Plans define the inspection activities of the site QC group. Five major areas are observed during the postplacement period. These areas are 1) curing method, 2) cold weather temperature control 3) form removal, 4) finishing, and 5) surface repairs. These attributes are listed on the Quality Control Inspection Record in Appendix 9.B and are explained in detail in the Inspection Plan. Curing conditions must be verified twice daily and documented on a separate Concrete Curing Record (not included).

7. Project G - The inspector must verify that finishing and curing operations are performed in accordance with the specifications. The detailed attributes checked are included on the Concrete Placement Inspection Checklist included in Appendix 9.A. Upon satisfactory completion, the Work Plan and Inspection Report, also included in Appendix 9.A., must be signed.

8. Project H - The Concrete Placement and Curing Record for Contractor H1 is included in Appendix 9.A. As can be seen, the form removal and curing activities are observed by Quality Control. The maximum and minimum temperatures are recorded on a thermometer which remains in place during the curing period. The Inspection Report for Concrete Placement used by Contractor H2 is also included in Appendix 9.A. It can be seen that the level of detail is comparable with the first contractor.

9. Project I - The inspector on Project I checks the placement during the curing period to insure that 1) the surfaces are kept moist, 2) there is proper protection, and 3) the proper temperatures are maintained. Surface defects and voids are also checked before and after repairs. The curing conditions must be checked twice daily and recorded on the Curing Record in Appendix 9.B. An attribute list (unavailable) similar to the one shown for Project F is used.

FORM REMOVAL

The principle criterion for form removal is that the concrete should have gained sufficient strength such that it 1) can carry its own dead weight plus any superimposed construction loads and 2) will not be damaged during the form removal process. As indicated in ACI 301, the minimum strength required should be stated in the project documents. The actual time, however, required to achieve this strength is dependent upon many factors, including the design mix and the concrete temperature. In arriving at a specified strength at which forms can be removed, ACI 347 indicates that as a general rule, forms for columns and piers can be removed before those for beams and slabs. The removal of forms and supports for suspended structures can be accomplished when the ratio of the cylinder strength to design strength exceeds 0.50 or exceeds the ratio of total dead load plus construction loads to the total design load, whichever is greatest. The information needed to use this latter approach as a removal criterion is generally not readily available, and hence, the former approach or some version thereof is normally used. Table 9.4 summarizes the ACI 347 recommended time intervals which should elapse prior to the removal of formwork. The times represent the cummulative number of days during which the temperature of the surrounding air is above 50° F. These time intervals should be modified according to the job mix, temperature of the concrete, and other unique project or job characteristics.

Project Requirements

Appendix 9.B contains the postplacement inspection documents for each of the projects. These provide an indication of the involvement of Quality Control in the form removal process. As can be seen, the scope of QC activities varies somewhat, but in general, is not particularly intensive. The various project approaches to form removal are presented below.

1. Project A - Removal of formwork is not an attribute which the QC

Inspector is required to verify. The project specifications and the construction procedure however, do specify that the forms should not be removed until sufficient strength has been gained, as verified by suitable control tests (presumably this means preparing concrete cylinders). No further information is available.

2. Project B - Quality Control is not involved in the form removal process. Neither the specifications nor the construction procedures establish a form removal criterion.

3. Project C - Forms for columns, walls, sides of beams and girders, and other parts not supporting the weight of the concrete can be removed as soon as practical in order to facilitate the repair of defective surfaces. Formwork for beams and girder soffits, slabs, and other parts that support the weight of the concrete should remain for a minimum of seven days or until the concrete attains 80% of the specified 28 day design strength. As can be seen on the Quality Control Inspection Record, the inspector is required to perform surveillance functions on this activity. The date and time of form removal must also be denoted on the Concrete Post Placement Report.

4. Project D - The removal criterion is similar to those requirements on Project C except that the achievement of 60% of the 90 day strength is satisfactory for those mixes that are accepted on the basis of 90 day tests. Quality Control is involved in a manner similar to that found on Project C, and the required documentation is comparable.

5. Project E - The unique feature about the Project E requirements is that the removal criterion considers the functional type of formwork (e.g., beams, columns, girders, shoring, slabs, etc.), dimension of the structural element, type of mix, and the concrete or ambient temperature. Table 9.5 shows the minimum time for form removal based on the class of concrete used and the following types of formwork:

Table 9.4. - Partial Summary of ACI 347
Minimum Suggested Times for Form Removal

Structural Element	Recommended Time Frame	
Walls	12-24 hr.	
Columns	12-24 hr.	
Sides of Beams and Girders	12-24 hr.	
Pan joist 30 in. wide or less[a]	3 days	
Pan joist greater than 30 in.[a]	4 days	
	Design Live Load < dead Load (days)	Design Live Load > dead Load (days)
Joist, beam or girder soffits[b]:		
clear span < 10 ft.	7[c]	4
10 ft. < span < 20 ft.	14[c]	7
span > 20 ft.	21[c]	14
Floor slabs[b]:		
clear span < 10 ft.	4[c]	3
10 ft. < span < 20 ft.	7[c]	4
span > 20 ft.	10[c]	7

[a] Of the type which can be removed without disturbing forming or shoring
[b] Distances between supports refer to structural supports and not temporary formwork or shores.
[c] Where forms may be removed without disturbing shores, use half of the values shown but not less than 3 days.

a) Type I - Side forms for mass concrete, walls, columns, beams, and girders whose least lateral dimension is greater than 8 feet.

b) Type II - Side forms for walls, columns, beams, and girders whose whose least lateral dimension is equal to or greater than 12 inches but less than 8 feet.

c) Type III - Side forms for walls, columns, beams, and girders whose least lateral dimension is less than 12 inches.

d) Type IV - Shoring and bottom forms of beams, girders, and slabs with spans up to and including 20 feet, whose design live load is greater than the dead load and whose construction loads are less than one-half of the dead load.

e) Type V - All other shoring and bottom forms.

As indicated in Table 9.5, no side forms can be removed in less than 12 hours and no shoring can be removed in less than three days. The time limitations for Types I, II, and III formwork are generally greater than the ACI 347 suggested times shown in Table 9.4. In cold weather, the times given in Table 9.5 may be modified depending on the cold weather protection requirements. Shoring and bottom forms are not removed as long as the average mean daily ambient temperature is less than 45^{o} F.

These provisions would appear to provide a significant degree of flexibility from the standpoint of recognizing the effect of the significant variables which influence the initial rate of strength gain. An additional advantage of this approach is that it is no longer necessary to prepare and test concrete cylinders.

No quality control documentation is required.

6. Project F - The requirements are similar to Project I and therefore will not be discussed.

7. Project G - The removal criteria for Project G is based on the type of form, thickness of the member, and structural function of the member. Forms for columns, walls, sides of beams, slabs and girders, and other parts not supporting the weight of concrete may be removed as soon as practical. Wood

Table 9.5. - Timetable for Project E[a]

Type of Form-work	Minimum Strength at Form Removal, (psi)	Average Mean Daily Temperature[b]		Time Required to Assure Minimum Strength of Classes A, B, and C Concrete at Form Removal				
		Concrete in Forms, (°F)	Ambient Air, (°F)	f'_c = 2000 PSI		f'_c = 3000 PSI		f'_c = 4000 PSI
				C (Days)	B (Days)	B (Days)	A (Days)	A (Days)
I	200	80	60	2	24 hr	16 hr	12 hr	
		70	50	3	36 hr	24 hr	18 hr	
		60	40	4	2	32 hr	24 hr	
II	400	80	65		2	1.5 hr.	16 hr	12 hr
		70	55		3	2	24 hr	16 hr
		60	45		4	2.5	32 hr	21 hr
III	600	80	70			2	1 hr	12 hr
		70	60			3	1.5 hr	18 hr
		60	50			4	2	24 hr
		50	40			5	2.5	30 hr
IV	1300	80	75			8	3	3
		70	65			12	5	3
		60	55			16	7	4
		50	45			20	9	5
V	2000	80	75			18	9	4
		70	65			28	12	5
		60	55			37	16	7
		50	45			47	20	9

[a] Time in days except as noted in hours.
[b] Temperature of concrete in the form controls. Ambient air temperatures may be used when concrete temperatures have not been measured.

forms or insulated steel forms for members greater than three feet in thickness must be stripped or loosened within 24 hours. Formwork for beams and girder soffits, slabs and other elements that support the weight of concrete must remain until the results of concrete cylinder tests indicate that the concrete has gained 80% of its specified 28 day design strength.

Quality Control must verify that the forms have been loosened and record the compressive cylinder strength used to justify form removal. This information is documented on the Work Plan Inspection Record included in Appendix 9.A.

8. Project H - On Project H the forms under floor slabs, beams, and girders may be removed when the concrete has reached 67% of the specified design strength. Centering under beams, girders, and flat slabs may be removed when 80% of the design strength has been reached. Removal is based upon the results of concrete cylinder tests. Two cylinders are prepared for every 100 cubic yards of concrete placed. It is not known whether all of the sets of cylinders are tested or whether one set is tested with the others held in reserve. Nevertheless, it does appear that this requirement is above the industry average. It should be pointed out that on those projects where compressive tests are used to justify adequate strength for form removal purposes only one set of cylinders is deemed necessary.

9. Project I - Minimum strengths are considered to be satisfied if the average strength of two field cured cylinders equals or exceeds the values presented in Table 9.6. In lieu of casting cylinders, the forms, except for the containment dome, may be removed based on the average strength of three probes determined in accordance with ASTM C 803 provided the average strength exeeds the values given in Table 9.6 by at least 20%. If the ambient air temperature that the concrete will be exposed to after removal is below $50^{o}F$, forms are not removed until seven days have elapsed after the placement.

Table 9.6. - Form Removal Timetable, Project I[a]

Structural Member	Minimum Strength (psi)	Number of Days
Nonbearing walls, mass foundations, sides of beams and girders	500	1
Columns and bearing walls, provided girders are shored to prevent appreciable load reaching column	1,500	4
Slabs, bottom of beams and girders	2,000	7
Containment Structure		
Internal walls	1,000	1
Internal slabs	3,000	5
Primary shield wall	1,000	1
Exterior cylindrical wall	1,000	2
Dome (top forms)	500	1
Dome (strong backs attached to inner steel liner)	2,000	7

[a]The number of days serves as a guideline. Form removal is based on the strength requirements given.

CONCRETE CURING

General Requirements

Curing is the process of maintaining a satisfactory environment, e.g., presence of moisture and favorable temperature, such that concrete will develop full strength and durability. Thus proper curing is essential in the production of quality concrete.

The basic document referenced by most of the projects studied is ACI 301, Chapter 12, which establishes several acceptable methods for curing. These methods are listed in Table 9.7 along with information related specifically to those projects studied. ACI 301 states that the curing period must be extended for seven days when type II cement is being used, unless the termination of curing is based on the results of field cured cylinders. When the average compressive strength reaches 70% of the specified design strength, curing may be terminated.

ACI 301 also states that where surfaces placed against wooden forms are exposed to the sun, extra caution must be taken to prevent moisture loss. This can be accomplished by keeping the forms wet until they can be safely removed.

The rate of temperature change must be controlled. Changes in temperature of the air immediately adjacent to the concrete during and immediately after curing should not be allowed to change by more than $5^{\circ}F$ in any one hour period or $50^{\circ}F$ in any 24 hour period.

Chapter 14 of ACI 301 provides specific recommendations for mass concrete. The most notable differences between mass and nonmass practices are that the curing period has been extended to two weeks and the forms and exposed concrete must be kept continuously wet for at least the first 48 hours after placing and at any time during curing when the surrounding air temperature exceeds $90^{\circ}F$. The first difference, of course, recognizes the fact that the design mixes for most massive structures, particularly gravity dams, contain less

than 400 lbs of cement per cubic yard, and therefore the rate of hydration is somewhat reduced. The data presented in Chapter 6 of this report would, however, indicate that this provision is not applicable to nuclear power plant construction. The second provision which requires the continuous wetting of forms reflects the need to dissipate the heat of hydration generated during the early curing period. This practice may or may not be applicable to nuclear construction. In addition to these provisions, Chapter 14 of ACI 301 also requires that the rate of temperature change during curing and immediately thereafter should not exceed $3^{o}F$ in any one hour period or $30^{o}F$ in a 24 hour period. This is of course a significant reduction from the rate of change of temperature in nonmass structures.

The Bureau of Reclamation (9.6) sets forth similar mass concrete curing practices except that when the curing method employs sealing membranes, e.g., plastic sheets or curing compounds, the curing period is extended to 28 days. Also the necessity of controlling the rate of change of the concrete temperature is applied only when cold weather practices have been initiated.

Project Requirements

Table 9.7 summarizes some of the important curing aspects related to each project. The methods which are acceptable on each site are listed. Most projects recommend and use, whenever possible, a moist cure method; the use of curing compounds is limited and is most often used when moist curing methods are impractical, such as during cold weather.

Several other points should be highlighted. The curing period as specified in the project documents is generally accepted as seven days, except for Project E which uses 14 days. The recommended two week curing period results from experiences gained from placing concrete on massive gravity dams and hydroelectric projects. There are many factors which make the massive placements on nuclear power projects different from gravity dams, and therefore, it does not appear that this extended period is necessary. This fact is also addressed

in ACI 308, Recommended Practice for Curing Concrete, which recommends two weeks for massive unreinforced sections and seven days for massive heavily reinforced sections.

Also related to curing, laboratory tests and field observations indicate that a curing period for sealing membranes (e.g., plastic sheets, curing compounds) of 28 days is required in order to be equivalent to 14 days of moist curing (9.6). Whether or not an extension to the seven day curing period should be applied under certain circumstances is not known, but perhaps the necessity of not doing so should be evaluated.

ACI 301 has also established a requirement that the rate of temperature change should be controlled. This is applicable not only during the curing period but also immediately after the removal of the forms and should be applied at all times of the year. As stated above, the Bureau of Reclamation only applies this requirement in cold weather, and only Projects F and I have chosen to impose a similar provision during normal weather.

Cold Weather Curing Aspects

During cold weather, sufficient protection must be provided to 1) safeguard the concrete against damage from freezing during the early critical curing period and 2) maintain conditions of moisture and temperature under which hydration may continue without interruption in order that the concrete will achieve satisfactory strength and durability. The length of the initial protection period depends upon many factors, but as stated in ACI 306, Recommended Practice for Cold Weather Concreting, the time at which the level of saturation of the concrete becomes reduced below the level which would cause damage from freezing, roughly corresponds to the time required to attain a compressive strength of 500 psi. At a temperature of $50^{\circ}F$, most well-proportioned concrete will reach this strength sometime during the second day. ACI 306 suggests a range of times that this protection should be provided depending upon the service category of the structure. These times

Table 9.7. - Project Specification Requirements For Concrete Curing[a]

Acceptable Methods	Projects								
	A	B	C	D	E	F	G	H	I
Ponding or Continuous Sprinkling	x		x	x	x	x	x	x	x
Absorptive Mats or Fabric, Burlap	x	x	x	x	x	x	x	x	x
Wet Sand		x	x	x	x	x	x	x	x
Steam									
Waterproof Sealing Membranes	x	x	x	x	x	x	x	x	x
Curing Compound	x		x	x	x	x	x	x	x
Curing Aspects									
Curing Period (days)	7		7	7	14	7	7	7	7[c]
Cooling Rate Specified						5%/hr 50°/24hr			3%/hr[d] 30°/24hr
Wetting of wood and steel forms required						x[b]		wood only	x[b]

[a] Provisions do not apply to cold weather curing
[b] Wetting of wood forms is required whenever the ambient temperature exceeds 50°F and steel forms must be wetted when the ambient temperature exceeds 70°F or the forms are exposed to sunlight
[c] An additional seven days of curing is required for mass concrete
[d] Applies to mass concrete or watertight structures

range from a minimum of two days to a maximum of six days when Type II cement is used.

The Bureau of Reclamation requires protection against freezing for at least 48 hours when the mean daily temperature is above 40°F.

When the mean daily temperatures are sufficiently low, usually defined as below 40°F, additional protection must be provided in order to maintain adequate conditions for continued curing. To accomplish this, insulated blankets or artificial heaters are used. ACI 306 recommends that a concrete temperature of no less than 50°F should be maintained under cold weather conditions. To minimize subsequent thermal shrinkage, however, the upper limit on this concrete temperature should be as close as practical to the maximum temperature to which the concrete will be subjected during service. ACI 301 clarifies this latter point by stating that the concrete temperature should not be less than 50°F or more than 70°F. The Bureau of Reclamation specifications require a minimum temperature of 50°F which should be maintained for a minimum of 72 hours. They do not establish an upper limit.

Another point should be made regarding the protection against cold temperatures. Since most of the heat of hydration is generated during the first three days, no heat from outside sources is required to maintain minimum concrete temperatures provided this heat is adequately preserved. This heat may be conserved by use of insulated blankets on unformed surfaces and by insulated forms (9.9).

There appears to be some confusion within the industry between the curing time requirements and practices stated in ACI 301 and 308 and the cold weather protection recommendations presented in ACI 306. The rationale presented in the discussion below is similar to that used as a justification for reducing the curing period for certain types of members from seven days to two or three days. Two projects in the study have submitted such requests to the NRC but

it is not known if these have been approved.

ACI 301, para. 12.3.1 references ACI 306 for detailed recommendations on curing and protection of concrete during cold weather. Para. 12.2.2 of ACI 301 specifies that the curing period should be seven days. Because this provision appears in a different paragraph from the one referencing the cold weather recommendations, it is concluded that the definitive reference for concreting methods during cold weather is ACI 306. Hence these two documents can be considered as separable.

ACI 306, para. 1.10.2 states that winter concreting practices must be adequate to:

> "Allow the concrete to develop whatever strength is necessary in its service catagory (Table 9.8) to assure safe removal of forms for prompt reuse, safe removal of shores and reshores, and safe loading of the structure when desired during and after construction."

Table 9.8 indicates that a minimum three day protection period is required for both safe strength and durability of concrete containing type II cement that will not be immediately subjected to service loads.

The above two paragraphs present the logic behind justifying that 1) the seven day curing period is not applicable during cold weather and 2) the curing period during cold weather should be three days as specified in Table 9.8. In reality this logic is diametrically opposite all engineering judgement which would suggest that cold weather slows the curing rate. This fact has, of course, been proven by research data and, hence, shortening the curing period during cold weather does not appear to be justified.

The misunderstanding seems to be that the duration periods presented in Table 9.8 are curing periods since these values are related to strength and durability. These time frames however are established to provide protection from freezing and to allow for the safe removal of forms. The fact that the strength

Table 9.8. - Protection Recommended for Concrete Placed in Cold Weather

Service Catagory	Protection recommended at temperature indicated Line 7, Table 1.4.1, ACI 306, Type II Cement only, days	
	For durability	For Strength
No Load, no exposure (See Section 4.1, ACI 306)	2	2
No Load, exposed (See Section 4.2, ACI 306)	3	3
Partial Load, exposed (See Section 4.3, ACI 306)	3	6
Full Load, exposed (See Chapter 5, ACI 306)	3	See Table 5.1.7, ACE 306

alone is adequate does not necessarily mean that the quality of the concrete is satisfactory. This point is clarified somewhat by ACI 308 which states:

> "Other properties of concrete, such as impermeability and resistance to abrasion, freezing and thawing, and sulfate attack, are also improved by curing. Consequently, curing beyond that needed to develop a certain strength is often desirable."

Thus the seven day curing period established in ACI 301 is still applicable and could perhaps be extended longer depending upon the design mix, concrete temperatures and ambient conditions. In this regard the design mixes would normally be designed to have an average strength that is 500 psi to 1000 psi above the design strength. Thus the time required to reach 70% of the specified strength (criterion for form removal as stated in ACI 301) roughly corresponds to seven days. For the projects mentioned above however, the mixes are over-designed to the point that 70% of the specified strength is usually reached in three days or less. The concrete however is still "green" despite the early strength gain. Perhaps the Code should be rephrased to indicate that to insure durability, the concrete should cure until 70% of the 28 day strength is reached.

If the surface is chilled rapidly when the forms are removed or when cold weather protection is discontinued, cracking and subsequent deterioration may result. For this reason the rate of change of the concrete temperature must be controlled. The rates of change for nonmass and mass concrete presented in ACI 301 which were discussed above are applicable during cold weather. The Bureau of Reclamation requirements are similar and state the following:

> "The surface temperature of mass concrete should not drop faster than 20°F each 24 hours because the probability of cracking from sudden chilling at the surface is great because of the differential between interior and exterior temperatures. Heat of hydration escapes from mass concrete slowly and may raise the initial temperature by 30°F at the surface and as much as 70°F in the interior. In thin sections, on the other hand, surface temperatures may drop gradually as much

> as 40°F in each 24 hours without damage because the heat of hydration is rapidly dissipated and the probability of excessive differential between the interior and exterior temperatures is not great."

The type of structures constructed by the Bureau are of course primarily massive unreinforced sections, and thus the restriction to 20°F per 24 hours seems to be too restrictive for nuclear construction. It would appear that the role played by the reinforcement in dissipating the internal heat of hydration would be significant. Further, as stated in ACI 308, internal concrete temperatures as high as 130°F have frequently been found in such heavily reinforced structures as blast off pads, heavy machinery foundations, and load transfer girders. However, due to the large amount of reinforcement in such construction, these high temperatures apparently have not been harmful. Another point worthy of note is the ACI requirement of controlling the rate of change to 3 or 5°F per hour. While this is a satisfactory guideline which one should strive to achieve, it is difficult to control the rate of change to this degree. On nuclear work this should be used as a guide but not established as a specification requirement.

Project Requirements for Cold Weather Curing

With the exception of Project E, the requirements of ACI 306 are generally followed. Enclosures are required to remain for 24 hours after artificial heating is terminated. There are some variations in the way the rate of change of temperature is administered. The requirement for limiting the rate of temperature change to 3° or 5° per hour appears to be one area where there have been some difficulties and hence has resulted in a number of nonconformance reports. Despite the fact that the temperatures have deviated to a greater degree than allowed by the specifications, no evidence was found to suggest that the quality of the concrete had been affected.

Project E does not follow the ACI 306 provisions as shown in Exhibit 9.2. The unique feature of the Project E specifications is that three levels of

Exhibit 9.2

COLD WEATHER PROTECTION REQUIREMENTS, PROJECT E

Provisions shall be made during cold weather to provide either minimum protection, full protection, or extended protection, as prescribed below, depending on the class of concrete used and the final exposure conditions to which the surface will be subjected. Substitution of one class of concrete for another for economics of the curing procedure may be made if approval is obtained from the Engineer.

Severe exposure. All exterior surfaces of concrete structures which will be subjected to alternately wetting and drying conditions. This includes all horizontal surfaces exposed to weather, all vertical or sloping surfaces from minimum operating headwater and tailwater elevations to 10 feet above maximum operating headwater and tailwater elevations, and all surfaces exposed to spray from spillways or other water release facilities.

Mild exposure. All other exterior surfaces. This included all surfaces below ground level or below minimum operating water levels, and all vertical and sloping surfaces which are more than 10 feet above maximum operating water levels and not subject to spray from spillways or other water release facilities.

Limited exposure. All interior surfaces, including construction joints, whose exposure to freezing conditions is limited to the construction period.

Minimum protection. Maintaining a temperature in the concrete of more than 50 F for a minimum period of 3 days.

Full protection. Maintaining minimum protection for 3 days plus protecting the concrete from freezing for an additional period of 3 days.

Extended protection. Maintaining minimum protection for 3 days plus protecting the concrete from freezing for an additional period of 14 days.

When high early-strength concrete is approved for face concrete by the Engineer, the above periods of protection may be reduced by one-third. Care shall be taken to avoid high temperatures and dry heating within enclosures.

Protection of concrete surfaces shall be provided as follows:

(Continued)

Exhibit 9.2 (Continued)

Exposure Condition	Concrete Class and Related Protection				
	f'_c = 2000 PSI		f'_c = 3000 PSI		f'_c = 4000 PSI
	Class		Class		Class
	C	B	B	A	A
Severe	-	-	Ext	Full	Min
Mild	-	Ext	Full	Min	Min
Limited	Ext	Full	Min	Min	Min

The maximum allowable gradual drop in temperature of the surface of the concrete during the first 24 hours after the end of protection shall be as follows:

f'_c, psi	2000		3000		4000
Class of concrete	C	B	B	A	A
Maximum temperature drop in °F	20	20	30	40	50

protection are provided, depending upon the level of exposure to which the structure will be subjected, the design strength, and the type of mix (Class A, B or C). The provisions shown in Exhibit 9.2 are not implemented until the ambient temperature has been or is predicted to fall below 20°F within 48 hours. When the temperature ranges between 20° and 40°, the concrete is protected with insulated blankets, but no artificial heat is used.

SUMMARY

A number of placement and post placement activities were discussed. The involvement of Quality Control for each project was presented and it was pointed out that the level of detail in the QC procedures may tend to draw attention away from the broader aspects of practices necessary to insure quality. Also presented was the fact that several projects have chosen to stress some of those aspects which should not be done. It was felt that stressing those aspects which should be done was the more favorable approach.

In discussing delivery systems the emphasis was placed on delivering, conveying, and placing as rapidly as possible. In this respect, the addition of supplemental water, sampling at the point of placement, and the frequency of testing were all important. To eliminate routine testing at the point of placement requires the completion of a correlation testing program. It was suggested that most programs did not appear to be well conceived and thus are very lengthy and costly. It was also suggested that the addition of supplemental water should perhaps be prohibited because of the testing requirements and delays encountered. In several cases the addition of water encourages the production of low slump concrete.

Construction joints were discussed, and it was shown that both starter mixes and grout were used. These practices were compared with the Bureau of Reclamation practices which suggested that starter mixes provided superior

joints and with less difficulties being encountered at the placement point. Two methods of cleaning the joint were used. From an economic standpoint, sandblasting is preferred over "green cutting". A number of projects reflect this in their specifications. Also related to cleaning, the requirement for exposing aggregate was discussed. Research data has shown that exposure of aggregate to a specified amphlitude offers no increased advantage in water-tightness or bonding characteristics.

Placement practices were also discussed with a particular emphasis on consolidation. The level of detail in the specifications and the QC procedures was shown, and it was felt that in several cases too much emphasis was being placed on the details rather than the overall aspects of consolidation. Several projects make mention of the fact that forms and reinforcement should not be touched. This has led to the hypothesis that the vibrator operators could become timid. No research data was available to support this hypothesis, however. On the other hand, three projects had provisions which stressed the importance of consolidating around embedments, reinforcement and in the corners. Revibration was discussed, and where this technique was not allowed or discouraged, it appeared to be contrary to industry practice.

The discussion on quality control involvement in post placement activities suggested that the aspects verified on each project were essentially the same with the primary difference between the projects being the method of documentation. In this respect, there were several opportunities for consolidating documents.

Form removal and curing aspects were presented and these compared with the industry standards. It was pointed out that most projects comply with the ACI provisions. There appears to be some confusion with the ACI 306 Cold Weather requirements regarding the curing period.

REFERENCES

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9.6. Concrete Manual, U.S. Bureau of Reclamation, Denver, Eighth Edition, 1975.

9.7. ACI Committee 304, "Recommended Practice for Measuring, Mixing, Transporting, and Placing Concrete," April 1973.

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APPENDIX 9.A

CONCRETE PLACEMENT INSPECTION DOCUMENTS AND ATTRIBUTE LISTS

This appendix contains the following project documents and records:

1. Project A--Concrete Pour Site Inspector's Report

2. Project B--Report of Concrete Placement
   Quality Control Checklist for Pump Placement of Concrete.

3. Project C--Quality Control Inspection Record

4. Project D--Quality Control Inspection Record

5. Project E--Concrete Pour Card

6. Project F--Quality Control Inspection Report

7. Project G--Standard Work Plan and Inspection Record
   Concrete Placement Inspection Checklist

8. Project H--Concrete Placement and Curing Report (Contractor 1)
   Inspection Report for Concrete Placement (Contractor 2)
   Concrete Placement Checklist (Contractor 2)

9. Project I--Quality Assurance Inspection Report

CONCRETE POUR SITE INSPECTOR'S REPORT--PROJECT A

Location _____ Date _____

Time - Start _____ Finish _____ Weather _____ Temp. _____

Type of delivery - Truck _____ Conveyer _____

Class of concrete - A _____ A2 _____ B _____

Condition of surfaces prior to pour _____

Grout applied _____ Horizontal joints _____ Vertical joints _____

Condition of concrete delivered _____

Minimum drop between belts? _____

Free fall under five feet? _____

Lateral flow of concrete five feet or less? _____

Proper consolidation _____

No. of vibrators in use _____

No. of discharge points _____

Belt wipers working properly? _____

Protection of finished surfaces from spillage _____

Replacing of rebar disturbed _____

Type of top finish _____

Curing method _____

Hold ups due to equipment failure or planning _____

_____

_____

_____

_____

QC Inspector(s)

REPORT OF CONCRETE PLACEMENT--PROJECT B

Pour Area:_____ Date_____

Location:_____

_____

FORMS	ACCEPTED
Properly Coated	____
Free From Holes	____
Seams Tight	____
Clean	____
Proper Shoring & Support	____

REINFORCEMENTS	ACCEPTED
Proper Clearance	____
Proper Support	____
Clean	____

Tie Rods Type:_____

Spacing: _____

EQUIPMENT:

No. & Size of Vibrators_____

Placement Equipment_____

Tremie Pipes - Number_____ Size_____Location_____

PLACEMENT:

Consolidation_____

Grouted_____ Time_____

Concrete - Lift Depth _____Direction of Pour_____

REMARKS:_____

_____

_____

_____

_____

_____ _____

Quality Control Inspector Date

SUMMARY OF QUALITY CONTROL CHECKLISTS FOR
PUMP PLACEMENT OF CONCRETE--PROJECT B

1. Inspectors Concrete Checkout Sheet
2. Concrete Status Report
3. Concrete Placement Check Out Sheet
4. Report of Concrete Placement
5. Quality Control Check List for the Placement of Concrete

Precautions

1. Extremely Hot Weather - The receiving hopper and pump lines shall be shaded and kept cool.
2. Extremely Cold Weather - Exposed piping insulated to prevent excessive heat loss.
3. Concrete should not be allowed to stand in pump lines for longer than 45 minutes.

QUALITY CONTROL CHECKLIST (CONTINUED)--PROJECT B

Equipment

1. Equipment clean and free of excessive concrete build-up.

2. Hopper agitator blades sound and not excessively worn.

3. Pipe connections sufficiently tight.

4. Screen in place over hopper to prevent large foreign objects from entering pump lines.

5. A slurry mix is used as a priming mix.

Tests

When placing concrete by pumping, the tests at the transit truck discharge remain the same as for other placing methods. (Except air shall be maintained ½% above minimum specified.) However, a full set of tests must be run at the pump discharge for each 500 cubic yards of concrete placed or a minimum of once each week.

POUR NO. _____ INSPECTOR _____ DATE _____

QUALITY CONTROL INSPECTION RECORD--PROJECT C

5. ITEM/S: A) FS-J-1 B) NOT APPLICABLE

C) NOT APPLICABLE D) NOT APPLICABLE

6. SCOPE/LOCATION: R/B 1 CONTAINMENT DIAPHRAGM SLAB

7. REFERENCE CRITERIA: ○ C-36 REV 6, C-11 NA, JR-C-3 8 ○ ADD 1.2 FA 11.35 ADDITION 1-12
DCN REV DCN

8. RECORD PREPARED BY: M Maxwell 9. RECORD REVIEWED BY: C Parker

10. A/T No.	11. DESCRIPTION	12. C	13. E	14. ITEM/S ACCEPTANCE A	B	C	D
1.0	PREREQUISITES						
1.1	Inspection and reference criteria reviewed for availability, familiarity, correct approval and revision status	R		CV 1-30-76			
1.2	Review performed for open NCRs affecting work operations	R					
1.3	Reviewed preplacement IR No._____ for acceptance.	R					
1.4	Verify concrete callout procedure properly implemented	R					
1.5	Required number of spare vibrators available.	I		CV 1-30-76			
1.6 △	~~Hot and~~ cold weather placing methods acceptable.	R		CV 1-30-76			
1.7	Final Inspection a. No debris, mud, snow, ice, or frozen surfaces exist. b. Form temperature for cold weather acceptable. c. Surfaces are thoroughly wetted.	I		CV 1-30-76			
1.8	Equipment Checks a. Communication system is operating properly. b. Cleanliness of conveying and placing equipment checked. c. Adequate weather protection available.	S		CV 1-30-76			
1.9	Concrete placement card properly signed off.	R		CV 1-30-76			
1.10	Preliminary or provisionary releases per JR-C-3.	I		CV 1-30-76			
1.11	QC-C12-1, 1 thru 9 completed and forwarded to QCE performing concrete receipt inspection.	R		CV			
1.12	Time limitations for vertical joints not exceeded.	R		1-30-76			
2.0	IN-PROCESS INSPECTION ACTIVITIES						
2.1	Surfaces kept in a moist condition.	I		CV			
2.2	Horizontal surfaces covered with grout or 3/4 inch starter mix.	I		1-30-76			
2.3	Concrete Placement a. Max. free drop of 6 feet not exceeded	I					

FOR INFORMATION ONLY

QUALITY CONTROL INSPECTION RECORD (CONTINUED)--PROJECT C

10. A/T No.	11. DESCRIPTION	12. C	13. E	14. ITEM/S ACCEPTANCE A	B	C	D
2.3	b. Max. 5 feet limit for concrete flow not exceeded. c. Max. concrete depth of 24 inches not exceeded. d. Conveying and placement equipment properly used. ~~e. Slab and soffit placements delayed one hour when placed with beams, walls, or columns.~~ f. ~~Water stops properly embedded.~~ C. Hayden 1-30-76 g. Spill concrete on rebar removed. h. ~~Rebar moved; returned to required location.~~ i. ~~Unformed slopes less than 1.5 horiz. to 1 vert.~~			CV 1-30-76			
2.4	Consolidation of Concrete a. Vibrators operated in near vertical position.	I		CV 1-30-76			
	b. Vibrators meet 7000 cpm frequency requirements. Device No. C-409 C-410 C-411 Cal. Due Date 6/76 6/76 6/76	S		CV 1-30-76			
	c. Surface vibrators and jitterbugs used properly. C. Hayden 1-30-76	I		CV 1-30-76			
2.5	~~Duct banks properly colored with yellow oxide.~~ NOT APPLICABLE	I					
2.6	Screed boards, pins, etc., checked for proper elevation.	S		CV 1-30-76			
2.7	Pre-finishing operations performed with no water present.	I		CV 1-30-76			
3.0	FINAL INSPECTION ACTIVITIES						
3.1	Concrete surface at specified rough finish grade and consolidated.			CV 1-30-76			
4.0	REVIEW OF SUPPLEMENTARY RECORDS						
	a. Concrete callout sheet b. Truck delivery ticket c. In-process Concrete Test Report QC-C12-1 d. Other supplementary records as listed:	R		CV 3-3-76			
5.0	EXCEPTIONS						
5.1 or	No exceptions noted.	R		CV 3-3-76			
5.2	Indicated exceptions are described in Remarks section.	R					

15. REMARKS

FOR INFORMATION ONLY

16. COMPLETED INSPECTION RECORD REVIEWED AND ACCEPTED BY: C. Hayden DATE: 3-3-76

QUALITY CONTROL INSPECTION RECORD--PROJECT D

ITEM/S: A) PLACEMENT NO. 183-W-03 B) N/A 1/12/77 GHW

C) N/A 1/12/77 GHW D) N/A 1/12/77 GHW

6. SCOPE/LOCATION: Reactor Bldg. Unit #2, Area 33 & 34, Exterior Wall on "U" Line from elev. 716'-10" to 747'-4". See attached sketch for location.

7. REFERENCE CRITERIA:

8. PREPARED BY: DHW DATE: 1/13/77 9. REVIEWED BY: T.A. McHenry DATE: 1-12-77

10. ACT No.	11. DESCRIPTION	12. C	13. E	14. ITEM/S ACCEPTANCE A	B	C	D
1.0	PREREQUISITES						
1.1	Inspection and reference criteria reviewed for availability, familiarity and correct approval and revision status.	R		DHW 2/4/77			
1.2	Reviewed preplacement IR No. ____ for acceptance and open NCRs affecting work operations.	R		DHW 2/2/77			
1.3	Verify proper class of concrete has been ordered.	R		DHW 2/2/77			
1.4	Final Inspection of Surfaces a. No debris, mud, snow, ice or frozen surface exist. b. Surfaces are thoroughly wetted.	I		DHW 2/2/77			
1.5	Equipment Checks a. Adequate communication system provided. b. Conveying and placing equipment checked for cleanliness and defects. c. Required number of vibrators available. d. Adequate weather protection available. e. Hot and cold weather placing method comply.	S		DHW 2/2/77			
1.6	Scope form QC-C12-1 and review criteria with concrete receiving QCE.	R		DHW 2/2/77			
2.0	IN-PROCESS INSEPCTION ACTIVITIES						
2.1	Construction Joint Treatment a. Horizontal surface covered with mortar, grout or starter mix.	I		2-2-77 MAL			
2.2	Concrete Placement. a. Conveying and placing equipment properly employed, maximum free drop (6') not exceeded. b. Maximum lift depth not to exceed the following: 1. 24" for members 2½' and greater in thickness or 2. ~~48"~~ 24" for members less than 2½' in thickness or 3. 12" for high density concrete; max. lift height 13'. 1/13/77 DHW c. Maximum horizontal flow (5') not exceeded. d. Rebar if moved, returned to proper position. e. Inserts protected from movement.	I		2-2-77			

QUALITY CONTROL INSPECTION RECORD (CONTINUED)--PROJECT D

10 ACT No.	11. DESCRIPTION	12. C	13. E	14. ITEM/S ACCEPTANCE A	B	C	D
2.3	Consolidation of Concrete						
	a. Vibrators operated in near vertical position.	I					
D	b. Vibrators meet frequency requirements (8000 cpm min.) or as specified in ACI 309-72, chapter 7-2. 1/12/77 RAW ~~Device No. Calib. Due Date~~ NOT USED			2-2-77			
	c. Surface and form vibrators not used.						
	~~d. High density concrete revibrated where required.~~ N/A RAW 1-12-77						
~~2.4~~	~~Screed boards, pins, etc., checked for proper elevation.~~ NOT APPLICABLE 1/12/77 RAW	S					
3.0	FINAL INSPECTION ACTIVITIES						
3.1	Concrete surface at specified rough finish grade and consolidated.	I		2-3-77			
3.2	Completed In-Process Concrete Test Report and Truck Delivery Tickets reviewed.	R		2-3-77			
4.0	REVIEW OF SUPPLEMENTARY RECORDS						
.1	Truck Delivery Tickets. (29 PAGES) 2-3-77	R		2-3-77			
4.2	In-process Concrete Test Report (QC-C12-1) & (QC-C12-2) (2 PAGES) 2-3-77 2-3-77	R		2-3-77			
5.0	EXCEPTIONS						
5.1 or	No exceptions noted.	R		2-3-77			
5.2	Indicated exceptions are described in Remarks SEction.	R					

CONCRETE POUR CARD--PROJECT E

POUR NO. _____ TO EL _____ DATE _____

LOCATION _____

CRAFTS	FOREMAN	ENGINEER	DATE	ACC. PER BNP-QCP
Carpenter				2.1 R
Boilermaker				
Mechanical				6.1 R
Electrical				3.1 R
Piping				6.1 R
Reinforcing				2.1 R
Struc. Steel				2.2 R
Sheet Metal				
Embedments Lines & Grades				2.1 R
Cleaning				5.3 R

FRONT

Remarks _____

Shift Engineer _____ Date _____ Time _____

FILED

INSPECTOR'S REPORT

INSPECTION	ACCEPTABLE
Surface Preparation and Cleanliness	☐
Form tightness	☐
Environmental conditions	☐
Condition of placing equipment	☐
Surveying and placing operations	
Deposit of concrete	☐
Layer thickness	☐
Concrete compaction	☐
Illumination	☐

ORIGINAL

BACK

Mix Number _____ Type finish _____

Conc. placing foreman _____

Date poured _____ Cu. yds. placed _____

Time: Started _____ Completed _____

Remarks _____

The above concrete placement and inspection was done in accordance with BNP-QCP-5.3,R____ and is acceptable.

The above repair poured with replacement concrete was done in accordance with BNP-QCP-5.3,R_ and BNP-QCP-5.4,R____ and is acceptable. Attachment D of BNP-QCP-5.4 has been completed.

The above grout or drypack operation was done in accordance with BNP-QCP-5.5,R____ and is acceptable. Attachment A of BNP-QCP-5.5 has been completed.

MTU Representative _____ Date _____

QUALITY CONTROL INSPECTION REPORT - PROJECT F

Project F
INSPECTION REPORT

No. I.D.

Page 1 of

Initiator

Building/Area SUBJ

Reference IP I.D.

Activity SUBJ

(CHECK ONE)
☐ In Process ☐ Install ☐ Final

Location

CAT - ☐ I ☐ II ☐ III CAT
ASME III - Class ☐ 1 ☐ 2 ☐ 3

Drawing No. DRWG ☐ E/C ☐ Vendor Issue No.

Spec. No. SPEC

No.	S	U	REWORK #1 S	REWORK #1 U	REWORK #2 S	REWORK #2 U	INSPECTION ATTRIBUTES	APPROVED DATE	APPROVED SQC SIGN.
S-81							Verify-Concrete Placement Card No.		
S-84							Verify-Approved Placement Procedure		
S-89							Verify-Preparation of Earth Foundation		
S-67							Verify-Placement Location is Clean		
S-102							Verify-Grouting of Construction Joint		
S-85							Verify-Cold Weather Concrete		
S-86							Verify-Hot Weather Concrete		
S-64							Verify-Concrete Testing		
S-83							Verify-General Placement Requirements		
S-103							Verify-18" Concrete Layers		
S-104							Verify-Vertical Drop Less than 6'		
S-92							Verify-Placement through Reinforcement		
S-90							Verify-Consolidation		
S-100							Verify-Protection of Concrete		
S-93							Verify-Concrete in Blockouts		

FOR INFORMATION ONLY

REMARKS:

RELATED DOCUMENTS

INSPECTION COMPLETE - UNSATS LISTED
Date Inspector

INSPECTION COMPLETE - ALL ATTRIBUTES SAT
Date Inspector

RELATED N & D | CLOSED DATE | APPROVED SIGNATURE

Project F
INSPECTION REPORT SUPPLEMENT

No.

