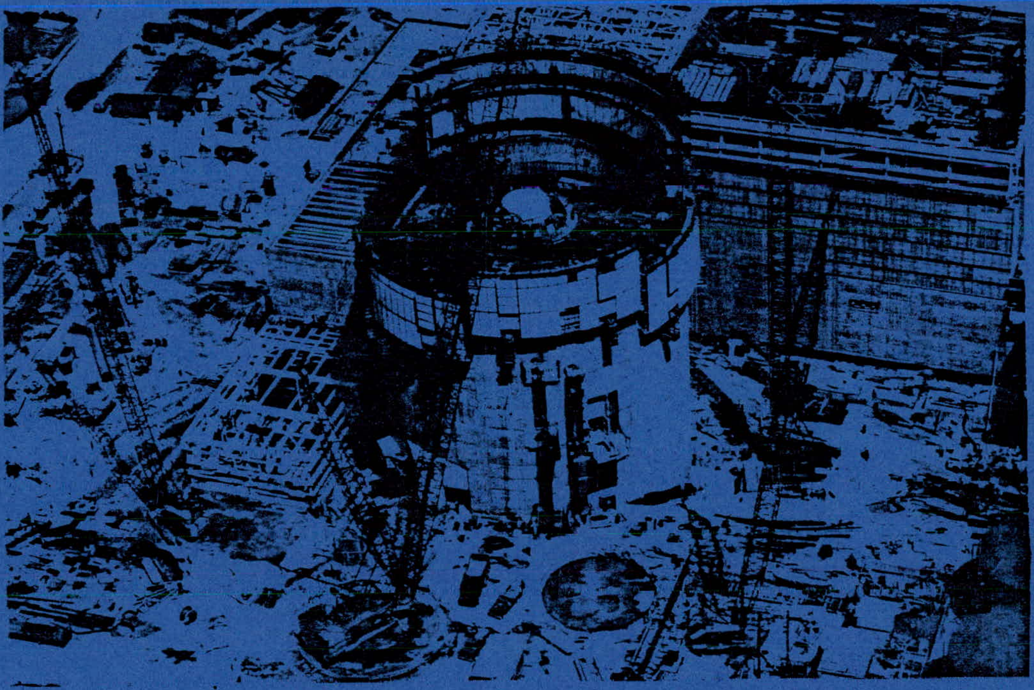
COO/4120-3

Department of Civil Engineering

Construction Management Research Series

Report No. 11

FINAL SUMMARY REPORT: A COMPARATIVE ANALYSIS OF STRUCTURAL CONCRETE QUALITY ASSURANCE PRACTICES ON NINE NUCLEAR AND THREE FOSSIL FUEL POWER PLANT CONSTRUCTION PROJECTS



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December 1978

Prepared For

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DISCLAIMER

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ABSTRACT

This report is a summary of two reports, COO/4120-1 and COO/4120-2, which were prepared for the United States Department of Energy. The research effort performed a comparative analysis of the Quality Assurance practices related to the structural concrete phase on nine nuclear and three fossil fuel power plant projects which are (or have been) under construction in the United States in the past ten years. For the nuclear projects the 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. For the fossil projects the analysis identified the response of each Quality Assurance program to criteria similar to those which were applicable in the nuclear situation. 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.

FOREWORD

This report is a summary of two reports: C00/4120-1 entitled "A Comparative Analysis of Structural Concrete Quality Assurance Practices on Nine Nuclear Power Plant Construction Projects" and C00/4120-2 entitled "A Comparative Analysis of Structural Concrete Quality Assurance Practices on Three Fossil Fuel Power Plant Construction Projects," which were prepared for the United States Department of Energy. The research effort was performed in relation to nuclear and fossil fuel projects which are (or have been) under construction in the United States in the past ten years.

The main body of this report presents Chapter 1 of both of the above mentioned reports, each of which provide a description of the research effort which was performed as well as the "Observations" and/or "Recommendations" which resulted from the research effort. Appendix A of this report presents the Table of Contents of each of the two original reports in order to indicate the scope of the research effort. Appendix B of this report presents an abridged version of Chapters 2 to 9, as well as Appendix A, of report C00/4120-1 (i.e., the one related to nuclear projects). Most of these chapter abridgements consist of an introduction and a summary of the original chapter as well as a presentation of the "Figures, Tables and Exhibits" which appeared in the original chapter. It is felt that this level of detail will satisfy the needs of most readers. For those that desire more information about the results of the research related to either the nuclear or fossil studies, it is suggested that the original reports be obtained.