Page 2 of

No.	S	U	REWORK #1 S	REWORK #1 U	REWORK #2 S	REWORK #2 U	INSPECTION ATTRIBUTES	APPROVED DATE	APPROVED SQC SIGN.
S-94							Verify-Concreting Underwater		
S-95							Verify-Watertight Concreting		
S-97							Verify-Surface finish		
S-105							Verify-Finished Tolerances		
S-111							Verify-Vibrators in excess 8000 rpm		

FOR INFORMATION ONLY

REWORK OF UNSAT ATTRIBUTES

REWORK #1	☐ Rework	☐ Engrg. Dispos. (N & D)	DISPOSITION WITHIN IP ☐ YES ☐ NO Date Contractor CQCS
REWORK #2	☐ Rework	☐ Engrg. Dispos. (N & D)	DISPOSITION WITHIN IP ☐ YES ☐ NO Date Contractor CQCS
N & D REQUIRED		☐ Engrg. Dispos. (N & D)	DISPOSITION Date CQCS

9.76

STANDARD WORK PLAN AND INSPECTION RECORD FOR CONCRETE OPERATIONS--PROJECT G

REV	DATE	REVISION DESCRIPTION	RFE	SUP	QCE	REV	DATE	REVISION DESCRIPTION	RFE	SUP	QCE
0						2					
1						3					

ITEM NO	WORK/INSPECTION ACTIVITY SEQUENCING REQUIRED YES ☐ NO ☐	INSTALLATION DOCUMENT #	REV	REV	HOLD PT	SUP'T	RFE	DATE	QCE	DATE	TYPE
	PREREQUISITES										
1	Estimated Concrete Quantity	NA				NA			NA		
2	Concrete Mix A B C D 1 2 PG					NA					
3	Grout Required Yes ☐ No ☐					NA					
4	Type of Finish					NA					
5	Type of Curing					NA					
6	Verify materials are available for installation	NA				NA	NA		NA		
7	Verify access to the work site is available, free of obstructions, adequate to accommodate the traffic and sequenced with other activities	NA				NA	NA		NA		
	CONCRETE OPERATIONS										
20	Prepare existing construction joints										
21	Verify joint surfaces (QCI 9.1-1)										I
30	Install waterproofing										
35	Install waterstop										
36	Verify waterstop (QCI 9.1-1)										I
40	Install reinforcing steel										
41	Verify rebar installation (QCI 9.1-1)										I

SIGNATURES	FOREMAN	DATE	SUPERINTENDENT	DATE	RFE	DATE	QCE	DATE

WORK PLAN AND INSPECTION RECORD (CONTINUED)--PROJECT G

ITEM NO	WORK/INSPECTION ACTIVITY	INSTALLATION DOCUMENT #	REV	REV	HOLD PT	SUP'T	RFE	DATE	QCE	DATE	TYPE
42	Verify cadweld splices (QCI 9.1-1)										R
50	Install forms/blockouts										
51	Verify forms/blockouts (QCI 9.1-1)										I
60	Install const., control, expansion/contraction joints										
61	Verify const., control, expansion/contraction joints (QCI 9.1-1)										I
70	Install embeds other than reinforcing steel										
71	Verify civil embeds (QCI 9.1-1)										I
80	Verify structural steel complete (QCI 9.1-7)										R
81	Verify Mech/Pipe embedded items (QCI 9.1-)										
82	Verify electrical embedded items (QCI 9.1-)										
83	Verify I&C electrical items (QCI 9.1-)										
84	Verify embed welding and NDE complete (QCI 9.1-9)										
85	Verify leak testing complete (QCI 9.1-)										
90	Survey complete										
100	Liner Plate completed (QCI 11.1-5)										R
101	Verify liner plate welding and NDE complete										
110	Perform preplacement cleanup/preparation										
111	Verify receiving surfaces, and placement equipment (QCI 9.1-1)										I
112	Verify weather protection/conditions (QCI 9.1-1)										I
113	Verify testing preparations made; Lab notified (QCI 9.1-1)										I
114	Final preplacement hold point release (QCI 9.1-1)				QC						R

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WORK PLAN AND INSPECTION RECORD (CONTINUED)--PROJECT G

ITEM NO.	WORK/INSPECTION ACTIVITY	INSTALLATION DOCUMENT #	REV	REV	HOLD PT	SUP'T	RFE	DATE	QCE	DATE	TYPE
120	Place concrete										
121	Verify grout, mix, test results (QCI 9.1-1)				QC						R
122	Verify grade (QCI 9.1-1)										I
130	Finish concrete										
131	Verify finish (QCI 9.1-1)										I
140	Cure concrete										
141	Verify type of cure, starting time, temperature (QCI 9.1-1)										I
142	Verify curing duration (QCI 9.1-1)										R
150	Forms Loosening/Shoring Removal										
151	Loosen forms on:										
152	Verify forms loosened (QCI 9.1-1)										I
153	Verify concrete has reached _____ psi compressive strength prior to removing shoring (QCI 9.1-1)										R
	Determine method of concrete repair:										
160	Standard repair with grout ☐										
161	Verify preparation (QCI 9.1-1)										I
162	Verify finish (QCI 9.1-1)										I
163	Verify curing (QCI 9.1-1)										I
	-Or-										
170	Standard Repair with Concrete ☐ (See WP&IR #)										
171	Review WP&IR (QCI 9.1-1)										R
	-Or-										
180	Defer repair to later date ☐ (See WP&IR #)										
181	Review WP&IR (QCI 9.1-1)										R
190	Perform architectural finish, type:										
191	Verify finish (QCI 9.1-1)										I
200	Verify concrete placement complete (QCI 9.1-1)										R
210	Review completed WP&IR (QCI 9.1-1)										R

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CONCRETE PLACEMENT INSPECTION CHECKLIST--PROJECT G

Inspection Item	Initials	Date
I. PLACEMENT		
A. Concrete and group class per Dwg _____ Rev._____ DCN_____		
B. Weather conditions are satisfactory		
C. Batch delivery ticket is ok		
D. Preplacement test results ok		
E. Truck delivery time is ok		
F. Delivery pipes are ok		
G. Mortar placed on horizontal surfaces		
H. Concrete drop distance is ok		
I. Horizontal layer depth is ok		
J. Flow distance is ok		
K. Vertical members concreted ok		
II. CONSOLIDATION		
A. Consolidation equipment is ok		
B. Vibrator insertion is satisfactory		
C. Duration of insertion is satisfactory		
D. Consolidation does not spread concrete		
III. FINISH		
A. Finish is per Dwg. _____ Rev._____ DCN_____		
B. Repair of form tie and spreader surface depressions ok		
C. All other repair ok		

CONCRETE PLACEMENT INSPECTION CHECKLIST (CONTINUED)--PROJECT G

Inspection Item	Initials	Date
IV. CURING		
A. Type of curing is ok		
B. Starting time is ok		
C. Liquid membrane is ok		
D. Curing time is ok		
E. Curing temperature is satisfactory		
F. Cold weather cure is ok		
G. Shoring and forms removal ok		

Reviewed by_____

Date_____

REFERENCE ONLY

CONCRETE PLACEMENT AND CURING REPORT--PROJECT H1

Customer
Project
Building
Pour Nos.
Class Concrete
Weather _____ Amb. Temp.
Placing Equipment Checked _____

Contract No. _____
Cust. P. O. No. _____
Date _____
Copies To _____
Finish _____

TESTING: (Per Requirements of T/QCP-3)

Slump	Accept ( )	Unaccept ( )
Air	Accept ( )	Unaccept ( )
Temperature	Accept ( )	Unaccept ( )

NOTE:
1. If any test is unacceptable, note test results and disposition under "comments" below.
2. Please note the number of tests performed of each category under "comments".

CONCRETE PLACEMENT:	Yes	No
Pour Area Clean	( )	( )
Tremies Used	( )	( )
Pour Area Damp	( )	( )
Correct Number of Vibrators	( )	( )
Spares	( )	( )
Proper and Adequate Consolidation	( )	( )
Has any Segregation Occurred	( )	( )
Lift Thickness (18" max.)	( )	( )
Free Fall (5' max.)	( )	( )
Placement Rate (T/QCP-3, Par. 11.1.1)	( )	( )

WEATHER PROTECTION & CURING

	DAYS AFTER POUR						
	1	2	3	4	5	6	7
SUMMER							
Tarpaulins							
Blankets							
Burlap							
Paper							
Sand							
Water							
Max. Conc. Temp. °F							
WINTER							
Tarpaulins							
Blankets							
Water or Compound							
Full Enclosure							
Heated							
Min. Temp. °F							
Max. Temp. °F							
Min. Conc. Temp. °F							

If Compound is used, it must be identified under "Comments" below.

Date Protection Removed _____

Form Removal:
No. of Days After Placement _____ . Basis of Removal Age ( ) Strength ( )

Comments _____

_____

_____

_____

_____

_____ by _____ Date _____

CONCRETE PLACEMENT INSPECTION REPORT--PROJECT H2

POUR NO. _____

CONCRETE PREPLACEMENT	DATE	APPV'D	REMARKS
1.0 Surface Preparation			
2.0 Forms			
3.0 Embedded Items			
4.0 Joints			
5.0 Line & Grade			
6.0			
REINFORCING STEEL PLACEMENT			
1.0 Cleanliness of Resteel			
2.0 Resteel Secured			
3.0 Placed for Drawings			
4.0 W eld Cutting			
5.0 Concrete Cover			
6.0 Placing Tolerance			
7.0 Field Bending (When Req)			
8.0			
9.0			
CONCRETE PLACEMENT			
1.0 Correct Mix			
2.0 Final Preparation			
3.0 Working Conditions			
4.0 Placing Equipment			
5.0 Mix Appearance			
6.0 Placement Method			
7.0 Consolidation			
8.0 Finishing Surface			
9.0			
10.0 _____			
AWINGS:			

CONCRETE PLACEMENT INSPECTION RECORD (CONTINUED)--PROJECT H2

POUR NO. _____

CONCRETE POSTPLACEMENT			DATE	APPV'D.	REMARKS
1.0 Curing					
2.0 Form Removal					Start Finish
3.0 Surface Repairs					
4.0 Line & Grade					
5.0 Finish					
6.0					
7.0					
DAY	AMB. TEMP °F	CONC. TEMP °F			Curing Method

CONCRETE TESTS

TEST	BATCH	SLUMP	AVG	TEMP	AIR	REMARKS
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						

CONCRETE PLACEMENT INSPECTION RECORD (CONTINUED)--PROJECT H2

CONCRETE PLACEMENT CHECKLIST

	ITEM	REFERENCE
1.0	Correct Mix	SP-201, 1:05
2.0	Final Preparation	
2.1	Clean-up, no dirt, gravel, sand etc.	SP-201, 1:12.2.2
2.2	Thoroughly dampened concrete surface	SP-201, 1:12.2.2
2.3	Subgrade not frozen or dry	SP-201, 1:12.2.1
2.4	No standing water	SP-201, 1:12.2.1
2.5	Forms snug and braced (lap tight)	ACI 301-72, 4.2.4
3.0	Working Conditions (Weather)	
3.1	Protection from rain, sleet and snow	ACI 301-72, 8.4.1
3.2	Adequate lighting	
4.0	Placing Equipment	
4.1	Adequate tools available for:	
	a. Proper placing	SP-201, 1:12.8
	b. Weather conditions	ACI 301-72, 12.1
	c. Consolidation (number and size of vibrators)	ACI 301-72, 8.3.4
4.2	Equipment clean	ACI 301-72, 8.1.1
4.3	Equipment surface to be in contact with wet concrete is not aluminum	SP-201, 1:12.8.4
5.0	Mix Appearance	
5.1	Slump, massive and non-massive max.slump 4"	SP-201, 1:06.1.3; ACI 301-72 3.5
	a. Tolerance: +1" provided the average of all or the most recent 10 batches, whichever is fewer has average less than 4"	ACI 301-72, 3.5
5.2	Air entrainment on concrete shall be: 3/4" aggregate 6% $\pm$ 2%; 1 1/2" aggregate 4 1/2 $\pm$ 1 1/2%	ACI 301-72 Table 3.4.1 ACI 301-72 Table 3.4.1

CONCRETE PLACEMENT INSPECTION RECORD (CONTINUED)--PROJECT H2

CONCRETE PLACEMENT CHECKLIST

5.3	Concrete placing temperature	
	a. Temperatures of concrete as delivered for shall conform to the table on page 4 of SP-201, 1.06.3	SP-201, 1:06.3
	b. QCA may apply tolerance of $\pm$ 5°F on maximum and minimum temperatures in table.	SP-201, 1:06.3
	c. When temperature of air surrounding concrete <40°F concrete shall not be placed	SP-201, 1:06.3
	d. Concrete surfaces contacting metal deck shall be considered exposed	SP-201, 1:07.2.10
	e. Delete	
5.4	Time - Elapsed	
	a. 1 1/2 hours - check B.P. ticket	FQ 81; ASTM C94-74, 10.7
	b. Max. revolutions of truck is 300. Check truck as required.	ASTM C94-74, 10.7
5.5	Correct concrete mix, check B.P. ticket	
5.6	If water is added, use COP 10.1	COP 10.1; QCA DP-C23 SP-201, 1:06.4
6.0	Placement Method	
6.1	Concrete placed as close to final position as possible	ACI 301-72, 8.3.3
6.2	Maximum free drop 5' - 0"	SP-201, 1:12.7
6.3	Prevent segregation	
	a. Use drop shoot when needed	ACI 301-72, 8.3.3
	b. Place concrete against itself	ACI 301-72, 8.3.3
6.4	Removal of spacers and blocks	ACI 301-72, 8.3.1
6.5	Max. placing rate is 5'-0"/hr. if evidence of bleeding is detected.	SP-201, 1:12.5
6.6	Massive concrete, approx. layers of 18"	ACI 301-72, 14.4.3
6.7	Space under blockouts filled postplacement	SP 201, 1:12.10
7.0	Consolidation	
7.1	Insert vertically at distance of 18" apart	ACI 301-72, 8.3.4
7.2	Time, generally 5 to 15 sec. of insertion not overworked or underworked	ACI 301-72, 8.3.4

CONCRETE PLACEMENT INSPECTION RECORD (CONTINUED)--PROJECT H2

CONCRETE PLACEMENT CHECKLIST

7.3	Thoroughly worked around rebar embedments, corners, etc.	ACI 301-72, 8.3.4
7.4	Vibrators shall penetrate approx. 6" into previous lift	SP-201, 1:12.1
7.5	Spare vibrator available	ACI 301-72, 8.3.4
7.6	Vibrator shall be spot checked on every pour over 50 cy. The results shall be documented on the placement checklist.	ACI 301-72, 8.3.4
8.0	Finishing Surfaces	
8.1	Type of finish in accordance with drawing and spec.	SP-201, 1:13.1
8.2	Floors sloped for drainage in accordance with dwg.	SP-201, 1:13.4
8.3	Tolerance for floors	
	a. $\pm$ 1/2" from floor elevation on drawing	SP-201, 1:13.5
	b. Maximum localized variation, $\pm$ 1/8 in 10 ft.	SP-201, 1:13.5
8.4	Protect concrete from running water until it has hardened	SP-102, 1:15.3

CONCRETE PLACEMENT INSPECTION RECORD (CONTINUED)--PROJECT H2

CONCRETE POST PLACEMENT CHECKLIST

ITEM	REFERENCE
1.0 Curing shall be performed to protect concrete from premature drying thus moisture loss shall be kept at a minimum.	SP-201, 1:15.1,2; ACI 301-72 12.1
1.1 Methods:	
a. water cure (ponding or sprinkling)	ACI 301-72, 12.2.1.1
b. waterproof sheeting	ACI 301-72, 12.2.1.5
c. Approved compound	SP-201, 1:15.2
d. absorptive mat kept wet	ACI 301-72, 12.2.1.2
1.2 Duration	
a. curing shall be continued for a minimum of 7 days. Except as follows:	SP-201, 1:15.1.1, ACI 301-72 12.2.3
i. If field cured cylinders break at 70% of specified strength then curing can cease.	SP-201, 1:15.1.1, ACI 301-72 12.2.3
1.3 Curing Temperatures	
a. when the mean ambient temperature is less than 40°F;	
i. Reinforced concrete members such as basemats, freestanding walls and other members not subject to flexural stresses during the construction period shall have a minimum curing temp. of 40°F regardless of size of member. (This temperature is required to be maintained for only 3 days.)	SP-201,1:15.1.4; ACI 306-66 Table 1.4.2
ii. Reinforced concrete members such as beams girders, suspended slabs and other members which will be subjected to flexural stresses during the construction period have a required curing temperature range of 50°F to 70°F. (This temperature is required to be maintained for a minimum of the duration under item 1.2 this is <u>not</u> for form removal.)	SP-201, 1:15.1.1
b. When the mean ambient temperature is greater than 40°F, there are no maximum or minimum curing temp.	
c. Rate of temperature change of air adjacent to concrete	SP-201, 1:12.1

CONCRETE PLACEMENT INSPECTION RECORD (CONTINUED)--PROJECT H2

CONCRETE POST PLACEMENT CHECKLIST

	i. Non-Massive ($\leq$48 inches) temp.change shall not exceed: $50^{\circ}F$ in 24 hour period, or $5^{\circ}F$ in any 1 hr. period.	ACI 301-72, 12.3.3
	ii. Massive ($>$48 inches) temp. change shall not exceed $30^{\circ}F$ in any 24 hour period, or $3\ ^{\circ}F$ in any 1 hour period	ACI 301-72, 14.5.4
	d. When ambient temperature is less than $40^{\circ}F$, insulation requirements for forms shall be per Table 7.2.1 and 7.2.2 of ACI 306-66 and contractor shall have written approval from QCA.	SP-201, 1:07.2.9
1.4	Within any one room or on any particular concrete surface, use only one type of curing compound.	SP-201, 1:15.2.2A
2.0	Form Removal (As follows per type of member and ambient temperature)	
2.1	Form removal will not be made until the field cured cylinders (2 per 100 cy) demonstrates the following strengths for the following types of forms:	SP-201, 1:07.6.1; ACI 301, 4.7.1
	a. Centerings under beams, girders and flat slabs require 2500 psi	SP-201, 1:07.6.2.d
	b. Forms under floor slabs, beams and girders require 2000 psi Exception: If the concrete member has been cured for the same length of time as the laboratory cured cylinder, and the laboratory cured cylinder reached the appropriate strength, curing can cease. The length of time that the concrete member has been cured in the structure shall be determined by the cumulative number of days or fraction thereof, not necessarily consecutive, during which the temperature of the air in contact with the concrete is above 50 F and the concrete has been damp or thoroughly sealed from evaporation and loss of moisture.	SP-201, 1:07.6.2.c
2.2	Sides of footings, beams, girders, columns, and walls may be removed as soon as the concrete has hardened sufficiently to resist damage from removal operations.	ACI 301-72, 4.5.4

CONCRETE PLACEMENT INSPECTION RECORD (CONTINUED)--PROJECT H2

CONCRETE POST PLACEMENT CHECKLIST

2.3	When the mean ambient temperature is less than 40°F	SP-201, 1:07.6.6a; ACI 306-66 Table 1.4.2
	a. If members are basemats, freestanding walls or other members not subjected to flexural stresses during the construction period, forms must stay in place for a minimum of 3 days.	
	b. If members are beams, girders, suspended slabs or other members subjected to flexural stresses during the construction period, forms shall not be stripped until the requirements of the above section 3.1.a and/or b (as applicable) is met.	SP-201, 1:07.6.1
3.0	Surface Repairs	
3.1	Surface not acceptable and will be repaired if it contains:	SP-201, 1:07.7.2
	a. Excessive holes	
	b. Voids	
	c. Honeycombing	
3.2	Determine extent of damage and notify "Engineer if necessary". Initiate NR in accordance with QP 15.1. (If applicable)	SP-201, 1:18.2
3.3	Preparation to replace concrete	ACI Manual of Concrete Practices "Durability of Concrete" Ch 7
	a. Chip back to sound uncracked concrete	
	b. Square edges and round corners	
	c. Slope at top (~1" rise to 3" horiz.) (Major repairs only)	
3.4	Final appearance of repair concrete	
	a. Blends with surrounding concrete	
	b. Follows finish schedule	
3.5	Curing	
	a. 7 day cure	
4.0	Line and Grade	SP-201, 1:11.8
5.0	Finish	SP-201, ACI 301-72
5.1	Nuclear Coating	
	a. Inside Containment, below grade, water proofed	SP-201 1:13.1.1
	b. Outside Containment	SP-201 1:13.1.1A
5.2	Exposed to View - No Nuclear Coating	SP-201 1:13.1.2

CONCRETE PLACEMENT INSPECTION REPORT (CONTINUED)--PROJECT H2

CONCRETE POST PLACEMENT CHECKLIST

5.3	Underside Coatings, floor beams and interior surfaces not exposed to view	SP-201 1:13.1.3
5.4	Surfaces of Slabs	SP-201 1:13.1.4
5.5	Rattlespace	SP-201 1:13.1.5

QUALITY ASSURANCE INSPECTION REPORT--PROJECT I

ITEM DESCRIPTION: CONCRETE PLACEMENT

IR NUMBER: S 0 0 | SHOP ONLY | A I | KEYCOND: C C N P L A | SYS. CODE | FILE LOCATION CODE: H B

TYPE INSP: T P | PURCHASE ORDER | LOT SIZE | SAMPLE SIZE | NO/QTY UNSAT ITEMS | CU. YD. | UNITS

CODE/CLASS | INSPECTION RESULTS: | S OR U | INITIALS | SIGNATURE | DATE: MO DAY YR

PRIME VENDOR CODE: A 2 | INSPECTION PERFORMED AT: | VENDOR NAME/LOCATION | WORK PACKAGE NO/SHOP ORDER NO. | SUB-VENDOR CODE

M&TE NOS: 1 2 3 4 5 6 7

A 3

ITEM	MAT'L/EQUIP IDENT NOS.	S OR U	ITEM NO.	MAT'L/EQUIP IDENT NOS.	S OR U
2 1					
ITEM		S OR U			

DO NOT KEYPUNCH

A 4

ATTR NO.	COLS.	ATTR. CODE	ATTRIBUTES	RESULT OR RESPONSIBILITY	NO/QTY UNSAT SUMMARY	REFERENCE N&D OR VIR/EGDCR NO.	USE FOR SINGLE UNSAT ITEM ONLY ACTION 1	ACTION 2	QC REINSP
1	14-22	W 2 4	PLACING EQUIPMENT						
2	23-31	W 0 2	ACCESS to AREA						
3	32-40	W 0 3	TIME LIMIT						
4	41-49	M 0 7	WATER ADDITIONS						
5	50-58	W 1 5	STACTER GROUT						
6	59-67	W 9 0	RATE OF PLACEMENT						
7	68-76	W 3 0	VERTICAL DROP						

A 4

ATTR NO.	COLS.	ATTR. CODE	ATTRIBUTES	RESULT OR RESPONSIBILITY	NO/QTY UNSAT SUMMARY	REFERENCE N&D OR VIR/EGDCR NO.	USE FOR SINGLE UNSAT ITEM ONLY ACTION 1	ACTION 2	QC REINSP
8	14-22	W 3 0	LATERAL MOVEMENT						
9	23-31	W 1 5	CONSOLIDATION						
10	32-40	W 3 0	LIFT THICKNESS						
11	41-49	W 2 4	CONVEYING EQUIPMENT						
12	50-58	W 1 7	VOIDS & SURFACE DEFECTS	N					
13	59-67	W 0 9	CONCRETE TEMPERATURE						
14	68-76	T 0 4	AIR ENTRAINMENT %						

A 4

ATTR NO.	COLS.	ATTR. CODE	ATTRIBUTES	RESULT OR RESPONSIBILITY	NO/QTY UNSAT SUMMARY	REFERENCE N&D OR VIR/EGDCR NO.	USE FOR SINGLE UNSAT ITEM ONLY ACTION 1	ACTION 2	QC REINSP
15	14-22	T 0 2	SLUMP (S & W)						
16	23-31	T 0 3	SLUMP (CONTRACTER)						
	32-40								
	41-49								
	50-58								
	59-67								
	68-76								

ACTION ASSIGNED: 1. | SIG/INITIALS DATE | 2.

ACTION COMPLETED: 1. | SIG/INITIALS DATE | 2.

QC REINSPECTION ALL ITEMS SAT | SIG/INITIALS DATE

JOB ORDER NO.

DWG. NO/REV.

SPEC. NO/ADD NO/REV. DATE: 2199.142-999 ADD. A / REV. 1. 7/6/76

PO CHANGE NO. (PCC ONLY): NA

ATTR. LIST NO/IPS NO.: D-10.8-2-3416

A 5

CLOSING INITIALS	NO OF REINSP	IR CLOSED DATE MO DAY YR	N&D NO.	N&D APPLIES TO THESE ITEMS: ITEM	ITEM	ITEM	ITEM	ITEM	N&D ISSUE DATE

A 5

IR CLOSED & REVIEWED BY

REMARKS

QUALITY ASSURANCE INSPECTION REPORT (CONTINUED)--PROJECT I

SUPPLEMENT SHEET S4 (FOR FULL HEADING SEE SHEET I

IR NUMBER | SHOP ONLY

REMARKS:

| | | |

APPENDIX 9.B

CONCRETE POSTPLACEMENT INSPECTION DOCUMENTS AND ATTRIBUTE LISTS

This appendix contains the following project documents and records:

1. Project B--Daily Concrete Curing Record

2. Project C--Quality Control Inspection Record
   Concrete Post Placement Record
   Daily Cure Record
   Temperature Record

3. Project D--Quality Control Inspection Record
   Concrete Post Placement Report

4. Project E--Form Support Removal

5. Project F--Quality Control Inspection Report

6. Project I--Curing Record

DAILY CONCRETE CURING RECORD—PROJECT B

Date of Pour: _____ Location: _____

_____

Inspect Concrete Curing for Compliance with: Winter Curing Method _____
Summer Curing Method _____

Prepared By _____ Date _____

_____ Insulated Forms

_____ Plywood Forms

_____ Covered with Wet Burlap

_____ Polyethylene

_____ Polyethylene, straw & tarps

_____ Heated and Vented

_____ Sealed with curing comp. (not in Reactor Building)

Date							
Concrete Temp. (^{o}F)							

REMARKS:

_____ _____
Quality Control Inspector Date

QUALITY CONTROL INSPECTION RECORD--PROJECT C

5. ITEM/S: A)_____ B)_____

C)_____ D)_____

6. SCOPE/LOCATION:_____

7. REFERENCE CRITERIA:_____

8. PREPARED BY:_____ DATE:_____ 9. REVIEWED BY:_____ DATE:_____

10.ACT NO.	11. DESCRIPTION	12. C	13. E	14. ITEM/S ACCEPTANCE A	B	C	D
1.0	PREREQUISITES						
1.1	Inspection and reference criteria reviewed for availability, familiarity, and correct approval and revision status.	R					
1.2	Review performed for open NCRs affecting work operation	R					
2.0	IN-PROCESS INSPECTION ACTIVITIES						
2.1	Slab Finishing	S					
	a. Concrete surface free of bleed and excess water.						
	b. Verify crack control joint saw cuts have been made as specified.	S					
2.2	Form Removal						
	a. Forms removed in such a manner to prevent damage to the concrete	S					
	b. Surfaces inspected for major defects	I					
	c. Thermal protection provided as required.	S					
	d. For forms that support concrete members, concrete cylinder test report reviewed to verify the concrete has attained the specified strength prior to the form removal.						
2.3	Major defects reported to the Project Field Engineer for dispositioning.	R					
	a. Damaged rebar and embeds reported to Project Field Engineer by Rework Notice	I					
	b. Major repair work of defective areas performed correctly per specification as dispositioned.	I					
	c. Call out sheet and delivery ticket reviewed, prior to placing concrete.	R					

QUALITY CONTROL INSPECTION RECORD (CONTINUED)--PROJECT C

10.ACT NO.	11. DESCRIPTION	12. C	13. E	14. ITEMS/ACCEPTANCE A	B	C	D
2.4	Curing a. Curing Method 1. Curing method used _____ 2. Surfaces moist until cure method started.	S					
	3. Cure properly implemented.	I					
	4. Concrete members properly cured by specified curing materials process and duration.	S					
	5a. Cold weather curing temperatures properly maintained and recorded on a concrete post post placement report. 5b. Enclosures in place for 24 hours. 5c. Temperature drop not greater then 30 degrees in 24 hours.	I					
2.5	Loading a. Beam support embeds and column baseplates in vertical concrete members not loaded for 48 hours after placement. /13	S					
3.0	FINAL INSPECTION ACTIVITIES						
3.1	Repair of surface defects are sound, bonded tightly and free from shrinkage cracks.	I					
3.2	Check as-built drawings for out-of-tolerance embed	I					
3.3 /13	Piping systems re-tested and re-energized as specified Piping QCE _____ Test No. _____	R					
4.0	REVIEW OF SUPPLEMENTARY RECORDS						
	a. Concrete Callout Sheet b. Concrete Delivery Ticket c. Concrete Post Placement Report QC-FF-C-13 & QC-FF-C-4 or 14	R					
5.0	EXCEPTIONS						
5.1	No exceptions noted	R					
or 5.2	Indicated exceptions are described in remarks section.	R					

REMARKS:

16. COMPLETED INSPECTION RECORD REVIEWED AND ACCEPTED BY: _____ DATE: _____

CONCRETE POST PLACEMENT RECORD--PROJECT C

4. PLACEMENT LOCATION & ELEVATIONS		5. PLACEMENT COMPLETED DATE _____ TIME_____	6. PLACEMENT NO.
7. TYPE CURE REQUIRED	8. SPECIFICATION REV.	9. CURE STARTED DATE _____ TIME_____	10. CONCRETE SECTION ☐ THIN ☐ MASS

FINISH

11. _____ FINISH REQUIRED				
ITEM	DATE	TIME	22. Q.C. ENGINEER	23. REMARKS
12. FINISH STARTED				
13. FINISH COMPLETED				

FORM REMOVAL

ITEM	COMPLETED		22. Q.C. ENGINEER	23. REMARKS
	DATE	TIME		
14. FORMS LOOSENED				
15. FORMS REMOVED				
16. FORM TIE HOLES PATCHED				

REPAIRS

17. REQUIRED ☐ YES ☐ NO 18. ☐ MAJOR ☐ MINOR

ITEM	DATE	TIME	22. Q.C. ENGINEER	23. REMARKS
19. REPAIR STARTED				
20. REPAIR COMPLETED				
21. REPAIR ACCEPTED				

DAILY CURE RECORD--PROJECT C

25. DATE	26. TIME	27. WEATHER	28. CURE CONDITION	29. TEMPERATURE OUTSIDE H	OUTSIDE T°	OUTSIDE L	ENCLOSURE H	ENCLOSURE T°	ENCLOSURE L	30. CONC. TEMPERATURE LOCATION**	31. CORRECTIVE ACTION TAKEN	32. O.C.I Int.
1/31/76	See attached Sheet	Partly cloudy	5							SEE ATTACHED SHEET	NOT APPLICABLE	DKy
2/1/76	See attached sheet	Partly Cloudy	4							SEE ATTACHED SHEET	Notified Supervision Never written	DKy
2/2/76	See attached Sheet	Clear Sunny	5							SEE ATTACHED SHEET	D. Miller 2-3-76 NOT APPLICABLE	DKy
2/3/76	See attached Sheet	Clear Sunny	4							SEE ATTACHED SHEET	Extended cure 1 DAY	DKy
2/4/76	See attached sheet	Partly Cloudy	4							SEE ATTACHED SHEET	Extended Cure 1 Day	DKy
2/5/76	See attached Sheet	Partly Cloudy								SEE ATTACHED SHEET	NOT APPLICABLE	DKy
2/6/76	See attached Sheet	Partly cloudy	5							SEE ATTACHED SHEET	NOT APPLICABLE	DKy
2/7/76	See attached Sheet	clear sunny	5							SEE ATTACHED SHEET	NOT APPLICABLE	DKy
2/8/76	See attached sheet	clear sunny	5							SEE ATTACHED SHEET	NOT APPLICABLE	DKy

33. **AREA SKETCH Sprayed with L&M membrane 1-30-76 D. Miller
CURE interupted for more than 8hrs cure extended for 2day D. Miller 2-3-76

FOR INFORMATION ONLY

TEMPERATURE RECORD--PROJECT C

5. Placement No. F5-5-1 6. Date Placed 1-30-76

7. LOCATION A		8. LOCATION B		9. OUTSIDE TEMPERATURE	
2 AM	52			2 AM	29
5 AM	55			5 AM	30
8 AM	57			8 AM	32
11 AM	56			11 AM	41
2 PM	55			2 PM	40
5 PM	56			5 PM	37
8 PM	56			8 PM	34
11 PM	56			11 PM	33

FOR INFORMATION ONLY

10. SKETCH:

11. REMARKS: This is a heated enclosure

Thermometer C-530

" " 2/2/76 - 0800 - 1600 - R. Lewis

9.100

1

TEMPERATURE RECORD (CONTINUED)--PROJECT C

Placement No. FS-J-1 6. Date Placed 1-30-76

8. LOCATION A

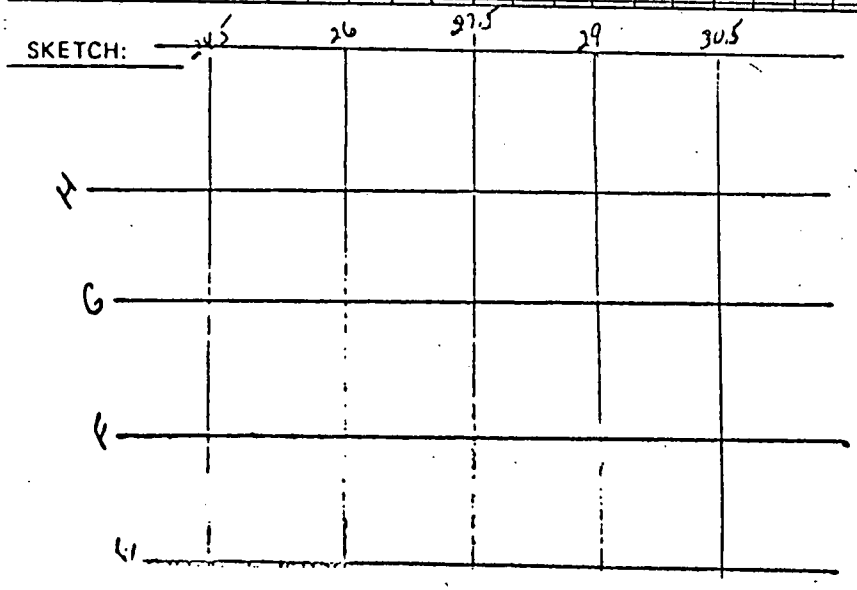
1/30		1/31		2/1		2/2		2/3		2/4		2/5		2/6	
69	7 PM	63	2 AM	50	7 AM	46	7 AM	52	2 AM	54	7 AM	42	7 AM	42	
	5 PM	61	5 AM	52	5 AM	50	5 AM	48	2 AM	46	5 AM	42	5 AM	40	
	8 PM	60	8 AM	56	8 AM	52	8 AM	50	8 AM	48	8 AM	46	8 AM	44	58
	11 PM	58	11 AM	74	11 AM	60	11 AM	56	11 AM	56	11 AM	56	11 AM	54	62
	2 AM	72	2 PM	70	2 PM	66	2 PM	68	2 PM	67	2 PM	65	2 PM	60	60
	5 PM	70	5 PM	70	5 PM	62	5 PM	54	5 PM	62	5 PM	54	5 PM	54	54
	8 PM	69	8 PM	70	8 PM	58	8 PM	57	8 PM	62	8 PM	62	8 PM	62	52
	11 PM	70	11 PM	68	11 PM	64	11 PM	55	11 PM	62	11 PM	60	11 PM	60	50

FOR INFORMATION ONLY

9. OUTSIDE TEMPERATURE

1/30		1/31		2/1		2/2		2/3		2/4		2/5		2/6	
11 PM	35	2 AM	28	2 AM	39	2 PM	34	2 PM	13	2 PM	21	2 PM	31	11 PM	25
		5 AM	25	5 AM	37	2 PM	25	5 PM	13	5 PM	19	5 PM	30	5 PM	26
				8 AM	35	8 PM	16	8 PM	17	8 PM	25	8 AM	29	8 PM	27
				11 AM	41	11 PM	18	11 PM	20	11 PM	45	11 AM	30	11 PM	29
				2 PM	45	8 PM	14	2 PM	21	2 PM	43	8 AM	29	2 PM	32
		5 PM	35	5 PM	46	5 PM	15	5 PM	26	5 PM	41	5 PM	27	5 PM	29
		8 PM	34	8 PM	46	8 PM	17	8 PM	22	8 PM	37	8 PM	26	8 PM	24
		11 PM	34	11 PM	41	11 PM	13	11 PM	20	11 PM	36	11 PM	25	11 PM	19

SKETCH:



11. REMARKS: This Take temp every 3 hours regardless of ambient temp. but treat as a non-heated enclosure

Thermometer C-530

Take temp of random locations

2 large heaters were on 2/1/76 & 2/2/76 which makes this a heated enclosure. D. Miller This is a heated enclosure!

See other sheet

9.101

QUALITY CONTROL INSPECTION RECORD—PROJECT D

5. ITEM/S: A) PLACEMENT NO. 183-W-03 B) N/A 1/12/77
C) N/A 1/12/77 D) N/A 1/12/77

6. SCOPE/LOCATION: Reactor Bldg. Unit #2, Area 33 & 34, Exterior wall on "U" Line from elev. 716'-10" to 747'-4". See attached sketch for location.

7. REFERENCE CRITERIA: C-8/ REV. 7/ ADDM #1 11/21/77 2-1-21-77

8. PREPARED BY: [signature] DATE: 1/12/77 9. REVIEWED BY: [signature] DATE: 1-12-77

10. ACT No.	11. DESCRIPTION	12. C	13. E	14. ITEM/S ACCEPTANCE A	B	C	D
1.0	PREREQUISITES						
1.1	Inspection and reference criteria reviewed for availability, familiarity, and correct approval and revision status.	R		1/12/77 2-3-77			
1.2	Review performed for open NCRs affecting work operations.	R		1/12/77 2-3-77			
2.0	IN-PROCESS INSPECTION ACTIVITIES						
	~~Slab Finishing~~ ~~a. Concrete surface free of excess water during finishing.~~ NOT APPLICABLE 1/12/77 b. Required finish applied.	S					
2.2	Form Removal (PARTIAL Removal) 2/10/77 2/10/77 a. Forms removed without damaging concrete.	S		2/10/77			
	~~b. Concrete surfaces inspected for major defects.~~ NOT APPLICABLE 2/10/77						
	c. Thermal protection provided as required.	S					
	~~d. For forms that support concrete members, concrete cylinder test report reviewed to verify the concrete has attained the specified strength prior to the form removal.~~ NOT APPLICABLE 2/10/77 2/10/77 2/10/77						
~~2.3~~	~~Major repair work by concrete replacement of defective areas performed correctly and the concrete made with the same design strength as in the original concrete.~~ NOT APPLICABLE 2/10/77						
2.4	Curing Curing Method a. Curing method used MOIST b. Concrete members properly cured by specified curing materials, process, and duration.	S		2/10/77			
	c. 1. Cold weather curing temperatures properly maintained and recorded on a Concrete Post-Placement Report. 2. Enclosures in place for 24 hours.	I		2/10/77			

QUALITY CONTROL INSPECTION REPORT (CONTINUED)--PROJECT D

10. ACT No.	11. DESCRIPTION	12. C	13. E	14. ITEM/S ACCEPTANCE A	B	C	D
2.5	Loading						
	~~a. For forms that support concrete members, Concrete Cylinder Test Report reviewed to verify the concrete has attained the specified strength prior to loading after placement.~~ NOT APPLICABLE JRD 2/10/77 JRW 2/11/77	S					
	b. Embeds in vertical concrete members not loaded until adequate strength attained.	S		JRD 2/10/77			
3.0	FINAL INSPECTION ACTIVITIES						
~~3.1~~	~~Repairs of surface defects are sound, tightly bonded, and free from shrinkage cracks.~~ NOT APPLICABLE JRD 2/10/77 JRW 2/11/77	I					
~~3.2~~	~~Review performed for concrete defect reports.~~ NOT APPLICABLE JRD 2/10/77 JRW 2/11/77 WRH 2/10/77	R					
4.0	REVIEW OF SUPPLEMENTARY RECORDS						
	~~a. Concrete Delivery Ticket (if applicable)~~ NOT APPLICABLE JRW 2/11/77	R					
	b. Concrete Post-Placement Report JRW 2/11/77			JRD 2/10/77			
	~~c. Concrete Defect Report (if applicable)~~ NOT APPLICABLE JRD 2/10/77						
	~~d. In Process Concrete Test Report QCC12-1 (if applicable)~~ WRH 2/10/77						
5.0	EXCEPTIONS						
5.1	No exceptions noted.	R		JRD 2/10/77			
or							
5.2	Indicated exceptions are described in remarks seciton.	R					

15. REMARKS

16. COMPLETED INSPECTION RECORD REVIEWED AND ACCEPTED BY J. E. Martinez DATE 2-11-77

CONCRETE POSTPLACEMENT REPORT--PROJECT D

4. PLACEMENT LOCATION & ELEVATIONS		5. PLACEMENT COMPLETED DATE _____ TIME _____	6. PLACEMENT NO.
7. TYPE CURE REQUIRED	8. SPECIFICATION REV.	9. CURE STARTED DATE _____ TIME _____	10. CONCRETE SECTION ☐ THIN ☐ MASS

DAILY CURE RECORD

11. DATE	12. WEATHER	13. AMBIENT TEMP.	14. CURE CONDITION	15. Concrete Surface Temperatures Cold Weather Only High Low	16. CORRECTIVE ACTION TAKEN	17. FIELD ENGINEER

FORM REMOVAL

ITEM	COMPLETED DATE	COMPLETED TIME	27. FIELD ENGINEER	28. Q.C. ENGINEER
18. FORMS LOOSENED				
19. FORMS REMOVED				
20. FORM TIE HOLES PATCHED				

CONCRETE REPAIRS

21. REQUIRED ☐ YES ☐ NO

ITEM	DATE	TIME	27. FIELD ENGINEER	28. Q.C. ENGINEER
22. REPAIR STARTED				
23. REPAIR COMPLETED				
24. REPAIR ACCEPTED				

FINISH

ITEM	DATE	TIME	27. FIELD ENGINEER	28. Q.C. ENGINEER
25. FINISH STARTED				
26. FINISH COMPLETED				

ITEM	29. REMARKS
CURE	
FORM REMOVAL	
REPAIRS	
FINISH	

FORM SUPPORT REMOVAL--PROJECT E

Date Poured	Pour Number	Elev.	Location	Type Curing	Curing Complete	Insp.	Stripping Date	Insp

QUALITY CONTROL INSPECTION RECORD--PROJECT F

	Date	Sheet 1 of	NO.
System/Structure Designation	Sub-System/Structure	Category	ASME III yes no
Location	P.O. No.	Reject Tag	Hold Tag
Drawing No. ☐ E/C ☐ Vendor / Issue No.	Spec. No.	Code	Reference SOC
In - Process / Pre - Install / Install	Final	Pretest	Initiator
Inspection Complete - All Attributes "Sat" Date / Inspector	Inspection Complete - "Unsats" Listed Below Date / Inspector		

No.	S	U	REWORK #1 S	#1 U	#2 S	#2 U	POST-PLACEMENT INSPECTION ATTRIBUTES	Quantitative Data	Date	SQC Sign
S-65							Verify-Proper Curing Method			
S-106							Verify-Approved Curing Compound			
S-107							Verify-Cold Weather Temperature Control			
S-101							Verify-Formwork Removal Strength			
S-108							Verify-Form Surface Finish			
S-109							Verify-Repair of Tie Holes			
S-110							Verify-Repair of Surface Defects			

FOR INFORMATION ONLY

CORRECTIVE ACTION PLANNED

☐ Rework ☐ Engrg. Dispos. (N&D) ☐ Scrap

Corrective Action Completed
Date / Contractor

Rework #1 ☐ Rework ☐ Engrg. Dispos. (N&D) ☐ Scrap

Disposition
Date / Contractor / QC Approval

Rework #2 ☐ Engrg. Dispos. (N&D)

Disposition
Date / QC Engineer

Remarks: (Measure/Test Device Identification No.)

Related N&D	Closed Date	Approved Signature

CURING RECORD--PROJECT I

Concrete Pour Card No.	

Type of Concrete	
☐ Normal	☐ Mass

General Location	
Building	
Member	
Elevation	

Dates	
Placement Completed	
Heat Discontinued	
Forms Removed	
Curing Completed	

Code

Type of Curing:
1 - damp burlap or fabric
2 - curing compound
3 - polyethlene sheets
4 - damp sand or earth
5 - water spray or ponding
6 - insulation
7 - not applicable

Construction Department	
signature:	date:

Field Quality Control	
signature:	date:

Record any additional temperatures or problems in the REMARKS section on the back of the form.

Day / Date	Time of Day (Hr.)	Outside Air Temperature (°F)	Temperature Within Enclosure (°F)		Concrete Surface Temperature (°F)		Type of Curing - see code			Construction Dept. Representative Initials
			High	Low	High	Low	Top Surface	Sides	Constr. Joints	
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
13										
14										

APPENDIX A

CASE STUDIES OF NINE NUCLEAR POWER PLANT CONSTRUCTION PROJECTS

INTRODUCTION

The Case Studies presented in this Appendix serve as reference points for each of the nine nuclear power plant construction projects which were examined in this research study. Each of these Case Studies is divided into the following three sections: (1) Project Organization, (2) Quality Assurance Program, (3) Quality Assurance Documents.

Chapter 3 of the report presents a comparative analysis of these Case Studies with respect to the following parts of 10CFR Part 50 Appendix B: (1) Introduction, (2) Criterion I: Organization, (3) Criterion II: Quality Assurance Program, (4) Criterion V: Instructions, Procedures and Drawings, (5) Criterion X: Inspections, and (6) Criterion XVIII: Audits. Chapter 4 of the report presents an analysis of the organizational and managerial aspects of the Quality Assurance programs covered by several additional 10 CFR Part 50 Appendix B Criteria which could not easily be incorporated into the Case Studies.

Reference may also be made to these Case Studies with respect to points which are raised in Chapters 5 to 9 of the report which emphasize the technical aspects of the Structural Concrete Quality Assurance program on the nine projects.

CASE STUDY--PROJECT A

PROJECT ORGANIZATION

Project A, which received its construction permit prior to the issuance of 10CFR Part 50, Appendix B is the first nuclear power plant built by Utility A. Although Utility A has the overall responsibility for the project, there are three other Utilities that are joint owners of the facility. The inter-relationship of the parties involved in the concrete phase of the project is shown in Figure A.1.

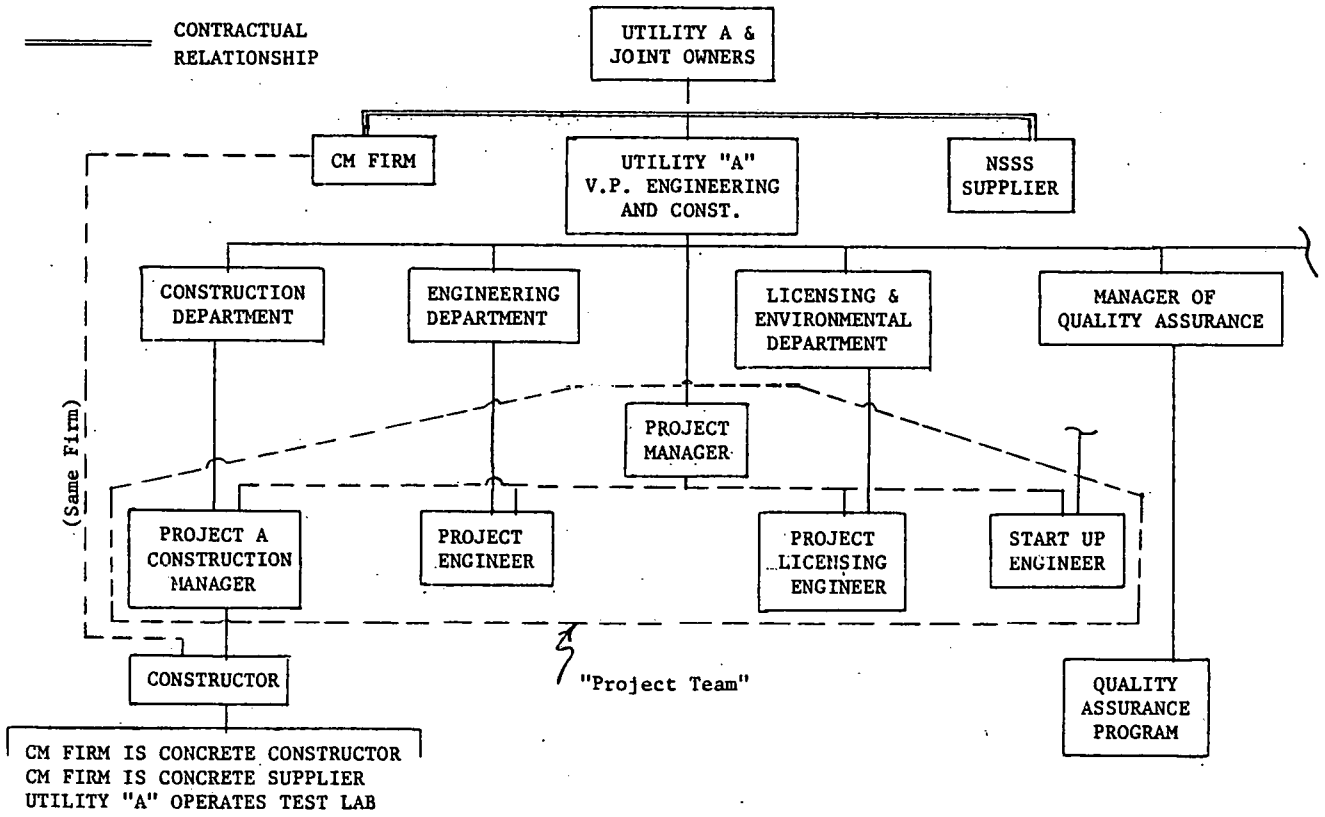


Figure A.1.--Project A: Interrelationship of Parties Involved In the Concrete Phase

Utility A, in addition to being the owner, is also providing all of the Engineering and Design services for this project through its home office Engineering and Construction Department. As shown in Figure A.1, the Vice President of that

department directs the activities of the: (1) Engineering Department (who, as noted above, is responsible for the total Engineering and Design effort for Project A), (2) the Project Manager and the Construction Department (who are responsible for staffing and managing the construction administration portion of Utility A's site organization), and (3) the Manager of Quality Assurance (who is responsible for developing the Quality Assurance Program for Project A).

As shown in Figure A.1, a C.M. firm has been retained to act as Utility A's construction arm in two capacities: as the Constructor, performing site construction work (which includes the concrete construction and concrete batch plant operation phases) and as Construction Manager, supervising and administering all site activities including other site contractors.

On Project A, the responsibilities for Quality Assurance and Quality Control have been fairly equally divided between Utility A and the C.M. Firm. The on-site Quality Assurance personnel of Utility A are responsible for both a Third level "Auditing" function as well as a Second Level "Surveillance" function. The on-site Quality Control personnel for the C.M. Firm are responsible for both a First Level "Inspection" function as well as a Second Level "Surveillance" function.

The above mentioned responsibilities are examined below in greater detail for each organization.

Utility A

The role of Utility A on the project can best be described in relation to Figure A.2. As shown, Utility A's efforts at the project site are directed by a Project A Construction Manager who is in charge of a staff of approximately 75 project administration personnel, some of whom are Utility A employees, and some of whom are on loan from the C.M. Firm. It should be noted that in addition

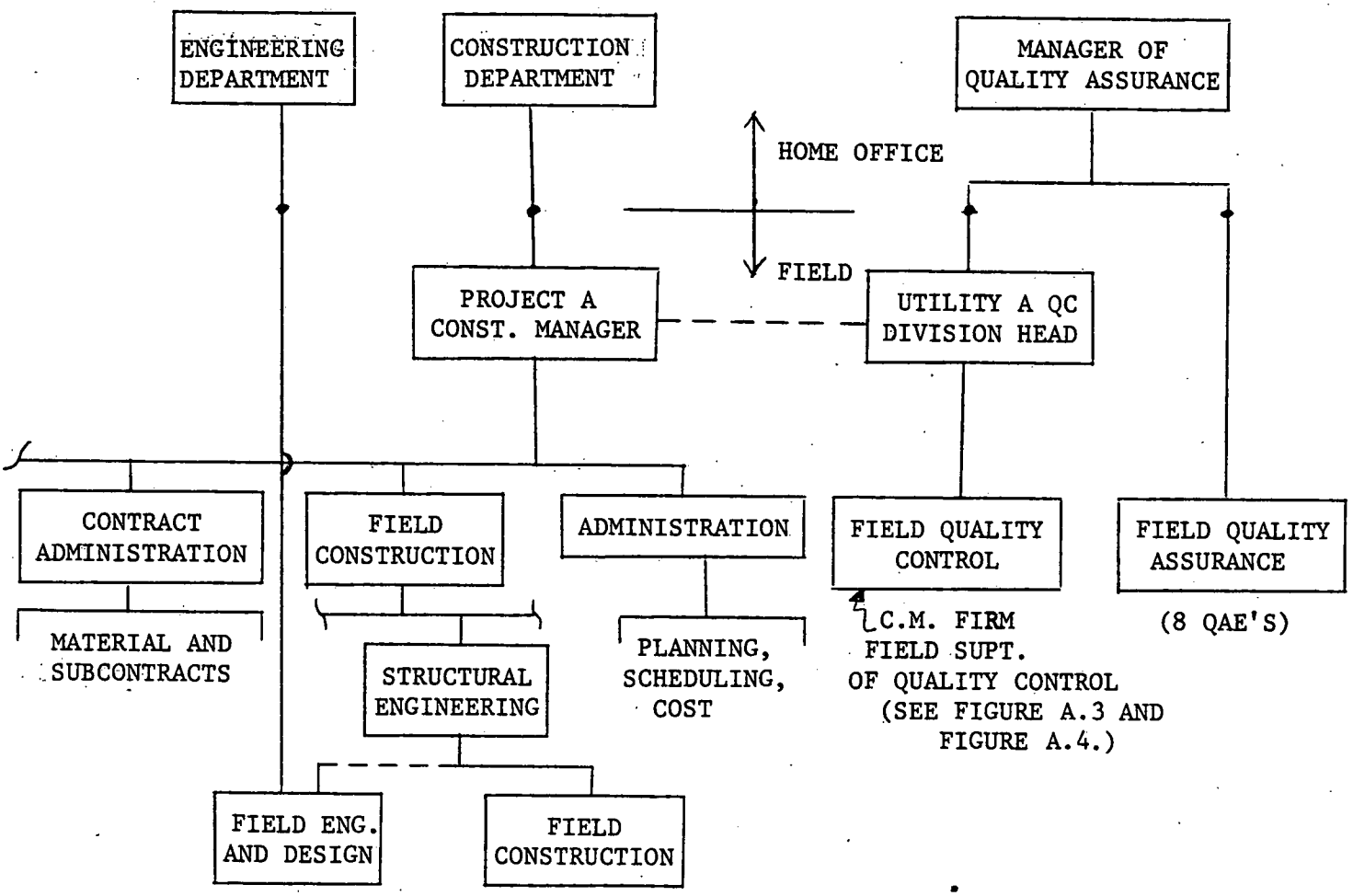


Figure A.2.--Utility A Organization

to providing a capability in: (1) Planning, Cost and Scheduling, and (2) Contract Administration, the staff also has a Field Construction group which is divided into technical specialty areas. The Structural Engineering function, which represents Utility A's concrete construction expertise at the job site (as indicated in Figure A.2) is further divided into both Field Construction as well as Field Engineering and Design. The large number of Utility A Personnel on the project site is probably due to the fact that as the Engineer-Designer, Utility A must also be intimately involved with all of the construction aspects of the project.

The Manager of Quality Assurance, as shown in Figure A.2, directs the efforts of a Field Quality Assurance group which serves both an Auditing as well as a Surveillance role. The responsibility of this group is to verify that the

programs covering the Construction as well as the Startup and Test phase are in compliance with the PSAR commitments and the applicable codes, standards, and regulatory requirements.

It should be noted in Figure A.2 that a Utility "A" QC Division Head has been placed at the project site to provide technical direction to the C.M. Firm's Field Superintendant-Quality Control. It is believed that this position was created to improve the line of communication between Utility A and the C.M. Firm and to provide owner visibility at the level in the organization where "quality of construction" type problems first become apparent.

C.M. Firm

The organizational structure of the C.M. Firm which is shown in Figure A.3 indicates that a Project Manager (who reports to the C.M. Firm's Vice President: Construction Division) has been assigned full responsiblity for Project A. He directs the activities of the Project Support Services, the Project Construction Manager

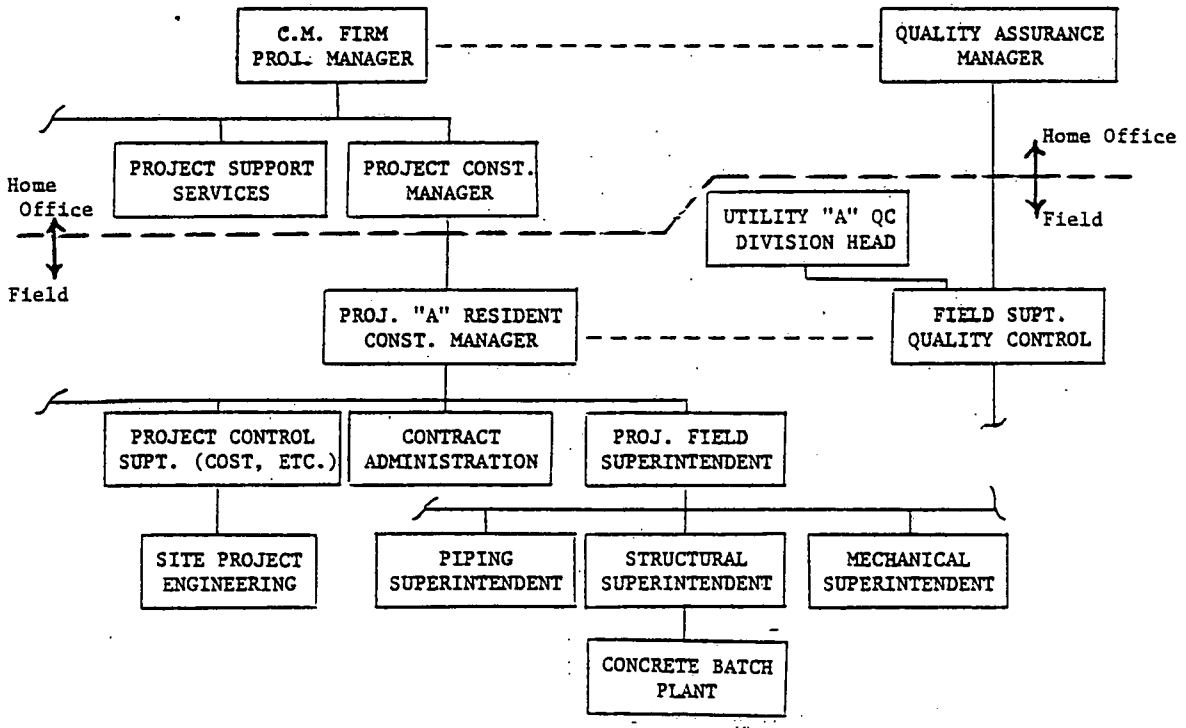


Figure A.3.--C.M. Firm Organization

and other project related groups in the home office. The independence of the construction effort and the quality assurance effort at the home office level is clearly shown in Figure A.3 which indicates that the Quality Assurance Manager does not report directly to the above mentioned Project Manager.

The Resident Construction Manager at the project site is in charge of a line-type organization which includes but is not limited to a number of functional superintendants (one of them is the Structural Superintendant who directs the craft labor that is involved in the concrete construction phase as well as the concrete batch plant operation) and a Project Control group that is responsible for planning and scheduling the day-to-day construction activities. The direct responsibility for the quality of the concrete work at the job site rests with these people. The responsibility for assuring that the necessary quality level is obtained rests with the Field Quality Control group that reports to the Field Superintendant-Quality Control. Figure A.3 indicates that the pattern of independence in the CM Firm's home office situation is repeated at the job site since the Quality Control group does not report directly to the Resident Construction Manager.

QUALITY ASSURANCE PROGRAM

For Project A, as noted earlier, the major responsibility for the Quality Assurance effort has been assumed by Utility A. The major responsibility for the Quality Control effort has been delegated to the CM Firm. Both of these organizations are also involved in Surveillance activities. These roles will be further clarified below.

Quality Assurance

1. Utility A. As noted in Figure A.2, Utility A maintains a staff of about

7 Quality Assurance Engineers and a QA Division Head at the project site. A breakdown of the various responsibilities of this group, in terms of the percentage of time expended, is shown in Table A.1. It will be noted that the majority of their time is spent in either an Auditing or a Surveillance role.

Table A.1. Principal Responsibilities of Utility A Field QA Engineers

QA Activity	Percentage of Time
1. Audits	26%
2. Analysis and Reporting	11%
3. Overall Surveillance of Site Construction Activity	20%
4. Liason with NRC during NRC Audits, etc.	15%
5. Training	14%
6. Review and Approval of Site Construction and Quality Control Procedures and Other Quality Assurance Program Documents	8%
7. Review and Approval of Procurement Bids and Requisitions	6%

In answer to a question regarding which of the above activities was the least cost effective (i.e. time consuming while not necessarily productive) a Utility A site Quality Assurance Engineer noted:

> "The least productive, though a good deal of time is expended on it, is the time required to cover the NRC when on site. The frequency and number of NRC auditors necessitates a good portion of our QAE's time satisfying their inquiries. It has been found through experience that it is to our advantage to spend as much time as possible with the Inspectors to prevent inaccurate information being presented by others who may not be totally aware of a situation and to also close out items prior to the time the Inspectors leave the site."

With regard to the concrete phase of the project, it should be noted that

QA and QC involvement only occurs with respect to safety-related concrete placements. Construction Superintendants and Engineers are responsible for enforcing the requirements in the specifications and on the drawings for non-safety related concrete.

For safety related concrete, the activities of Auditing and Surveillance were compared by a Utility A site Quality Assurance Engineer as follows:

A. Auditing

1. Responsibilities

"Site QA conducts periodic formal audits on Concrete Placement, Topping, Grouting, and Repair. The scope of these audits is designed to verify through examination of activities and objective evidence that site concrete operations are being effectively implemented in accordance with applicable procedures and specifications. A QA engineer performs an Audit with a pre-arranged Audit Plan and Check List. The Audit usually also involves surveillance of concrete activities during the time frame of the audit. The activities witnessed may include such areas as (1) Batch plant operation, (2) Delivery of concrete to placement site, (3) Observation of placement site (including wood forms), and (4) Slump tests and other concrete testing being performed by the Testing Laboratory. Observation of QC personnel performing required job inspection functions are also made. All documentation is reviewed during the audit to assure specification compliance including H_2O analysis reports and all Testing documentation. No Inspections are performed by QA."

2. Accountability

"The QA Auditor must perform sufficient pre-audit homework and planning to enable him to develop expertise relevant to batching, mixing and placement of concrete (including testing and curing). Whenever the auditor witnesses any procedural violations during the concrete operation, the appropriate supervisor is notified and the nonconformance is appropriately corrected. The QA auditor is trained and has sufficient experience in both the audit procedure and understanding of concrete placement to enable him to make decisions that may be required during the conduct of the audit."

3. Authority

"The QA Auditor is qualified and certified to perform an intensive in-depth investigation/audit within the scope of the criteria and commitments of concrete placement activities for Project A. He has the authority to notify the appropriate levels of supervision and/or Management via Corrective Action Requests or other appropriate correspondence, of any violations, nonconformances or deviations of the applicable procedures and/or specifications."

B. Surveillance

1. Responsibilities

"The QA Division Head on site issues a schedule for daily site surveillance in which each QA Engineer is assigned specific areas to be surveyed. The scope of these surveillance assignments encompasses practically the entire job site and all of its on-going activities. These surveillance activities include any concrete form installation and/or removal, placement of concrete, mixing and placement of grout, etc. They also include the entire batch plant operation, the usage of concrete mixer trucks and pumping equipment as well as the storage area for stone, sand, and flyash. The surveying QA Engineer observes all of the daily construction activities in progress in his particular area of concern and assures that each activity is progressing in accordance with the appropriate procedure. Actual inspection functions are not performed by QA, these functions are performed by QC Department."

2. Accountability

"The QA Engineers who perform daily surveillance activities observe the various construction activities in detail and are familiar with the basic detailed construction procedures in addition to most other specifications and memoranda relevant to methods of concrete operations. If any infractions or deviations from the normal methods for construction are observed during his surveillance, immediate steps are taken to notify the appropriate craft supervisor so that proper corrective action is assured."

3. Authority

"The QA Engineer who performs daily site surveillance activities is trained to identify quality problems and has the authority to initiate recommendations or solutions for all construction anomalies that may affect quality. He can, either through his own effort or higher levels of supervision and/or management, assure that proper corrective measures are taken."

2. C.M. Firm. In addition to its site level Quality Control activities, the C.M. Firm is also involved in what might more accurately be called Quality Assurance activities at the home office level within the Quality Assurance Department. At that level, a Project A Quality Assurance Engineer is reponsible for establishing, integrating and maintaining the site Quality Control Program consistent with both the CM Firm and Utility A's requirements. He also assists in the development of the Quality Control Procedures that are implemented at the project site level.

In addition, a home office level QA Manager of Audits organizes and conducts field level audits of all operations and activities that are within the scope of the CM Firm's responsibility as Construction Contractor, Construction Manager and Construction Manager's Quality Control. The audit program provides for auditing each activity affecting quality at least once a year. The intent of the audit program is to assess the effectiveness of the CM Firm's quality related activities and to provide responsible management of both the auditing and audited organizations with current factual data for their evaluation of program effectiveness. A determination of compliance of the CM Firm's activities with the commitments in the Quality Control Procedures, their Field Construction Procedures, Utility A's Quality Assurance Instructions and the FSAR instructions is also made.

Quality Control

The role of both Utility A and the CM Firm with regard to Quality Control will be explained below in relation to Figure A.4.

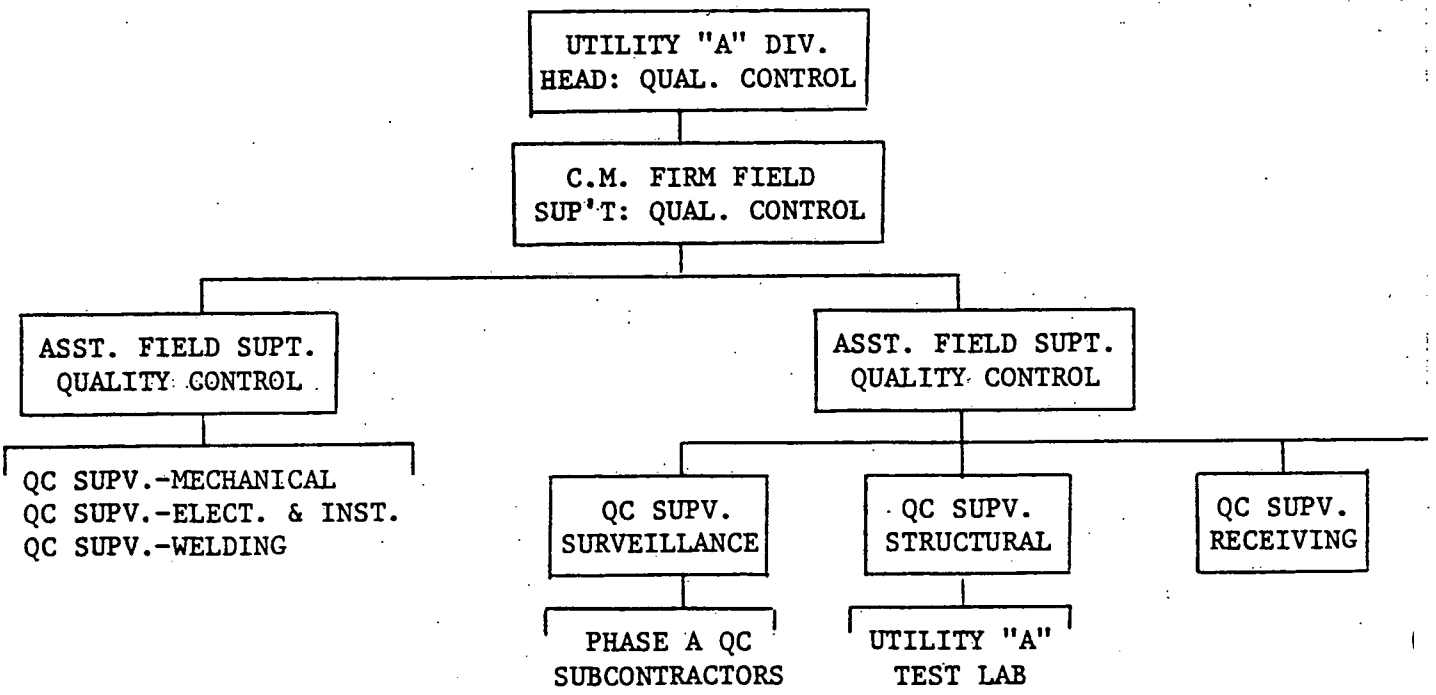


Figure A.4.--C.M. Firm Quality Control Organization

1. Utility A. The only direct involvement of Utility A in quality control activities on the project site is through the technical direction which the Utility A Division Head of Quality Control provides to the CM Firm Field Superintendant of Quality Control. The direct responsibilities which Utility A has with regard to the CM Firm's QC program are associated with providing the following information:

a. Approved drawings and specifications.

b. Approved Quality Assurance Instructions (QAI).

c. Other written directives and instructions, as required.

d. Lists of drawings and specifications.

e. Definition in the purchase order, specification or on a master listing of the Nuclear classification and quality assurance requirements of all equipment.

f. Pertinent information relative to the CM Firm's interface with other prime contractors and vendors.

2. CM Firm. As mentioned previously, the CM Firm has been assigned the prime responsibility for implementing the quality control program for Project A. As shown in Figure A.4 , there are QC Supervisors assigned to the various functional areas (i.e. Mechanical, Structural, Receiving, etc.) and there is a QC Supervisor assigned to Surveillance. With respect to the concrete phase, the following relationships exist:

a. The CM Firm's Construction Department, through its designated superintendants and other supervisory personnel is responsible for assuring the quality of concrete operations within the scope of its construction activities.

b. The responsibility for verifying that the necessary quality level of concrete is achieved rests with the QC Structural Supervisor and his inspectors who perform batch plant inspection and visual inspection at the concrete

placement location.

c. The Central Testing Laboratory of Utility A is responsible for performing the concrete tests which are required. Their inspectors are present at concrete placement locations to take the required slump tests and prepare the required concrete cylinders. The activities of the testing group at the project site are under the direction of the CM Firm's Field Superintendant-Quality Control.

One important aspect of the quality control activities is that it includes 2 phases. Phase "A" consists of the conventional "First Level" Inspection of the CM Firm's construction activities by either the Field Quality Control group or the appropriate craft personnel that are involved. This group is also responsible for performing Phase "A" inspection on certain other contractors on the site who do not have Phase "A" responsibility.

Phase "B" Quality Control is a "Second Level" Surveillance activity which is conducted to determine whether or not phase "A" inspection activities are being performed in accordance with the applicable procedures. It is performed on both the CM Firm's inspection program (where it represents an example of one section of the Field Quality Control Group checking on the other section) as well as on the Phase A inspection program of other site contractors.

Surveillance of this type is based on a site surveillance schedule and is performed in accordance with a prepared checklist (Quality Log). Nonconforming conditions are detailed on a Surveillance Report.

As characteristics are checked, the surveillance engineer indicates satisfactory (S), unsatisfactory (U), or not applicable (X) in the appropriate column of the checklist (Quality Log). Nonconforming items are brought to the attention of the QC Supervisor responsible for the activity being surveyed.

The cause of the nonconformance is either corrected immediately or the activity is curtailed.

A weekly summary report is submitted to the Field Superintendent-Quality Control. The report is in a memorandum format and should as a minimum address the following categories:

1. Activities surveyed
2. Nonconformances noted during surveillance
3. Recommended changes in the Quality Control Procedures, when applicable.

Surveillance reports become part of the Master Quality Control File for the project.

QUALITY ASSURANCE DOCUMENTS

The total Quality Assurance Program discussed above is implemented through a series of manuals and procedures which describe the specific duties and responsibilities of each party. An explanation of some of these documents, (which are indicated in Figure A.5) will be presented below with special emphasis being placed on those that are specifically related to the concrete phase.

Utility A

1. Quality Assurance

   a. Quality Assurance Procedures (i.e., QAP's). These procedures enlarge on the Utility A corporate policy statements about Quality Assurance which are made in the QA Manual. They are structured according to the 18 Criteria of 10 CFR Part 50, Appendix B, and are applicable to all of Utility A's nuclear generating stations.

   b. Quality Assurance Instructions (i.e., QAI's). These instructions

Note: The relative position of documents in Figure A.5 does not necessarily represent a hierarchy relationship.

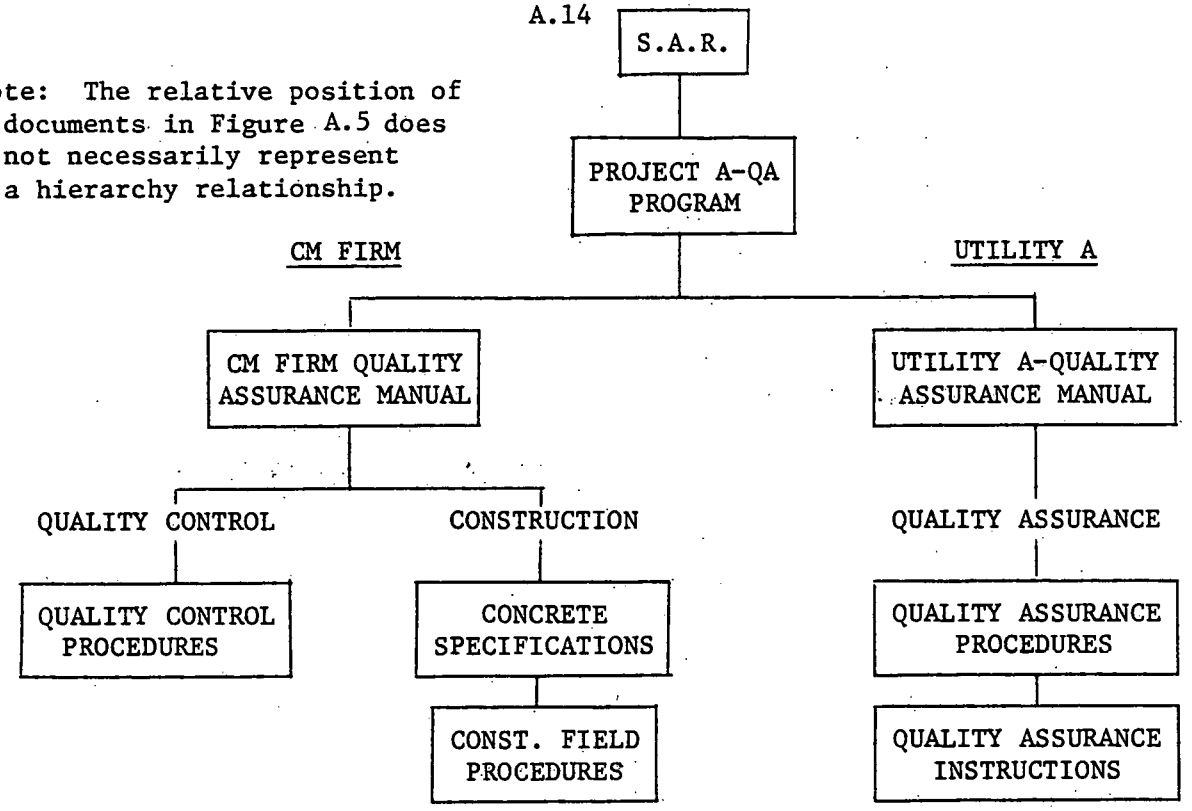


Figure A.5.--Project A Quality Assurance Documents

provide specific guidance to Utility A's Quality Assurance personnel as well as to the principal contractor on Project A. They apply specifically to Project A and are also structured according to the 18 Criteria of 10 CFR Part 50, Appendix B.

CM Firm

1. Construction

a. Technical Specifications. One of the primary sources of guidance for concrete quality from the construction group's standpoint, is presented in the concrete related specifications that are used on Project A. The primary one is:

Spec.	Title	No. of Pages	No. of Revisions
1	Concrete	13	Addendum No. 6 of Revision 2

It should be noted that in many areas (i.e., reinforcement, formwork, etc.) the above specification does not present as much detail as was

found in the specifications on projects of a later vintage. It was probably assumed that the references which were made in the specifications to the various ACI, ASTM Codes and Recommended Practices, etc., would assure the incorporation of all these requirements into the construction effort. This concept placed a considerable reliance on the ability of the construction staff and the QC inspectors to incorporate (without the benefit of a definite statement of the details) all of the important details into the concrete construction process.

b. Construction Field Procedures. These procedures were prepared specifically for Project A from a set of the CM Firm's corporate-level field procedures. They define the C.M. Firm's acceptable construction practices and are one of the documents(along with the drawings and specifications) which the Quality Control group can use as a reference to determine if a particular construction activity is being performed in a satisfactory manner.

There were approximately 150 Field Procedures (both active and inactive) on Project A during the Summer of 1977. The primary F.P. related to concrete was simply entitled "Concrete" (8 pages, 5 revisions) although others were written to cover specific construction activities (i.e., "Construction of Exterior Reactor Containment Walls", etc.).

2. Quality Control

a. Quality Control Procedures (i.e., QCP's). The basic guidance for the Quality Control Inspectors is found in the individual Quality Control Procedures which are developed and prepared to cover each specific functional quality control activity necessary to implement the QC Program. There were approximately 40 QCP's being implemented on Project A during the Summer of 1977 covering such areas as: (1) Receiving Inspection, (2) Structural Concrete, (3) Reinforcing Bars and Splices,

(4) Control of Nonconforming Conditions, etc.

Several points should be made with regard to the QCP entitled "Structural Concrete". It appears that the level of detailed guidance provided in the QCP regarding the acceptability of the various attributes related to concrete is minimal when compared with the level of guidance provided on later vintage projects that were in the research study. It also appears that the QC inspectors were primarily involved only in the "Concrete Placement" phase with the responsibility for the "Preplacement" phase being placed directly with the Construction group. Both of the points can be illustrated by noting the following definition of the duties of pour site inspectors found in the above mentioned QCP.

> "The Field Quality Control Group shall perform inspection of every concrete pour. Duties of the pour site inspectors are:
>
> a. Prior to the start of a pour, check for the existence of a signed Concrete Placement Checkout Sheet.
>
> b. Perform surveillance of concrete placement operations to assure compliance with specification requirements. Particular attention shall be paid to:
>
> 1. Homogeneity of mass
>
> 2. Proper vibration (consolidation)
>
> 3. Requirements unique to a specific pour.
>
> c. Report any deficiencies immediately to the craft supervisor responsible for the pour and the QC Supervisor-Structural, for immediate correction.
>
> d. Complete a "Concrete Pour Site Inspector's Report" for each pour."

SUMMARY

The material which was presented describes the current stage of evolvement of a Quality Assurance Program which began prior to the issuance of 10 CFR Part 50, Appendix B. Because of this, many of the standards, codes, and the NRC

Regulatory Guides which influenced the other projects in the research study were not directly applicable to Project A. It appears however that Utility A and the CM Firm, under the influence of the NRC, attempted to adapt to as many of the changes in the regulatory environment as possible.

Since the majority of the concrete phase of Project A occurred during the early 1970's, which also represented the early stages of the evolvement of the QA Program, it is quite probable that the QA efforts were not as well defined as they presently are. Site QA as well as site QC have undoubtedly grown in importance over the years as the influence of the NRC has grown stronger.

CASE STUDY--PROJECT B

PROJECT ORGANIZATION

Project B, which is Unit 2 of Utility B's first nuclear power plant, received its construction permit at about the time that 10 CFR Part 50, Appendix B was being proposed. The inter-relationships of the parties involved in the concrete phase of the project is shown in Figure A.6.

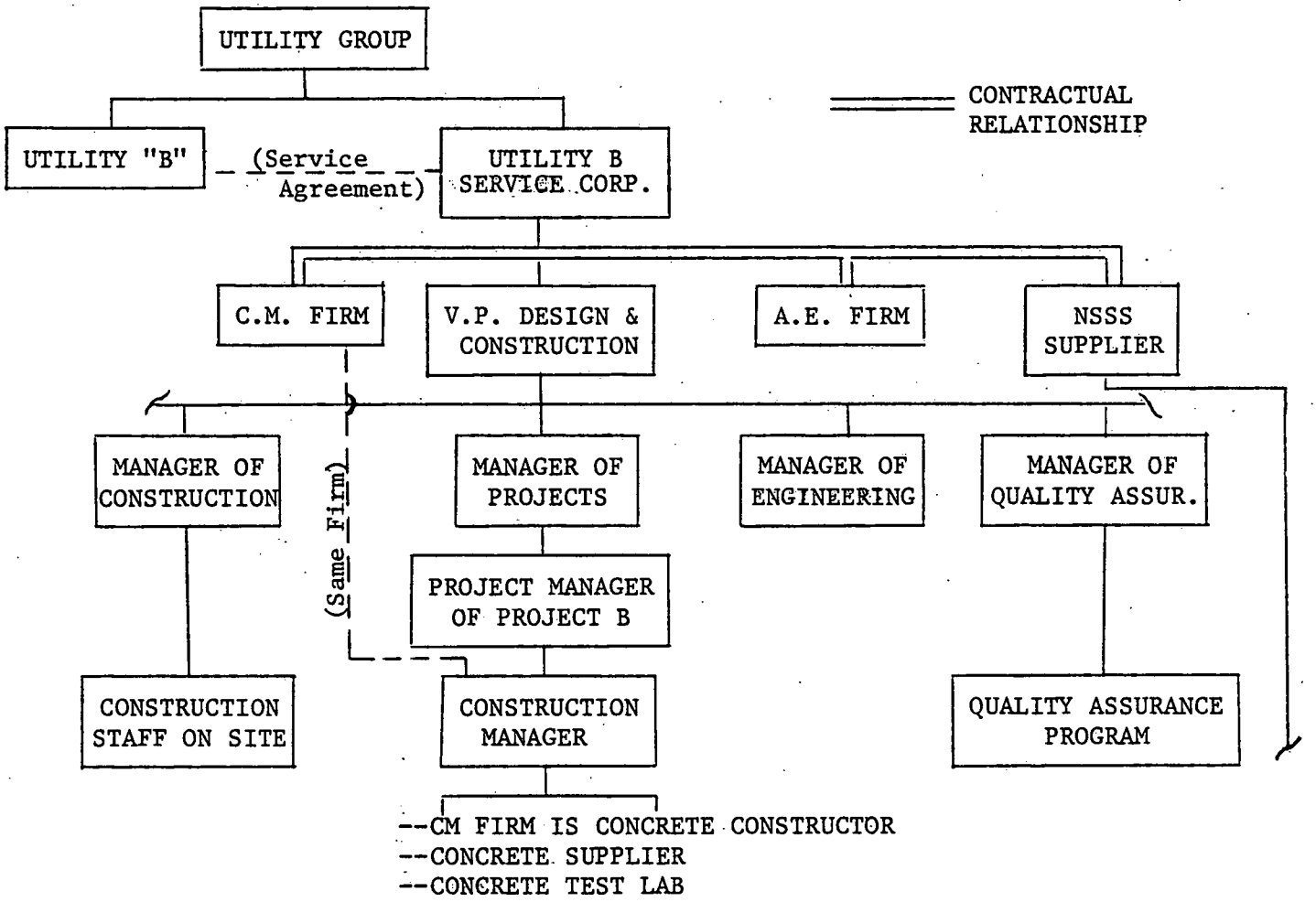


Figure A.6.--Project B: Interrelationship of Parties Involved In the Concrete Phase

As shown in Figure A.6, Project B is being built under a Construction Management mode. Utility B, which will ultimately operate the power plant, is a subsidiary of a Utility group. It delegated the project responsibilities to the Design and Construction Division of the "Service Corporation" of that group through a "Service Agreement" mechanism. The Service Corporation, (which, for purposes of simplicity will be called the Utility B (SC) in this case study) had derived prior nuclear power plant experience on a facility built for another subsidiary utility of the group.

As shown in Figure A.6, the Manager of Projects for the Utility B (SC) (who is responsible for the establishment of project management operations for all projects) and the Manager of Quality Assurance (who is responsible for the coordination and direction of quality assurance measures for all projects) both report to the Vice President for Design and Construction.

On Project B, the responsibilities for (1) Engineering and Design and (2) Construction Management, have been delegated to separate A.E. and C.M. firms. The C.M. Firm is also responsible for some construction functions, one of which is the concrete phase of the project. It should be noted that an independent concrete supplier is responsible for the operation of the batch plant and an independent Testing Laboratory has been retained to perform concrete testing services. The QA/QC functions which are under the direction of the Manager of Quality Assurance are divided between the two firms mentioned above and the Utility B (SC).

The interrelationships of responsibilities for both the construction management and the quality assurance efforts can be highlighted by separately examining the role of each organization.

Utility B (SC)

The Utility B (SC), through its Project Manager of Project B, acts

for the responsible owner and applicant, Utility B, in all matters related to design, construction and licensing of the power plant. The Project Manager's responsibility includes but is not limited to:

a. Direction of project-related activities of the A.E. firm (including approval of plans and specifications, etc.)

b. Direction of project related activities of the C.M. firm (including approval of construction procedures, etc.)

c. Control of project schedule and budget.

d. Project Quality Assurance implementation, etc.

In fulfilling these responsibilities, he receives technical support from the Utility B(SC)'s Design and Construction Division. One of these areas of technical support is supplied by the Manager of Quality Assurance who is responsible for the preparation of the project Quality Assurance Plan. Within this plan is a description of the surveillance and auditing program which is implemented on the project. He also advises the Project Manager whenever non-compliance with the QA Plan is discovered.

A.E. Firm

The A.E. Firm is responsible for plant design on the entire project except for those items provided by the NSSS Supplier or Utility B. It provides the normal engineering services for a project of this type (1. preparation of drawings, 2. preparation of equipment, construction and installation specifications, 3. placement of equipment purchase orders, etc.). It is also an active participant in the quality assurance program whenever the C.M. Firm is acting as the constructor. In such cases, the A.E. Firm performs Second Level Surveillance type inspections.

C.M. Firm

The C.M. Firm is responsible for planning and scheduling the construction

phases of the project in accordance with the engineering drawings and specifications provided by the A.E. Firm. Some of the specific responsibilities which should be noted are:

a. Equipment procurement services

b. Preparation of construction and plant equipment installation procedures.

c. Award of contracts for construction packages and assurance that work meets specification requirements.

d. Performance as a construction contractor in certain instances (concrete construction, etc.)

e. Preparation and establishment of systems for accumulation and retention of QA/QC documentation for the project.

Members of the C.M. Firm, under the managerial direction of the Utility B(SC) are also heavily involved in the quality assurance and quality control activities at the project site. As will be noted later in this section, this includes both first level inspection and second level inspection activities.

QUALITY ASSURANCE PROGRAMS

The total Quality Assurance Program for Project B is divided into three levels. The definition and functions of these three levels with regard to site construction are as follows:

First Level--"Quality Control and Inspection"

The First Level, which is defined as a Quality Control and Inspection function, is performed by construction contractors. The individual constructors are required contractually to have a quality control and inspection program for the end-product which they construct. The contracts require site constructors to be responsible for production of the end-product and for the testing,

inspection, and quality control to demonstrate that the final end-product has the specified degree of quality. Contractors in this category are referred to as "First Level Contractors" and include the NSSS supplier, the reactor coolant pump supplier, the concrete contractor, etc.

Second Level--"Quality Assurance Surveillance"

The Second Level is defined as the Quality Assurance Surveillance function. It basically consists of a surveillance of each contractor's Quality Control and Inspection Program to insure that the design and quality requirements are in fact being met.

Third Level--"Quality Assurance Auditing"

The Third Level, which is defined as a Quality Assurance Auditing function, is performed by the Utility B(SC) or a QA Consultant. Before an audit is performed, the specifications and other requirement documents prepared by the A.E. Firm are reviewed to check that the necessary quality requirements have been incorporated in these documents. Then, the Utility B(SC) Home Office, Site QA Auditor and/or a QA Consultant perform, on a spot-check monitoring basis, quality assurance audits to ensure that the quality assurance surveillance programs of the C.M. Firm and the Utility B(SC) and the first level quality control programs of the various constructors are actually functioning as required.

The organizational responsibilities related to these three levels of quality assurance for the concrete construction phase (where the C.M. Firm is acting as a constructor) is shown in Figure A.7.

Utility B(SC)--(Third Level Auditing)

The Utility B(SC) has a full-time Site Quality Assurance Auditor and group at the construction site to perform audits of the quality control and

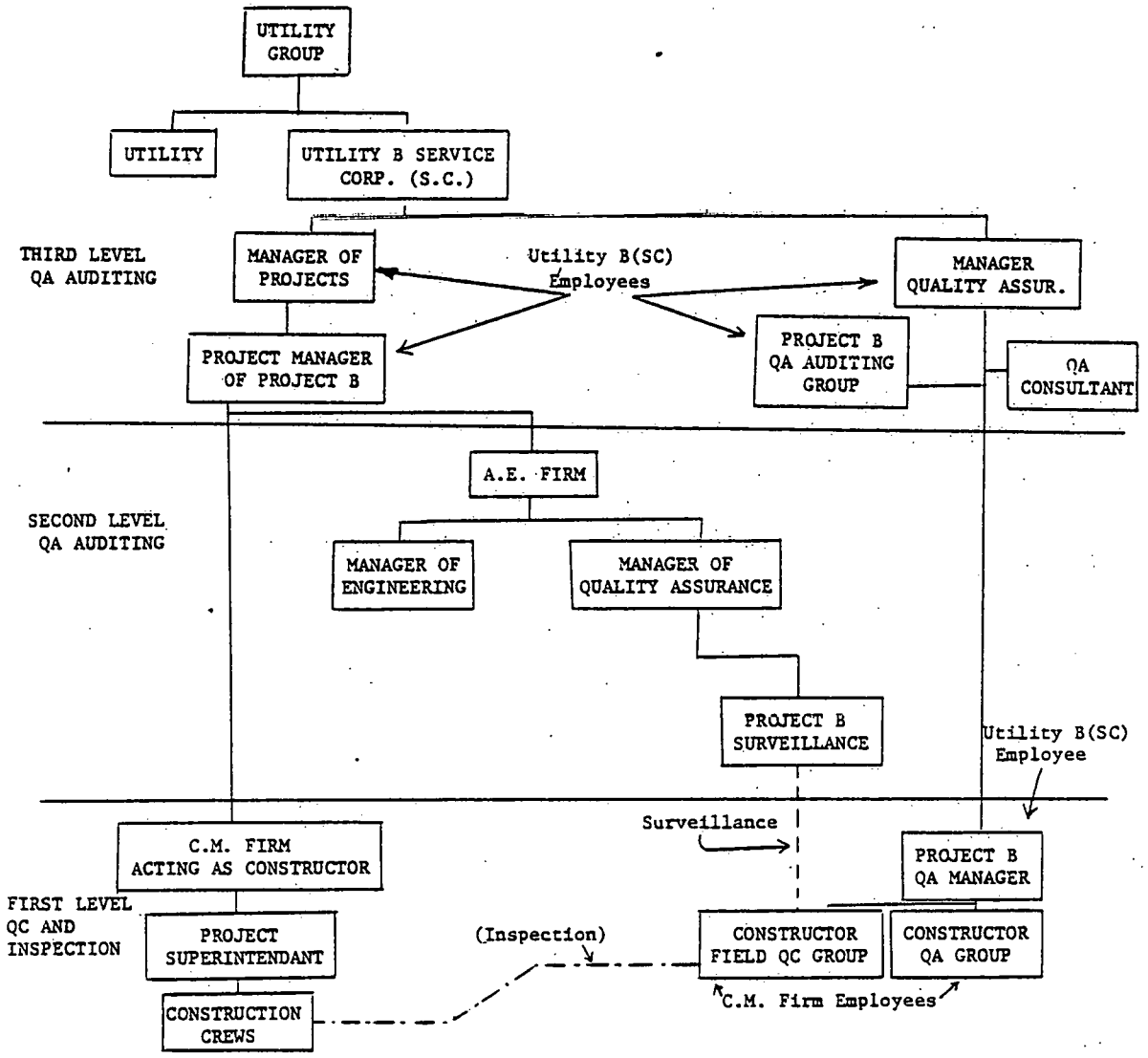


Figure A.7.--Organizational Responsibilities for Three Levels of Quality Assurance

assurance of construction work. As shown in Figure A.7, the Site Quality Assurance Auditor reports administratively to and receives technical direction from the Utility B(SC) Manager of Quality Assurance. The auditing group performs the conventional Third Level QA auditing function carried out by Utilities on most Nuclear project sites. The purpose of this function is to ensure that the overall quality assurance system, consisting of the site construction contractor's quality control system and the Second Level surveillance program (which monitors these systems) is functioning adequately, and as required by the applicable specifications and procedures.

As noted in Figure A.7, the Utility B(SC) is assisted in monitoring the overall quality assurance program for the nuclear related portions of the plant by a Consultant. Among other tasks, the consultant performs on a spot-check auditing basis: (1) Review of specifications, drawings, procedures; inspection checklists and other pertinent documents to assure that the quality control and test requirements for components and systems are adequate and are consistent with statements made in the PSAR/FSAR, (2) Periodic quality assurance audits at manufacturers' plants and at the construction site to evaluate the performance of the contractors and subcontractors in implementing the specified quality control requirements and maintaining the necessary records.

Service Corporation--C.M. Firm (First and Second Level)

In addition to the auditing function mentioned above, the Utility B(SC) also is directly involved with the day-to-day Quality Assurance/Quality Control operations on the project site. As shown in Figure A.7, the Constructor's (i.e., C.M. Firm) Field Quality Control Group as well as its Field Quality Assurance Group report directly to the Project B QA Manager

who is a Utility B (SC) employee. He provides the management direction for the Field Supervisor-Quality Control and the Lead Quality Assurance Engineer, who as C.M. Firm employees, respectively supervise the two above-mentioned groups. The QC and QA engineers and the QC inspectors in these two groups (who are also C.M Firm employees) are responsible for:

First Level "Quality Control and Inspection". This type of inspection occurs in those situations where the Construction Manager acts as the Constructor (i.e., for the concrete phase, etc.) Some of the responsibilities of the Field Quality Control group with regard to this First Level are:

1. Conduct the quality control and inspection actions defined in the applicable detailed Quality Control Procedures and Quality Control checklists or holdpoints attached to or incorporated in the C.M. Firm Construction procedures in order to ascertain conformance to applicable specification and/or drawing requirements, and code criteria. It should be noted that all C.M. Firm Procedures affecting activities within site QC scope are required to have such Quality Control checklists or holdpoints. These procedures will define the inspections and indicate compliance and/or acceptability action by the Quality Control Group prior to proceeding to the next operation.