For the nuclear projects that were examined the analysis identified the response of each Quality Assurance program to the applicable criteria of

10 CFR 50, Appendix B, as well as to other pertinent regulatory requirements and industry standards. For the fossil projects the analysis identified the response of each Quality Assurance program to criteria similar to those which were applicable in the nuclear situation.

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 or fossil fuel power plant project. It is felt, however, that as a result of the research effort, 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 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. The research effort could not have been completed without the excellent cooperation provided by all of these individuals.

The "Comparative Analysis" 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 Power Plant Construction industry.

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Chapter 1: CHAPTER 1 OF REPORT COO/4120-1

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)[2] , 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] Page number in brackets [1.1] refers to pagination in this report, page number without brackets refers to pagination in the original reports COO/4120-1 & COO/4120-2

[2] 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.

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.

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. Selection 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.

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. Selection of Fossil Projects

In addition to the nine nuclear projects mentioned above it was decided that data should be collected for the Quality Assurance practiees 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. <u>Concrete Delivery, Placement and Acceptance</u> (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 cadwelding 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: CHAPTER 1 OF REPORT COO/4120-2

INTRODUCTION

One of the areas of power plant construction which has an impact, in terms of both the cost and duration of projects, is structural concrete. 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 or near the project site.

DESCRIPTION OF RESEARCH EFFORT

Need for Research: Fossil Projects

The Quality Assurance practices related to structural concrete on nuclear power plant projects are more formalized and extensive than those found on fossil fuel projects. An extensive research effort for the U.S. Department of Energy entitled "A Comparative Analysis of Structural Concrete Quality Assurance Practices on Nine Nuclear Power Plant Construction Projects" (1) was undertaken by the writers in the Fall of 1976. In order to provide an appropriate frame of reference for that study, it was felt that a similar, but more limited, research effort on fossil fuel power plant projects was also necessary. This report summarizes those efforts.

Objective of Research: Fossil Projects

The basic objective of the research effort was to perform a comparative analysis of the Quality Assurance practices related to the structural concrete phase on three fossil fuel power plant projects which are (or have been) under construction in the United States in the last ten years. An attempt was made to analyse the practices in a fashion which paralleled the approach used in the nuclear study (1) mentioned above, although it was recognized that a set of 18 Quality Assurance Criteria for fossil plants [similar to the 18 Criteria of 10 CFR 50 Appendix B (2)] did not exist.

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 tesing 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 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.

Limitations of Research: Fossil Projects

It was not possible, within the time and budgetary constraints of this research project, to consider the topic from a fossil viewpoint in as great a depth as the comparative analysis of the nuclear projects (1) cited above. The interested reader is encouraged to first examine the nuclear report (1) since the explanation and analysis which is provided in that report is much more extensive. It is felt, however, that utilities, engineers and constructors will be able to compare the levels of QA/QC emphasis on the two types of power plant projects with respect to structural concrete when this fossil report is evaluated in relation to the nuclear report.

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.

   b. The pertinent Quality Assurance requirements, codes, standards, and guides. These essentially 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. Selection of Nuclear Projects

   The interested reader is referred to (1, pg. 1.7) for details.

3. Selection of Fossil Projects

A total of three fossil fuel power plant projects were selected for this phase of the comparative analysis. The specific details related to these projects is found in Tables 2.1 and 2.2 in Chapter 2 of this report.

It should be noted that a direct comparison between this fossil based report and the one related to Nuclear Power Plant Construction Projects (1) 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., 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. It should be noted that since there are no formal governmental regulations with regard to QA/QC programs on fossil power plant construction projects the data which was received was often not as extensive as was found on the nuclear projects examined in (1).

Each fossil plant was visited at least twice and an effort was made whenever possible to interview representatives of each of the parties involved with the project. The level of detailed coverage was not uniform on all projects because two of the projects were essentially beyond the major concrete stage. The material presented for each of the projects in this report is therefore not complete in a number of cases. The data received was also dependent upon the availability of information on the project sites. In a number of cases, topics were not discussed, detailed information was either not supplied or not made available to the writer and interpretations had to be made.

5. Comparative Analysis

The final phase of the research effort involved a comparative analysis of the three fossil projects. The information which resulted from this comparative analysis is presented in this report as follows:

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

OBSERVATIONS

The results which were obtained from the research study, as noted above, are presented in Chapters 2 to 7 of the report. Some of the important observations which we felt to be of particular significance are presented below.

1. On two of the fossil projects (i.e., Projects X and Y) the Utility served as its own Construction Manager. The construction phase of Project Z was managed by the same A.E. firm that was responsible for the design phase.

The direct influence of the Utility on Project X was rather significant even though the number of Utility X personnel committed to the project was not very large. Utility X personnel were placed in the key managerial positions within the field organization. They were supplemented by personnel from the AE Firm.

On Project Z the AE/CM Firm appeared to play the more significant role although there was a good deal of coordination between the small project site staff of Utility Z personnel and the AE/CM Firm personnel.

Offsite concrete batch plants were utilized on all three projects. The concrete testing responsibility was placed with an independent testing laboratory on 2 of the 3 projects. Testing on the third project was directed by the Utility.

2. It appears that all three projects had active QC programs, some parts of which clearly showed the influence of nuclear construction practices. On Project X for example, the Nonconformance Report, Corrective Action, Surveillance and Inspection Log, etc. elements were key parts of the QC program. On Project Y the Utility retained a Constructor to develop and direct a QA/QC program which would later serve as the model to be implemented on Utility Y's next nuclear project. Utility Y was therefore effectively using Project Y as a "testing ground" for the development of a more formal QA/QC program than had previously existed.

It appears that a formal QA program was developed on Project X after the QC program was operational. At the time of the project visits by the writer no formal Auditing program had been established. This element has, however, been added since the site visit. On Project Y a QA program which includes formal Audits, follow up procedures, etc. was found to be operational. It is interesting to note, however, that there is no on-site QA group; all Audits are preformed by home office personnel who make periodic visits to the project. There does not appear to be a fixed schedule or minimum frequency for these Audit visits.

On Project Z both the AE/CM Firm as well as Utility Z are involved in QA activities such as Audits, Surveillances, etc. All of these QA activities are implemented through a set of well defined QA procedures.

3. It appears that the level of documentation has increased on fossil projects and now often includes a series of formalized instructions and procedures which supplement the more traditional drawings and project specifications used on construction projects. As an example, Project X has two separate quality related "Instructions" (i.e., "Performance of Field Q.C. Inspection and Surveillance" and "Development and Implementation of Inspection Point Program") which provide Quality Control guidance. The latter type of document, which was initiated by the A.E. firm, provides guidance to inspectors when they are performing shop inspections. It includes a description of the material or equipment to be inspected and the reference documents, Inspection and Test Procedures and Quality Assurance Checklists which will be required.

4. As noted in (2) above the fossil projects exhibited Nonconformance Report and Corrective Action practices which were very similar to those found on nuclear projects. On Project X for instance a formalized Nonconformance and Corrective Action procedure which includes Hold Tags, Stop Work Action and Disposition Categories has been implemented. On Project Y two different Nonconformance Report (i.e., NCR) categories (based upon criticality) are used. Class 1 NCR's are evaluated and dispositioned by a Material Review Board consisting of the Construction Manager, Project Engineer and Q.C. Supervisor. The disposition categories are: Use As Is, Repair, Rework or Reject.

5. Another aspect of documentation which bears some relationship to nuclear practices is the emphasis which is placed on the maintenance of Quality Assurance Records. All three fossil projects had specific requirements related to the development of a "historical record" for the project. Project Y's requirements included 5 separate classification designations which specified different duration conditions for the maintenance of records in the "historical file".

6. Chapter 4 of this report presents a rather extensive analysis of the requirements which are found on each of the three fossil projects with regard to the concrete components (i.e., cement, aggregates, water, ice and admixtures) which are used in the production of concrete. Several comments of a general nature can be made.

a. There appears to be an extensive reliance on references to existing ASTM, ACI, etc. documents in the project specifications when the concrete component properties are defined. It is interesting to note that very little mention was made of problems involved with these requirements. It appears that "engineering judgment" is still extensively used in fossil plant construction when these requirements are evaluated in the field.

b. Statistical concepts related to the "Quality Control of Construction Materials" were not used on the fossil projects in the research study. The techniques of random sampling, evaluation of both the mean and standard deviation of material properties, etc. were not being implemented. This appears to be an area which should be examined in more detail by the industry.