It should be noted that site policy dictates that this inspection by Quality Control personnel does not relieve the first line construction supervision of primary responsibility for the quality of the construction activity. The Quality Control Inspectors only exercise final accept/reject responsibility for all inspection operations.

2. Report any discrepancies to the applicable production supervisor for correction. Field QC is responsible for follow-up, as well as documenting the corrective action, to ensure that reported discrepancies have been corrected; if necessary, this follow-up can include initiating action to stop work.

3. Conduct receiving functions on shop-fabricated equipment.

4. Receive, review and maintain the required and prescribed quality control records.

5. Schedule and conduct internal audits on all applicable site construction activities for ascertaining effectiveness and compliance to approved procedures and specification requirements. The Field Supervisor-Quality Control must effect corrective action with cognizant on-site personnel for all non-compliance conditions.

6. Receive and maintain documentation on all material procured and received.

It should be noted for the concrete phase, the C.M. Firm has retained an independent Testing Laboratory to assist the C.M. Firm's Field QC Group with concrete inspection. This laborabory acts as an extension of the Field QC Group and as such reports for management direction to the Field Supervisor-Quality Control.

Some of the responsibilities of the Field Quality Assurance group with regard to this First Level are:

1. Review, concur, or request changes in site construction and quality control procedures pertinent to the C.M. Firm's construction activities in conjunction with the A.E. Firm.

2. Prepare, secure formal approval, and implement applicable quality control and inspection procedures for site-related activities.

3. Perform liason duties with the A.E. Firm, the Utility B(SC), the C.M. Firm, the Project Manager, Project Superintendent and the Field Supervisor-Quality Control relating to formal approval and implementation of quality control and inspection procedures.

Second Level "Quality Assurance Surveillance". This type of inspection occurs on all site construction work for which the C.M. Firm is not acting as the

constructor (i.e., where another construction firm is responsible for the work). In this case the Field Quality Control Group is responsible for the second level quality assurance functions related to the site constructor's work. The function is fulfilled by the performance of surveillance of the site constructor's performance and adherance to the provisions of their own Quality Assurance Manual and procedures. This surveillance is directed by the Field Supervisor-Quality Control and conducted by members of his staff. The Quality Control Group is responsible for the review and accumulation of all Quality Control reports, records, and documents related to this work, and maintains them or insures that they are maintained in a logical and complete manner.

The surveillance function includes but is not limited to:

1. Perform liason duties with the A.E. firm, the Utility B(SC), the C.M. Firm Project Superintendent and Quality Assurance Engineers relating to quality assurance activities.

2. Receive, review and maintain the required and prescribed quality control records.

3. Schedule and conduct audits of all site quality assurance actions for ascertaining compliance to approved procedures and specifications, and effectiveness of site contractors' quality control and inspection efforts. The Field Supervisor-Quality Control shall effect corrective action with appropriate on-site personnel for all non-compliance conditions.

4. Insure that all subcontractors have approved procedures prior to start of work. The Quality Control Group will instruct the sub-contractors' quality control personnel that work must not proceed without formal approval of required procedures.

Some of the responsibilities of the Field Quality Assurance group with

regard to this Second Level are:

1. Review and comment on applicable specifications, amendments, and revisions prepared by the A.E. Firm prior to issue. This action will pertain to quality control requirements (tests, inspection, and documentation) incorporated in the documents.

2. Review purchase orders prepared by the Purchasing Departments to ascertain if all quality control requirements have been incorporated therein.

3. Review, concur, or request changes on the vendor's quality control procedures pertinent to the purchased item(s) or site contractor's construction activities in conjunction with the A.E. Firm.

4. Set up the extent of quality assurance and surveillance as required by the specifications and purchase order, and inform the vendor of these requirements. The extent is determined by:

a. Specification requirements.

b. Criticality and sophistication of item.

c. Vendors' history of past performance.

d. Results of manufacturers' facilities surveys.

e. Manufacturing cycle time.

5. Schedule plant or source visits in conjunction with the Vendor Surveillance Supervisor.

6. Prepare, secure formal approval and implement applicable quality control procedures (as designated by the Utility B(SC) Quality Assurance Manager) for monitoring both site constructor and component vendors.

7. Review specifications to ascertain quality control requirements and establish the scope of QC duties pertinent to items received at the site. For site procured items, review and comment on applicable procurement documents to verify incorporation of applicable quality control requirements (tests, inspections, and documentation).

QUALITY ASSURANCE DOCUMENTS

The total Quality Assurance Program discussed above is implemented through a series of manuals and procedures which describe the specific duties and responsibilities of each party. As indicated in Figure A.8, both the Utility B(SC) and the CM Firm have a Quality Assurance Manual which describes the policies and procedures that are applicable to Project B.

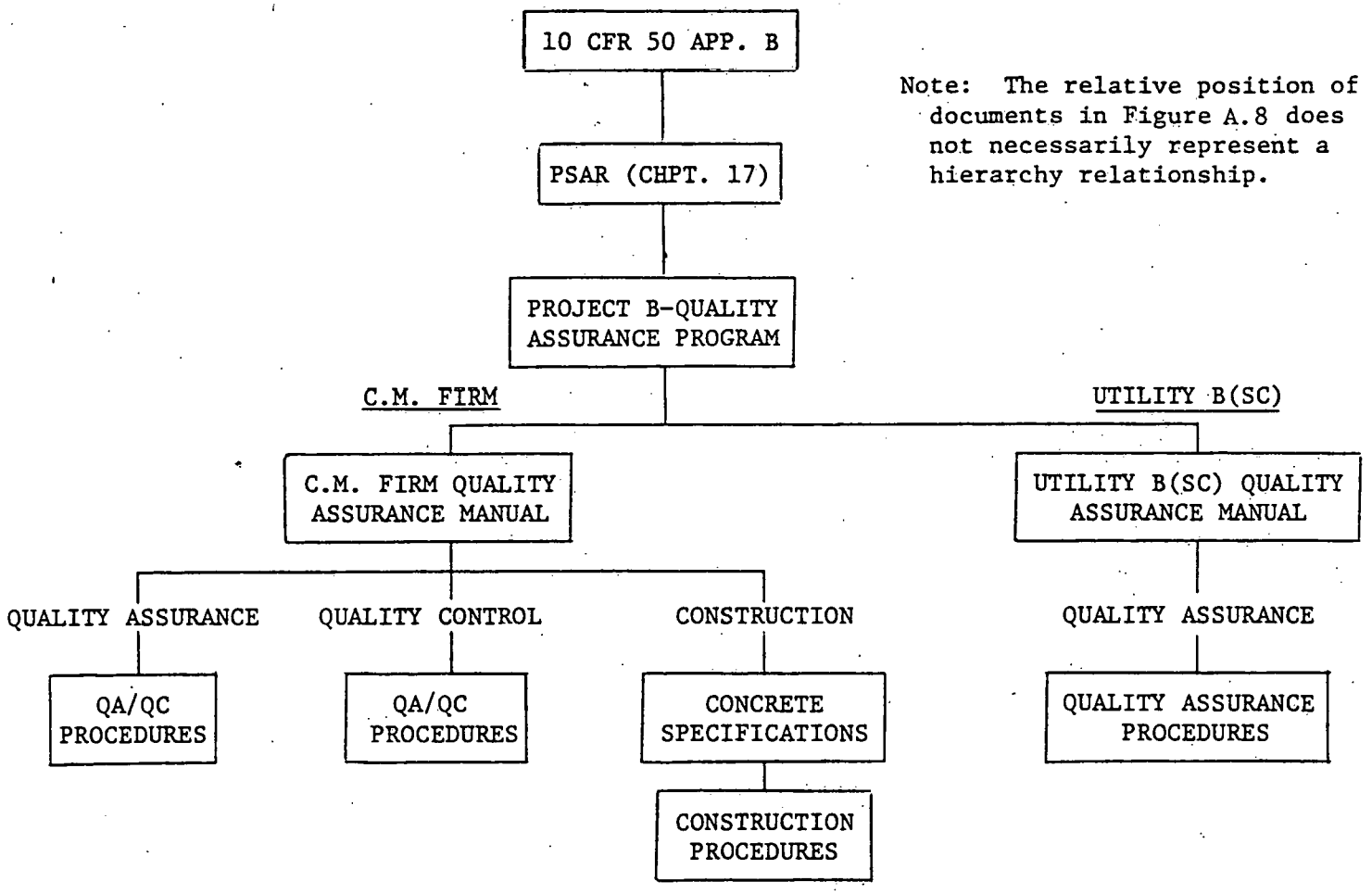


Figure A.8.—Project B Quality Assurance Documents

An explanation of some of the documents which are used will be presented below, with special emphasis being placed on those that are specifically related

to the concrete phase.

Utility B(SC)

The site QA group activities are defined by Quality Assurance Procedures (i.e., QAP's) which provide the "how to" instructions related to such topics as Auditing, Nonconformance Control, etc.

C.M. Firm

1. Construction

a. Construction Specifications. The primary guidance regarding acceptable construction operations are found in the Construction Specifications which are issued by the A.E. Firm. The ones which are specifically related to the concrete phase are:

Spec.	Title	No. Pgs.	No. of Amendments
1	"Production and Delivery of Concrete"	42	15
2	"Reactor Building Concrete"	27	13
3	"Substructure"	30	25
4	"Superstructure	30	35

It is interesting to note that the second specification which is listed above refers to the exterior and cylindrical wall and dome of the Reactor Building and the structural light weight concrete over the bottom liner plate. The requirements for concrete on the remainder of the project are covered by Specification 3 and 4 above as well as one of the Quality Control Procedure (which is discussed below).

b. Construction Procedures. The C.M. Firm on Project B has developed an extensive set of Construction Procedures to outline and detail the methods which are to be used by the Construction group. These approximately 110 procedures are divided into the following areas: (1) General (i.e., Drawing, Specification and Document Control, Construction Procedure

Development Plan, etc.), (2) Civil (i.e., the major concrete related procedures are "Containment Shell Structural Concrete" and "Pump Conveying of Concrete") (3) Electrical, (4) Mechanical, (5) Nuclear, and (6) Piping.

2. Quality Control

A. QA/QC Procedures. The series of documents which provide guidance for Quality Control personnel are the QA/QC Procedures that address the various contruction phases of Project B. The QCP related to structural concrete is entitled "General Construction and Structural Concrete". The above mentioned concrete-related specifications and construction procedures, along with the applicable ACI and ASTM standards, provide the references upon which this QCP is based. The purpose of the procedure is to outline the controls and inspection that will be applied by the Quality Control Group on the production of concrete, the placement of reinforcing steel, and the concrete preplacement and placement phases on all "Class I" Structures, components and systems which are identified as being within the Quality Assurance Boundaries of responsibility. The Batch Plant production and sampling of concrete requirements in the QCP also apply to conventional concrete identified as Class II. Both the inspection and testing requirements are defined and the forms and checklists which are to be used by QC are provided.

3. Quality Assurance

a. QA/QC Procedures. Some of the QC Procedures, which might on another project be called QA Procedures, provide guidance to the C.M. Firm's QA activities. Examples of these are: (1) Quality Assurance Surveillance Plan, (2) Control of Nonconforming Conditions. The majority of the approximately 45 QA/QC Procedures which are used, however, appear to have a Quality Control emphasis.

CASE STUDY--PROJECT C

PROJECT ORGANIZATION

Project C represents an addition to Utility C's existing nuclear generating capacity. The interrelationship of the parties involved in the concrete phase of the project is shown in Figure A.9.

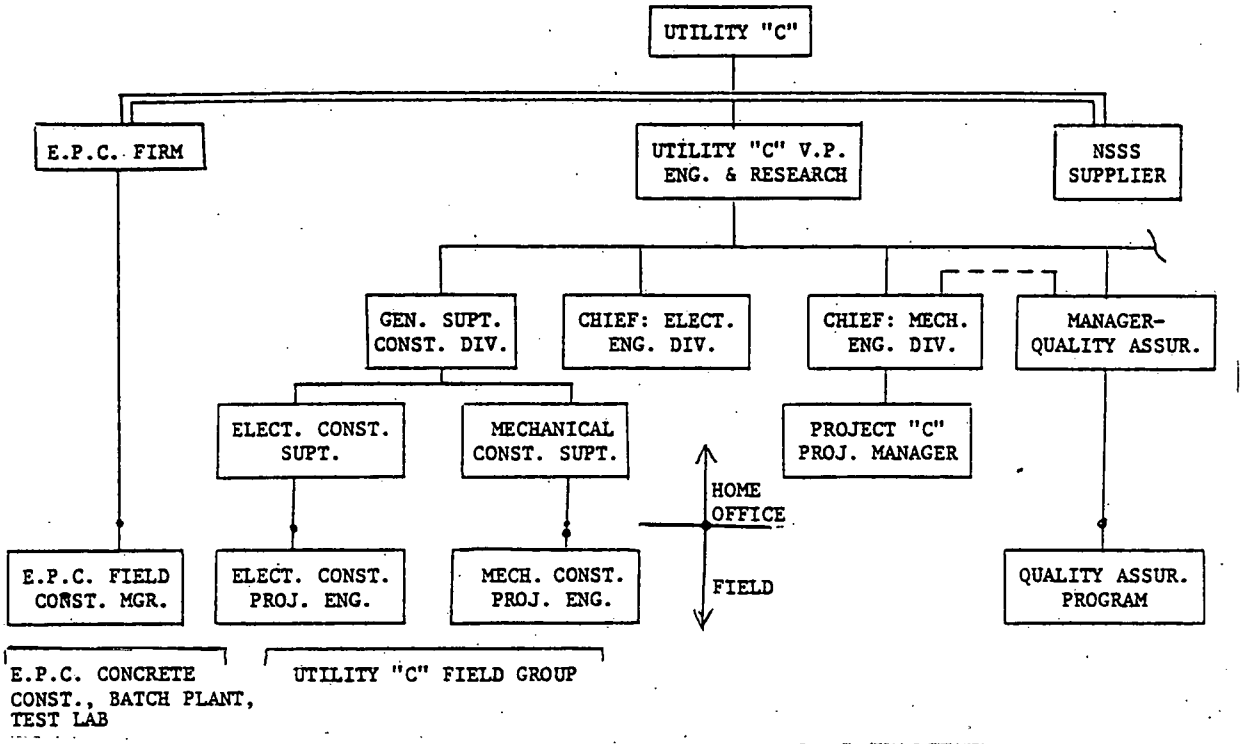


Figure A.9.--Project C: Interrelationship of Parties Involved In the Concrete Phase

As noted in Figure A.9 , Utility C's Vice President, Engineering and Research, has the lead responsibility for the project. The major design, project coordination and construction responsibility for Project C rests with the Chief Mechanical Engineer who directs a Mechanical Engineering (i.e. M.E.) division consisting of 5 major technical sections (i.e. Nuclear Engineering, Civil Engineering, etc.) and a Project Management Group. The M.E. Division is also responsible for the third level design review of mechanical equipment and components. The Electrical Engineering (i.e. E.E.) Division is responsible for the third level design review

of electrical plant equipments and components.

The primary efforts related to the Engineering, Procurement and Construction of Project C, however, have been delegated, under contract, to a single EPC Firm. This firm, as will be noted below, is also responsible for the major Quality Assurance/Quality Control effort on the project site.

Utility C

A Project "C" Project Manager from the M.E. Division has been assigned to coordinate Utility C's efforts with regard to design, procurement and construction at the home office level. He utilizes the services of the various specialty areas within Utility C to perform reviews and approvals of engineering specifications, drawings, cost estimates, price quotations, capital authorizations, contracts, etc. He also acts as Utility C's central coordinating point for contact with the EPC Firm, the NSSS Supplier, etc.

Utility C's Construction Division, which is shown in Figure A.9, is divided into two major sections. The lead representative of Utility C at the project site is a Project Engineer from the Mechanical Construction Section of that division. He directs an on-site construction group whose responsibilities include: (1) Providing contract administration services, (2) Monitoring the construction activities of the EPC Firm and other contractors on the project site (as related to compliance with drawings, specifications and procedures, safety, cost and schedule) (3) Providing on-site liason between Utility C, the EPC Firm, the NSSS Supplier and other contractors. As noted in Figure A.9, there is also a Project Engineer from the Electrical Construction Section assigned to the project site. He works with the Mechanical Construction Project Engineer and lends support to the project in his discipline area.

There is also a Quality Assurance group from Utility C on the project

site under the direction of a Field Quality Assurance Branch Head who reports directly to tha Manager of Quality Assurance. Their responsibilities will be discussed later in this report.

During the summer of 1977 a total of 18 Utility C employees were involved in the above mentioned activities. Their functional responsibilities were in the following areas:

1. Field Engineering-5
2. Subcontract Administration-1
3. Cost and Scheduling-1
4. Quality Control (for balance of plant)-7
5. Quality Assurance-4

EPC Firm

The EPC Firm is retained on Project C as both the Architect Engineer as well as the Constructor. Some of the services provided are:

a. Engineering for the design and construction of the project. These services include mechanical, electrical, civil and structural: designs, studies, specifications, drawings, bills of material, schedules, cost estimates, etc.

b. Procurement of all materials, equipment, supplies and subcontracts for the project that are not under the NSSS contract or not purchased directly by Utility C.

c. Construction of that portion of the entire project which is not separately contracted to the NSSS supplier. This includes an extensive involvement in both Quality Assurance and Quality Control. It should be noted that Utility C's QA on-site personnel monitor and audit the C.M. Firm's activity for conformance to the PSAR, Quality Assurance Program, etc.

The EPC Firm, as shown in Figure A.10, is using a "Project" type organization

to fulfill its responsibilities. The Project Manager of Project C, who is responsible for the overall coordination of the EPC Firm's efforts, is actually in charge of

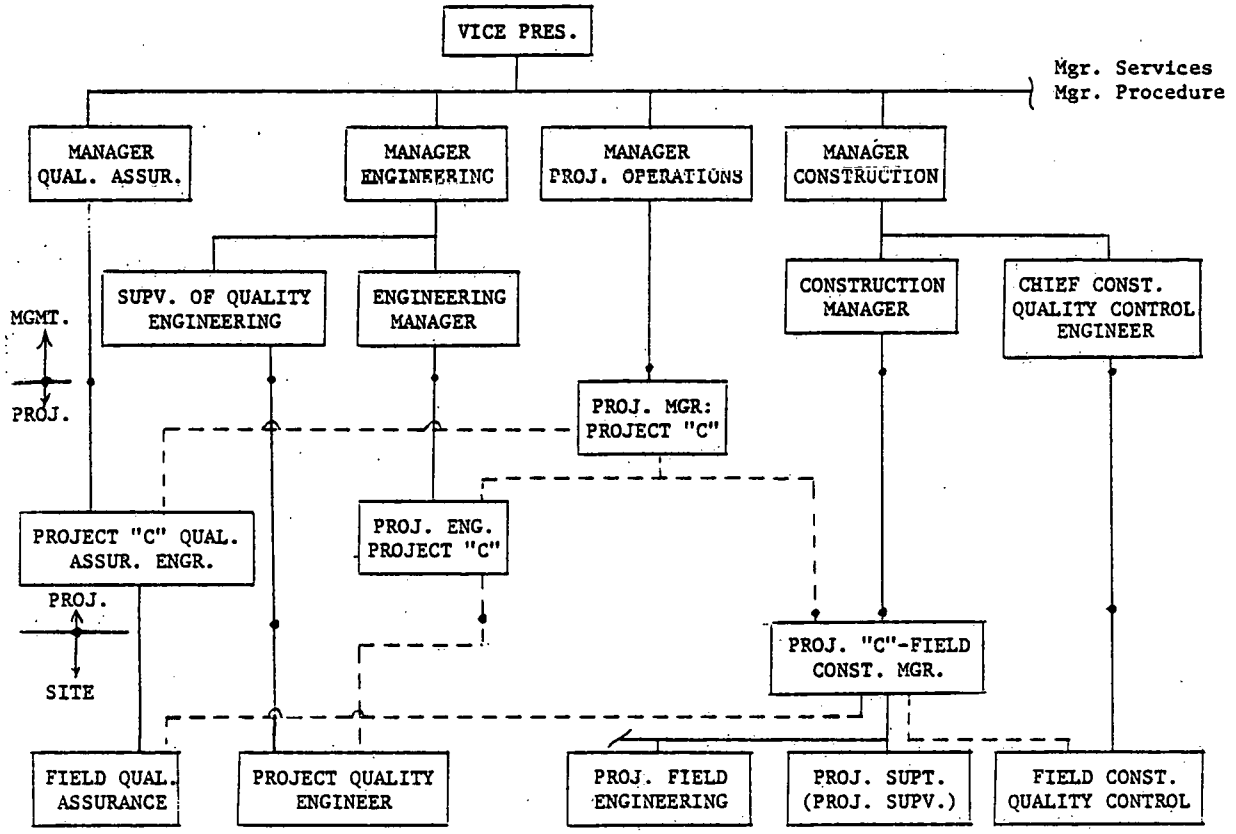


Figure A.10.--EPC Firm Organization _____ Technical and Administrative Direction

_ _ _ _ _ Project Coordination

a matrix organization which is designed to bring together many company specialists to work on the project. It will be noted that for some positions there are two lines of responsibility shown. This serves to indicate that these positions receive direction from two different management sources.

The Project C Field Construction Manager who directs all on-site activity receives "technical and administrative" direction from the Construction Manager

and "project" direction from the Project Manager-Project C. It should also be noted that at the top management level, the Construction Manager and the Chief Construction Quality Control Engineer report to the Manager-Construction. The net effect of this arrangement at the project level is that even though the Project C Field Construction manager provides "technical and administrative direction" to the Field Engineering and Field Superintendant groups, he only provides "Project coordination" direction to the Project Construction Quality Control group. This arrangement was made to provide the necessary "independence" which is required in Appendix B of 10CFR Part 50.

At the top management level, although the Manager of Construction (as noted above) is in charge of both Construction and Construction Quality Control, he is not in charge of Quality Assurance.

It should be noted in fact that the Field Quality Assurance Group reports directly back to the home office to a Project C Quality Assurance Engineer. This individual receives project direction from the home office Project Manager: Project C. This arrangement insures that the QA function is independent of project site influence.

It is estimated that during the peak of the concrete phase of Project C that the EPC Firm will employ the following number of non-manual employees at the project site (total=314).

1. Supervision-24
2. Field Engineering-66
3. Sub Constract Administration-26
4. Cost/Scheduling-32
5. Finance/Accounting-59
6. Procurement-35
7. Quality Control-67
8. Quality Assurance-5

QUALITY ASSURANCE PROGRAM

The Quality Assurance Program on Project C applies to those structures, systems and components of reactor facilities which are "safety related", i.e. those that

are either: (1) essential to the prevention of accidents which could affect the public health and safety or (2) essential to the mitigation of the consequences of such accidents. A "Q" list which identifies these structures, systems and components was jointly prepared by the EPC Firm and Utility C.

The Quality Assurance Program is divided into three levels. For the concrete construction phase (where the EPC Firm is also the constructor) these levels are:

1. First Level-Quality Control and Inspection

This level is performed by the Field Construction Quality Control Group. In the area of structural concrete, Utility C has chosen to consider all concrete that is placed on the project in essentially the same way as Q-listed concrete (concrete placements involving systems, structures or components on the "Q" list) is treated. In general, the QC group is responsible for (1) Material receipt inspection, (2) Storage verification, (3) Inspection of the on-site concrete batching operation, (4) Preplacement, Placement, and Post placement inspection of concrete. In addition on Project C, the QC group is also in charge of the Concrete Testing Laboratory operation.

It appears that the only differences between Q-listed concrete placements and "Balance of Plant" (i.e., B.O.P.) concrete placements is in the extent of documentation and that for the latter case the QC Engineer is not fully involved during the "Preplacement" stage. For B.O.P. concrete the Q.C. Engineer: (1) documents the results of his inspection in only a general manner on a daily Field Inspection Report, (2) performs pre-placement inspection only for cleanup, temperature in forms and rebar cover and (3) releases concrete from the batch plant.

2. Second Level-Quality Assurance Surveillance

This level, which includes auditing and/or surveillance, of the activities of both the EPC Firm's Field Construction Quality Control Group as well as the

EPC Firm's entire site organization. It is performed by the EPC Firm's Field Quality Assurance group.

It should be noted that in those situations where the EPC Firm's Construction group has subcontracted site construction work the Field Construction Quality Control group performs the Surveillance function (Second Level) on the sub-contractor's quality control and inspection efforts.

3. Third Level-Quality Assurance Auditing

This level is the responsibility of Utility C's Field Quality Assurance organization. Quality Assurance Audits are performed on a spot check monitoring basis by this group to insure that the Quality Programs of the first and second level groups are actually functioning as required.

Quality Assurance.

1. Utility C. As noted earlier, the Manager of Quality Assurance is responsible for the development and implementation of Utility C's Quality Assurance Program. He directs an organization which is indicated in Figure A.11.

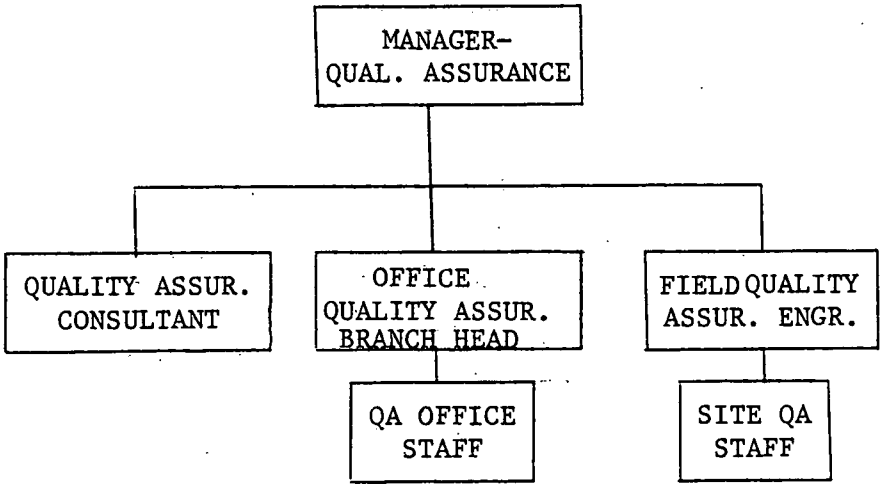


Figure A.11.--Utility C Quality Assurance Organization

The Office QA staff, in addition to preparing QA plans and procedures for Utility C, reviewing the EPC Firm and other contractors' QA plans and procedures, etc. also performs periodic audits on Utility C Project, as well as Site Quality Assurance, groups. A Quality Assurance Consultant is sometimes retained to assist in these efforts.

The duty of the Field QA Branch Head and his staff (4 people on the staff in 1977) is to evaluate the adequacy, effectiveness, and degree of implementation of the quality assurance program on site as delineated in the EPC Firm QA Manual and the various applicable specifications and procedures. They exercise their duties by day-to-day auditing and surveillances of the various quality-related work activities at the site for compliance with the applicable requirements. Primary emphasis is placed upon activities affecting "essential" or "Q-list" structures, components or systems. Deficiencies noted on other work is however also reported.

It should be noted that Utility C QA policy requires that both First Level as well as Second Level activities are subjected to auditing and surveillance. This policy exists because it is felt that the degree to which the Second Level function is implemented can be measured by the conformance of First Level activities to specification requirements.

As an example of some of the items which would be checked in a formal audit related to structural concrete are:

a. EPC Firm's Quality Control System

b. QC Records, Procedures and Results

c. Previously Noted QC System Discrepancies

d. Construction Practices

e. Results of EPC Firm's Second Level QA Surveillance

The above items (and more) also form the basis for the day-to-day auditing approach which is also followed by Site QA. All of these items are not audited

in any one day or week but audits are made of applicable areas as the construction work progresses. The depth of audit of any item on the list is left to the discretion of Site QA. The depth, however, is sufficient to assure that the site quality assurance effort in that area is adequate and that no major deficiencies exist. If deficiencies are found, the depth is increased so as to clearly define the deficiency.

Deficiencies noted are reported and followed up. The responsibility of correcting such deficiencies rests with the organization doing the work resulting in such deficiencies.

Site QA maintains a close communication with the Manager Quality Assurance and informs him by telephone of major deficiencies as soon as such deficiencies are clearly defined. In particular, they immediately inform him of instances where they intend to instruct the site to stop work.

2. EPC Firm. The EPC Firm, through the Manager of Quality Assurance (see Figure A.10) is responsible for monitoring to assure that the quality control requirements for the storage of components and materials, and the installation and construction of the components and systems are effectively implemented. A Lead Site Quality Assurance Engineer assisted by a Staff of Discipline Quality Assurance Engineers is located at the construction site to monitor construction quality control activities. He reports directly to the Project Quality Assurance Engineer. The Site Quality Assurance Engineers (there were 4 on the site in 1977) are the field representatives of Project Management and perform the Second Level quality assurance function at the site. The Quality Assurance Engineers are assigned by, and administratively report to, the Quality Assurance Manager.

The Quality Assurance Engineers perform quality assurance surveillance of field activities including engineering, quality control, and construction. They

review reports of non-conformances, perform surveillance of construction inspection work, and monitor the implementation of the overall quality control program.

The Lead Site Quality Assurance Engineer has the authority to stop field work for which the EPC Firm has direct construction responsibility, and can stop subcontract work through the Field Construction Manager in the event of non-conformance with the drawings, specifications, and procedures for structures, systems, and units on the Q-List. The Quality Assurance Engineers also serve as field contacts for Utility C's Quality Assurance organization and others concerned with quality assurance in the field.

The reports of the EPC Firm's Quality Assurance personnel concerning the monitoring of the EPC Firm's quality control effort become a part of the quality control history file for the plant and are turned over to Utility C at the end of the project.

Quality Control

1. Utility C. Utility C does not have a Quality Control program associated with the Q-listed phase of Project C. They do however have an on-site group (in 1977 there were 7 Utility C QC people on site) to inspect the non-Q construction activities. These activities primarily involved the mechanical, electrical and welding phases of the project since all concrete placements were covered by the EPC Firm's Field Construction Quality Control group.

2. EPC Firm. In order to understand the role of the EPC Firm's QC effort the control of quality must be placed with the framework of the entire site construction organization which is shown in more detail in Figure A.12. The following points should be noted:

(a) The EPC Firm Construction Department through its Project Construction Manager is responsible for construction of the plant to approved engineering

specifications, drawings and procedures. The Project Construction Manager has the prime authority and responsibility for Construction, Field Engineering and Subcontractor activities in the field. Site construction procedures (called Job Rules) are prepared to define the important construction procedures.

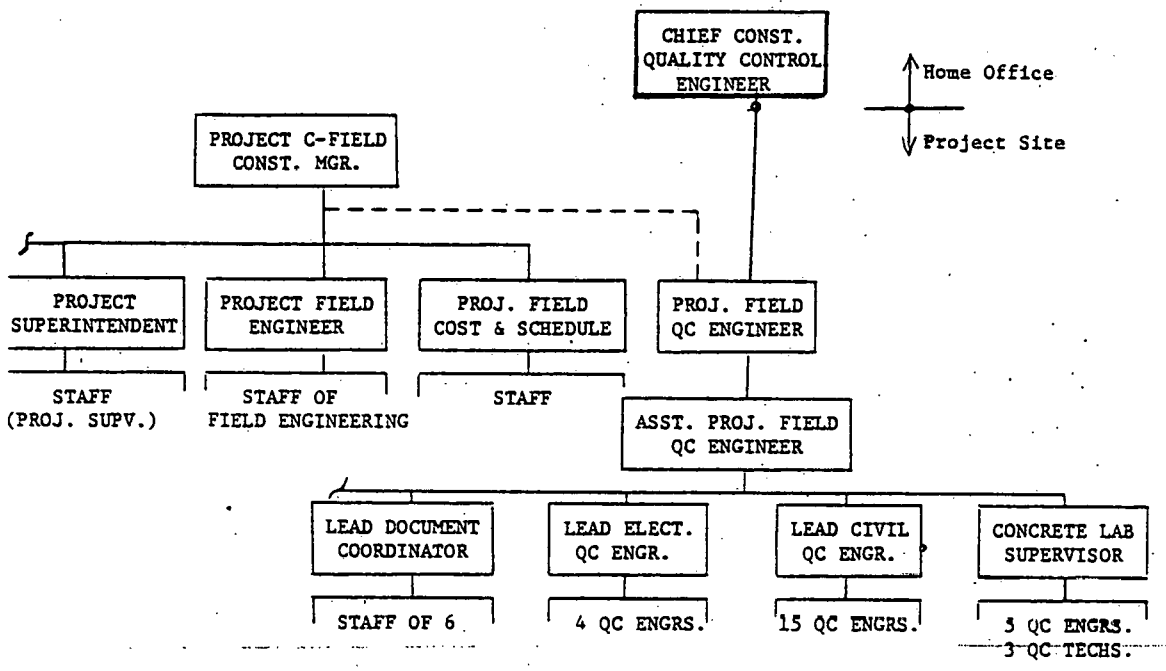


Figure A.12.--E.P.C. Firm Quality Control Organization

(b) The Project Field Engineer is responsible to the Project Construction Manager for supervision of field engineering activities at the jobsite. In performing this function, he assigns qualified Field Engineers through the associated Lead Discipline Field Engineer within each discipline to provide engineering direction and monitor construction activities. The Project Field Engineer is responsible for the accuracy and completeness of engineering documentation, ascertaining that work is properly performed, and that defects

are removed and repairs are carried out in accordance with the applicable codes, engineering drawings, project specifications, and quality control procedures. He maintains liason with project design engineers.

Some of the quality related responsibilities of the Field Engineers are:

1) Interpretation and clarification of drawings and project specifications through liason with discipline design engineers.
2) Verify Construction activities for compliance with Quality Program Criteria. Perform inspection activities of record as assigned by approved Inspection Plans.
3) Surveillance of special methods and procedures utilized by the Contractor/ Subcontractor.
4) Prepare prescribed nonconformance reports and provide for field disposition.
5) Coordinate with the responsible QC Engineers regarding identification of QC inspection and Hold Points. Notify QC Engineers and schedule sufficient time to perform inspections.
6) Planning and coordination of construction activities.
7) Initiating field change requests (FCR's) to resolve discrepancies or conflicts in project drawings and specifications

(c) The Project Field Quality Control Engineer (PFQCE) reports to the Chief Construction Quality Control Engineer for "technical" and "administrative" direction and to the Field Construction Manager for project coordination. The PFQCE supervises the quality control and inspection functions and sees that the quality of the work is properly inspected and documented. The PFQCE provides direction and supervision of the concrete testing laboratory and is responsible for the maintenance and safeguarding of the field quality files.

The PFQCE has authority to stop work. This authority, exercised through

the Project Construction Manager, shall require immediate cessation of work operations or construction activities determined to be improperly controlled and where corrective action would be extensive or may not be fully effective. Some of his field Quality Control tasks include:

1) Supervision of jobsite quality control, construction inspection, and documentation.
2) Preparation of jobsite quality control documentation and maintenance of the quality control files.
3) Second level Surveillance inspection of other contractor's/subcontractor's quality control programs.
4) Provide supervision for Concrete Testing Laboratory.
5) Supervise the preparation of field prepared Inspection Plans and provide technical direction regarding determination and selection of inspection points.
6) Determination of additional inspection steps to those appearing on the Master Inspection Plans and requesting approval of additional QC Hold Points by the Chief Construction Quality Control Engineer.
7) To supervise and maintain a systematic quality control inspection program for the corrective actions resulting from nonconformance reports. The quality inspections for repair or rework to resolve a nonconformance report will be at least equal to those imposed on the original work.

(d) The Quality Control Engineers and Technicians report to the PFQCE and perform the following Quality Control responsibilities (partial list):

1) Prepare detailed Field Inspection Plans (from the home office prepared Master Inspection Plans) to include the inspection steps which will be performed to assure compliance to the Quality Program Criteria requirements. The QC Engineer will identify to the Field Engineer the QC

inspection Hold Points. QC Hold Point inspections shall be performed by QC Engineers.

2) Perform quality control inspection tasks in accordance with the requirements of approved inspection plans.

3) Sign and date inspection reports for the inspection steps performed, including final acceptance sign-off of all prescribed inspection reports signifying to the completeness of the report.

4) Initiate Nonconformance Reports and monitor for compliance to procedure the Nonconformance Reports initiated by others.

It should be noted that during the summer of 1977 there were approximately 67 QC personnel employed by the EPC Firm on Project C. As noted in Figure A.12, there were 16 involved in the Civil function and 9 in the concrete inspection and testing function.

QUALITY ASSURANCE POLICY DOCUMENTS

The total Quality Assurance Program discussed above is implemented through a series of documents and manuals which describe the specific duties and responsibilities of each party. The development of these policy documents is a combined effort of Utility C and the EPC Firm. Figure A.13 depicts the relationship between these documents and manuals. It should be noted that the policy documents which apply to engineering/design, procurement and subcontractors have been deleted for the sake of clarity.

An explanation of the documents which specifically apply during the concrete phase will be presented below.

As noted in Figure A.13 the PSAR and the Project C Quality Assurance Program are developed in response to the guidelines in 10CFR50, Appendix B. Both Utility C

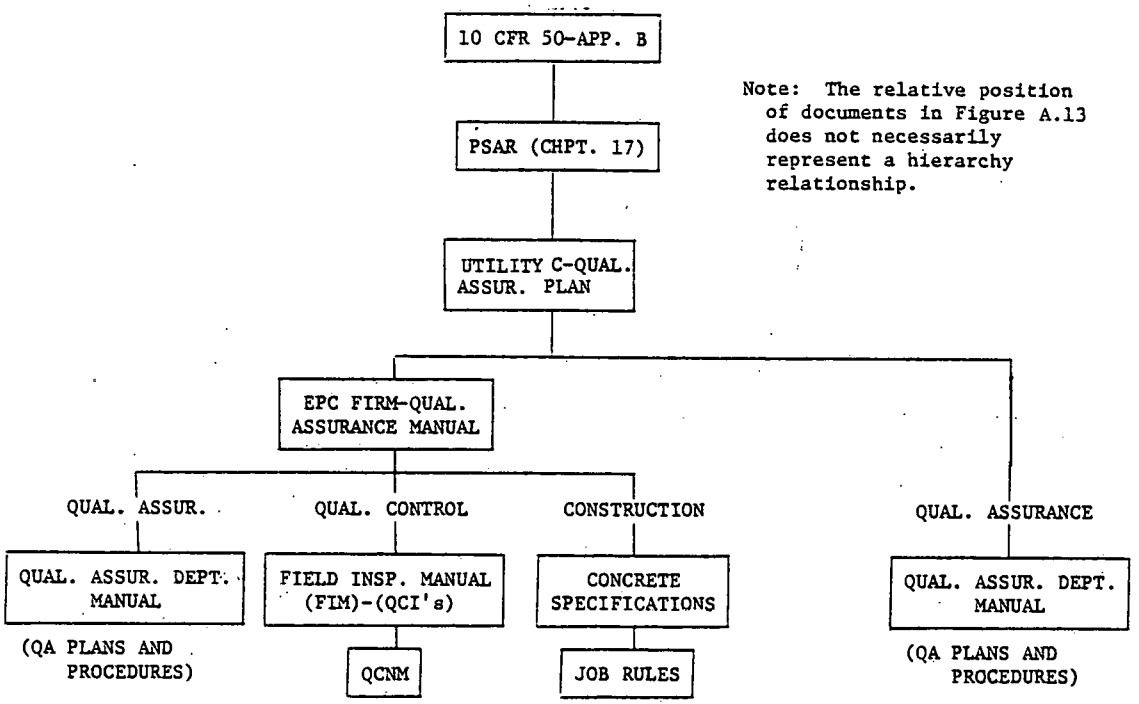


Figure A.13.--Project C Quality Assurance Documents

and the EPC Firm have a Quality Assurance Manual which describes in an overview fashion what type of a role they will each have with regard to Quality Assurance. The remainder of the documents shown in Figure A.13 provide more specific guidelines.

Utility C

The site QA group activities are defined in a QA Department Manual which consists of a series of QA Plans and Procedures which provide the "how to" instructions for auditing, surveillance and reporting.

EPC Firm.

1. Construction. The basic documents which the Field Construction group uses are Technical Specifications and Job Work Rules (i.e. Construction Procedures).

a. Technical Specifications. Specifications provide guidance for both Field Engineers as well as Craft Supervisors. The specifications insure that the proper design requirements are implemented during the construction phase and that the stipulations in the latest industry codes and standards are implemented. On Project C the following specifications are related to the concrete phase.

Spec	Title	No. pages	No. of[1] Revisions	No. of Addenda[1] or Additions Between Rev.
1.	Furnish and Erect Batch Plant	12	3	3
2.	Furnishing and Delivery of On-Site Concrete	38	6	46
3.	Furnish, Detail, Fabricate and Deliver Reinforcing Steel	11	8	11
4.	Forming, Placing, Finishing and Curing of Concrete	28	9	37
5.	Testing of Concrete, Soils and Reinforcing Steel	7	1	6

[1]Approximate Number in Summer 1977.

b. Job Work Rules. In order to provide more explicit guidance to the construction group with regard to specific phases of construction at Project C, the requirements in the specifications and the specific construction practices which will be followed are incorporated into a series of specific Job Work Rules. The basic one for the concrete phase on Project C is: "Job Rule for Concrete Construction"--16 pgs, 11 Revisions.

These specific Job Work rules are prepared at the Project site by Project Field Engineering. They are modified versions of a series of "General Work Rules" and "Standard Work Rules" (which are used by the EPC Firm on all projects) which reflect the practices on Project C. These Job Work Rules, including all revisions and amendments, are reviewed and approved by the Project Field Quality Control Engineer for compatibility with the requirements of the applicable quality control inspection plans.

2. Quality Control. The basic documents which the Field Quality Control group uses are the Field Inspection Manual (i.e. FIM) and the Quality Control Notices Manual (QCNM).

a. FIM. The Field Inspection Manual is the program manual for the Quality Control Department. The manual describes the standard field quality control program for the EPC Firm personnel concerned with the control of quality during the construction of Nuclear Power Plants. It identifies areas of authority and responsibilities, describes functions and tasks, and authorizes procedures and forms to be used for conducting inspection/surveillance of construction activities.

The FIM also contains the procedures to be used by the EPC Firm personnel to perform the necessary inspection/surveillance required to ascertain compliance with the Program Criteria, i.e. project specifications, drawings and other applicable requirements. Included in the FIM are the Quality Control Instruction (or QCI's) which are field working instructions that specify what inspection is required for a particular activity, and what sequence the inspection will follow. The QCI's are generally prepared in the Quality Control Home Office but individual projects may modify them as required. These QCI's incorporate the requirements found in the technical specifications as well as the Job Work Rules into a document which allows the QC Inspector to determine if the actual construction practices he witnesses, surveys, or inspects are in agreement with the commitments that were made.

An example of a concrete related QCI is entitled "Preplacement Inspection of Concrete". This instruction guides the inspector with regard to: (1) Prerequisite Review, (2) In Process Inspection (surveillance, monitoring by observation) and (3) Final inspection (close visual examination or measurement) of this phase.

The Quality Control Inspection Report (QCIR) on the last page of the QCI is filled out according to the type of inspection or surveillance that is required. After the QC Inspector has "signed off" on all of the items on the QCIR the placement is released by him for concrete delivery.

Two other QCI's which apply to the concrete phase are: (1) Concrete Placement Inspection and (2) Post Placement Inspection of Concrete. All three of these QCI's are discussed in greater detail in the main chapters in this report.

b. QCNM. In addition to the FIM, a Quality Control Notices Manual (QCNM) provides administrative instructions and technical direction to QC personnel. Three types of Quality Control Notices are issued by the Chief Field Quality Control Engineer to supplement the standard procedures contained in the Field Inspection Manual. These notices are issued in the form of memoranda as either General Administrative Notices, General Technical Notices or Project Special Provisions Notices (PSP's). Project Special Provisions Notices are used to convey special and unique project administrative instructions and technical directions that supplement and/or supercede the standard procedures contained in the Field Inspection Manual for a specific project. For any given project, modifications of the standard QC program described in the basic FIM are contained in the Project Special Provisions QC Notices issued for that project.

3. Quality Assurance. The EPC Firm site QA group activities are defined in a QA Department Manual which consists of a series of QA Plans and Procedures which provide the "how to" instructions for auditing, surveillance and reporting.

CASE STUDY--PROJECT D

PROJECT ORGANIZATION

Project D is the first nuclear plant and the largest project, both in terms of size and cost, ever attempted by Utility D. The interrelationship of the parties involved in the concrete phase of the project is shown in Figure A.14.

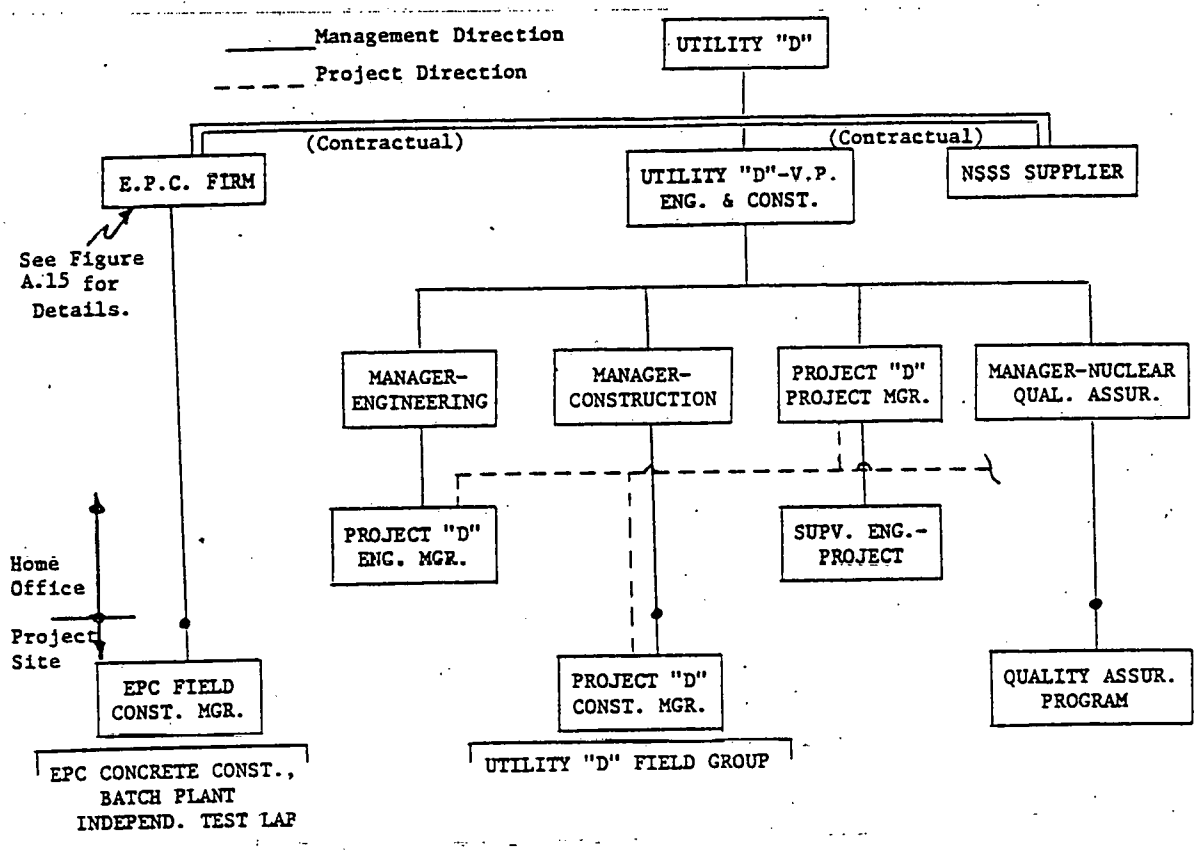


Figure A.14.--Interrelationship of Parties Involved in the Concrete Phase

As noted in Figure A.14, the Vice President of Engineering and Construction, through his appropriate managers, is responsible for Utility D's involvement related to Engineering, Construction, Project Management, and Quality Assurance.

The primary efforts related to the Engineering, Procurement and Construction

of Project D however have been delegated, under contract to a single EPC Firm. It should be noted that this is the same firm that is under the EPC contract on Project C. This firm, as will be noted below, is responsible for the major Quality Assurance/Quality Control on the project site. With regard to Quality Control it should be noted that a difference between Projects D and C is that on Project D the EPC Firm has contracted the concrete testing responsibility to an independent Testing Laboratory.

Utility D

As shown in Figure A.14, the overall home office coordination responsibility for the project has been delegated to a Project D Project Manager. He provides project direction for a Project Team consisting of a Project D Engineering Manager, a Project D Construction Manager, and a Supervising Engineer. Other members of the Project Team not shown in Figure A14 are representatives of the Plant Operations, Startup and Testing group. The Project Manager is accountable for all: (1) licensing, (2) environmental, (3) budget and schedule management, and (4) prime contract (i.e. EPC and NSSS Firms) activities related to Project D. It should be noted that the Manager of Nuclear Quality Assurance is considered to be independent of the project team.

The head of Utility D's staff at the project jobsite is the Project D Construction Manager who reports for "management direction" to the Manager of Construction in the home office and for "project direction" to the Project D Project Manager. The on-site project staff during the summer of 1977 consisted of approximately twenty-three personnel. Engineering disciplines such as Civil, Electrical, Mechanical and Start-up and Test along with Finance and Accounting are represented in the site organization. The size of each specialty varies with the particular stage of the project. The responsibilities of the field

organization are to monitor the EPC Firm's construction activities and to provide coordination of construction and procurement activities as the owner's representatives. In addition, Utility D's on-site Quality Assurance personnel have the responsibility for verifying that the EPC Firm's construction and quality control activities, which affect the quality of installation of al permanent plant materials and equipment are in adherence with sound, established construction installation practices and quality requirements.

EPC Firm

As noted above, the EPC Firm on Project D is also serving in a similar capacity on Project C. The organizational structure originally shown as Figure A.10 in the Project C case study is included here as Figure A.15 for ease of reference purposes. The interested reader is referred to the Project C case study for the accompanying

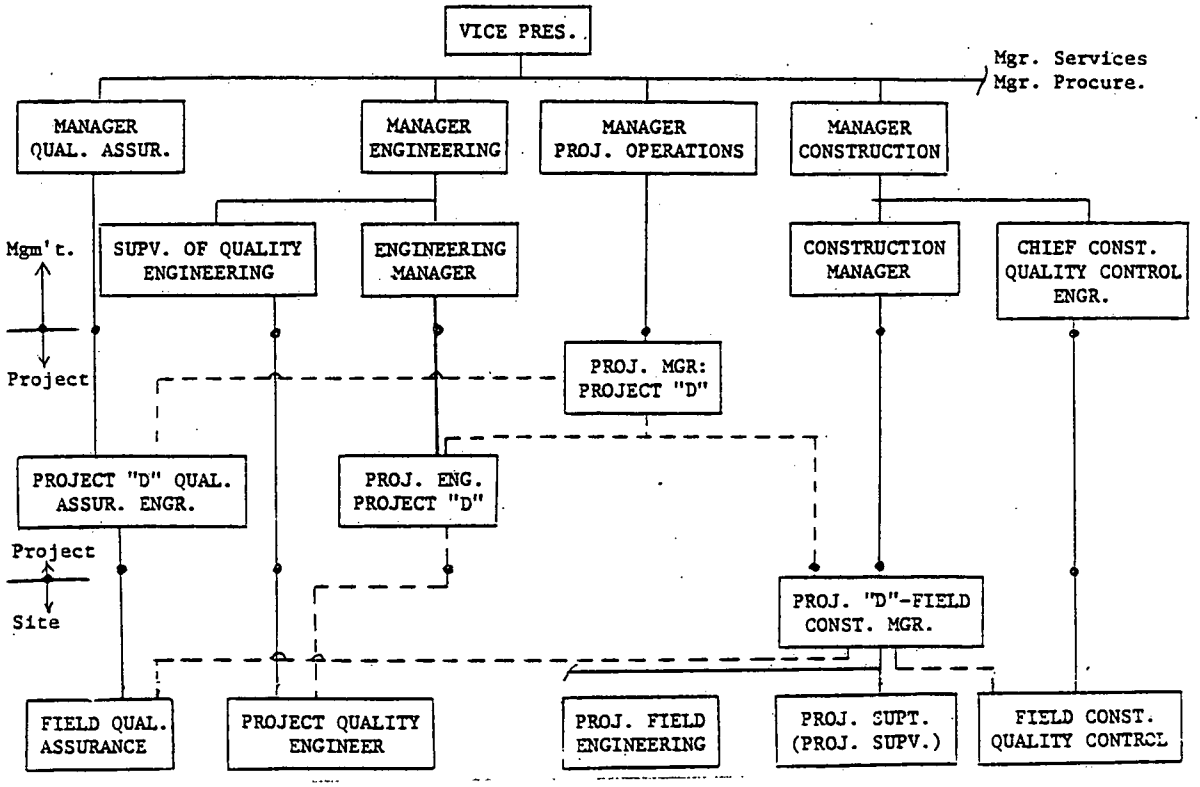


Figure A.15.--E.P.C. Firm Organization

explanation since the organizational structure at the upper management levels on both projects is essentially identical.

It is estimated that during the peak of the concrete phase on Project D, (Sept. 1976) the EPC Firm employed the following number of non-manual employees at the project site (total = 485).

1. Supervision 60
2. Field Engineering 163
3. Subcontract Administration 14
4. Cost/Scheduling 33
5. Finance/ Accounting 116
6. Procurement 26
7. Quality Control 65
8. Quality Assurance 8

QUALITY ASSURANCE PROGRAM

The Quality Assurance Program on Project D applies to those structures, systems and components of reactor facilities which are safety related. A "Q" list which identifies these structures, systems and components was jointly prepared by the EPC Firm and Utility D.

On Project D, the involvement of both QA and QC personnel is limited to construction activities associated with these "Q" Listed items. For "Q" listed concrete placements, EPC Firm Quality Control personnel monitor and inspect to about the same level of detail that was discussed for Project C. During the pre-placement phase, for example, after the QC inspector is satisfied with the performance, he "signs off" the Concrete Placement Form to indicate that the concrete can be released. Quality Assurance personnel (from the EPC Firm and possibly also from Utility D) oversee the effort to verify that the correct procedures have been followed and that correct documentation has been provided. For Non-"Q" concrete placements, however, there is no involvement of QA or QC, the responsible field engineer "signs off" the appropriate Concrete placement Form and follows the placement through to its "Post Placement" stage.

Quality Assurance

1. Utility D. As noted earlier, Utility D's Manager Nuclear Quality Assurance (MNQA) is responsible for the QA Program related to Project D. He directs a group of about 23 field and home office personnel in various quality verification functions. Figure A.16 indicates that a Resident Quality Assurance Engineer (RQAE), Supervising Engineer NQA-Engineering, and Supervising Engineer NQA-Procurement report to him. The RQAE and his staff (consisting of approximately 12 people during the summer of 1977) monitor and audit the site activities of: (1) Utility D, (2) The EPC Firm, and (3) Various other subcontractors. The two supervising engineers mentioned above direct a home office staff which monitors and audits the home office and/or fabrication facilities of Utility D, the EPC Firm and the various vendors and subcontractors.

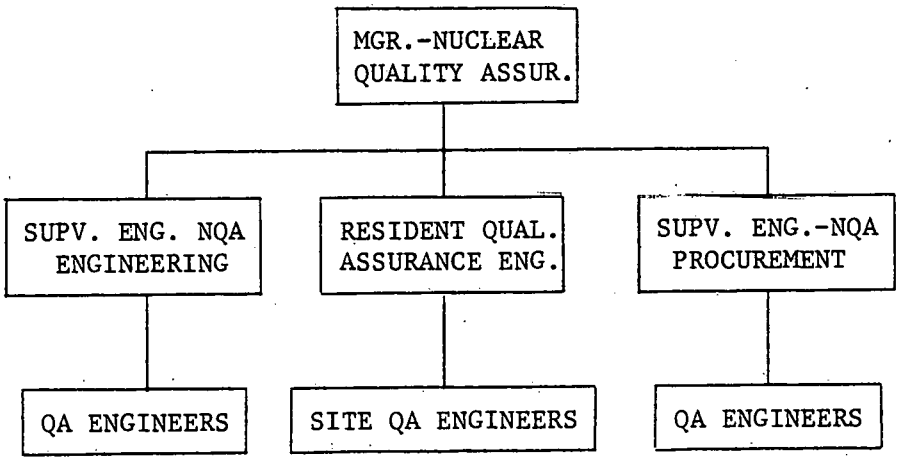


Figure A.16.--Utility D Quality Assurance Organization

The RQAE directs the daily operations of the site QA engineers (who are technically skilled in the mechanical, civil, and electrical disciplines) in the accumulation and control of QA/QC documentation and records, the review of the EPC Firm's quality related procedures, the conduct of site Audits and

impromptu monitoring activities and the reporting, controlling and dispositioning of nonconformances.

The major QA emphasis is placed in the three quality verification functions below which are defined on Project D as follows:

1. Auditing: A function performed by Utility D's QA group to determine, through investigation of the EPC Firm's Construction, QC and QA activities, the adequacy of, and adherence to, established procedures, instructions, specifications, codes and other applicable contractual and licensing requirements, and the effectiveness of implementation. Audits are conducted on a periodic basis or when there is accumulated evidence, based upon the results of random, impromptu monitoring, that a need exists for a comprehensive audit of a specific area or activity.

2. Random, Impromptu Monitoring: A function performed by Utility D's QA group to provide immediate feedback on the day-to-day quality related activities of the EPC Firm and subcontractors.

3. Site Surveillance: A function performed by Utility D's QA group to verify that the EPC Firm's construction and quality control activities, which affect the quality of installation of all permanent plant materials and equipment, are in adherence with sound established construction installation practices and quality requirements.

Audits are usually preplanned and performed periodically by an audit team consisting of Utility D's QA personnel (who are sometimes joined by the QA personnel from the EPC Firm). A checklist is developed based upon all of the pertinent information, guidelines, codes and standards, procedures and specifications related to the activity scheduled to be audited. Quality is then judged by adherence to the checklist through a pre-audit conference, the audit and a post audit conference. A pre-audit conference is basically an introduction of

members of the organization or departments involved and a brief description of what will be audited. The post-audit conference reveals the findings of the audit and the necessary action required. The audit is closed when the corrective action (if needed) is completed.

2. EPC Firm. As shown in Figure A.15, the EPC Firm also has a Quality Assurance group at the project site. During the summer of 1977, it consisted of 1 Lead Field QA Engineer who directed a staff of six QA Engineers. Since their organizational relationship within the EPC Firm and their responsibilities are very similar to those on Project C, the interested reader is referred to the appropriate section of the Project C Case Study (pgs. A.40 to A.41) for additional details.

Quality Control

On Project D, the EPC Firm has been given total responsibility for the Quality Control effort. The interested reader is again referred to the Project C case study for a discussion of the EPC Firm's QC program since there is a great deal of similarity between the two projects.

During the summer of 1977, the Project Field Quality Control Engineer (PFQCE) on Project D directed a staff of approximately 69 QC Engineers (with 24 in the Civil area) and 20 Construction Assistants and Clerks. It was anticipated that the group would peak at about 90-95 as the project enters the electrical and mechanical phases.

The organizational structure on Project D is similar to that shown in Figure A.12 of the Project C case study. The major difference occurs with regard to the concrete testing function. On Project D the PFQCE merely coordinates activities with the personnel from the independent Concrete Testing Laboratory. He does, however, provide QC inspectors for the concrete batch plant operation.

The overall objective of the QC group is to implement a Quality Control Program which applies to all safety related items, and to provide service as requested by either Utility D or the EPC Firm. The activities that are performed related to the concrete phase include:

Quality Verification and Inspection (commonly referred to as First Level Inspection) which includes:

1. Receipt Inspection of Concrete Materials
2. Storage Inspection
3. Preplacement, Placement, and Post Placement Inspection

They also perform a Second Level "Surveillance" role on subcontractor activities.

QUALITY ASSURANCE POLICY DOCUMENTS

The series of basic documents and manuals which describe the specific duties and responsibilities of each party on Project D are very similar to those shown in Figure A.13 in the Project C case study. The discussion below will therefore be limited to only providing information which is particular to Project D.

Utility D

The site QA group activities are defined in a QA Department Manual which consists of a series of QA Plans and Procedures which provide the "how to" instructions for auditing, surveillance and reporting.

EPC Firm

1. Construction.

a. Technical Specifications. The following concrete related specifications

are used on Project D:

Spec.	Title	No. Pgs.	No. of[1] Revisions
1.	Concrete Mixing Plant	15	3
2.	Furnishing and Delivery of Concrete	33	9
3.	Furnish, Detail, Fabricate and Deliver Reinforcing Steel	14	6
4.	Forming, Placing, Finishing and Curing Concrete	42	7
5.	Material Testing Services	34	8

[1]Approximate Number in Summer 1977.

b. Job Rules. The following Job Rules are used on Project D: "Job Rule For Concrete Construction"-- 10 pgs., 6 revisions.

2. Quality Control

a. FIM. The QCI's related to the concrete phase on Project D are very similar to the ones on Project C with only minor modifications to reflect site practices.

b. QCNM. The same basic approach used on Project C regarding adminstrative instructions and technical direction to QC personnel is followed on Project D.

3. Quality Assurance

The EPC Firm site QA group activities are defined in a QA Department Manual which consists of a series of QA Plans and Procedures which provide the "how to" instructions for auditing, surveillance, and reporting.

CASE STUDY - PROJECT E

PROJECT ORGANIZATION

Project E is unique among the power plant projects in the research study because the owner, Utility E, is also serving as the Engineer Designer, Constructor, Concrete Supplier (with an on-site batch plant)and Concrete Testing Agency. Utility E has vast experience in the design of hydroelectric, fossil, and nuclear generating facilities. The organizational structure which they have developed to manage their continuing need for new generating capacity is shown in Figure A.17.

In order to maintain a degree of independence between the functions of: (1) ownership and operation and (2) engineering and construction, different offices within Utility E are involved in Project E. As noted in Figure A.17, the Office of Power which is primarily concerned with plant operations, and hence has a relatively limited involvement in the design and construction phases of the project, is considered to be the "Owner" of Project E. The Office of Engineering Design and Construction (OEDC), which is located in another city, is considered to be the "Engineer/Constructor" of Project E.

The total Quality Assurance effort of OEDC is under the direction of the OEDC Quality Assurance Manager. He is assisted in these efforts by QA staffs which are permanently assigned to both the Division of Engineering Design (DED) and the Division of Construction (DEC).

Engineering

The engineering/design effort related to Project E is under the direction of the Manager Design: Project E who is a member of the "Design Projects" group which reports to the Director - Division of Engineering Design. The Manager Design: Project E is in charge of the three functional groups: Civil, Electrical

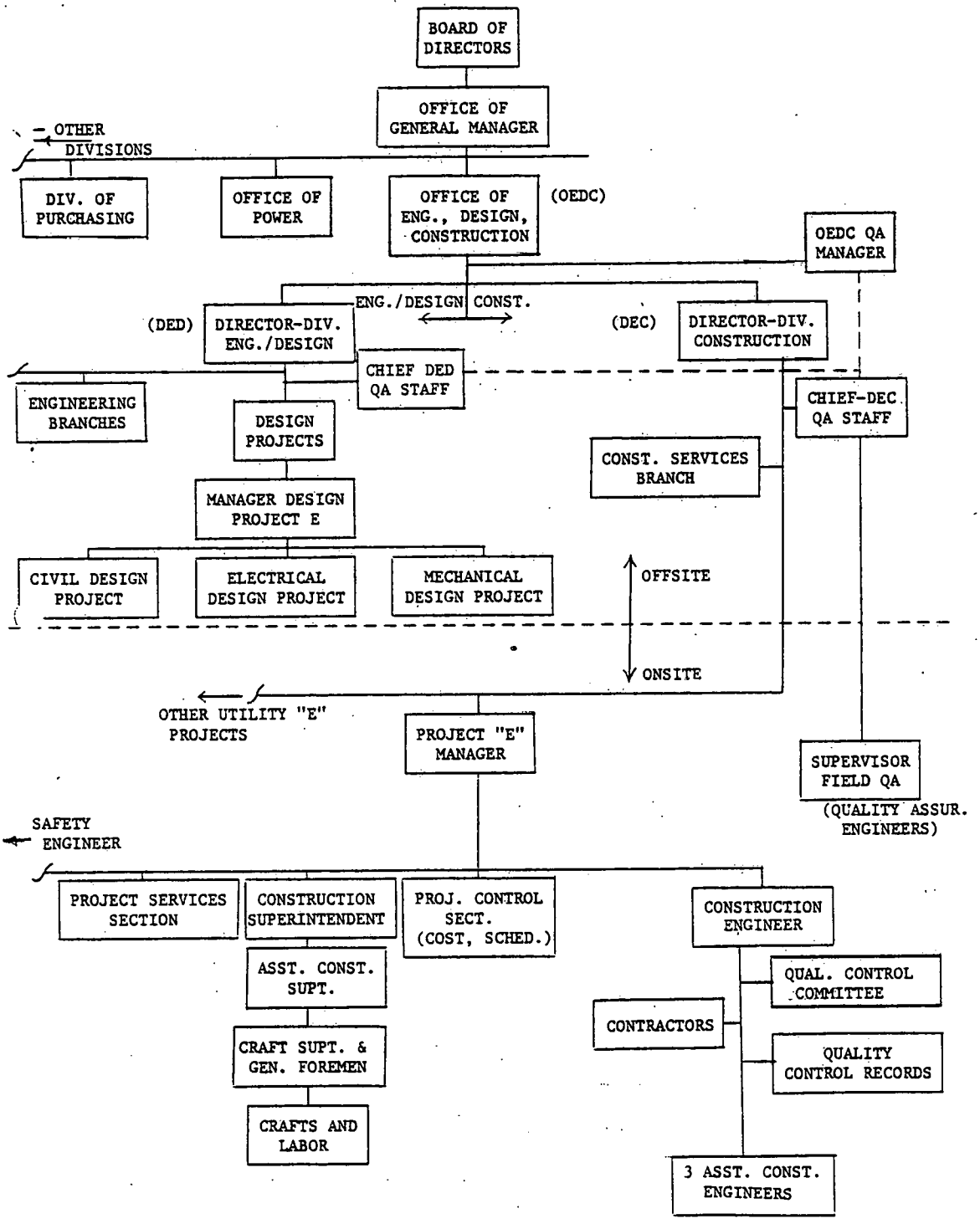


Figure A.17.--Utility E Organization

and Mechanical that are responsible for basic engineering related services which are required.

Construction

The Director of Construction is responsible for Utility E's construction program throughout its entire system. One of the home office staff departments within the Construction Division, as mentioned above, is the DEC "Quality Assurance" staff. The Chief of the Q.A. group is in charge of Utility E's Quality Assurance effort within the Construction Division. He is represented on the project site by a Supervisor of Field Quality Assurance. The organizational position of the Quality Assurance group directly within the Construction Division represents an alternative to the "independence" requirement in 10 CFR Part 50, Appendix B, which has not been observed on any of the other projects in the research study.

The on-site construction group is under the direction of a Project E Manager. The division of responsibility between Construction Supervision, Construction Engineering, Project Control, etc. is fairly typical of the arrangements found on other projects. It should be noted,however, that the function of Quality Control is not separately identified in Figure A.17 since it falls within the responsibility of one of the three Assistant Construction Engineers that report to the Project Construction Engineer. There is a staff group to the Project E Construction Engineer which is designated as a "Quality Control Committee" and a staff group to the Construction Engineer which is responsible for Quality Control Records.

The role of the Quality Assurance as well as the Quality Control group will be discussed later in this case study in more detail. It should be noted, however, that the Quality Control alternative presented in Project E also represents a unique approach to insuring independence between those who perform the work (i.e., the organization which is under the direction of the Construction Superintendent) and those that inspect the work (i.e., the Quality Control group which is under the direction of the Construction Engineer).

An estimate of the number of Utility E personnel that will be on the project site during the peak concrete phase (which will occur in the spring of 1979) is: Total = 625.

1. Craft Supervision - 50
2. Field Engineering -378 (including Quality Control)
3. Trades and Labor Administration -15
4. Project Controls & Scheduling -15
5. Materials Receipt & Storage -50
6. Quality Assurance -12
7. Project Services -60
8. Other (Training, Public Safety,Personnel, Medical) -45

QUALITY ASSURANCE PROGRAM

The Quality Assurance Program on Project E applies to those construction quality - affecting activities involving structures, systems and components that prevent or mitigate the consequences of postulated accidents that could cause undue risk to the health and safety of the public. The Division of Engineering Design (DED) is responsible for the identification of the items which are covered by the above-mentioned QA Program (i.e., Q list). The Division of Construction (DEC) is responsible for the physical identification at the project site, as appropriate, of the items covered by the QA Program. It should be noted, however, that it appears that the construction and quality control practices are essentially the same for all of the concrete on Project E.

Quality Assurance

The Quality Assurance effort within the Office of Engineering, Design and Construction (OEDC) can be viewed from two levels, the one being the responsibility of the OEDC QA Manager, the other being the responsibility of the QA staffs directly within DED and DEC.

1. OEDC Quality Assurance

One of the primary functions of the OEDC Quality Assurance staff is to perform both announced and unannounced Management Audits of the Quality Assurance programs of both DED and DEC. The purpose of the auditing effort is to evaluate the existence and effectiveness of, and compliance with the Quality Assurance Program; and to identify and make recommendations in areas that need improvement for compliance with Utility E policies, regulatory requirements, and accepted workmanship practices.

Audits embrace such functions as site investigations, design, procurement, vendor surveillance, receiving inspection, material control, excavation and soil compaction, concrete mixing and placement, reinforcing steel fabrication and installation, equipment storage and installation, preoperational tests, personnel qualifications, quality control, quality assurance and documentation.

The OEDC QA Manager approves the overall audit schedule and directs the overall auditing effort. These audits are usually performed by the OEDC QA Audit Section. The Audit Section consists of permanently assigned, qualified auditors, completely independent of any direct responsibility for the activities which they will audit. The audit schedule and the subject of the audit are arranged in accordance with two important considerations: (1) They are conducted early enough in the project schedules so that corrective action can be taken in a timely and efficient manner; and (2) Interference with the activities being audited are minimized.

The scope of an OEDC audit will consist of four major elements. These include: (1) Examination of procedures and instructions, (2) Observations of activity or product inspection and personnel interviews, (3) Examination of representative quality assurance records, and (4) Collection of objective evidence to support findings and recommendations.

2. Division of Construction Quality Assurance

The QA effort at the DEC level, under the direction of the Chief-DEC QA staff, is also primarily focused on the performance of Audits. Both internal audits (on portions of the DEC home office or project level organization) and external audits (in relation to a project site subcontractor's QA Program) are performed.

The project site audits on the Utility E Construction group are planned and conducted by QA Engineers located at the site and are scheduled by the Supervisor, Site QA. The QA Engineer is responsible for: (1) Identifying Quality Assurance Program deficiencies, (2) Recommending Corrective Action, (3) Preparing audit reports, and (4) Verifying corrective action implementation. Construction Project Supervision is responsible for (1) Signing and dating the Audit Finding Sheet to indicate understanding of the finding, (2) Designating on the finding sheet, the date of corrective action response to the finding, (3) Implementing mutually agreed corrective action and establishing measures to prevent recurrence, and (4) initiating resolution of disputed findings.

In addition to auditing, site QA personnel review (1) purchase requisitions to insure that all QA requirements are being met, and (2) QA and QC procedures for safety related materials and components to insure that they correspond to the commitments of the SAR. They also perform informal surveillance of site operations to insure that appropriate procedures and quality requirements are followed. Site QA is also responsible for administering certification tests to QC inspectors at project site.

Quality Control

1. Responsibility for Quality Control.

It was noted at the beginning of this Case Study that both Field Engineering and Quality Control and Inspection were under the direction of the site Construction

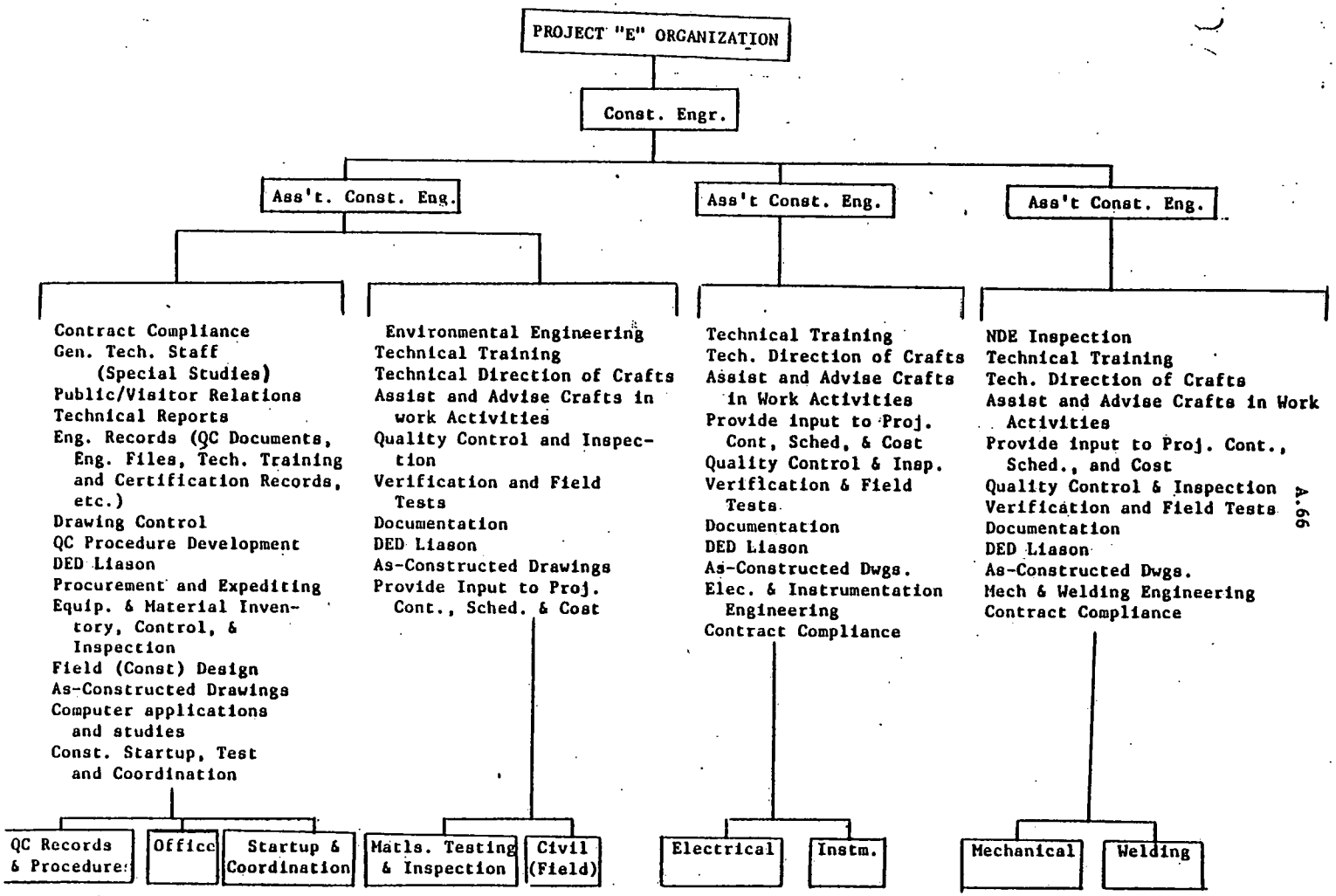
Engineer. Figure A.18, which is an extension of Figure A.17 below the Assistant Construction Engineer level, indicates more clearly the functions and responsibilities which define Field Engineering. It should be noted that both the Assistant Construction Engineer, who directs the Electrical and Instrumentation phase, and his counterpart, who directs the Mechanical and Welding phases, also have: (1) Quality Control and Inspection, (2) Verification and Field Test responsibility.

The responsibilities of the Third Assistant Construction Engineer are divided into the Office Administration area (which includes the maintenance of QC records and the development of Field QC Procedures) and the Civil area. The latter area includes the Quality Control and Inspection responsibilities related to concrete placements as well as the Concrete Batch Plant Inspection and Concrete Testing program.

As noted earlier, this arrangement represents a unique approach among the nuclear power plants in the study with respect to the separation of the construction and the quality control functions. The advantage to this approach, as will be noted below, is that it places the major burden for the quality of concrete directly in the construction organization level.

2. Concrete Quality Control.

The quality control of concrete on Project E is defined in a Project E Quality Control Procedure (QCP) entitled, "Concrete Placement". The Supervisor of Materials Testing and Inspection (who reports to the Assistant Construction Engineer-Civil) directs the activities of the Materials Engineering Unit, which consisted of approximately two engineers, thirteen Construction Inspectors and three Materials Testers during the Summer of 1977. This group acts as a field extension of Utility E's Central Testing Laboratory on Project E.



NOTE: Field Engineering and Inspection functions are in the same organization unit.

Figure A.18.--Responsibilities of Utility E Field Construction Organization

A.66

The division of responsibility for concrete quality is defined in the above mentioned QCP as follows:

1. The Materials Engineer shall be responsible for the quality of concrete produced and the inspection and documentation of placement of concrete.

2. The Civil Engineering Unit shall be responsible for ensuring all prerequisite requirements for placing of concrete are complete and that concrete is placed in the correct pour. This shall be done with a tag placed on the form that corresponds with the inspector's pour card.

3. The Construction Superintendent is responsible for all concrete transporting and placing activities.

A "Concrete Pour Card" is used as an inspection and control record for each concrete placement. The front side of the card serves as a "release" when signed by each craft and countersigned by the appropriate Construction Engineer. The rear of the card forms the inspection record for concrete placement. The inspector merely indicates that the following four items are "Acceptable": (1) Surface Preparation and Cleanliness, (2) Form Tightness, (3) Environmental Conditions, and (4) Conditions of the Placing Equipment. Once this has been completed, the concrete placement is officially "released".

It appears, therefore, that the major quality control effort during the pre-placement stage is the responsibility of the Construction Superintendents and Engineers. The Quality Control effort does not of itself generate its own documentation in the form of "Checklists", "Inspection Reports", etc. Quality Control Inspectors follow the acceptance criteria in the QCP entitled "Concrete Placement".

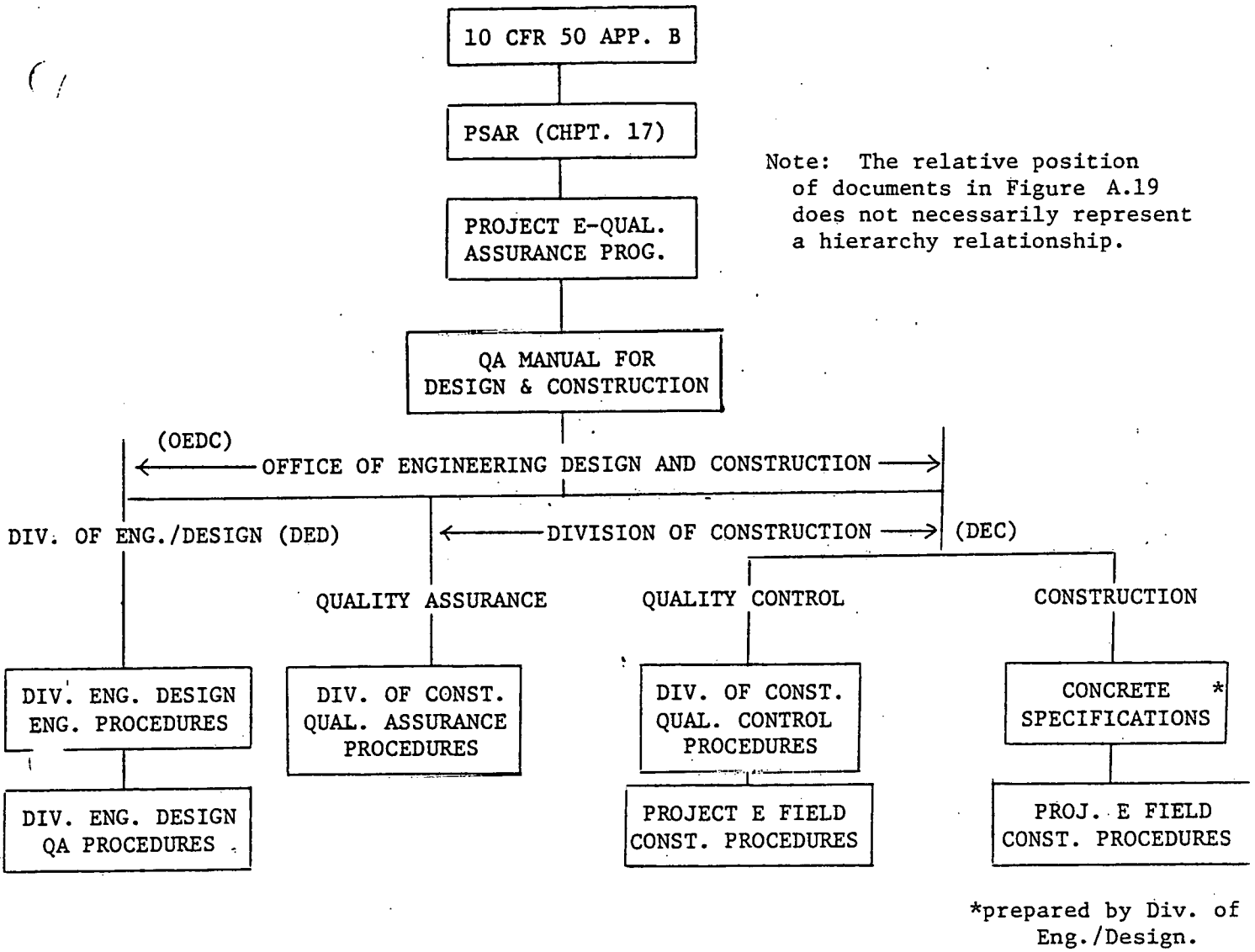
Quality Control inspectors are present during the placement, both for concrete testing and inspection purposes. An inspector, again using the guidelines in the QCP, must indicate on the Concrete Pour Card that the following

items are acceptable: (1) Deposit of Concrete, (2) Layer thickness, (3) Concrete Compaction, and (4) Illumination. A separate QCP entitled, "Concrete Curing and Repairing" indicates that the Supervisor of Materials, Testing, and Inspection is also responsible for the inspection and documentation of all concrete curing and repairing operations.

With regard to the testing function, the same Quality Control group mentioned above is also responsible for the concrete batch plant inspection function, testing of all concrete component materials and the performance of sampling and testing of concrete with regard to slump, air content, compressive strength, etc.

QUALITY ASSURANCE DOCUMENTS

The total Quality Assurance Program discussed above is implemented through a series of manuals and procedures (shown in Figure A.19) which describe the specific duties and responsibilities of each organization within Utility E. As noted in Figure A.19, the framework for the entire set of documents is established in the Project E Quality Assurance Program (which is described in the Safety Analysis Report). Utility E's Quality Assurance Program for design and construction of nuclear power plants is described in the OEDC Quality Assurance Manual for Design and Construction (DCM). Included in the DCM are the NRC requirements (10 CFR 50) and the procedures which define responsibilities and methods for satisfying those requirements. Volume 1 contains general requirements, including 10 CFR 50, OEDC procedures, and Interdivisional procedures. Volume 2 contains DED Quality Assurance Procedures, and Volume 3 contains DEC Quality Assurance Procedures and DEC Quality Control Procedures.



Note: The relative position of documents in Figure A.19 does not necessarily represent a hierarchy relationship.

Figure A.19.--Quality Assurance Documents

An explanation of some of the documents which are used by each Utility E organization will be presented below, with special emphasis being placed on those that are specifically related to the concrete phase.

Construction Group

1. Construction Specifications

The primary guidance regarding acceptable methods of performing construction operations are found in the Construction Specifications which are developed by the Division of Engineering/Design (i.e., DED). "General Construction

Specifications" apply to all Utility E projects while "Project Specifications" describe situations unique to a particular project or combination of projects.

The General Construction Specification entitled, "Plain and Reinforced Concrete" (Original issue--Feb. 1970, Rev. 1--April 1976, 52 pages) governs the production, preplacement, placement and post placement stages for all concrete. It is interesting to note that the only reference to reinforcing steel in this specification is "All details of reinforcement shall be in accordance with the latest ACI Standard Building Code Requirement for Reinforced Concrete". Formwork is also briefly mentioned, with reference being made to ACI 347 and another Utility E General Construction Specification entitled "Forms for Concrete Masonry" (Original issue--Feb. 1940, Rev. 1--October 1976, 12 pages). It is interesting to note that although a table entitled, "Tolerances for Formed Surfaces" is provided in "Forms for Concrete Masonry" specification , the reference to inspection of forms is very short (i.e., "Before placing concrete, forms shall be inspected for location, dimensions, surface finish, leak tightness, and cleanliness").

It should be noted that the Division of Engineering Design (i.e., DED) has concrete specialists in direct contact with field construction operations. In this way, designers can verify that the specifications are being interpreted in the manner that was intended. This also allows DED to identify misinterpretations without having to wait for them to turn up in QA audits and NRC inspections. Utility E also maintains a Central Materials Lab that can be used to verify design mixes and also perform research to find solutions to existing problem areas.

2. Project E Field Construction Procedures (FCP's)

In certain instances, Field Construction Procedures at the project site are prepared to supplement the information which is available in the Construction Specifications. An example of an FCP is the one entitled "Grouting of Rock

Foundations".

Construction Quality Control Group

1. DEC Quality Control Procedures (QCP's)

These are detailed instructions which apply to all of Utility E's nuclear plants which are under construction. They typically provide a method to control and/or measure the characteristic of an activity and the acceptance criteria and documentation requirements associated with that activity. An example is the QCP entitled, "Quality Assurance Requirements for Concrete Mixture Proportioning".

2. Site Quality Control Procedures (QCP's)

QCP's directly related to Project E are prepared by the Construction Engineering group at the project site and approved by the Site Quality Assurance Group. Project E QCP's are divided into two categories: Inspection QCP's (for example, "Batch Plant Inspection") and Test QCP's (for example, "Concrete Slump and Air Content Testing").

Inspection QCP's contain the following information:

A. Identification of characteristics to be inspected;

B. Identification of the individuals or groups responsible for performing the inspection activity;

C. Adequate and appropriate equipment;

D. Acceptance and rejection criteria;

E. Environmental conditions;

F. A description of the method of inspection;

G. Verification of completion and acceptability of inspection; and

H. A record of the results, acceptable and unacceptable, of the inspection activity.

Inspection QCP's, along with necessary drawings and specifications, are available

for review by the inspector prior to performing inspection operations. Mandatory inspection hold points may be established by Field Engineering, which require QC representation at the work area location. These hold points are usually established by the nature of the work being performed.

The results of each inspection must be documented. The documentation must include:

A. Identification of the item inspected;

B. Identification of the procedures, instructions, and/or drawings, including revisions, supporting the inspection activity;

C. Identification of the inspection activity;

D. Conditions encountered which were not anticipated, including nonconformances;

E. Statement of acceptability; unacceptable inspection results shall include traceable means of identifying corrective action documentation; and

F. Inspector or data recorder identification and date.

The QCP entitled "Concrete Placement" for instance describes the preplacement and placement inspection and documentation which is to be performed in relation to the following referenced documents: (1) the General Construction Specification entitled "Plain and Reinforced Concrete" and (2) ACI 304. Postplacement Inspection is covered in a QCP entitled "Concrete Curing and Repairing".

Construction Quality Assurance Group

1. DEC Quality Assurance Procedures

These are written policy statements which are prepared at the Utility E home office by the DEC QA staff and are applicable to all nuclear projects. They define the Quality Assurance/Quality Control program by describing

objectives, requirements, procedures and responsibilities related to such topics as: (1) Preparation, Review and Distribution of Inspection Reports, (2) Inspection, (3) Auditing Construction Activities, etc.

Division of Engineering/Design

1. Engineering Procedures

DED Engineering Procedures (EP's) are prepared to describe DED practice relating to design, procurement, and other engineering activities. Division-level EP's are prepared for activities which involve more than one organization within DED. An example of one of these is "Nonconformances--Reporting and Handling". Engineering Procedures can also be written pertaining to design project activities.

2. Quality Assurance Procedures

DED Quality Assurance Procedures are written to define the objectives, requirements, procedures and responsibilities related to the QA aspect of the Division of Engineering/Design's activities. The one entitled "Preparation, Review and Distribution of Inspection Reports", for instance, outlines the considerations and actions required of an inspector relating to inspection reports associated with nuclear power plant materials and equipment.

CASE STUDY--PROJECT F

PROJECT ORGANIZATION

Project F is the second unit of a two-unit PWR facility, the first of which has been in commercial operation since 1976. Although Utility F has the overall responsibility for the project, there are four other Utilities that are joint owners of the facility. The interrelationships of the parties involved in the concrete phase of the project are shown in Figure A.20. As noted in Figure A.20, the responsibility for the general direction of Project F through the design and construction stages has been assigned to the Vice President of the Engineering and Construction Division. A Project "F" Project Manager, who reports to him, supervises and coordinates a home office project team composed of members of the other departments within the division as well as members of the operating division. The Construction Department representative on the project team (who is located at the home office) supervises and coordinates the Project F activities in the construction area and the Quality Assurance Manager (who is located at the project

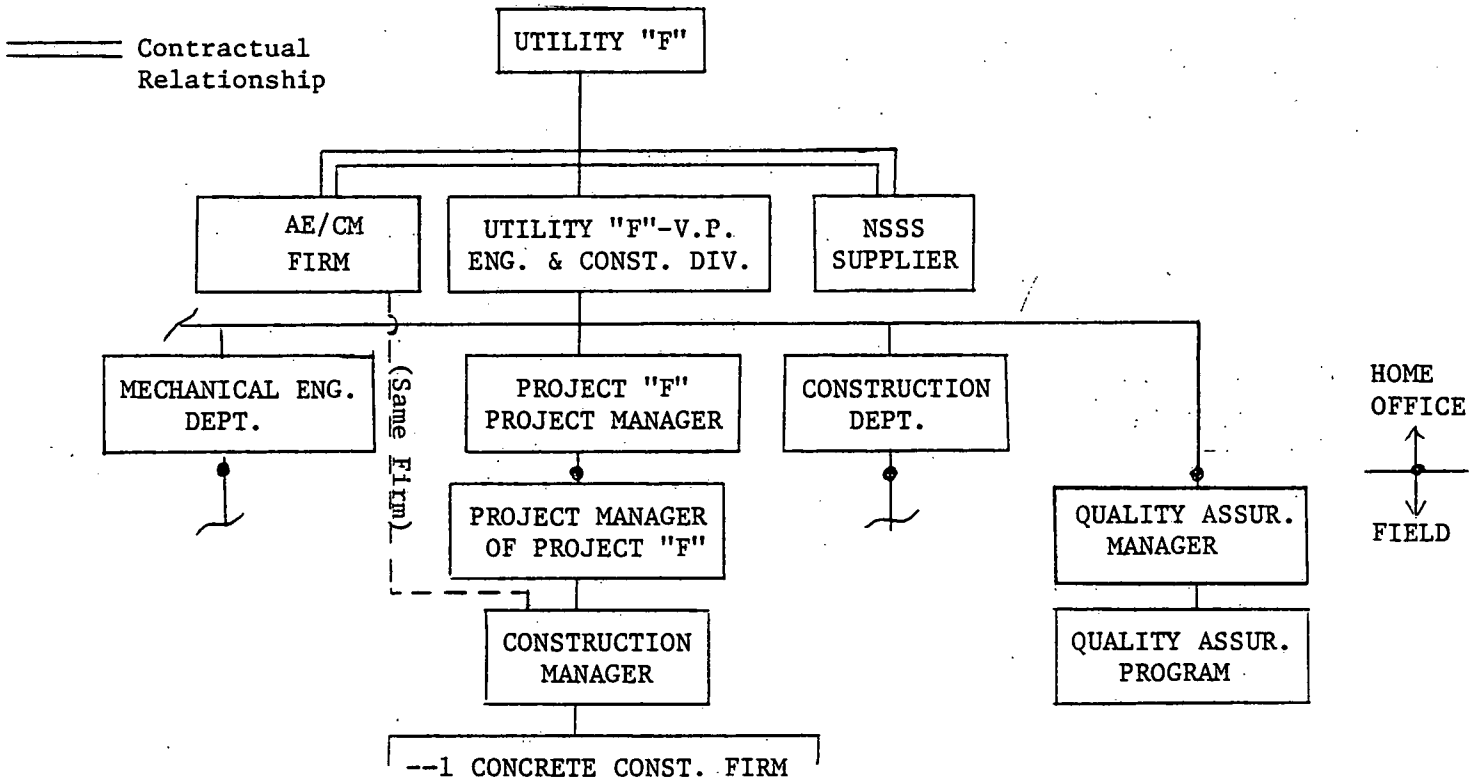


Figure A.20.--Project F: Interrelationship of Parties Involved In the Concrete Phase

site) directs the quality assurance program in accordance with engineering, construction and regulatory requirements.