6. There do not seem to be as many problems on fossil projects with regard to the definition of "Mass Concrete" and the interpretation of "Cold and Hot Weather" conditions as was found on the nuclear projects. This may be due to the fact that "engineering judgment" on the part of the QC inspector is often applied in those situation where problems have arisen.

Concrete placements on fossil projects are also generally not as congested from a reinforcement point of view as they are on nuclear projects. The use of Cadwelding also appears to be limited so the problems associated with this process on nuclear projects do not carry over into fossil projects.

7. The level of involvement of the QC inspectors on the fossil projects was not as extensive as found on some of the nuclear projects. Although concrete checklists which evaluated some of the attributes associated with concrete

placements were utilized, the impact on the overall concrete phase was more in line with the practices found on conventional construction. Very little mention was made of problems associated with formwork tolerances, cleanliness requirements (with regard to both formwork and reinforcing steel), or changes in concrete properties due to pumping or curing conditions. On one of the projects (i.e., Project Z) it was noted that concrete is delivered to the placement location in a dry state. Mixing water is metered and mixing of the concrete components occurs after the truck arrives at the site.

8. The concrete placement practices which were in existence on the three fossil projects are reviewed in Chapter 7 of this report. Placement, consolidation and curing practices as they were defined in the project specifications are presented.

REFERENCES

1.1 Willenbrock, J. H., Thomas, H. R., Burati, J. L., "A Comparative Analysis of Structural Concrete Quality Assurance Practices on Nine Nuclear 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.

1.2 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.

APPENDIX A: TABLE OF CONTENTS

i. TABLE OF CONTENTS OF REPORT COO/4120-1

2. TABLE OF CONTENTS OF REPORT COO/4120-2

APPENDIX B: ABRIDGEMENT OF CHAPTERS OF REPORT C00/4120-1

SECTION

1 ABRIDGEMENT OF CHAPTER 2 OF REPORT C00/4120-1: "OVERVIEW OF NUCLEAR REGULATORY AND QUALITY ASSURANCE ENVIRONMENT"

2 ABRIDGEMENT OF CHAPTER 3 OF REPORT C00/4120-1: "IMPLEMENTATION OF 10 CFR PART 50, APPENDIX B CRITERIA I, II, V, X, XVIII"

3 ABRIDGEMENT OF CHAPTER 4 OF REPORT C00/4120-1: "ANALYSIS OF 10 CFR PART 50 APPENDIX B CRITERIA III, VI, XV, XVI, AND XVIII"

4 ABRIDGEMENT OF CHAPTER 5 OF REPORT C00/4120-1: "PROCUREMENT AND TESTING OF CONCRETE COMPONENTS"

5 ABRIDGEMENT OF CHAPTER 6 OF REPORT C00/4120-1: PRODUCTION AND EVALUATION OF FRESH CONCRETE"

6 ABRIDGEMENT OF CHAPTER 7 OF REPORT C00/4120-1: "MAJOR ASPECTS RELATED TO CONCRETE CONSTRUCTION"

7 ABRIDGEMENT OF CHAPTER 8 OF REPORT C00/4120-1: "PREPLACEMENT ACTIVITIES"

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9 ABRIDGEMENT OF APPENDIX A OF REPORT C00/4120-1: "CASE STUDIES OF NINE NUCLEAR POWER PLANT CONSTRUCTION PROJECTS"

SECTION 1

ABRIDGEMENT OF CHAPTER 2 OF REPORT COO/4120-1

"OVERVIEW OF NUCLEAR REGULATORY AND QUALITY ASSURANCE ENVIRONMENT"

INTRODUCTION

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.

SUMMARY OF CHAPTER 2

Chapter 2 can be summarized as follows:

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.

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.

1. 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.

2. 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 appear to be overly restrictive Quality Assurance practices related to the structural concrete phase.

3. 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.

4. 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.

5. 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.

6. 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 committment to Quality Assurance been made.

7. 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 (6). Several opinions from industry representatives were presented and one estimate of the costs which are involved was cited.

10 CFR Part 50, Appendix B Criteria

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.