An A.E./C.M. Firm has been retained to perform the engineering work which includes: design of all systems and components not supplied by the NSSS supplier, preparation of engineering drawings and specifications, procurement of a large percentage of the permanent plant equipment, etc. The same firm has also been retained as the Construction Manager and as such provides project site management and coordination services during the construction phase.

The original management design also placed the majority of the Field Quality Assurance and Quality Control responsibility with the same A.E./C.M. Firm. This was changed in 1976, however, when Utility F assumed direct responsibility for both of these areas.

The management interface of the A.E./C.M. Firm and Utility F with a typical construction firm at the project site can be shown in Figure A.21 for the case of the concrete contractor. It should be noted that with respect to construction related activities, the Construction Firm Project Site Manager, Resident Engineer and Craft

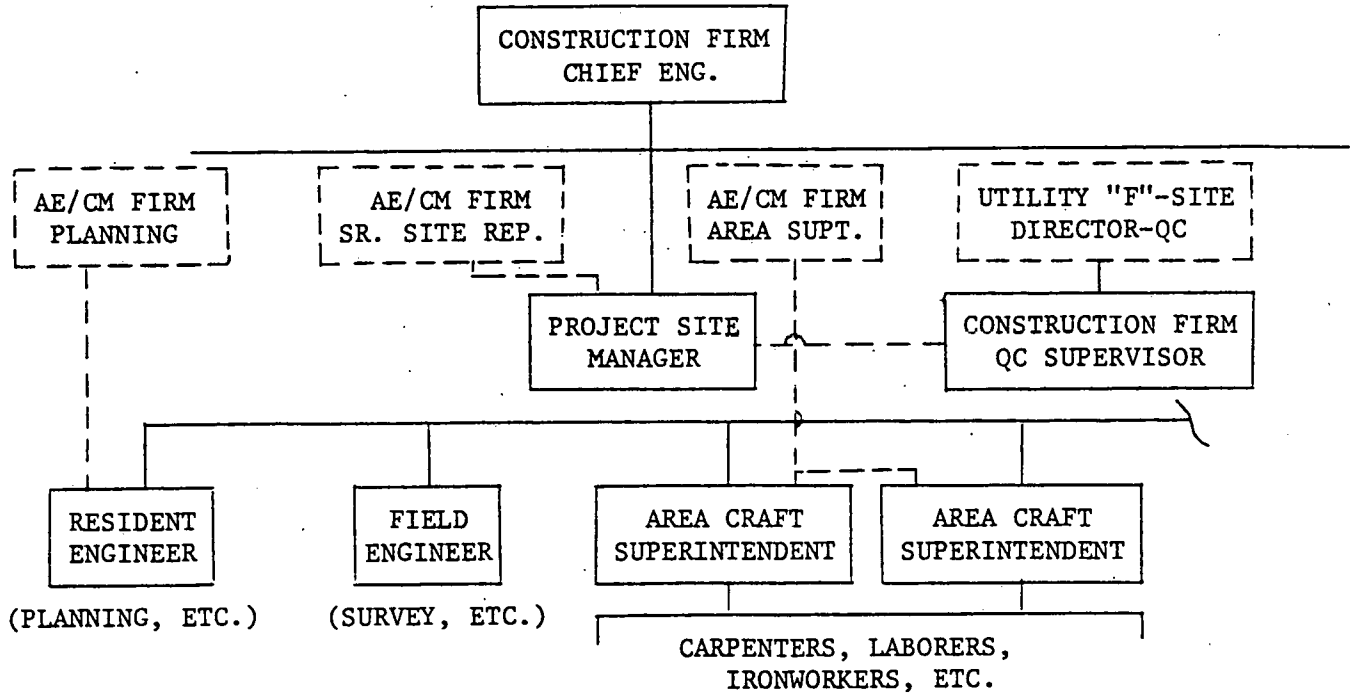


Figure A.21.--Management Interface Between: (1) the Concrete Construction Firm and (2) the A.E./C.M. Firm and Utility F

Superintendents receive site-related direction and interface contact from their respective counterparts on the AE/CM Firm's project management staff. With respect to Quality Assurance/Quality Control, however, the Construction Firm does not have an independent Quality Assurance Program; it in fact operates under the Utility "F" QA Program. The net result of this situation, as shown in Figure A.21, is that the construction Firm QC Supervisor is under the direct control of the Utility F Site Director-Quality Control who is located at the project site.

A separate contract was placed by the AE/CM Firm for an on-site batch plant with a concrete supplier who is responsible for the production and delivery of concrete, the receipt and testing of incoming concrete material components, etc. Although the Utility F-Site Director-Quality Control is represented at the batch plant by a Batch Plant Inspector he does not have the same level of control that is indicated in Figure A.21 because the concrete batch plant is operated under an independent Quality Assurance Program developed by the concrete supplier.

On Project F, all testing related to concrete, cadwelding, etc., is performed by personnel from the on-site Structural Testing Laboratory which is ultimately under the direction of the Utility F Site Director-Quality Control.

QUALITY ASSURANCE PROGRAM

Utility F's corporate Quality Assurance organization is located at the Project F jobsite and consists (as shown in Figure A.22) of a Quality Assurance Department directed by the Quality Assurance Manager. The QA Department, as shown in Figure A.22, is divided into the five major sections of:

1. Design, Procurement, and Construction--headed by the Quality Assurance Supervisor-Engineering/Construction.

2. Operations--headed by the Quality Assurance Supervisor-Operations.
3. Records--headed by the Quality Assurance Records Supervisor.
4. Site Quality Control--headed by the Site Quality Control Director.
5. Vendor Surveillance--headed by the Vendor Surveillance Supervisor.

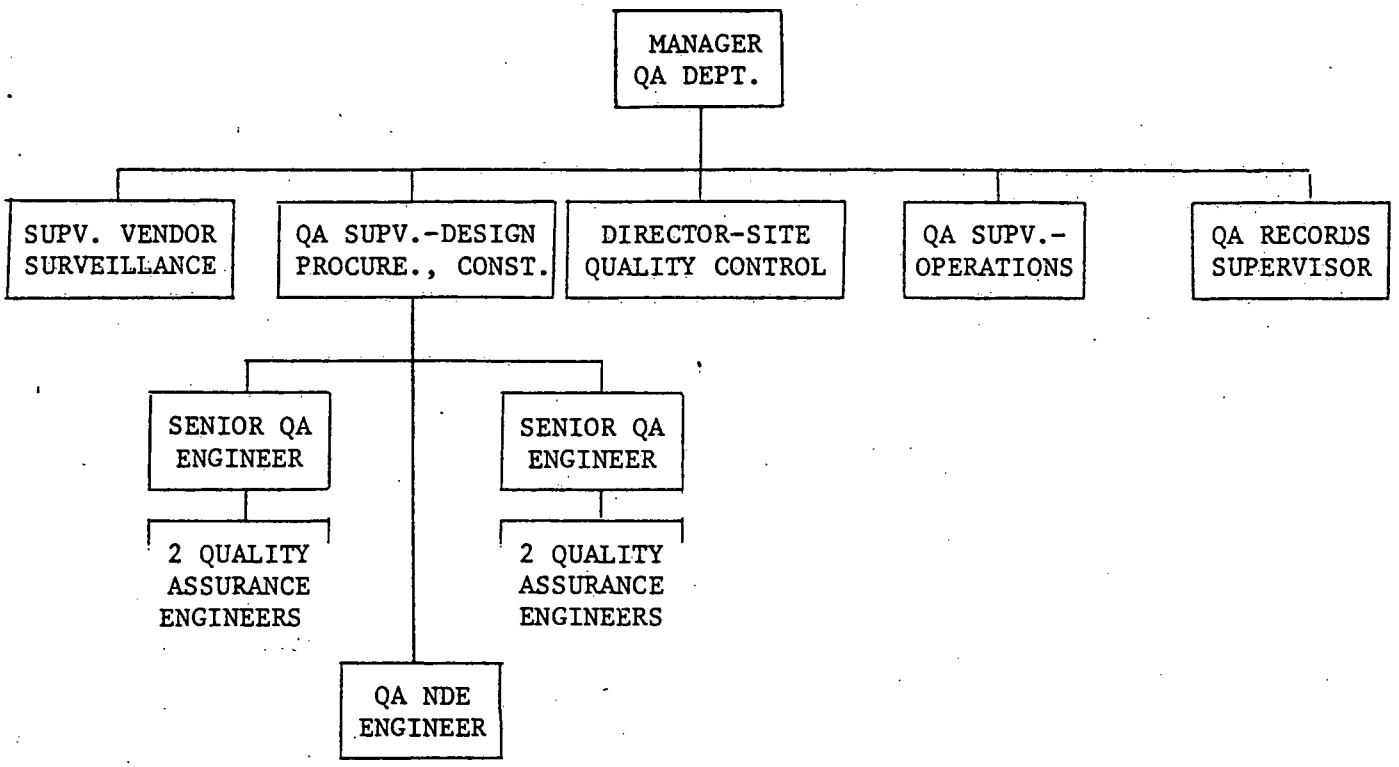


Figure A.22.--Utility F's Quality Assurance Organization

The discussion below will concentrate on the responsibilities of the Design, Procurement and Construction Section since this is the one that is of major interest from a construction QA standpoint (Operations is concerned with the QA requirements for Utility F's nuclear power plants which are already in operation). The Site Quality Control Section, which is under the direction of the same Manager of QA, will be discussed later in this chapter.

Quality Assurance Program Emphasis. The primary emphasis of the Design, Procurement

and Construction Section is involved with Third Level Quality Assurance Auditing. Utility F's Quality Assurance Program requires that a comprehensive system of planned and periodic audits be carried out to verify compliance with all aspects of the quality assurance program and to determine the effectiveness of the program. The Audits are performed in accordance with the written procedures or check lists by appropriately trained personnel not having direct responsibilities in the areas being audited. Audit results are documented and reviewed by management having responsibility in the area audited. Follow-up action, including re-audit of deficient areas, is taken where indicated. Audits include, but are not limited to, an objective evaluation of QA program contents, such as practices, procedures and instructions, and their implementation as well as an evaluation of work areas, activities, processes and items. They should include a review of documents and records pertaining to the subject work including implementation of corrective action.

In addition to preplanned and scheduled audits, random, unscheduled auditing is conducted whenever any of the following conditions exist:

a. When it is necessary to determine the adequacy of the Quality Assurance Program (Architect Engineer's, Constructor's, NSSS Supplier's, Contractor's, Subcontractor's) prior to awarding a contract or purchase order.

b. When, after award of a contract, sufficient time has elapsed for the implementation of a Quality Assurance Program, and it is appropriate to determine that the organization is truly implementing the program and adhering to applicable codes, standards and other contract documents.

c. When significant changes have been made to the Quality Assurance Program including organizational changes or procedural revisions.

d. When the safety, performance or reliability of an item or items

is suspect because of the number of deficiencies and nonconformances found, indicating a possible breakdown in the Quality Assurance Program effectiveness.

e. When it is considered necessary to verify implementation of required corrective actions.

Analysis of Responsibilities. The major responsibilities of the personnel in the Design, Procurement and Construction Section, in light of the above emphasis, is:

A. Quality Assurance Supervisor

1. Supervises the auditing and surveillance of Utility F's Organizations, Architect-Engineer, Nuclear Steam System Supplier, vendors and contractors performing work during design, engineering, procurement, construction, or modification of Nuclear Power Stations.

2. Supervises the translation of Regulatory requirements for design, engineering, procurement, construction and modification activities into the Quality Assurance Program.

B. Senior QA Engineer

1. Reviews audit reports of architect-engineers, vendors/subvendors, contractors/subcontractors...to determine compliance with procedures, instructions and regulatory requirements.

2. Recommends or initiates, as appropriate, corrective action resulting from reviews of the audit/surveillance program...

3. Prepares Quality Assurance procedures, instructions, audit plans to accomplish goals of the Quality Assurance Program.

C. Quality Assurance Engineer

1. Prepares, conducts and reports audits of architect-engineers, vendors/subvendors, contractors/subcontractors...

2. Reviews and understands the applicable codes, standards and regulatory requirements including changes, revisions and addenda as they pertain to the

Quality Assurance Program.

3. Reviews the contents of the Preliminary/Final Safety Analysis reports including all amendments and utilizes such documents in Quality Assurance evaluations for compliance with them...

4. Reviews specifications, drawings and special instructions for Quality Assurance requirement inclusion.

5. Reviews and evaluates nonconformity or deficiency reports and assesses corrective action recommendations and resolutions.

Quality Control

The Site Quality Control Effort on Project F, as noted earlier, is also under the direct control of Utility F. A plan was developed by Utility F's Manager of Quality Assurance in early 1976 whereby Utility F, in conjunction with the prime concrete, electrical and mechanical constructors, would jointly perform the Quality Control function.

Organizational Responsibility. Figure A.23 indicates that the line of authority goes from the QA Manager through the Site Director-Quality Control to the contractor (note that only the portions of the organization specifically related to concrete are shown in detail). The contractor's quality control activities are in effect absorbed into Utility F's QC organization. Some of the QC responsibilities of the parties involved related to the concrete phase are indicated below. Particular attention should be given to the major involvement of Utility F in the administration of the entire Quality Control effort.

A. Utility F

1. Directs the Site Quality Control Section and establishes the policy, authority, and program. The head of the Site Quality Control Section is the Director. He is assisted by three Supervisors.

2. Reviews and approves all Contractors' and Engineer/Constructor's procedures and manuals for quality related work on Project F.

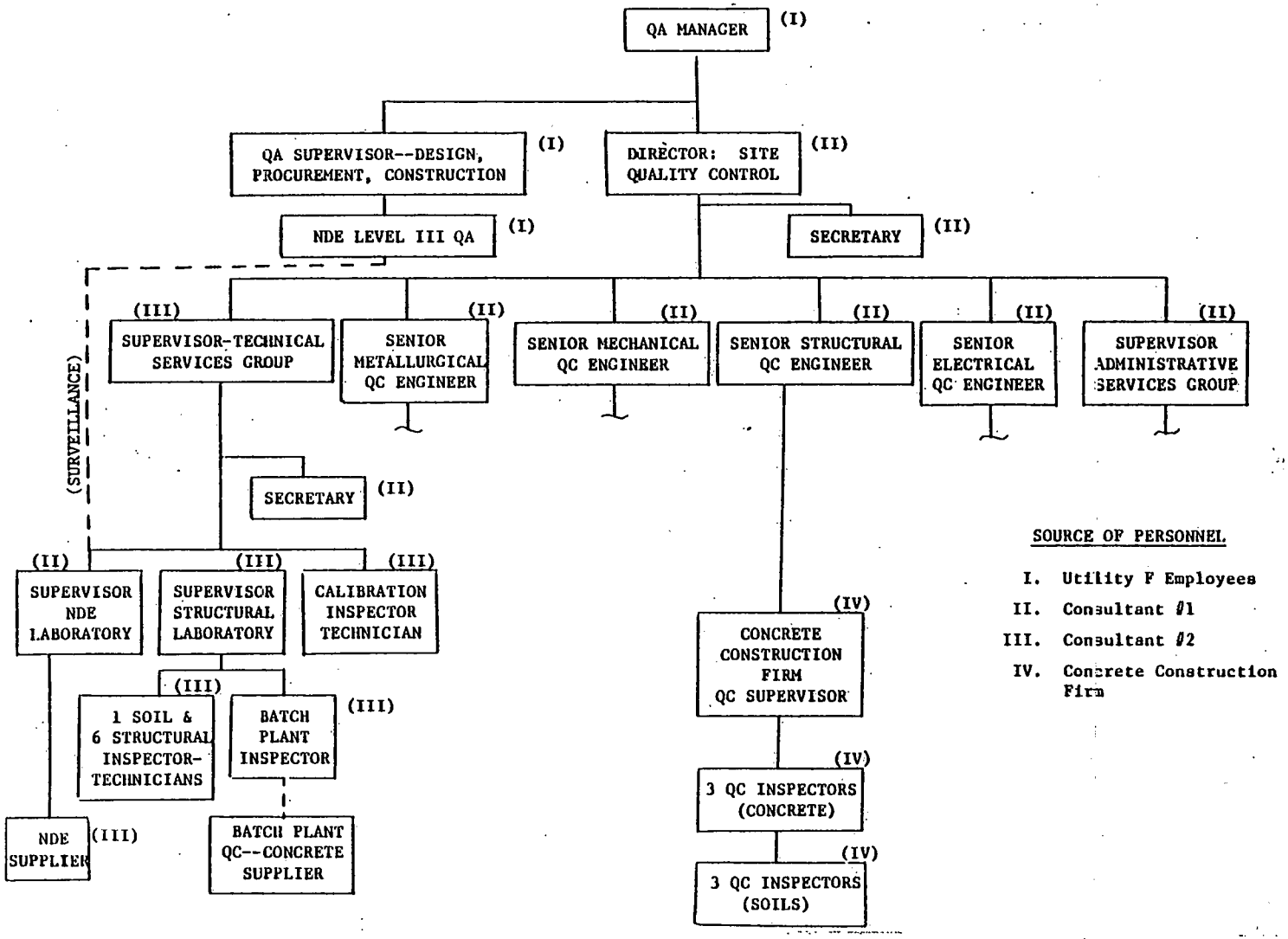


Figure A.23.--Utility F's Quality Control Organization

3. Provides, issues, and controls a manual and procedures to cover all phases of quality control activities which the Contractors shall adhere to completely.

4. Provides a glossary of terms to allow for complete understanding and common terminology.

5. Provides Contractors with a maximum or minimum manpower figure for quality control personnel for different stages as work progresses.

6. Provides all training to quality control personnel.

7. Prepares inspection plans, and from them prepares and issues Inspection Reports containing all inspection criteria to the Contractors which the Contractors' quality control personnel shall implement.

8. Sets the responsibilities and control for all inspections, stop work, nonconformances, dispositions and corrective action.

9. Performs receipt inspection of all quality related materials for Project F.

10. Assigns Material Control personnel to monitor the storage, maintenance, and release of all quality related material for Project F.

11. Provides procedures, inspection plans, and inspection report criteria from the Site Quality Control Quality Engineering Group to the Concrete Constructor for their related work in:

a. Concrete
b. Cadwelding
c. Protective Coating
d. Waterproof Membrane
e. Grouting

12. Performs all Structural Laboratory functions (Technical Services Group).

13. Performs all Batch Plant quality control (Technical Services Group).

14. Performs all Calibration Laboratory functions for test and measuring equipment (Technical Services Group).

15. Qualifies all welders and all weld procedures (Technical Services Group).

16. Provides data analysis (including trend analysis).

B. AE/CM Firm

1. Provides all training for construction personnel.

2. Provides the Site Quality Control Section with latest drawings, specifications, manufacturers' information, and special instructions.

3. Holds coordination meetings with the Contractors and the Site Quality Control Section before initiating new or unusual work phases.

4. Provides or assures that sufficient construction procedures exist prior to the commencing of the activity the procedure is designed to control.

C. Concrete Construction Firm

1. Performs the quality control inspection function for structural work on Project F as defined in the Site Quality Control Section Manual.

2. Provides one Quality Control Engineer, able to be qualified as a Level III, to head the Construction Firm's quality control function. The Quality Control Engineer is responsible for his inspectors and is directly responsible to the Senior Structural Quality Control Engineer.

3. Provides inspectors, the number being determined by the Director, Site Quality Control depending on work load, that are able to be qualified as Level III,II, or I, and are directly responsible to the Construction Firm's Quality Control Engineer.

4. Utilizes all applicable forms, provides all pertinent documentation, and complies completely with the system and requirements of the Site Quality Control Section Manual.

Individual Responsibility. The division of responsibility within Utility F's Quality Control organization can be indicated with reference to Figure A.23. It should first be noted that the QA Manager directs the activities of

the QA Supervisor of Design, Procurement and Construction and the Director: Site Quality Control (Figure A.22 also indicated this relationship). Some of the responsibilities of the other positions are:

A. Supervisor of Technical Services (Responsible for):

1. A testing program for structural materials using the personnel in the Structural Testing Laboratory. This group includes structural inspector-technicians (who perform all of the concrete tests at the placement location) and a batch plant inspector (who verifies that the Concrete Supplier's QA/QC program is being implemented correctly).

2. A program for the maintenance and calibration of construction test equipment.

3. A site welder qualification program.

4. An NDE inspection program.

B. Senior Structural QC Engineer (Responsible for):

1. Review of the design drawings, specifications and applicable code requirements.

2. Development of procedures and instruction for performing tests and inspections in accordance with design drawings, specifications and applicable code requirements.

3. Evaluation of the effectiveness of the designated contractor's quality control activities.

4. Review of the results of inspection and tests. (He forwards the inspection and test documentation to the Administration Services Group for processing.)

5. Review of the results of trends indicated by the Administrative Services Group. (He initiates action to correct those trends which are detrimental to quality.)

C. Concrete Construction Firm's QC Supervisor (Responsible for):

1. Planning, scheduling and supervising activities related to the inspection of construction activities.

2. Hiring, training and assigning personnel performing quality control inspections and tests.

3. Reporting to the Site Quality Control Sections, through the Senior Discipline Quality Control Engineer or his designee.

4. Reviewing Inspection Reports for completeness and accuracy.

5. Assuring that corrective action dispositions are cleared and documented.

6. Reporting to contractor's responsible management on the effectiveness of the inspection program.

7. Reviewing the results of inspections for compliance to quality criteria.

D. Concrete Construction Firm's QC Inspectors (Responsible for):

1. Performing inspection and tests of construction activities in accordance with SQC Procedures and Instructions.

2. Reporting directly to the Contractor's Quality Control Supervisor for direction and work assignments.

3. Documenting results of tests and inspections and forwarding documentation to the Contractor's Quality Control Engineer.

4. Notifying the Contractor's Quality Control Supervisor of all conditions which may adversely affect the quality of the nuclear power plant.

5. Assisting the contractor's construction personnel in the implementation and carrying out of procedures and instructions which are required to determine and document the quality of construction activities.

6. Being familiar with recognized and approved industry practices for performing inspections and tests.

7. Being familiar with inspection and testing criteria specified by specifications, procedures, and instructions and insuring implementation and documentation.

8. Assuring adherences to Quality Control hold points.

QUALITY ASSURANCE DOCUMENTS

The total Quality Assurance Program discussed above is implemented through a series of manuals and documents which describe the specific duties and responsibilities of each party. As indicated earlier in this Case Study, and illustrated in Figure A.24, Utility F is directly involved with both the Quality Assurance and Quality Control aspects of the construction process.

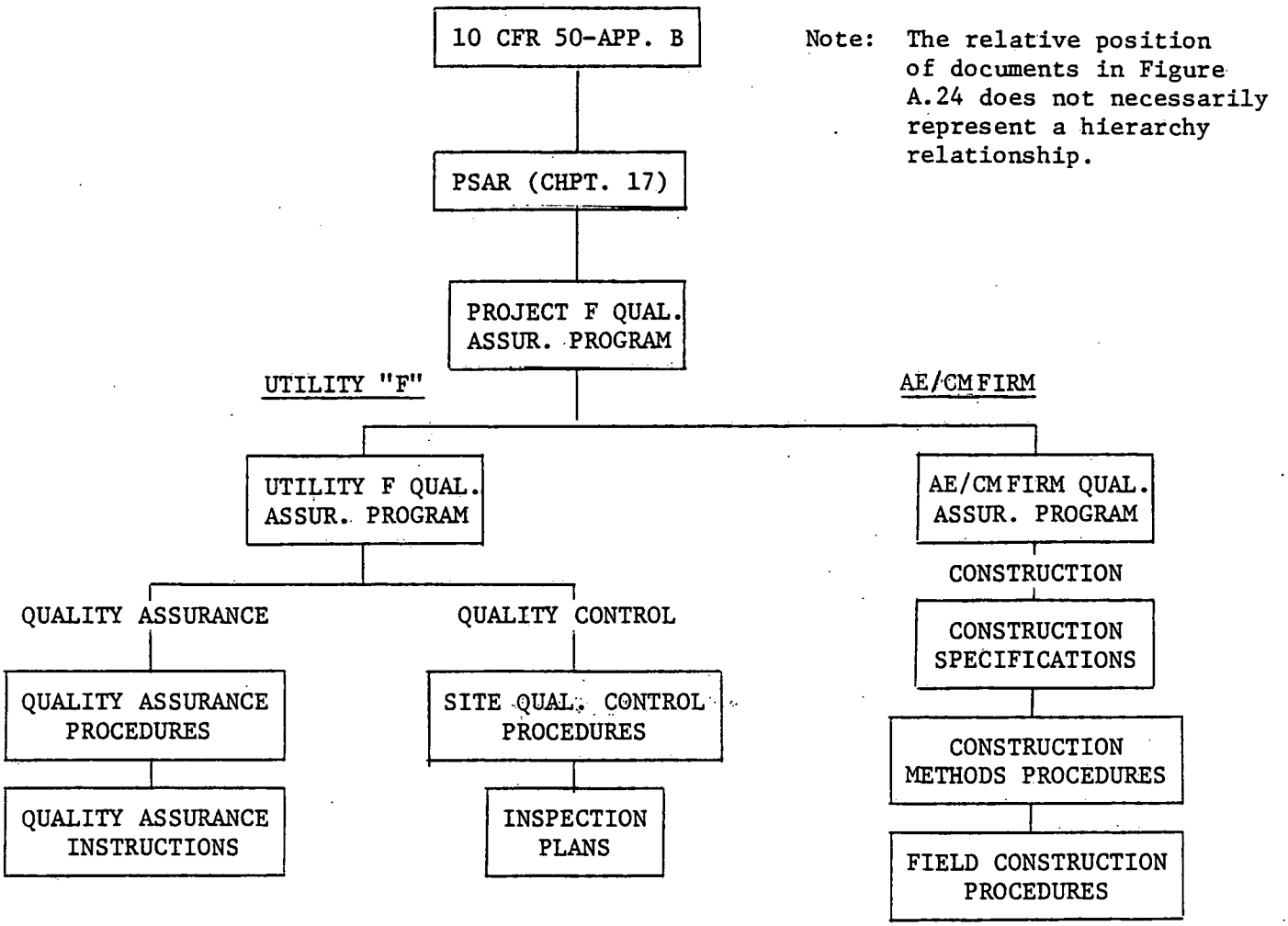


Figure A.24.--Project F Quality Assurance Documents

An explanation of the documents which are shown in Figure A.24 is presented below with special emphasis being placed on those that are specifically related to the concrete phase.

AE/CM Firm

The entire construction phase is under the direction of the AE/CM Firm. As noted earlier in this Case Study, an independent construction firm is responsible for the concrete construction phase and an independent concrete supplier is responsible for the operation of the concrete batch plant. The Concrete Testing Laboratory is directly managed by Utility F. The operations of these parties are directed by the AE/CM Firm documents discussed below.

1. Technical Specifications

The technical specifications prepared by the AE/CM Firm, in conjunction with the referenced industry codes and standards, provide the basis for the Field Construction Procedures and Inspection Plans which are developed for each construction phase. The three primary concrete related specifications are:

Spec.	Title	No. Pages	No. of Revisions
1.	Mixing and Delivery of Concrete		2
2.	Placing Concrete and Reinforcing Steel		3
3.	Concrete Testing Services		2

It should be noted that whenever an addendum or a revision to the specification is issued, an attempt is made to incorporate as many of the pertinent Engineering and Design Coordination Reports (i.e., E & DCR's) as possible into the revision. E & DCR's are used by the AE/CM Firm Engineering group to approve changes to specifications and practices on a case-by-case basis.

2. Construction Methods Procedures

The AE/CM Firm has a series of corporate level Construction Methods Procedures (i.e., CMP's) which are applicable to all nuclear power plant projects. These procedures are used as guidelines by the individual contractors in the development of the Field Construction Procedures which define the construction practices actually implemented on Project F.

3. Field Construction Procedures (FCP's)

The FCP's related to the concrete construction phase are developed by the Resident Engineer of the Concrete Construction Firm, receive concurrence approval from Utility F's Construction and Site Quality Control Departments, and are approved for use and issued by the AE/CM Firm.

Some of the concrete FCP's are general in nature: (1) Placement of Concrete (17 pages), (2) Placement of Reinforcing Steel (9 pages) and (3) Cadwelding of Reinforcing Steel (26 pages). There are also specific FCP's which are directed to specific phases of the construction operation which deserve specific attention. An example of this type is: "Reactor Containment Mat Concrete Placement" (38 pages) which is essentially a detailed "Pre-plan" which defines the individual tasks which must be accomplished.

FCP's define acceptable construction practices by distilling and incorporating the various requirements in the Concrete Specifications and the applicable ACI and ASTM codes into a working document which can be easily understood and implemented by the Construction group. FCP's serve as "translation documents". If they are properly prepared, then all of the concrete related committments which Utility F has made in the PSAR, etc., will be satisfied if the construction group follows the FCP. The achievement of this objective is ascertained by the Site Quality Control group when they review the FCP's.

Utility F

1. Quality Control

Utility F has designed its Quality Control system so that the basic Quality Control documents mesh directly with the requirements in the specifications, codes and standards and the commitments which are made in the FCP's mentioned above. This system is explained below in relation to the pertinent QC documents.

a. Site Quality Control Procedures. A Site Quality Control Manual, developed by the Director of Site Quality Control, presents a series of Site Quality Control Procedures (i.e., SQC's) which define the means by which the Site Quality Control members of the Quality Assurance Department will implement the requirements of the SAR and the Utility F Quality Assurance Procedures.

b. Inspection Plans. The primary guidance for the Quality Control Engineers and Inspectors is provided in the Inspection Plans Manual which consists of a series of Inspection Plans (i.e., IP's) for each of the construction phases of Project F. These are prepared in the concrete area under the direction of Utility F's Senior Structural QC Engineer. IP's involve the following two separate documents:

--The Inspection Plan--a detailed description of the attributes to be inspected, the methods used, hold points required and acceptance criteria. It will also include any tables, graphs, sketches or other supporting information required to perform the inspection. The specific attributes described include a reference to the source documents from which they were obtained.

--Inspection or Attribute List--a numerical listing of all the attributes described in the Inspection Plan. This will become part of the Discipline Attribute List (a separate list is compiled by each discipline) to be used as an aid in preparing future Inspection Plans and ultimately as a means of computerizing all inspection results for purposes of trend analysis. This list is not part of the Inspection Plan.

The Inspection Plans and associated Inspection Attribute lists for the concrete area result in Inspection Reports (i.e., IR's) which are used by the Quality Control Inspectors of the Concrete Construction Firm and the Concrete Testing Laboratory for the concrete preplacement, placement, and post placement stages as well as for the concrete batch plant. Each attribute on the IR is verified and the acceptance status ("UNSAT" or "SAT") is reflected.

As noted earlier, the Inspection Plans and Inspection Reports are developed in response to the pertinent specifications, codes and standards and Field Construction Procedures. If they are correctly prepared, then they also "translate" all of the commitments made by Utility F into a document which "assures" from a QC standpoint that all of the commitments are being met.

2. Quality Assurance

   a. Quality Assurance Procedures. The Quality Assurance Procedures (QAP's) are the documents which define the Design and Construction QA Program which appears in the Utility F Quality Assurance Program Manual. They are divided into a series of 18 categories, each of which parallels and defines Utility F's approach to one of the 18 Criteria of 10 CFR Part 50, Appendix B.

   b. Quality Assurance Instructions. These documents, again paralleling the 18 Criteria of 10 CFR Part 50, Appendix B, define the means and methods by which the QA group implements the requirements of the SAR and the Utility F Quality Assurance Procedures.

SUMMARY

Utility F Corporate Strategy

On the surface it would appear the Utility F has made a rather large organizational commitment of permanent employees in order to establish a viable site QA/QC effort. The problem which Utilities such as Utility F must face is that unless they have a continuous program of Nuclear Power Plant construction, there will be a need to either: (1) find other employment for the QA/QC personnel after the project is completed, or (2) terminate the entire organization. The latter approach appears to be contrary to the general objectives of Utilities, which is to provide a fairly stable employment future for their employees.

Two approaches have actually been taken by Utility F. The Quality Assurance personnel shown in Figure A.22 are all Utility F employees. This is probably due to the fact that after Project F is completed, there will be increased requirements for QA related to the operational phase of the facility.

With regard to Quality Control, however, the strategy has been to staff the QC organization with personnel who are on loan from consulting firms, or as noted earlier, with personnel directly employed by the constructors at the project site. Figure A.23 indicates that the only Utility F permanent employees in the entire SQC section are the QA Manager and two members of the QA department who are shown in the organizational structure to indicate the interface between Utility F QA and Utility F QC. An organization has been skillfully molded by the QA Manager who has hired or incorporated QC personnel from 7 different organizations. (Note: this includes specialties other than concrete). As shown in Figure A.23, the first level (represented by the Supervisor of Technical Services, the Senior Quality Control Engineers and

the Supervisor of the Administration Services Group) have all been hired, for the duration of the project, from two different consulting firms.

As noted earlier, the next tier of QC personnel on the project is provided by the respective construction firms (i.e., metallurgical, mechanical, concrete, etc.) The personnel in the Technical Services Group are also on loan from consulting firms.

The pooling of resources from 7 different organizations also has another managerial advantage. It is felt by Utility F that the above-mentioned arrangement has eliminated the development of any "power groups"; all positions must therefore look to the top (i.e., the QA Manager) for policy decisions and direction.

CASE STUDY--PROJECT G

PROJECT ORGANIZATION

Project G represents an addition to the generating capacity of a group of utilities, one of which (called Utility G in this Case Study) has been designated project responsibility for the facility. The interrelationship of the parties involved in the concrete phase of the project is shown in Figure A.25.

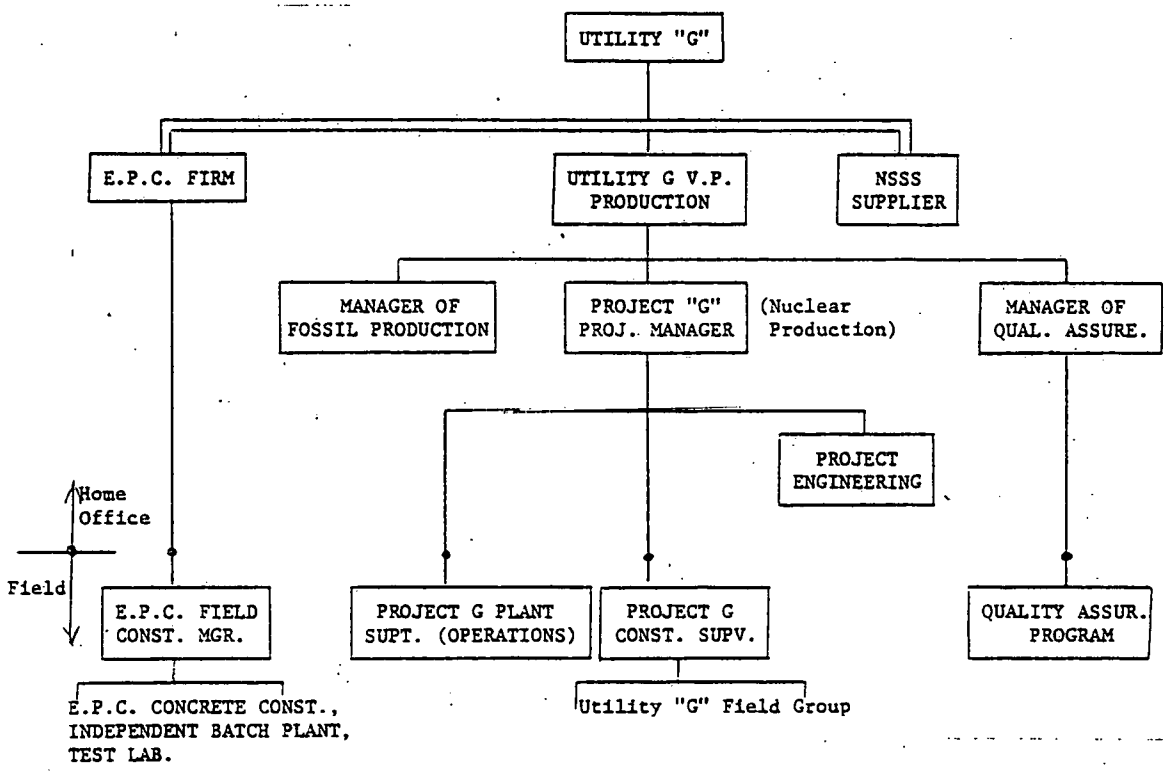


Figure A.25.--Interrelationship of Parties Involved in the Concrete Phase

As noted in Figure A.25 the administrative support for the project is the responsibility of the Vice President of Production. It should be noted that the Manager of Quality Assurance is independent of the Managers of Production (Fossil and Nuclear). The Project "G" Project Manager is also the Manager of Nuclear Production. He is responsible for monitoring the construction activities

and upon plant completion will also be responsible for the operation of the facility.

Utility G does not maintain a large engineering and construction staff for power plants. It has therefore engaged the services of an EPC firm to provide overall project direction including Engineering, Procurement, Construction, Quality Assurance and Startup Services. It should be noted that although this is the same firm that is under EPC contracts on Projects C and D, a different "Area Office" has been given the responsibility for Project G.

Utility G

As shown in Figure A.25, the Project "G" Project Manager delegates responsibility to three distinct groups. The first group is under the direction of the Project G Plant Superintendent. This group, which is located at the project site, is oriented towards the operation of the plant and is responsible for the startup and test activities that will be performed.

The Nuclear Project Engineer (who is in charge of the Project Engineering group) is responsible for plant engineering and design. The entire group (which is located in Utility G's home office) consists of eight engineers who represent the licensing, nuclear fuel, environmental, civil, electrical and mechanical disciplines. Because of the relatively small size of the group, it is reasonable to assume that the level of owner involvement in the review of EPC Firm specifications, drawings, etc. is probably less than was found on Projects C and D.

The third group which is under the supervision of the Project G Project Manager is the on-site construction group directed by a Project G Construction Supervisor. The seven members of this group monitor the construction schedule, project costs, environmental problems, and assist in other construction related capacities. It would again appear that the size of this group as well as the fact that it does not receive technical direction from a home office

Manager of Construction (as is the case for Projects C and D) limits the amount of direct influence which Utility G has on the construction process. The number of changes which are made by this group to either the drawings or the specifications which govern the concrete phase is probably less than at either Project C or D.

Utility G is also represented at the project site by a Quality Assurance group consisting of a QA Field Supervisor and nine QA Engineers. Their activities and responsibilities will be discussed in greater detail later in this case study.

The estimated number of Utility G personnel on the project site during the peak concrete phase will be: (total = 28)

1. Supervision - 1
2. Field Engineering - 9
3. Cost/Scheduling - 2
4. Finance/Accounting - 4
5. QA - 11
6. Environmental - 1

EPC Firm

As noted above, the EPC Firm on Project G is also serving in a similar capacity on Project C. The organizational structure originally shown as Figure A.10 in the Project C Case Study is included here in a slightly modified form as Figure A.26. (See page A.105 for an explanation of the modification.) The interested reader is referred to the Project C Case Study for the accompanying explanation since the upper management organization levels on both projects are essentially identical.

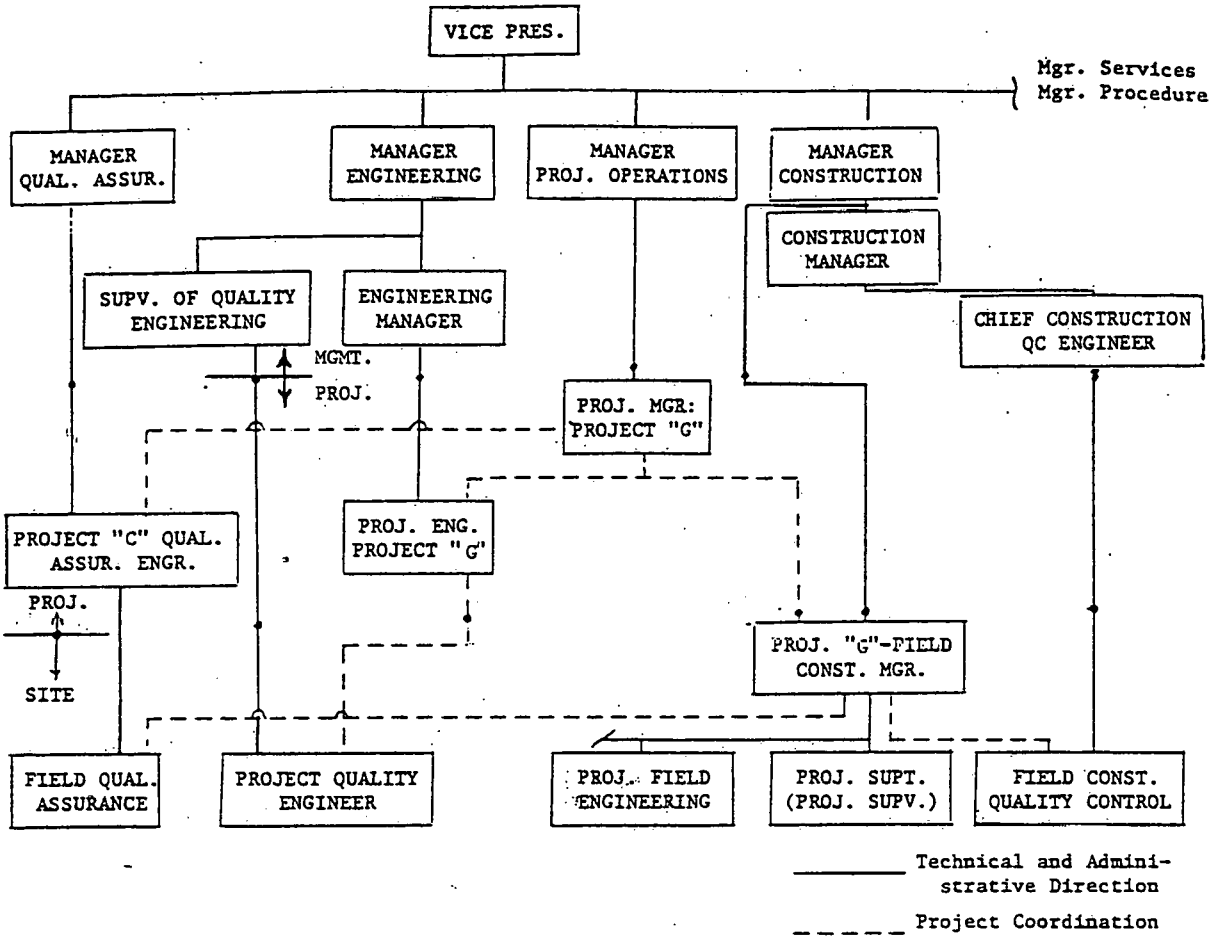


Figure A.26.--E.P.C. Firm Organization

It is estimated that during the peak of the concrete phase on Project "G" the EPC Firm will employ the following number of non manual employees at the project site (Total - 600)

1.	Supervision	70	5.	Finance/Accounting	70
2.	Field Engineering	260	6.	Procurement	36
3.	Subcontract Adm.	24	7.	Quality Control	95
4.	Cost/Scheduling	25	8.	Quality Assurance	13
			9.	Personnel	7

QUALITY ASSURANCE PROGRAM

The Quality Assurance Program on Project G applies to those structures, systems and components of reactor facilities which are safety related. A "Q" list which identifies these structures, systems and components was jointly prepared by the EPC Firm and Utility G. It is interesting to note that with regard to the concrete phase, the Field QA group of Utility G appears to have a different degree of involvement than either the EPC Firm's Field QA or QC groups. Utility G's QA group essentially treats all concrete equally since theyperform the same type of Surveillance and Inspection activities on both Q and non Q listed concrete.

In the EPC Firm's case, involvement with every concrete placement, whether Q listed or not, begins when the responsible Construction Field Engineer prepares a Work Plan and Inspection Report (WP & IR's will be discussed later) which defines both the work to be accomplished and the inspection effort that is required. The QC and QA groups of the EPC Firm, however, only became involved with those WP & IR's which relate to Q listed concrete. For non Q-listed concrete the Construction Field Engineer is responsible for all inspections and documentation through the preplacement, placement and post-placement stages. In addition, QC witnesses non-Q placements on a limited basis.