PRESENTATION OF FIGURES, TABLES AND EXHIBITS

The figures, tables and exhibits which appear in Chapter 2 of the original report[1] are presented below. They are presented without explanation in the order in which they appeared in the original report. (The original page

[1] "Original Report" refers to Report COO-4120-1

numbers have been retained.) The interested reader is referred to the original report for a supportive detailed explanation.

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

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)

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

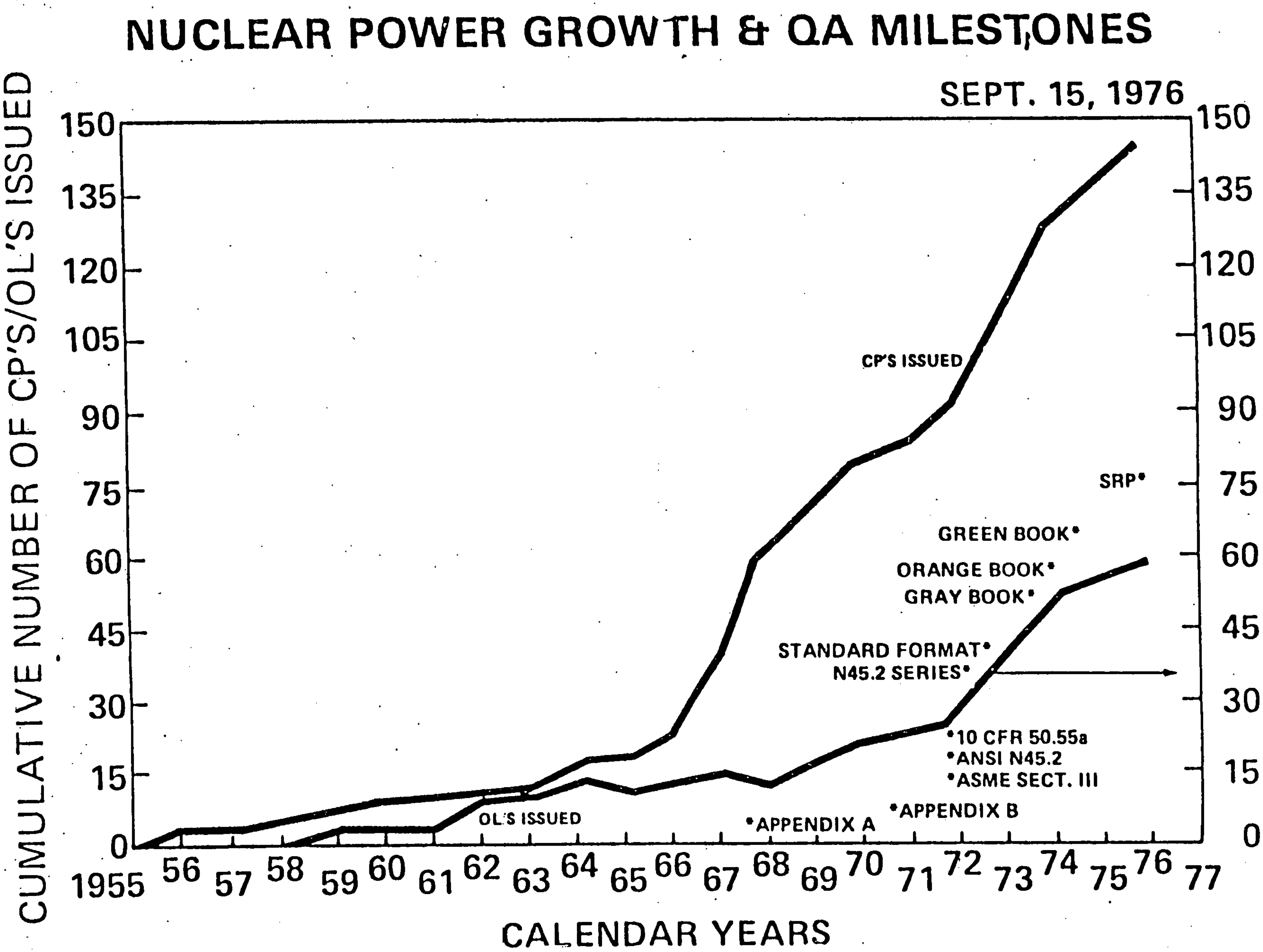

Figure 2.1.--Nuclear Power Growth and Milestones

(from Heltemes (25, pg. 7))

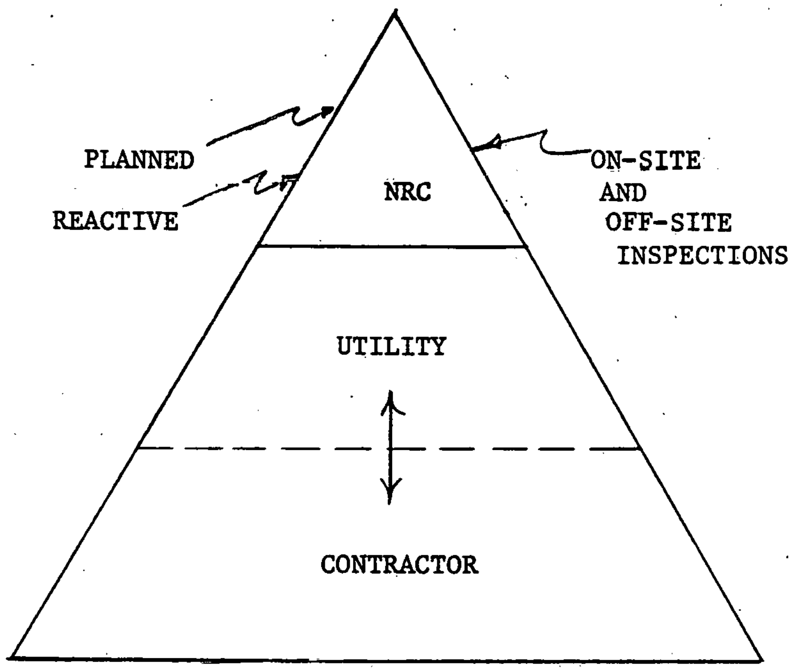

Figure 2.2--Relative Nuclear Power Plant Inspection Efforts
(from Volgenau (36))