Quality Assurance

Utility G. As noted earlier, the QA Program for Project G is under the direction of the Manager of Quality Assurance who, as shown in Figure A.27, directs a staff of four Quality Assurance Representatives in the home office and a QA Field Supervisor and nine site QA Representatives at the project site.

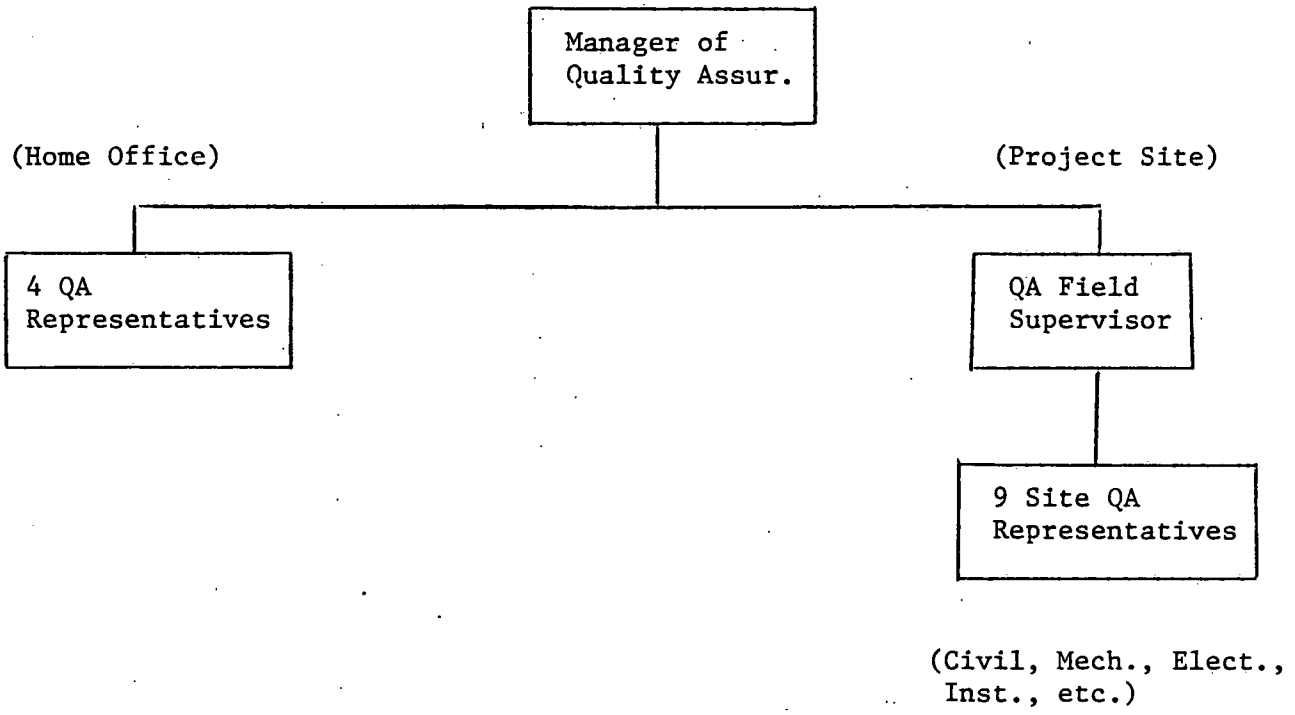


Figure A.27.--Utility G Quality Assurance Organization

a. Home Office Group. The home office staff is divided into two areas of responsibility - Quality Engineering and Quality Systems. Quality Assurance Representatives in the Quality Engineering area of responsibility perform (1) Supplier audits, surveys, inspections, and surveillance; (2) Related documentation reviews and quality planning; (3) Technical reviews of standards, codes, specifications, drawings, and procedures; (4) Surveillance of Utility G technical support functions; (5) Training; and (6) Quality problem investigation and resolution activities.

Quality Assurance Representatives in the Quality Systems area of responsibility perform (1) Internal and external quality program development, maintenance and planning (including internal audit, inspection and training; and supplier QA Program requirements) (2) Internal audits of Utility G personnel (Construction, Quality Assurance, etc.) at the home office and on the project site; (3) External audits of the EPC Firm, NSSS Supplier, etc.; (4) Required quality reporting and trend analysis; and (5) Quality records initiation and review.

In addition, both groups assist the Manager of Quality Assurance during Nuclear Regulatory Commission inspections.

b. QA Field Supervisor. The QA Field Supervisor, who has been delegated "Stop Work" authority by the Manager of Quality Assurance, is responsible for supervising the site QA Representatives in the performance of their primary activities (i.e., (1) Audits, (2) Inspections, (3) Surveillance , and (4) Reviews.) He prepares a monthly schedule of these activities and produces a weekly report which documents the results of these activities. In addition he must (1) Inform the manager of Quality Assurance of any item which he judges to be a possible significant deficiency as defined under 10CFR50.55(e), (2) Resolve any questions, situations or discussions of a general nature during NRC Inspection or Utility G Management Audits, and (3) Inform the Manager of Quality Assurance of any conditions which exist that would prohibit effective quality inspections or the detection of possible quality program deficiencies.

c. Site Quality Assurance Representatives. The Site Quality Assurance Representatives are assigned by discipline or by the specific area of responsibility in which they have specialized training and/or expertise. They provide an interface between Utility G, the EPC Firm and the NRC during NRC Audits. In addition, they are responsible for the examination, verification,

evaluation and documentation of quality assurance activities in accordance with Utility G's Quality Assurance Procedures.

As noted earlier both Q and non-Q listed concrete receives Utility G QA coverage. This coverage is usually performed simultaneously with the actual construction and quality activities associated with the particular area of interest. Where conflicting schedules or activity priorities preclude observation of actual construction and quality efforts, a surveillance review, or audit of the Contractor's records and inspection verification documentation shall be substituted.

The four primary QA activities which are performed are (1) Audits, (2) Inspections, (3) Surveillances and (4) Review. They will be explained below in order to clarify the depth of involvement of Utility G in the QA area.

1. Audits. Audits represent the most formal in depth analysis which is performed and documented in a report fashion. There are typically two or three of them performed on the project site each year and are of such breadth that the entire site QA group may work as a team to perform each audit.

2. Inspections. Inspections are more frequently performed; four or five of them for each discipline appear on the monthly schedule prepared by the QA Field Supervisor. A detailed checklist, prepared by the individual QA Representative in advance, is used as the base document for the inspection report. It includes a list of criteria developed from the appropriate documents (i.e. Project Specifications, Quality Control Instructions, etc.) and allows the status of compliance to be indicated. In the concrete area, these checklists (which may include 15-25 items) cover not only the inspection of actual construction practices but also an analysis of QA, QC and EPC Firm documents (i.e., test records, batch plant tickets, concrete test reports, aggregate gradation, cement qualification, etc.) as well as a review of personal

qualification records. As an example, an Inspection Report for the Concrete Testing Laboratory is 7 pages long, covers approximately 20 checklist items and contains 8 pages of supportive calculations.

3. Surveillances. Surveillances occur more frequently than either Audits or Inspections and although they may not be documented, the results appear as periodic log sheet entries. If they are documented they follow the checklist type framework mentioned above (i.e., they are called Quality Surveillance Inspection Reports) and may be as long or longer than Inspection Reports.

Within the Civil discipline there will be Surveillance inspections of specific concrete pours which will include concrete testing during production, proper use of vibration equipment, proper placing of concrete, proper curing, and proper storage and loading of aggregate. There will also be Surveillance inspections of the Work Plan and Inspection Record document package to check for compliance with pre-pour inspection sign-off by Field Engineering and Quality Control. Surveillance checks are also made at the testing lab once each week. These can be conducted more often if necessary in order to maintain the desired confidence level. The following items are typically checked:

Testing Laboratory	Batch Plant
Cylinder Storage Room (proper temperature and humidity)	Stockpiling Method (cleanliness, cooling)
Reinforcing Bar Tensile Testing	Counter Setting Back to Zero
Cylinder Capping Operation	Proper Sampling Techniques
Cylinder Testing	Proper Number of Revolutions
Admixture Storage	QC inspector Sign-Off
Personnel Qualifications	Cement and Admixture storage
Use of Latest Spec. Revision	

Occasional problems encountered in the past were: (1) Temperature and humidity in the cylinder storage room (due partially to inadequate piping), (2) Aggregate

storage and (3) Use of the latest revision of design specifications or project procedures.

4. Review. The Site Quality Assurance Representatives also participate in the review process related to existing or new Utility G or EPC Firm procedures. These are usually routed to the project site through Utility G's home office QA group.

EPC Firm. As shown in Figure A.26, the EPC Firm also has a Quality Assurance group at the project site. During the summer of 1977 it consisted of one Project Quality Assurance Manager (PQAM) and a staff of nine Quality Assurance Engineers who represented the disciplines of Civil, Piping, Electrical, etc. Since their organizational relationship within the EPC Firm is very similar to those on Project C, the interested reader is referred to the appropriate section of the Project C Case Study (pgs.A.40-A.41) for additional details. Only their specific activities on Project G will be discussed below.

The EPC Firm site QA group is given the primary responsibility for insuring construction quality. The primary functions which they perform are:

1. Auditing - Approximately 15-27 announced audits are conducted by field QA per quarter. These are preplanned, in depth, scheduled, and conducted to a preplanned checklist prepared by the QA engineer performing the audit. Some of the concrete related audits which are performed are:

a. Material receiving and storage

b. Inspection/Surveillance of Concrete Batch Operations and Concrete Placement

c. Calibration of measuring and test equipment

d. Installation of reinforcing steel and cadwelds

e. Design document control

f. SAR change control

g. Processing of nonconforming materials

It should be noted that the Quality Assurance Procedure that addresses the scheduling of Audits recommends that the above activities should be audited at least annually (or once during the life of the activity if it lasts less than a year). The frequency of audits may however be modified as appropriate to respond to project conditions and in accordance with the importance of specific activities. These audits are in a greater depth than those performed by the Utility G QA group. As an example, the Quality Element Checklist related to the audit entitled "Material Test Lab Subcontractor Control" is 22 pages long and covers almost every conceivable item that is found in the Concrete Testing Laboratory QA Manual as well as related Quality Control Procedures. It is interesting to note that two of the items that were listed relate to the fact that the Concrete Testing Laboratory QA Manager is committed to: (1) Audit their own QC Program a minimum of once a year and (2) Perform an internal audit of the entire operation monthly.

2. Surveillance--This involves monitoring or review of an ongoing activity on an unannounced basis. Surveillances are unscheduled, have no preplanned checklist but are documented in a daily log. There are approximately 3 to 4 conducted per week. Unacceptable findings are reported on a Quality Assurance Finding (QAF) form.

3. Review and Approval of Quality Control Instructions (i.e., QCI's). The QCI's are generated by the site QC group and are approved by site QA. They amplify the Quality Control Manual (QCM). The QCM and some Work Plan and Procedures are reviewed and approved by the QA Manager at the home office.

4. Review of Nonconformance Reports (i.e., NCR's) and Condition Reports as part of the corrective action program.

5. Auditing of the NSSS supplier (usually as part of a team which includes Utility G personnel).

Summary. It should be noted that the Utility G and the EPC Firm QA groups appear to have similar functions and perform system audits using similar techniques. Although it is recognized that they are probably performing these functions for different reasons there appears to be some duplication of effort. As cited above, in the case of the Concrete Testing Laboratory, these functions are superimposed on those performed internally by the QA Manager of the Laboratory facility (who is performing them to comply with his own QA Program committments).

Quality Control (EPC Firm)

As noted in Figure A.25, Utility G's project organization does not include a Quality Control Department. They have assigned the QC function to the EPC Firm. They rely on their site QA group to verify conformance to that function. The discussion below will therefore apply directly to the EPC Firm.

EPC Firm QC Organization. On Project G as noted in Figure A.28, a Project Field QC Engineer, (PFQCE) (who receives quality control technical and administrative direction from a Chief Field Quality Control Engineer (CFQCE) located at the home office) implements and supervises the site QC effort. During the summer of 1977 he directed a staff of approximately 75 Quality Control Engineers, (representing the Civil, Electrical, Welding, etc., disciplines), Technicians, and Documentation and Planning personnel. The size of the staff is expected to increase to about 95 as the project moves toward a heavier emphasis on the electrical and mechanical phases of construction.

The similarity, at the project site level, between the QC groups on Project G and on Project C should be evident. This similarity also extended

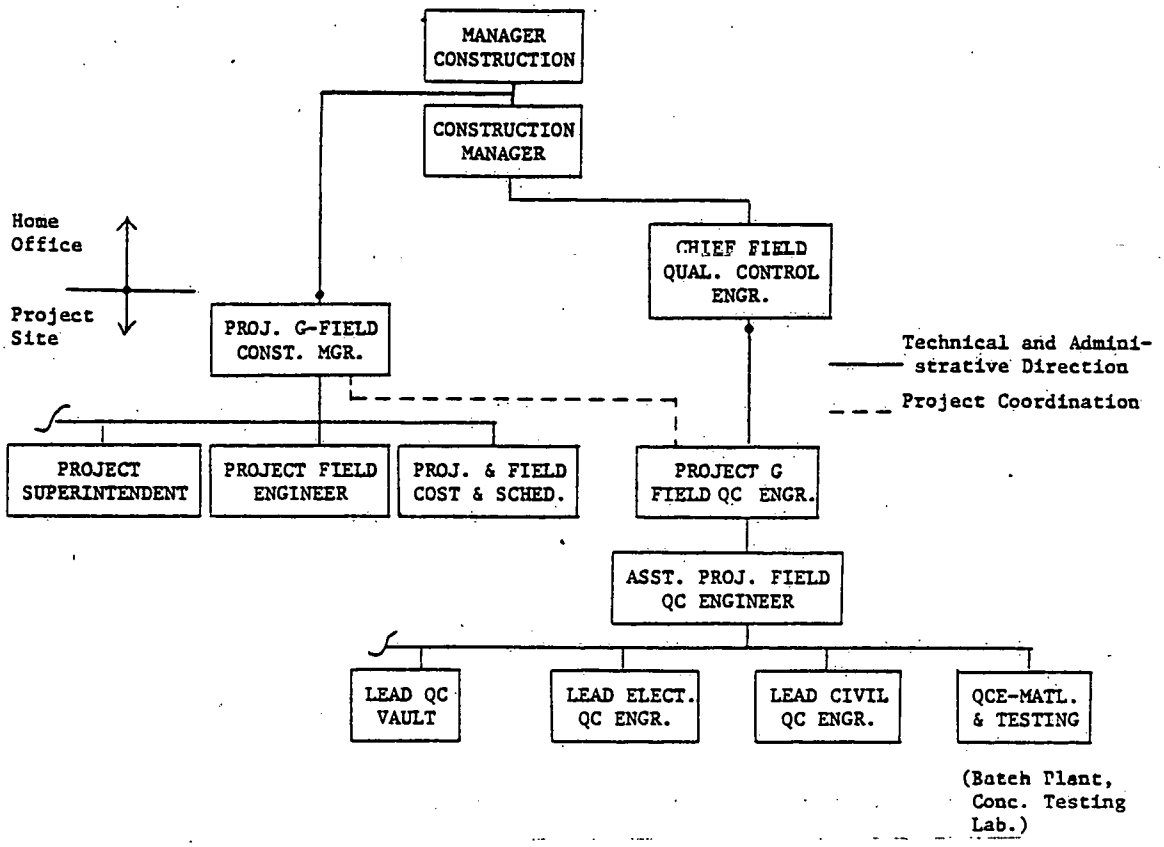


Figure A.28.--EPC Firm Quality Control Organization

to the upper management levels until the summer of 1977. Figures A.26 and A.28 both indicate that the change which occurred at that time resulted in: (1) the CFQCE reporting to the Construction Manager (who in turn reports to the Manager Construction) and (2) the Project G-Field Construction Manager reporting to the Manager Construction. It will be recalled from Figure A.10 in the Project C Case Study that for Project C, the CFQCE reported directly to the Manager of Construction. The new arrangement on Project G still separates the Construction and Quality Control functions.

QC Involvement in Concrete Phase. Figure A.28 indicates that the Field QC group is involved in the Civil as well as the Concrete Batch Plant and Concrete Teating Laboratory areas. The involvement of QC in the preplacement, placement, and postplacement phases of structural concrete will be thoroughly explained below with regard to the QC systems that were developed as well as the QC documents (found in the Quality Assurance Documents section of this Case Study) that are used.

With regard to the Concrete Testing Laboratory and the Concrete Batch Plant, the following points should be noted. The Testing Laboratory, although independent, is really an extension of the EPC Firm's Quality Control efforts on the project. The Testing Laboratory personnel compile all of the test data and transmit it in a timely fashion to the EPC Firm's QC department for storage. If any nonconformances appear on test reports, QC is notified immediately. The EPC Firm QC group performs a review of the data daily in order to accept or reject the data before filing it. QC also prepares a QC Daily Surveillance Report on Test Lab operations.

QC also performs a daily review of concrete component (cement, flyash, admixtures, etc.) inspection as well as the concrete curing laboratory (check of moisture content, temperature, etc.) A monthly review is also made of the Test Lab's specifications to insure that the specifications are current and of the latest revision. Laboratory calibrations are also inspected every 90 days.

The EPC Firm's QC personnel also inspect the batch plants on a daily basis regarding (1) protection of materials, (2) measuring, mixing, and transporting equipment, (3) batch plant documentation, etc.

In order to fully understand the role of the QC group in the above concrete areas, however, it is necessary to understand the "Quality Verification" and the "Process Control" Systems which are used on Project G.

Quality Verification System. The Quality Control Group on Project G operates under a "Quality Verification System" consisting of (1) Quality Verification and (2) Monitoring techniques which apply to all safety related items.

1. Quality Verification. The technique is used to verify the acceptability of phases of construction or individual construction items based on pre-specified acceptance criteria. Sign off responsibility for quality verification activities is required. The techniques used for performing the quality verification activities are as follows:

   a. Witness (W)--To watch over, observe, or visually examine a specific work operation, or test which is performed by others under construction supervision.

   b. Review (R)--To examine any form of documentation for the purpose of establishing acceptability to specific requirements.

   c. Inspect (I)--Visual examination or measurement to verify the conformance of an item to predetermined quality requirements.

   d. Test (T)--Activities performed to determine or verify the capability of a component, structure, or system to meet specified requirements by subjecting the item to a controlled set of physical, chemical, environmental, or operational conditions.

Hold points are applied to verification activities, beyond which work shall not proceed until the appropriate verification is performed and the Hold Point is released.

Quality Control Instructions (i.e., QCI's), which will be discussed later, describe the minimum verification activities which QC Engineers must perform to verify that work performed by the EPC Firm Construction Group

conforms to the program criteria. These QCI requirements as well as the required Hold Points are identified in the Work Plan and Inspection Report prepared by the Construction Engineer for each construction activity. For Q-listed concrete placements, for example, the Work Plan and Inspection Report indicates that joint surfaces, rebar installation, etc. must be verified and that a QC Hold Point be established at the "Final Preplacement Release" as well as the "Grout, Mix and Test Result" stages.

If incomplete work is noted at a quality verification activity, acceptance is withheld and the item of incomplete work is documented. Items of incomplete work found at a quality verification activity which can be completed during the course of the inspection are documented on the Work Plan and Inspection Report. Items which cannot be accomplished during the course of the inspection are documented on a Condition Report.

2. Monitoring. Monitoring activities are accomplished by observing or watching over work operations to provide indirect control of processing methods, equipment and personnel. Results of observations are recorded, but "sign off" responsibility is not required.

Process Controls. Quality Control Engineers assure that installation processes are controlled by performing quality activity/tasks associated with each work operation in the following phases:

1. Pre-Process Control. Pre-process activities are performed to assure that the necessary prerequisites are complete before beginning the in-process monitoring or verification activities. "Sign off" responsibility for the pre-process quality activities is not required.

2. In-Process Control. In-process monitoring begins at the start of the work operations and terminates at a quality verification activity or when a mandadatory Hold Point is reached.

3. Post-Process Control. Post-process activities are performed to assure that specific quality requirements have been met, a basis for acceptance of the item/installation has been achieved, and satisfactory results have been obtained.

The above-mentioned in-depth coverage by the QC group allows the QC Engineer to assume a rather large role in the day-to-day operations related to concrete formwork installation, placement of reinforcing steel, etc. The continual ongoing monitoring as well as the verification activities which QC performs appear to go far beyond the basic final inspection activity necessary for acceptance.

Even though the Construction Superintendents and Field Engineers are directly responsible for daily quality related activities (as noted in the Work Plan and Inspection Report for each concrete placement) a very subtle shift in responsibility can easily occur which results in a reliance on QC for the identification of items which require correction.

QUALITY ASSURANCE DOCUMENTS

The total Quality Assurance Program discussed above is implemented through a series of manuals and documents which describe the specific duties and responsibilities of each party. As indicated in Figure A.29, both Utility

G and the EPC Firm have a Quality Assurance Manual which describes the policies and procedures that are applicable to Project G.

An explanation of the other documents which are noted in Figure A.29 will be presented below with special emphasis being placed on those that are specifically related to the concrete phase.

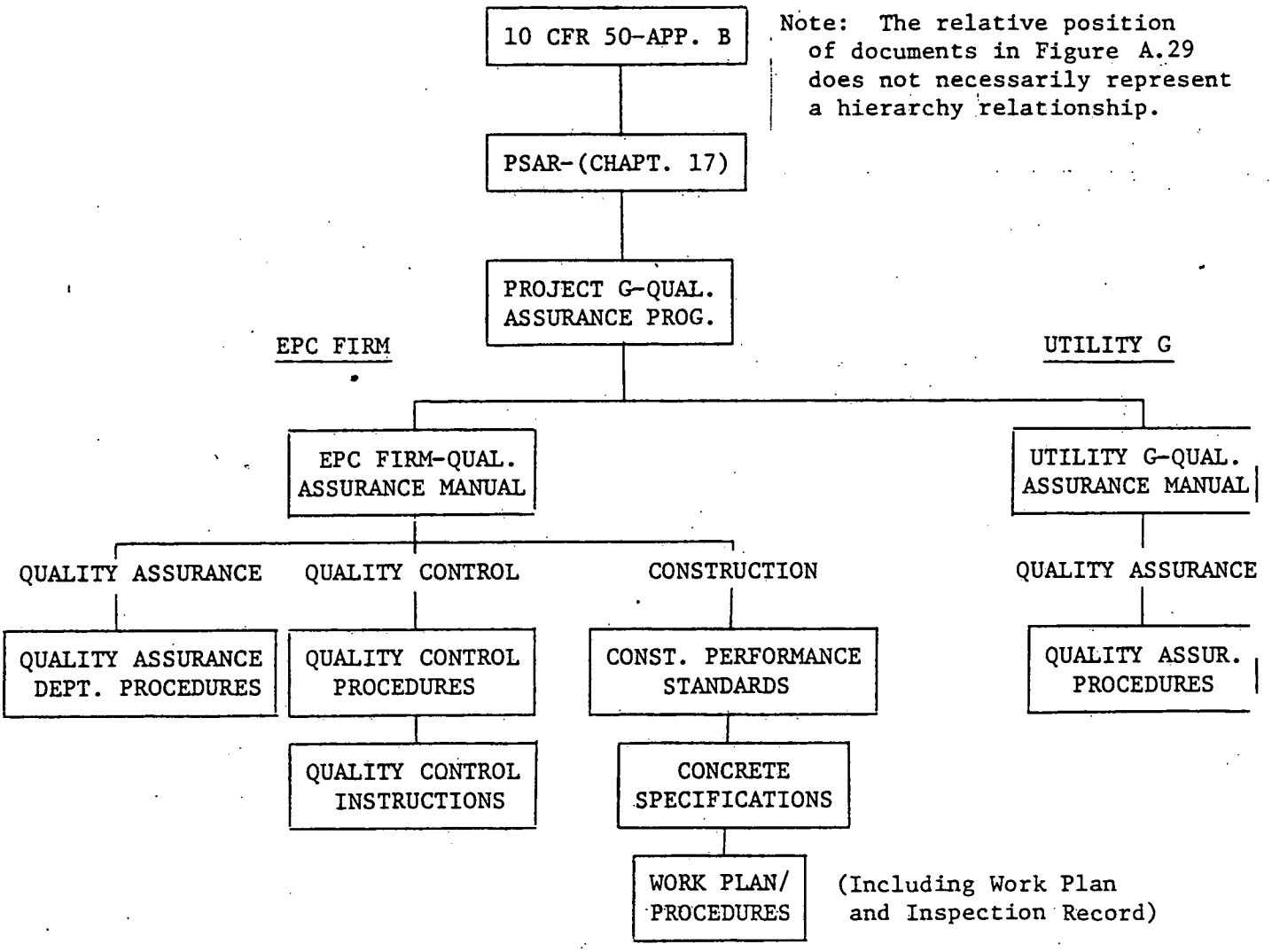


Figure A.29.--Project G Quality Assurance Documents

Utility G

The site QA group activities are defined by Quality Assurance Procedures (QAP's) which provide the "how to" instructions related to such topics as Auditing, Corrective Action Requests, etc.

EPC Firm

1. Construction

   a. Construction Performance Standards (CPS's). These documents, which are prepared at the home office level, are general EPC Firm documents which contain requirements and guidelines on how to perform certain construction operations. The one entitled, "Planning and Performing Concrete Placements", for instance, establishes the basic criteria (i.e., stages of planning, batching control, selection of equipment, etc.) which must be considered when more detailed project level planning is done by the site construction group. It should be noted that in the Civil area, QC does not inspect against the CPS's.

   b. Technical Specifications. The following concrete related specifications are used on Project G:

Spec	Title	No of Pgs.	No of Revisions[1]
1	Furnish and Deliver Concrete	31	13
2	Furnish, Detail, Fabricate and Deliver Reinforcing Steel	6	11
3	Placement of Reinforcing Steel	5	9
4	Form, Place, Finish and Cure Concrete	23	10
5	Material Testing Services	21	10

[1] Approximate Number in Summer 1977

c. Work Plan/Procedures (WP/P). The Construction Department on Project G operates under a formalized Work Plan/Procedures framework (developed at the home office level) which defines the preplanning, controlling and verification requirements for all of the major construction phases (concrete, piping, electrical, etc.). The WP/P related to "Concrete Operations" for instance contains a suggested Work Plan and Inspection Record (i.e., WP & IR) which Construction Field Engineers use as a model from which they develop specific WP & IRs for each concrete placement which occurs. A WP & IR is a self contained document which is used to: (1) preplan construction activities, (2) control installation, (3) assure verification, inspection and acceptance and (4) provide objective evidence after the work is complete.

WP & IRs, which are developed for concrete placements related to both Q-listed as well as Balance of Plant (i.e., B.O.P.) components, systems and structures, provide a list of all of the important key work and inspection activities which are necessary to control the work. WP & IRs for Q-listed work must be approved by the site QC group to insure that the proper witness, review inspection and test activities have been listed and that mandatory inspection points (hold points) have been included.

The Field Engineer and the Superintendent in charge of the construction operation are responsible for the necessary in-process inspection required to control the work activities and for verifying that the work operations are technically correct and complete. In general, upon completion of the work, the foreman should and the responsible superintendent shall sign the WP & IR signifying that the work is complete in accordance with the WP & IR. The Field Engineer then signs the WP & IR signifying that the installation is technically correct and complete.

For BOP items, the signature of the Field Engineer indicates final acceptance. For Q-listed items the Quality Control Engineer must sign the WP & IR to indicate final acceptance.

It should be noted that a typical WP & IR for a Q-listed concrete placement requires that a total of approximately 52 Work or Inspection activities be individually "signed off" by the responsible Superintendent, Field Engineer and Quality Control Engineer during the preplacement, placement and post placement stages. This number is reduced to about 24 for B.O.P. concrete placements with the added stipulation that QC is not involved at all.

It should also be noted that the design documents which govern the work activities are listed on the WP & IR with the provision that the responsible Superintendent and Field Engineer will enter the latest design document revision number when they verify technical corrections and completeness at each work activity sign off point.

2. Quality Control

a. Quality Control Procedures (QCPs). The Project G Quality Control Manual (i.e., QCM) contains a series of QCPs entitled for example: Quality Verification System, Installation Control, Inspection and Test, etc. which define the responsibilities of QC personnel and provide direction for meeting the QC requirements that were established in the Project G Quality Assurance Manual. The QCP which deals with "Installation Control" establishes the requirement that each Quality Control Engineer must assure that each construction work operation to which they are assigned is controlled by performing quality activity/tasks in the following systematic phases: (a) Pre-process, (b) In-process, and (c) Post-process.

b. Quality Control Instructions (QCI's). The QCI's which appear in a Quality Control Instruction Manual (QCIM), provide detailed direction to the Quality Control personnel who are preforming inspection activities in specific technical areas. As an example, some of the QCI's which apply to the concrete phase are:

1. Concrete Inspection Activities--21 pgs.
2. Concrete Testing Laboratory Control and Interface--10 pgs.
3. Concrete Batch Plant Control and Interface-11 pgs.

The first QCI noted above, when applied to Q-listed concrete placements, contains the three basic "Inspection Checklists" (i.e., for Concrete: Preplacement, Placement, and Post Placement) that delineate the QC Engineer's interface with the WP & IR used by the Superintendent and Construction Engineer assigned to a particular concrete placement. The Concrete Preplacement Checklist, for instance, contains 26 items/activities, each of which must be signed and dated by the QC Engineer as he performs his responsibilities. The attributes for reinforcing steel must be signed and dated at least twice, once under "Preliminary Inspection" and once under "Final Acceptance". The QCI provides a definition of the attributes for each of these items/activities as a guide to the QC Engineer.

When the QC Engineer has completely "signed off" his checklist, he is then able to also sign the WP & IR for the particular concrete placement in question. It should be noted that for BOP installation activities, the Field Engineer uses the checklist as a guideline for performing inspections prior to "signing off" the WP & IR.

3. Quality Assurance

A. Quality Assurance Department Procedures (QAP's). Section 2 of the Project G Quality Assurance Manual contains a series of QAP's which establish the requirements with regard to such topics as: (1) Project Quality Assurance Surveillance, (2) Project Quality Assurance Audits, (3) Stop Work, etc. Guidance with respect to planning, performing, reporting, etc., in these areas is usually provided to the Quality Assurance personnel in these QAP's.

Note: The comments mentioned above with regard to the Case Study-Project G reflect the practices which were in existence during the Summer of 1977 site visit. All of the revisions to these practices which have occurred since the initial site visit have not been incorporated into the case study.

CASE STUDY--PROJECT H

PROJECT ORGANIZATION

Project H is the first nuclear power plant and the largest project, both in terms of size and cost, ever built by Utility H. The inter-relationships of the parties involved in the concrete phase of the project is shown in Figure A.30.

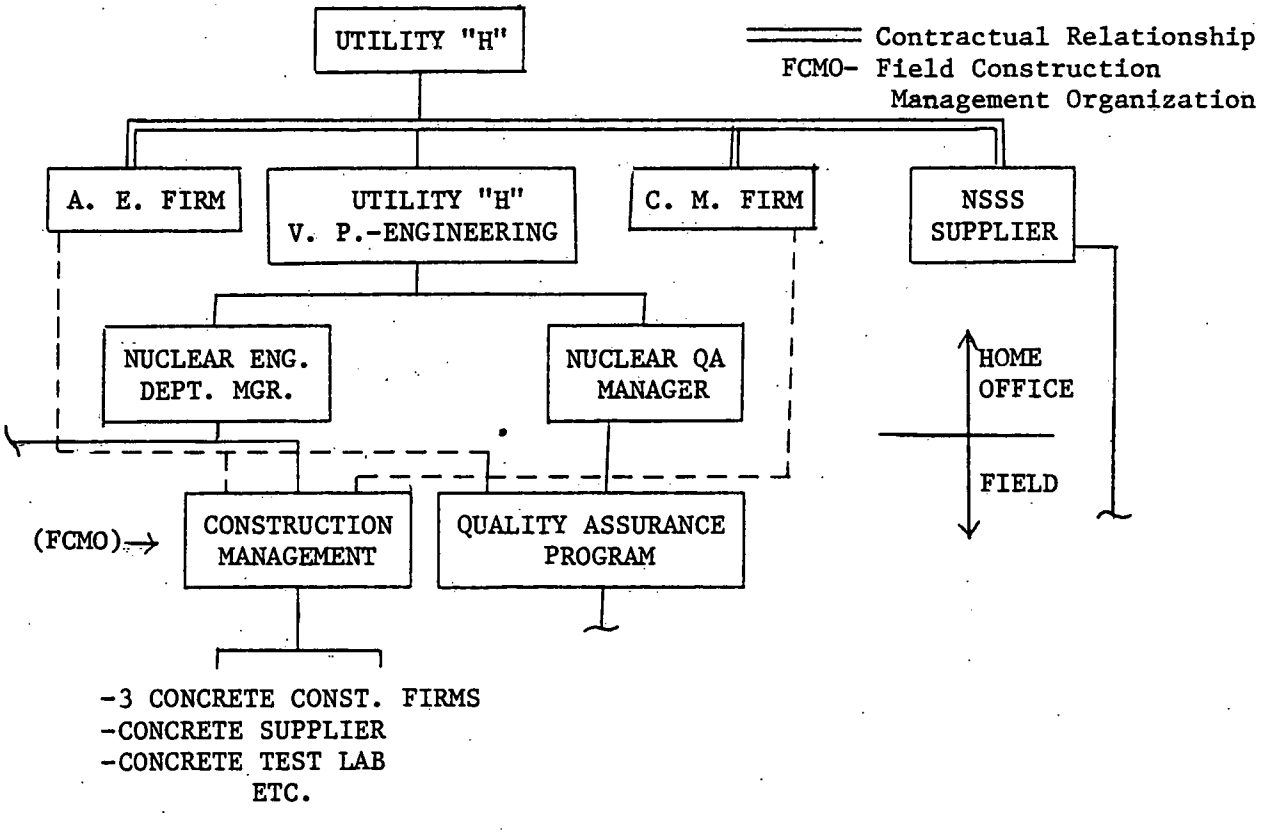


Figure A.30.--Project H: Interrelationship of Parties Involved In the Concrete Phase

As noted in Figure A.30, the project is under the direction of the Vice President: Engineering who supervises both the Nuclear Engineering and the Nuclear Quality Assurance Departments. Project H is administered under the construction management mode by a Field Construction Management Organization (FCMO) located at the project site. The FCMO, which fulfills the construction

planning and construction site responsibilities, is an integrated team comprised of personnel from: (1) Utility H's Nuclear Construction Section of the Nuclear Engineering Department, (2) the C.M. Firm, (3) the A.E. Firm and (4) other consultants.

The FCMO is unusual because engineers from each of the principal firms can be found reporting to the same supervisor. Utility H felt that it was essential that they be in charge of the project but they recognized that their in-house staff would not support such a large project. The result was an integrated organization which in December 1977 consisted of 100 CM Firm, 11 AE Firm and 24 Utility H employees at the project site.

The QA/QC effort, which is under the direction of the Nuclear Quality Assurance Manager located at Utility H's home office, is also an integrated effort. On-site Construction Quality Assurance (CQA) functions are handled primarily by Utility H under the direction of the CQA Supervisor who is a Utility H employee. Working in the CQA group are Utility H, C.M. Firm, and A.E. Firm personnel. On-site Construction Quality Conctrol (CQC) functions are performed primarily by the C.M. firm under the direction of the CQC Supervisor who is a C.M. firm employee. It should be noted that for Project H each contractor that is performing quality related work has been contractually committed to providing their own Quality Control (i.e., first line inspection).

The inter-relationship of responsibilities for both the construction management and the quality assurance efforts can be highlighted by separately examining the role of each organization.

Utility H

The construction management and quality assurance role of Utility H can be explained in relation to Figure A.31 which is an expanded version of Figure A.30.

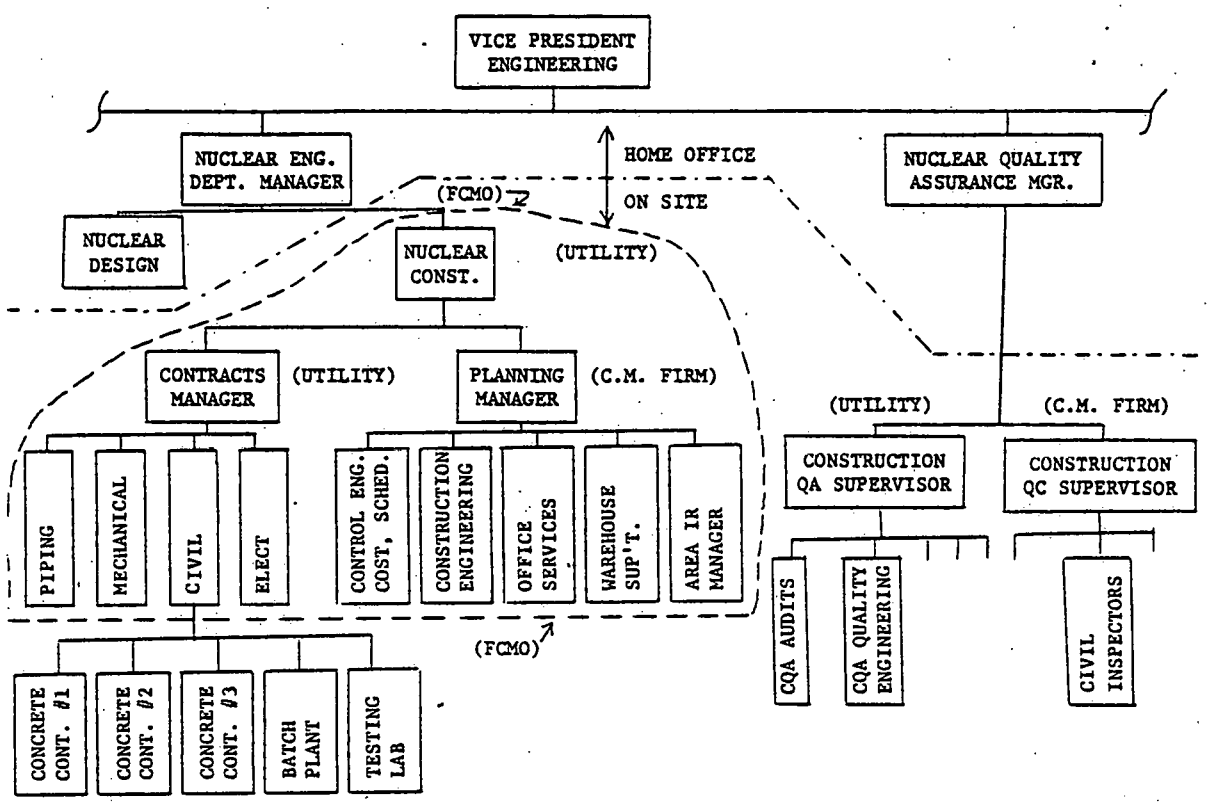


Figure A.31.--Project H: Field Construction Management Organization (FCMO)

Engineering and Management Services. The Design Section and the Licensing and Administration Section (not shown in Figure A31) of the Nuclear Engineering Department review SAR amendments that are proposed, designs submitted by the A.E. firm and the NSSS Supplier, etc.

The Nuclear Construction Section administers, directs and controls the functions of the FMCO and the various construction contractors through a General Supervising Engineer. In addition it:

1. Approves planned construction site activities, methods and procedures.

2. Provides direction for resolution of site problems.

Quality Assurance Services. Utility H, through the Construction Quality Assurance (CQA) and Construction Quality Control (CQC) groups at the project site coordinate the Nuclear Quality Assurance Program. In addition to coordination, they:

1. Review and accept the QA programs of principal agents, consultants, vendors and contractors.

2. Control, direct and monitor the functions and activities of QA/QC agents who supplement Utility H's QA efforts.

3. Assure through audit or other quality assurance techniques that established systems are implemented, adequate and effective methods of obtaining quality objectives.

A. E. Firm

The A.E. Firm is responsible for development of the engineering drawings, specifications, etc. for all of Project H which is not supplied by the NSSS supplier. In addition, the AE Firm handles on-site design problems, evaluates non-conformance and change requests related to design documents, notifies Utility H about significant deficiencies, etc.

With regard to Quality Assurance, the A. E. Firm: (1) Provides Surveillance and Audits of off-site vendors, (2) Assists Utility H's Construction Quality Assurance Group (CQA) in performing audits of site contractors, and (3) Conducts Audits or Surveillances of CQA/CQC activities at the project site.

C. M. Firm

The C.M. Firm is responsible for both Management Services as well as Quality Assurance services. With regard to the former services, the C.M.

Firm provided preconstruction planning, coordinates overall construction planning and administers construction contracts (mostly of the fixed price, work package type) to insure that all contracted commitments are met.

With regard to Quality Assurance services, the CM Firm, in support of Utility H's Nuclear QA Department efforts:

1. Coordinates contractor's and subcontractor's quality assurance activities, (which includes developing and implementing construction quality control plans, procedures, and/or instructions)

2. Provides Second Level inspection of the day-to-day safety-related work performed by contractors and subcontractors at the site.

3. Provides First Level inspections on non-safety related work performed by contractors and subcontractors at the site.

Concrete Related Firms

As noted in Figure A. 31, separate contracts for the concrete construction phase have been let to three concrete construction firms, an independent concrete supplier and an independent concrete testing laboratory. In addition to their functional responsibilities, each contractor who is involved with construction activities related to safety related structures and equipment must have its own approved quality assurance program. It should be noted that this program must include responsibility for First Level Inspection of their work.

QUALITY ASSURANCE PROGRAM

As noted above, Utility H's total quality assurance program at the Project H site is divided into two primary elements: CQA and CQC. A further explanation of these elements is presented below.

Construction Quality Assurance (CQA)

The Construction Quality Assurance element is the primary on-site component of the overall QA Program. CQA has five basic functions, these are: (1) procedure reviews, (2) configuration (design) control, (3) audits, (4) non-conformance control, and (5) quality records.

1. Procedure Reviews. All contractors supplying safety related services and materials must have their detailed procedures and/or instructions reviewed by the appropriate responsible organization. Contractor's procedures are grouped under two general categories, work related and quality related. The quality related category is further divided by inspection, special process and administrative type procedures. In general, CQA has responsibility for review and approval of quality related procedures. The technical engineering group in FCMO has responsibility for review and approval of work related (i.e., construction) procedures.

CQA performs two types of procedure reviews: (1) primary reviews and (2) secondary reviews. When CQA performs primary review (as in the case of QA or QC procedures) it performs and documents the review in accordance with detailed CQA procedures and/or instructions. When secondary review is performed (in cases where the A.E. home office performs primary review) CQA comments are forwarded to the primary reviewer for incorporation or resolution.

CQA is also responsible for providing contractor procedure review status tracking. Status tracking includes maintenance of logs indicating document receipt, identification of reviewer, review disposition, review request, and file information.

In addition to the above responsibilities, CQA performs a QA review of the site initiated contractor purchase orders for safety related materials and services.

2. Configuration (Design) Control. CQA Quality Engineering utilizes five measures of configuration control at the construction site. These measures are: (1) Field Variance Authorizations (FVA's); (2) Engineering Change Notices (ECN's); (3) Nonconformance Reports (NR's); (4) Field Questions (FQ's); and (5) Quality Trend Analysis. Quality engineers either review configuration control documents and advise the QEC accordingly or participate directly with the A.E. Firm engineer in the resolution of NR's and FVA's. These measures will be discussed later in the report as part of a comparative analysis of each measure for all of the power plant projects in the research study.

3. Audits. CQA performs two basic types of audits at the construction site: (1) Program Reviews and (2) Process Audits. They are responsible for performing audits and program reviews on (1) all site contractors performing safety related work, (2) all site organization elements of the Nuclear Engineering Department engaged in safety related activities (part of Utility H's internal audit program), and (3) CQC, when they are performing First Level Inspection. The A.E. Firm site engineering contingent is audited by their own corporate QA Department.

Program reviews are performed to provide either an in-depth review of a single contractor's QA Program implementation and effectiveness or an in-depth review of multiple contractors implementation of a single program criterion or activity.

Process audits are comprised of a combination of observance of construction, in-process inspection or testing activities and review and evaluation of the resulting documentation.

Process audits assess the performance of the personnel and/or equipment to assure compliance to specification and procedural requirements; verify the use of inspection/testing hold points; assure accurate and proper use of

acceptance criteria; and effectiveness of the quality assurance program.

Process audits also provide an evaluation of the resulting documentation and quality assurance records to assure completeness and accuracy of the final documents.

Both types of audits require a written report which is closed when the report is written, approved and distributed. Adverse conditions observed during a Process Audit are documented on an Audit Action Request (AAR), a Nonconformance Report (NR), or a Corrective Action Request (CAR), which remain open until the responsible organization's response is received, evaluated, and verified.

It is worthwhile to point out Utility H's philosophy with regard to site audits. It is felt that a program involving a limited number of extensive but infrequent audits enhances the possibility that program deficiencies may go undetected for a significant period of time. Therefore, the auditing concept is that they be frequent but limited in scope, perhaps covering only a few of the 18 criteria. During the calendar year 1977 over 100 such audits had been performed.

It is also important to mention that there are very few process audits conducted. This type of an audit would be similar to the surveillance activities found on other project sites. On Project H, for example, less than 1% of the concrete placements have undergone process audits.

4. Nonconformance Control. CQA activities such as reviews, observations and audits are conducted in accordance with the applicable procedures. Deficiencies discovered during these procedural activities and during impromptu observations are analyzed and a decision is made as to the necessary corrective action measure. This decision is based upon the QA observer's judgment of the condition with regard to the magnitude and end product effect of the nonconformance.

The deficiency requests for identification/corrective action mechanisms of the Quality Assurance program are: (a) the Nonconformance Report (NR), (b) Audit Action Report (AAR), and (c) the Corrective Action Request (CAR). It is worthwhile to note that for Project H a "Review Board" of responsible members of construction, engineering and quality assurance who have the authority to approve or disapprove nonconformance disposition is used to expedite the process.