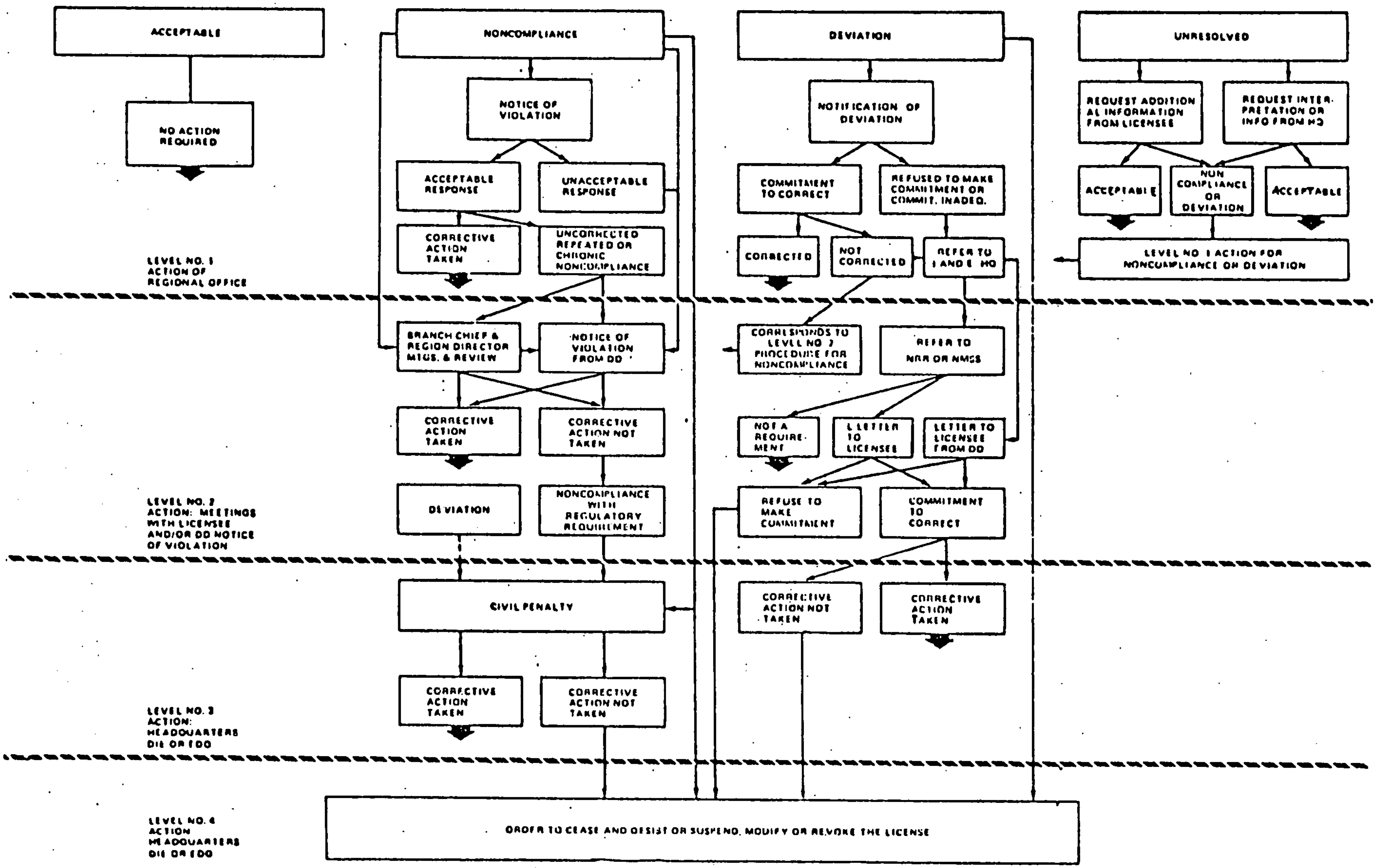

Figure 2.3.--NRC Inspection-Investigation Findings and Enforcement Action
(from Carlson (35, pg. 10B.29))

SECTION 2

ABRIDGEMENT OF CHAPTER 3 OF REPORT COO/4120-1

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

INTRODUCTION

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 the original report[1]). Chapter 4 presents an analysis of those topics which could not easily be incorporated into the Case Studies.

Each Case Study in Appendix A of the original report 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 introduciton 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.

Appendix A of the original 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.

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[1] "Original Report" refers to Report COO/4120-1.

DESCRIPTION OF PROJECTS IN THE RESEARCH STUDY

(Excerpt from Chapter 3 of the original report)

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 three distinct modes with regard to the Type of Management on the projects 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 the original report. There are a number of approaches which would result in a comparative analysis of these projects. The one that has been selected consists of a comparative analysis between projects within the same "Mode Class". It is felt that this approach will 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 in Chapter 4 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 appears in Chapter 3 of the original report. It was not designed to provide a detailed presentation complete with Tables, Figures, etc. That would have essentially duplicated the information which was presented in the individual Case Studies found in Appendix A of the original report. The comparative analysis did, however, provide a general orientation to the different alternatives which are being used. The reader was 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. It was found that 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.

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. Table 3.4 indicates the involvement during the concrete phase of the QC group on each of the 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 3.2.--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% Unit 2--22% (12/77)	Unit 1--51% Unit 2--40% (12/77)	Unit 1--57% Unit 2-- 2% (12/77)	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.

Table 3.3.--EPC Mode :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

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.G.-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.

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, 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.

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

An independent Concrete Supplier and an independent Testing Laboratory round out the total organizational design.

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.

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" when contrasted with the E.P.C. Mode, represents the other end of the scale with respect to Utility involvement.

The Office of Engineering, Design and Construction (i.e., OEDC) 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 10 CFR Part 50 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

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. <u>Safety Related Concrete</u>				
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. <u>B.O.P.[1] Concrete</u>				
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.

arrangement also represents a unique alternative to the 10CFR Part 50 Appendix B "Independence" criteria among the projects in the research study.

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

Table 3.7.--Description of Project E 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

SUMMARY OF CHAPTER 3

Chapter 3, which is devoted to a comparative analysis of nine nuclear power plant 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 representatives 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 on one of the four projects in this group since the E.P.C. QA group for that project was located in the home office and therefore was only at the project site during the period when formal Audits were being conducted.

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 which have occurred 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 the particular role which was taken by the Utility. It was found that on all projects 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 acitivities 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 since the concrete work was divided among 3 independent contractors, it may have been 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 10CFR Part 50 Appendix B Independence criterion for 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.