5. Quality Records. The CQA Element is responsible for the collection, storage, and maintenance of quality records at the construction site. These records may be divided into five categories:

a. Vendor Records (BOP other than NSSS)

b. Contractor Records

c. Construction Management Records (CQA, CQC, and Site Organization)

d. NSSS Records

e. Engineering and Purchasing Records

Summary Several interesting points with regard to CQA were presented during the interviews at the project site. It was felt that one of the least cost effective (i.e., time consuming while being unproductive) activities was procedure reviews, especially when only minor revisions were involved. These problems are amplified under the CM/Work Package approach being used since there are more than 25 major contractors and 200-300 contractor procedures. A second area of least cost effective work mentioned involved the tracking (and subsequent paperwork associated with tracking) of contractor procedure reviews. This problem is also amplified in the CM/Work Package approach. Finally, the review of purchase orders for compliance to quality aspects is considered to be time consuming and somewhat unproductive. The multitude of programs and

forms from these contractors place an additional burden on CQA. Although many contractors have been convinced to use standard reporting forms, some insist on using their own company form.

There are several unique features with respect to Utility H's quality organization. First, Quality Assurance and Quality Control are under the direction of the same individual, and secondly, there is only one quality assurance organization on site. There is little doubt that the non-existence of other QA organizations reduces the amount of duplication of effort that has been found on other projects. Furthermore, it appears that CQA has been relegated primarily to a role of performing Third Level audits with very little involvement with field activities or overlap with CQC. Whether or not this is the result of better coordination afforded by common leadership is not clear.

Construction Quality Control (CQC)

The overall Quality Control program has been established by Utility H and is made up of two key elements, (1) Contractor Quality Control, and (2) Utility H Construction Quality Control.

1. Contractor Quality Control. On Project H all on-site First Level inspection of safety-related items is done by the contractor's own quality control personnel Utility H's philosophy is that the contractor's bid would be excessively high if First Level inspection were performed by an independent quality control group. Thus there are more than 25 different QC programs (not all concrete related) currently in use at the project site. One very important point should be made with respect to the concrete contractor's QC program. It is felt that for the placement of quality concrete, the QC inspector is not required to be physically present 100% of the time.

2. Utility H Construction Quality Control. As noted in Figure A31, the Construction Quality Control (CQC) element at the inspector level is divided according to technical discipline. The CQC supervisor (a C.M. Firm employee) directs the activities of twenty-three individuals. In December 1977, eighteen of them were C.M. Firm employees, four were Utility H employees, and one was a Testing Lab employee.

On safety related items, CQC performs Second Level surveillance since First Level inspection is handled by the individual contractors. At the request of Contract Administration, CQC will do First Level inspection. At present, extensive First Level inspection is being done on non-quality related items since the contractors are not required to perform these duties. CQC will also do unofficial reviews of work procedures.

QUALITY ASSURANCE DOCUMENTS

The total Quality Assurance Program discussed above is implemented through a series of manuals and documents which describe the specific duties and responsibilities of each party. Figure A.32 indicates that First Level Quality Control is the responsibility of each concrete contractor (only two of those on Project H are shown) and Second Level Quality Control is the responsibility of Utility H's QC group.

An explanation of the documents which are shown in Figure A.32 is presented below with special emphasis being placed on those that are specifically related to the concrete phase.

Construction

The entire construction phase is under the direction of a Field Construction Management Organization (FMCO) which in the concrete area directs the activities of three independent Concrete Contractors. The operations of these parties

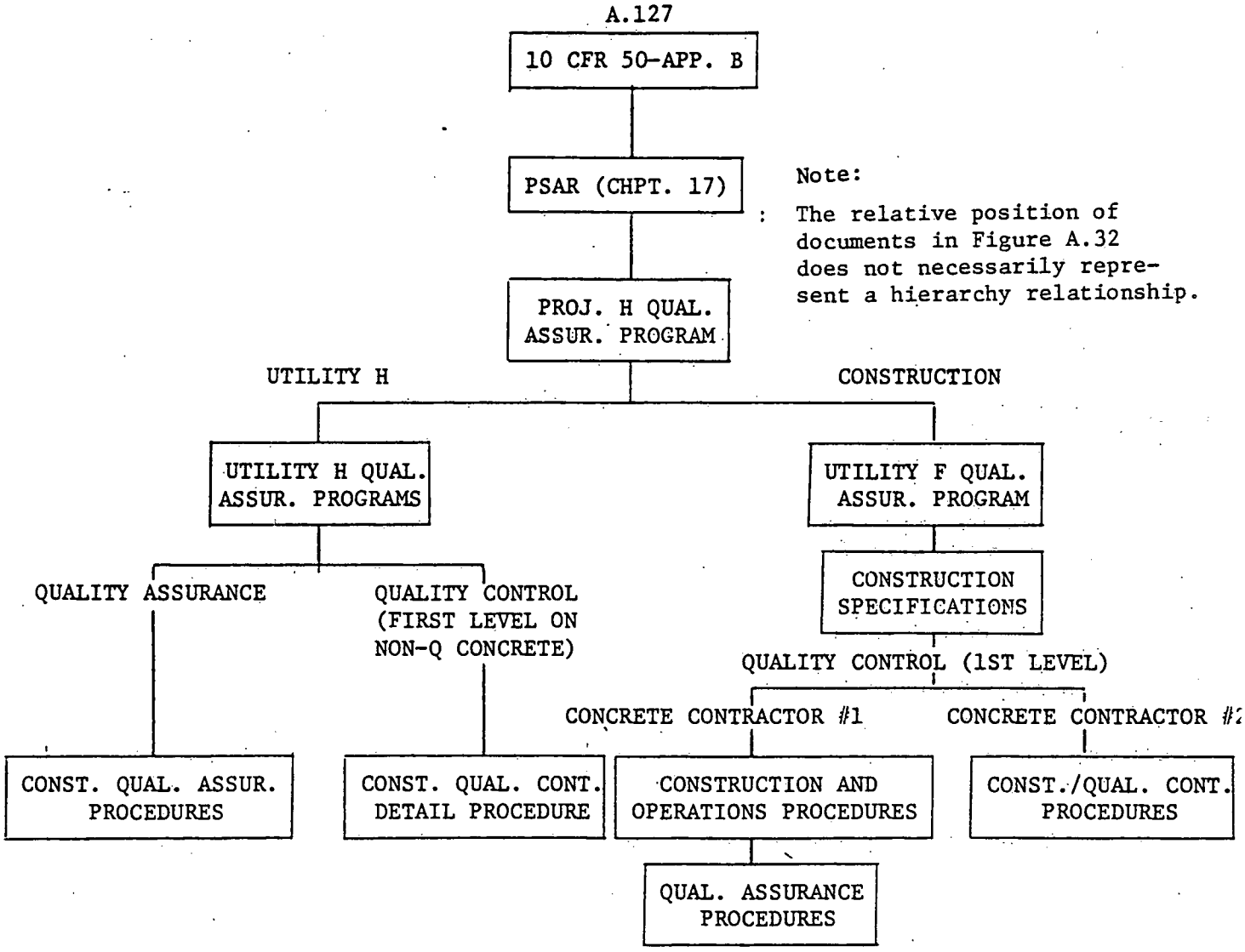


Figure A.32.--Project H Quality Assurance Documents

are directed by the A.E. Firm Concrete Specifications as well as the QA/QC documents of each individual concrete contractor. The discussion below provides examples of how two of these contractors defined their individual QC programs.

1. Technical Specifications

The concrete related specifications which were developed by the A.E. Firm include:

Spec.	Title	No. Pgs.	No. Revisions
1.	Concrete Supply (includes "Supply and Delivery of Structural Concrete" and "Concrete Plant")	61	7
2.	Placement of Structural Concrete-Safety Class Structures	22	4
3.	Placement of Structural Concrete-Non-Safety Class Structures	20	4

The specification denoted as (2) defines the scope of work which it covers as follows: "This specification defines the requirements for the procurement, placement, consolidation, finishing, curing and repairing of fill concrete, structural concrete and grout for all safety class structures on Project H." It is interesting to note that the specification denoted as (3) is almost identical to (2). Since it applies to non-safety class structures, however, the major difference is that it does not include a section entitled "Quality Assurance-Testing, Documentation and Procedures", which includes (1) A reference to Quality Program Program Requirements, (2) Documentation requirements, and (3) Construction Procedures. This test requirement states:

> "QUALIFIED PROCEDURES for the concrete phase shall be prepared by the CONTRACTOR and shall be submitted to the SITE ORGANIZATION, unless directed otherwise by this Specification, at least four weeks prior to the start of construction in accordance with the requirements of this Specification."

The issuance of two almost parallel concrete specifications is unique to Project H as far as the other nuclear plants included in this research study are concerned. This practice may be justified since one of the concrete contractors working on Project H may only be involved with Non-Safety class concrete. It may have been more efficient, however, to issue one specification for all cases with an indication of the sections that should be deleted for the non-safety case. This is particularly true for the situations where specification changes must be made which affect related construction and quality

control procedures.

2. Concrete Contractor #1

   a. Construction and Operations Procedures (COP's). The series of COP's are used to establish the acceptable construction practices related to the various phases of construction. The COP entitled "Concrete Placement"-(11 pages) assigns the responsibilities for the Construction, Field Engineering and QA/QC Inspection groups of Contractor No. 1. It references the A.E. concrete specification and the appropriate ACI Codes and provides the procedure for Concrete Procurement, Formwork, Concrete Placement, and Curing. It also provides the documentation forms which the Construction Group will use.

   b. Quality Assurance Procedures (QAP's). The series of QAP's are used to establish the procedures for the inspection that is required on the various phases of construction. The QAP entitled "Concrete Inspection" defines the responsibilities of the QA/QC effort of Contractor No. 1 and defines the levels of inspection required for the concrete Preplacement, Placement, and Postplacement phases. It also provides samples of the required documentation related to the concrete phase (i.e., Concrete checklists, Inspection Reports, etc.).

3. Contractor No. 2

   a. Construction/Quality Control Procedures (T/QCP's). The series of documents entitled (T/QCP's) form the basis for both acceptable construction practice as well as the Quality Control aspects related to that practice. The T/TCP entitled "Concrete Placement", for instance, defines both of the above mentioned aspects and also provides the documentation forms required by both the construction as well as the QA/QC groups.

Utility H Quality Control

Construction Quality Control Detail Procedures (DP's). These procedures provide the guidelines for Utility H QC personnel with regard to the inspection of construction practices. The DP entitled "Construction Quality Control First Line Inspection of Concrete Work" was used by Utility H QC at the beginning of the project on all concrete when the QC programs of the individual contractors were not considered to be satisfactory. It essentially represented the "model" around which the individual QC programs were finally developed. It outlines the responsibilities of all of the parties involved, the interfaces between Utility H QC and the contractor, and the inspection procedures and documents required for each concrete placement. It also includes an extensive QC checklist for the Preplacement, Placement, and Post Placement activities which has been modified for usage by each of the individual contractors.

It should be noted that even though the individual concrete contractors are now responsible for First Level inspection on safety-related concrete, Utility H QC is responsible for First Level inspection on all non-safety related concrete placements.

Utility H Quality Assurance

1. Construction Quality Assurance Procedures (CQAP's). The QA Program at the Project F construction site is defined by a series of QCAP's which deal with such topics as: (1) Review of Contractor QA/QC personnel, (2) Trend Analysis, (3) Control of Nonconformances, etc. They each contain the following sections: (1) Purpose, (2) Scope, (3) Definitions, (4) Responsibilities, (5) Procedure, (6) References, and sometimes (7) Attachments. The last section usually indicates the appropriate documentation forms which should be used.

2. Quality Assurance Instructions (CQAI's). The CQA Site Instructions are detailed instructions of a clerical nature to assure uniformity in routine document and record control processes of the CQA Element. They are developed by the CQA Element approved by the CQA Senior Engineer or Site QA Coordinator in accordance with the Instructions Preparation and Maintenance Procedures.

SUMMARY

At this particular point it is worthwhile to reflect upon the role of QA in the traditional three level QA/QC hierarchy of inspection and verification. Typically, the First Level involves direct quality verification or inspection, the Second Level involves a monitoring or surveillance of construction activities as well as the First Level inspection activities. The Third Level involves auditing functions which verify that the objective evidence is being properly documented and that the programs are in compliance with commitments made in the P3AR. First Level inspection has always been reserved for QC and Third Level auditing has always been reserved for QA. For Second Level surveillance, however, there has never been any clear, definitive procedure established. Indeed, on most quality programs encountered, the surveillance functions are usually performed by both QA and QC, although to a greater extent by QC. This seeming duplication of effort has traditionally brought cries of harassment from those whose primary function is production.

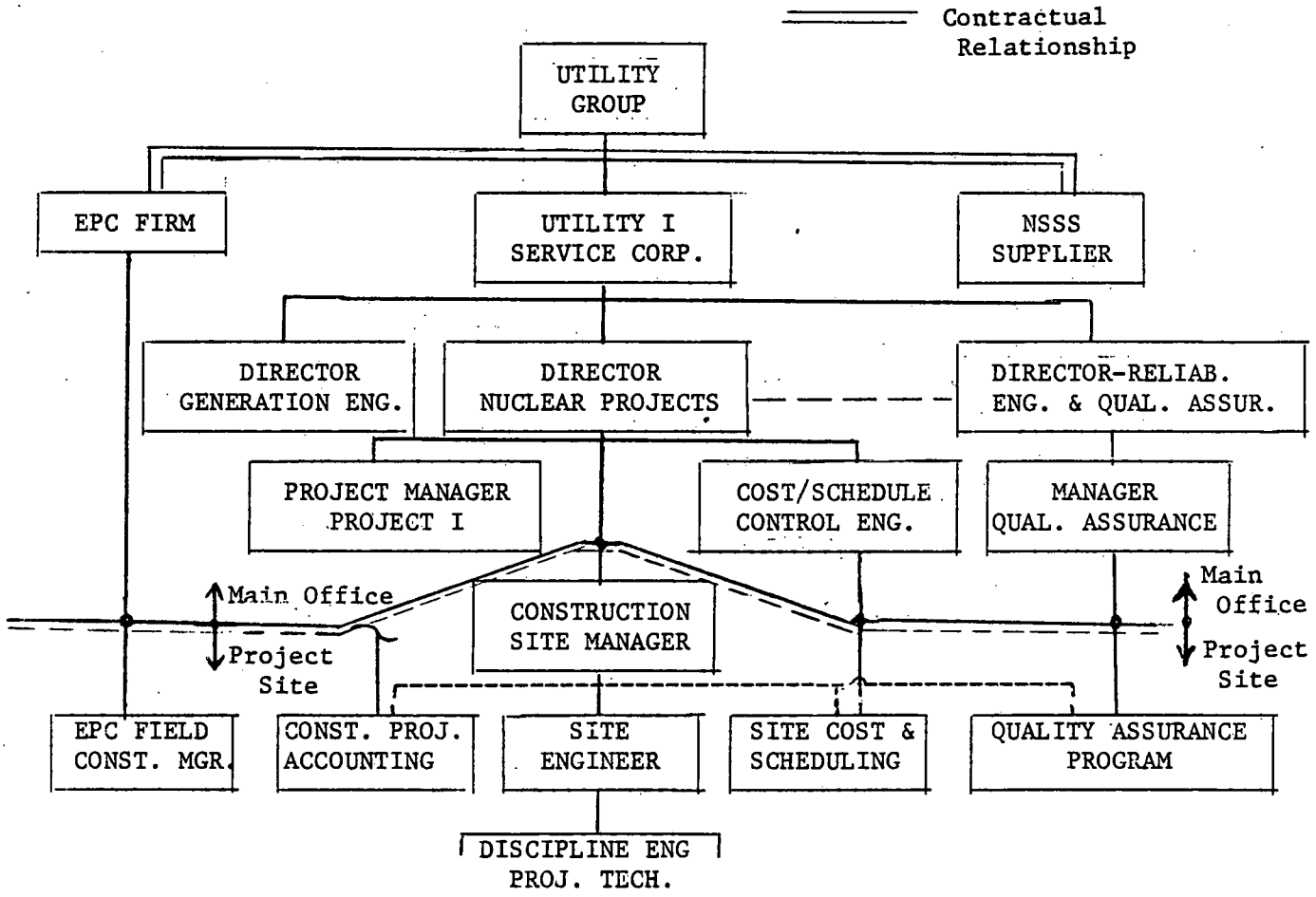
There is, however, a very important factor which establishes whether or not both QA and QC should be involved in surveillance-type activities. The factor concerns the identity of the group that is given the responsibility for resolving the many Field Variance Authorizations (FVA's), Engineering Change Notices (ECN's) and Field Questions (FQ's) which may result in changes to the

project plans, specifications, or procedures. As noted in the CQA Detailed Procedures, CQC is not a participant in the resolution process. Therefore, in the case of Project H, it would appear that QA does have justification for performing second level surveillance provided, of course, that the intended purpose is to insure the proper implementation of extensive or complex changes. This practice may not be justified on other sites. It is interesting to note that for Project H, CQC monitors approximately 10% of the placements (first line inspection is performed by each contractor) and CQA monitors less than 1% of the placements.

CASE STUDY--PROJECT I

PROJECT ORGANIZATION

Project I represents an addition to the existing nuclear generating capacity of a group of utilities. The interrelationship of the parties involved in the concrete phase of the project is shown in Figure A.33.



Project A.33.—Project I: Interrelationship of Parties Involved In the Concrete Phase

Utility I (SC)

As noted in Figure A.33, the Utility I group has placed the responsibility for Project I with its Service Corporation, which for purposes of simplicity, will be called Utility I(SC) in this case study. The Director: Nuclear Projects of Utility I(SC) administers the project through a Project Manager (who has overall project coordination responsibility) and a cost and schedule control engineer, both of whom are located at the home office, and a Construction Site Manager who is located at the project site.

The Construction Site Manager for Utility I(SC) is in charge of a staff of Discipline Engineers (i.e., Civil, Mechanical, Electrical, etc.) and Cost and Schedule specialists. This staff is responsible for on-site liason between Utility I(SC) and the EPC Firm and other contractors. This liason effort includes a review of all project related documents, specifications, procedures, etc., an overall surveillance of work progress, and an inspection of certain phases of work to insure conformance with the above mentioned documents, etc.

As noted in Figure A.33 a separate organization and Director is responsible for the Quality Assurance efforts, although, as signified by the dotted lines in Figure A.33, there is a "coordination" relationship between: (1) The Director of Quality Assurance and the Director of Nuclear Projects at the home office and (2) The Lead Site Quality Assurance Engineer and the Construction Site Manager at the project site. The responsibilities of this group will be discussed later in the case Study.

During the summer of 1977, a total of sixteen Utility I(SC) employees were involved in the above mentioned activities. Their functional responsibilities were in the following areas:

1. Field Engineering - 7
2. Cost and Scheduling - 2
3. Quality Assurance - 7

EPC Firm

As noted in Figure A.33 the primary efforts related to the Engineering, Procurement and Construction of Project I have been delegated under contract to a single EPC Firm. This firm is also responsible for the major Quality Assurance/Quality Control efforts on the project site.

As noted in Figure A.34, the EPC Firm's corporate organization is divided into the five functional departments of: (1) Construction, (2) Projects, (3) Engineering, (4) Quality Assurance and (5) Purchasing. The "Project" type organizational structure is dominant with both Construction and Engineering Departments reporting for direction to the Project Manager of Project I. The Engineering Department has both an Engineering Division as well as an Engineering Assurance Division to insure the independence required by 10 CFR Part 50, Appendix B. The Quality Assurance Department, thru the Manager of Quality Assurance, is responsible for both the Field Quality Control effort as well as the Quality Assurance effort (which for this particular EPC Firm is located at the home office).

It should be noted that there is organizational independence between the Construction effort at the project site and the Quality Assurance (both QC and QA) effort, it is however achieved differently than was achieved by the EPC Firm on Projects C, D and G. It will be recalled from those case studies that the QC effort was part of the Construction Department.

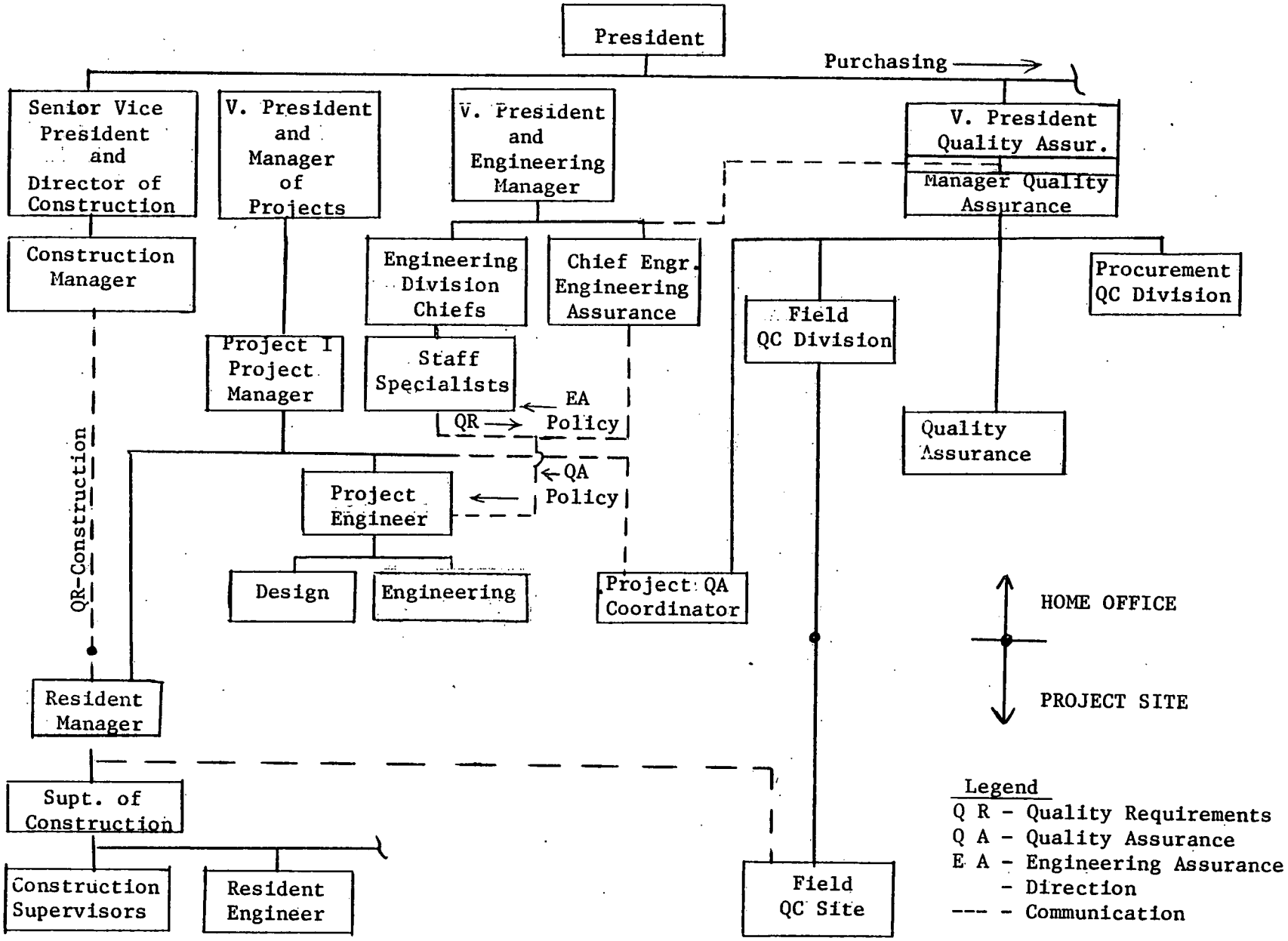


Figure A.34.--EPC Firm Organization

QUALITY ASSURANCE PROGRAM

Quality Assurance

1. Utility I(SC)

The Quality Assurance Department of Utility I(SC), shown in Figure A.35, consists of a total of 23 personnel, 7 of which are located at the project site.

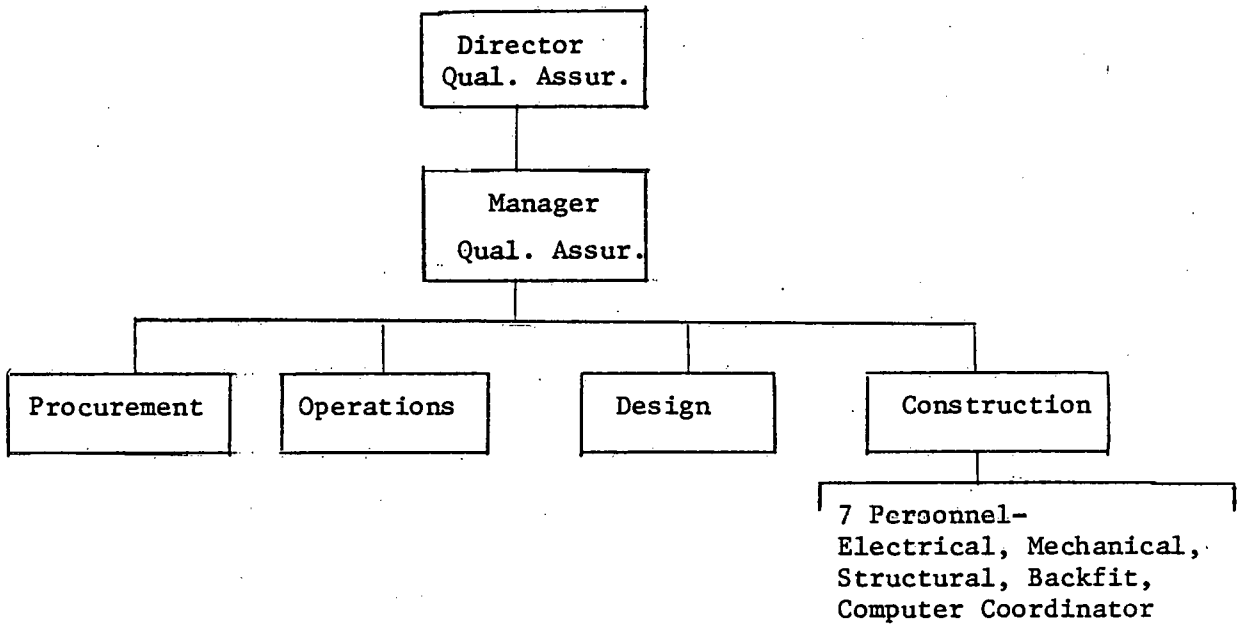


Figure A.35.—Utility I(SC) Quality Assurance Organization

The Procurement group (which is involved with outside vendors) and the Operations group (which is concerned with existing operating facilities) do not interface directly with Project I. The Design group does to the extent that they are involved with: (1) Initiation and review of the QA Manual and QA Department Procedures, (2) Description of the QA Program in the S.A.R., (3) Maintenance of QA Records and Documentation, (4) Review of major contractors' QA Programs, (5) Development of QA computer programs etc.

The seven member construction QA group which is located on the project site is responsible for:

1. Site Audits
2. Surveillance Inspection
3. Status Computer Program
4. Field Procedure Review
5. Maintenance of Site Records

Audits, which represent in-process verifications of the establishment of and the compliance with QA Programs, are performed approximately once per month for each discipline according to a computerized scheduled. Audits include the development of a checklist, and entrance interviews, the development of audit findings, an exit interview and follow-up correspondence related to problem resolution.

Surveillances are basically unplanned observations which can evoke either an immediate audit or perhaps a work stoppage.

A Computer Coordinator in the construction QA group is responsible for the computerized "Quality Assurance Deficiency Surveillance" system. This system provides for the control and accountability of deficiencies, nonconformances and other pertinent QA report data. In addition, a computerized "Audit Survey and Inspection" system is used to provide schedule and follow-up guidance for audits and surveillances.

2. EPC Firm

It was indicated in Figure A.34 that the Manager of Quality Assurance, who reports to the Vice President of Quality Assurance, is responsible for both Quality Assurance (which is located in the home offfice) and Quality Control (which is primarily located at the project site). Figure A.36 provides additional detail with regard to the division of responsibilities of the QA Department.

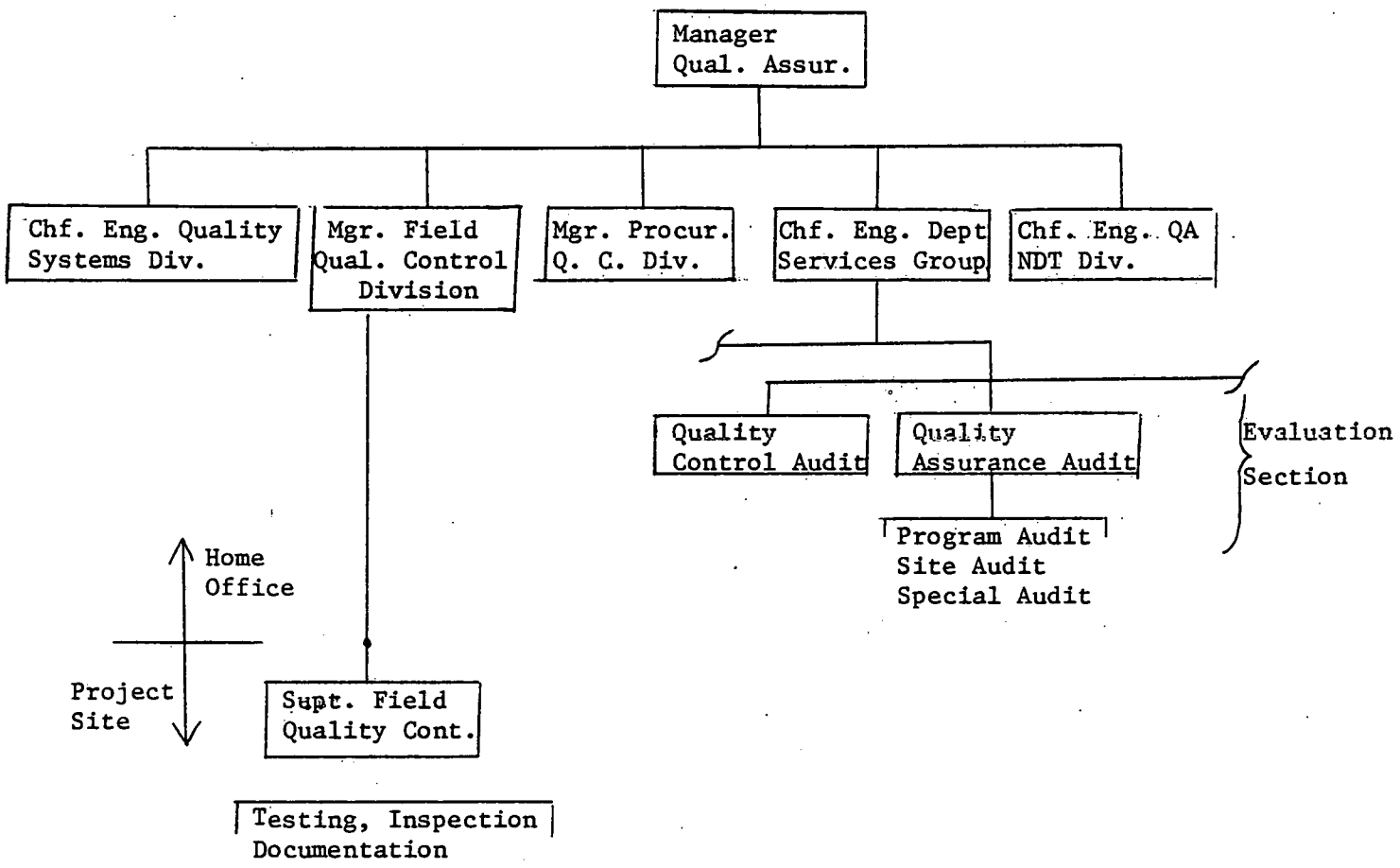


Figure A.36.--EPC Firm Quality Assurance Organization

The two groups which most directly interface with Project I are the Field Quality Control Division (which will be discussed later in this Case Study) and the Department Services Group (i.e., DSG).

The Evaluation Section of DSG, which is shown in Figure A36, is primarily responsible for the Auditing function which is divided into: Quality Control, Program, Site, and Special Audits. Quality Control Audits, as the name implies, are concerned with the EPC Firm's QC efforts. Special Audits involve the evaluation of the various QA divisions shown in Figure A.36.

Program Audits are conducted in the home office on a yearly basis with regard to a specific project quality assurance program to determine if the SAR and Utility I(SC) requirements are properly reflected in the various QA manuals and are being

or initially are capable of being fulfilled. Site Audits determine compliance with, and the effectiveness of approved procedures. They include Contractor Audits, which are audits of jobsite contractors to assure that their QA programs continue to be adequate and are being implemented in accordance with contract terms.

Each construction site is normally audited every three months, commencing four months after the start of construction until commerical operation. Each Site Audit covers at least one quarter of the criteria of 10CFR Part 50, Appendix B related to ongoing construction activities so as to cover all applicable portions of the site quality assurance program on an annual basis.

Both Program and Site Audits follow the same basic procedure. For a Site Audit for example there is a preliminary stage which includes a research effort (involving project procedures, specifications, etc.) which culminates in an Audit Plan. A Preaudit Conference is held with the Superintendent of Field Quality Control (FQC) and the Senior Construction Representative on site. During the Audit, any infractions or conditions of a serious nature are bought to the immediate attention of the responsible superintendent. Those of a serious nature result in "Significant Deficiency" reports. At the conclusion of the Audit a "Post Audit" conference is held. The Audit Report which is issued is not considered to be complete until a "Corrective Action Follow-up Log" has all of the entries marked "Satisfactory."

Quality Control (EPC Firm)

Utility I(SC)'s project organization does not include a Quality Control group . They have assigned the QC Responsiblity to the EPC Firm. The discussion below will explain this function with respect to the structural concrete phase.

1. EPC Firm QC Organization

The Field Quality Control (i.e., F.Q.C.) organization, which is shown in

Figure A.37 is under the direction of a Superintendent who directs the activities of Senior Quality Control Engineers in the Civil, Piping, Electrical and Mechanical disciplines.

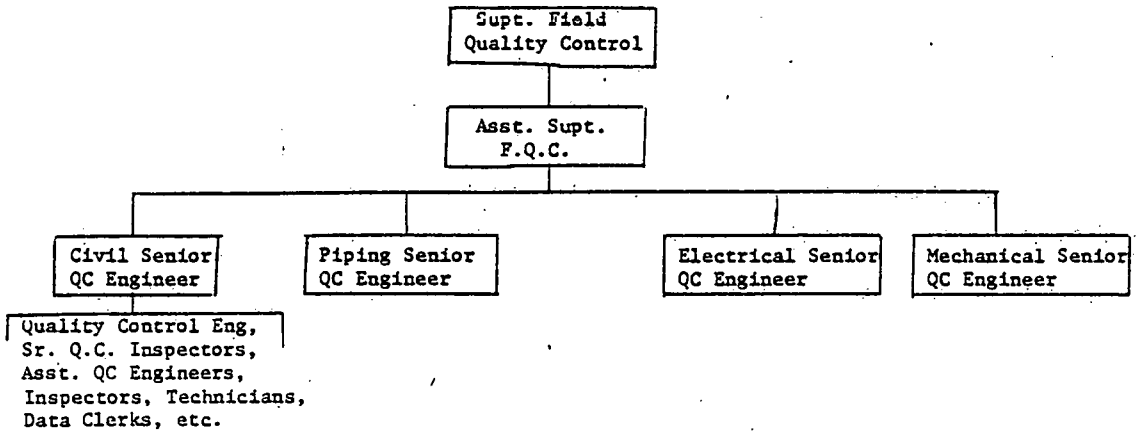


Figure A.37.--EPC Firm Field Quality Control Organization

The Civil Senior QC Engineer is responsible for all site surveillance, test and acceptance activities related to the Concrete, Soils and Steel construction phases of Project I. An appreciation of the role of QC can be obtained by examing some of the specific responsibilities of a Senior QC Engineer:

Reviews all specifications, drawings, applicable standards, codes, procedures and other documentation for conflicts and to assure their proper implementation in the construction phase.

Plans and schedules surveillance, test and acceptance inspection activities within assigned areas of responsibility.

Supervises Quality Control Engineers, Inspectors, and Technicians in the surveillance, test, acceptance inspection, and documentation of equipment installation, structural erection, concrete pours, and equipment received within functional areas of responsibility.

Coordinates with construction supervision and site engineering extension offices in order to rectify problems and dispose of nonconformities that arise during the construction phase.

2. QC Involvement in Concrete Phase

The F.Q.C. Group is involved with the concrete phase in 3 areas:

a. Concrete Batch Plant Inspection - Batch plant inspections are made for each day of concrete production. They include attributes in the: (1) Receiving, handling and storage of concrete components, (2) Batching Equipment, (3) Central Mixer, (4) Ticketing System, and (5) Delivery Systems categories.

b. Concrete Placement Inspection - F.Q.C. is involved with inspections during the Preplacement, Placement and Postplacement stages on all Category I concrete placements.

c. Concrete Testing - F.Q.C. performs all of the day to day testing of concrete components, in-process fresh concrete, and hardened concrete, for concrete in Categories I, II and III. Certain tests requiring specialized equipment etc. are subcontracted to an independent testing laboratory.

3. Quality Verification System

With regard to Category I Concrete mentioned in 2 above, the following division of responsibility should be noted.

a. Construction Department - Responsible for complying with applicable project specifications, drawings and procedures. Notifies FQC when work is ready for inspection at preplanned hold points.

b. FQC - Responsible for planning [i.e. preparation of an Inspection Plan which lists Hold Points and includes an Inspection Report (i.e., I. R.) which identifies the "attributes" which are being verified] and documenting Quality Verification activies. During the inspection,

either a satisfactory (i.e., SAT) or an unsatisfactory (i.e., UNSAT) entry is made on the IR for each attribute. It should be noted that the EPC inspector receives guidance for interpreting attributes from the EPC Firm's Quality Assurance Directive entitled "Inspection of Concrete and Reinforcing Steel."

c. Construction Department. Receives a copy of the IR at the conclusion of the FQC inspection and is responsible for determining the corrective action to be taken to correct the "UNSAT" conditions that are delineated. Correction could consist of rework, request for an Engineering Department decision, scrap or return-to-vendor decision. In certain instances, FQC may issue a "Stop Work Action" regarding a particular UNSAT condition.

It should be noted that the EPC Firm uses a data processing format which allows the results presented on each Inspection Report to be keypunched and placed into the computer history file. This greatly facilitates the analysis and presentation of data so that trends of unsatisfactory work, etc. can be established.

4. Summary

The differentiation between Category I concrete and other concrete should be noted. A Field Engineer of the Construction group prepares a Concrete Pour Card for each concrete placement. After all the appropriate Construction Department signatures have been obtained for the preplacement checks, the Concrete Pour Card is signed by the Chief Engineer for "release to pour". For Category I concrete, and certain other concrete designated in the specifications or by the Resident Engineer, the Concrete Pour Card is then submitted to the FQC inspector for his final "release to pour." In order to

do this the FQC inspector must have completed the Inspection Report requirements, mentioned earlier. For Category I concrete the FQC inspector continues his involvement through the Placement and Post-placement stages.

QUALITY ASSURANCE DOCUMENTS

The total Quality Assurance Program discussed above is implemented through a series of manuals and documents which describe the specific duties and responsibilities of each party. As indicated in Figure A.38, both Utility I(SC) and the EPC Firm have a Quality Assurance Manual which describes the policies and procedures that are applicable to Project I.

An explanation of the other documents which are noted in Figure A.38 will be presented below with a special emphasis being placed on those that are specifically related to the concrete phase.

Utility I(SC)

Utility I(SC) has defined the responsibilities and the activities which must be performed by their QA personnel in a set of QA Department Procedures.

EPC Firm

1. Construction

   a. Construction Methods Procedures (CMPS) These procedures, prepared at the home office level, present the requirements and guidelines for the EPC Construction Department on any nuclear project with regard to how to perform certain construction work operations. Additional site prepared procedures are not required. Examples are: (1) Jobsite Document Control, (2) Mixing and Delivery of Concrete, (3) Placing Concrete etc. The basic documentation related to a concrete placement which the Construction group must prepare, as outlined in the CMP entitled "Placing Concrete" is the Concrete Pour Card and the Curing

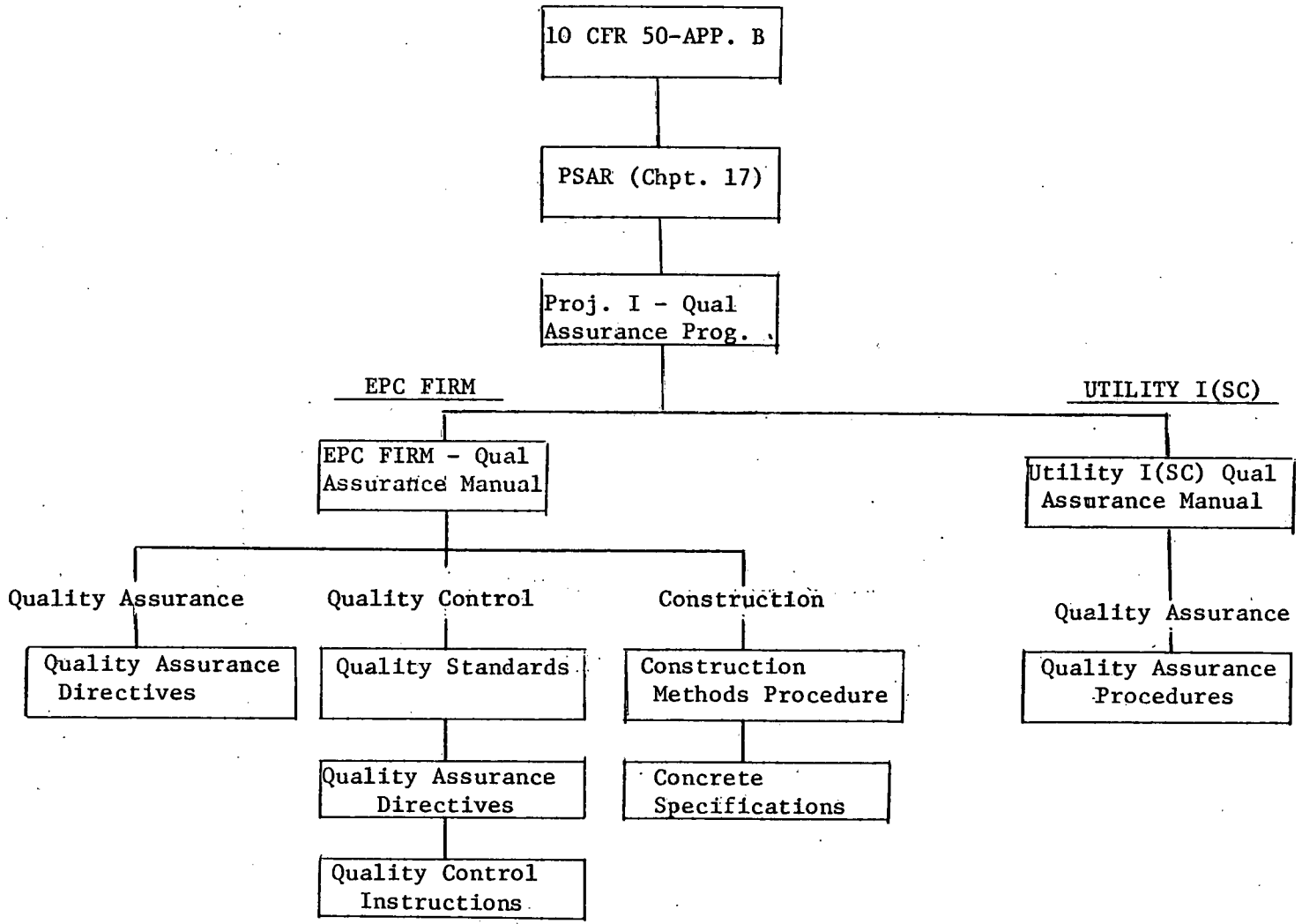


Figure A.38.-- Project I Quality Assurance Documents

Record. CMP's typically reference the EPC Firms "Master Specification" for the area under consideration.

b. Technical Specifications The following concrete related specifications are used on Project I.

Spec	Title	No. Pgs.	No. of Addenda[1]
1	Mixing and Delivering of Concrete	27 (with a 27 page Appendix)	5
2	Reinforcing Steel	21 (with a 20 page Appendix)	4
3	Placing Concrete and Reinforcing Steel	73 (with a 16 page Appendix)	6 (with 1 Revision)
4	Concrete Testing Services	32 (with a 14 page Appendix)	5

[1]Approximate number in Summer 1977.

2. Quality Control

a. Quality Standards. As noted in Figure A38, the first documents listed under QC are the Quality Standards. They actually define, at the corporate level, the various elements of the total Quality Assurance system. They range from general standards such as: (1) "Quality Audit Program", (2) "Quality Verification System" etc. to technical standards such as: (1) Mixing and Delivery of Concrete, (2) Placing Concrete and Reinforcing Steel etc.

b. Quality Assurance Directives (i.e., QADS). The actual instructions for the inspection of the various technical areas are contained in a series of QAD's. The one entitled "Batch Plant Inspection" describes the inspection Attributes which are to be used on the Batch Plant Inspection Report. In a similar fashion the QAD entitled "Inspection of Concrete and Reinforcing Steel" describes the inspection requirements and Attributes related to Preplacement, Placement and Curing of concrete. They

reference and are based on the above mentioned Quality Standards as well as the appropriate Project Specifications.

c. Quality Control Instructions (i.e., QCI's). A series of QCI's which are directly related to Project I define in greater detail the role and responsibilities of the Field Quality Control group.

3. Quality Assurance

a. Quality Assurance Directives (QAD's). The EPC Firm QA group responsibilities are defined in the form of Quality Assurance Directives (part of the same series noted above under "Quality Control.") Guidance is provided in QAD's such as (1) Audit of Site Operations, (2) Program Audits, (3) QA Site File, etc.