PRESENTATION OF FIGURES, TABLES AND EXHIBITS

The tables which appeared in Chapter 3 of the original report were all presented in the section of this chapter entitled "Description of Projects in the Research Study" which began on page [B.14]. The only figure which was in Chapter 3 of the original report appeared on page 3.16. It's included below.

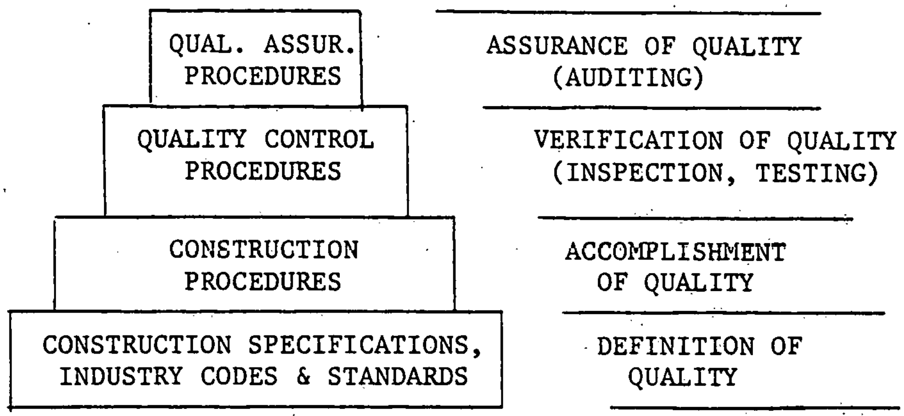


Figure 3.1.--Relationship of Quality Related Documents

SECTION 3

ABRIDGEMENT OF CHAPTER 4 OF REPORT COO/4120-1

ANALYSIS OF 10CFR PART 50 APPENDIX B

CRITERIA III, VI, XV, XVI, AND XVIII

INTRODUCTION

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 the original 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.

SUMMARY OF CHAPTER 4

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 process and that the level of involvement of these parties 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 referenced on most projects were probably never intended for the "literal" interpretation stance which occurs on nuclear construction projects. In the nuclear situation, it was noted that the Design Engineer must assume a very active "interpretive" role if later quality related problems are to be avoided. It was felt 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 as one which required less Engineering effort during the specification development stage, but could create later problems when a "literal" interpretation of certain sections of the cited code were made by the QA/QC groups. 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. It was felt that 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 the approval of Engineering Changes and a formal revision to the project concrete 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 would 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 sepcification 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 summarized some of the more important aspects of the Nonconformance Control systems on the projects which were discussed.

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.

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 dispostion 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 presented indicates 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 be 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 problem 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

---

[1] Rice, H. E., "How to Prepare an Acceptance Nuclear QA Program Implementing An Accepted Quality Assurance Program," Proceedings of the Third Annual National Conference on Nuclear Power, ASQC, San Francisco, Calif., October 1976.

> 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."

It is felt that 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 which may arise 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 condsidered, 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 lengthy. 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.

PRESENTATION OF FIGURES, TABLES AND EXHIBITS

The figures, tables and exhibits which appear in Chapter 4 of the original report are presented below. They are presented without explanation in the order in which they appeared in the original report (the original page numbers have been retained). The interested reader is referred to the original report for a supportive detailed explanation.

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.			
		Q.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. ____________

____________ ____________ ____________ ____________

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

Exhibit 4.3.--Project C Nonconformance Report

NONCONFORMANCE REPORT

1. PAGE 1 OF ____ | 14. NCR NO

2. DRAWING/PART NO. | REV
3. ITEM DESCRIPTION
4. SERIAL NUMBER
5. PURCHASE ORDER NO
6. CONTRACTOR/LOCATION
7. PROJECT NO.
8. ITEM LOCATION
9. STARTUP SYSTEM NO
10. QC FIELD INSPECTION PLAN NO.
11. ASME CODE ITEM ☐ YES ☐ NO
12. REPORTED BY | DATE
13. VALIDATED BY | DATE
15. REPLACEMENT PART NO. | REV.
16. REPLACEMENT SERIAL NO
17. SOURCE

25. DISPOSITION CONCURRENCE

REWORK	REJECT	REPAIR	USE AS IS	PSE.

PROJECT FIELD ENGINEER ____ DATE ____
PROJECT ENGINEER ____ DATE ____
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. IS 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 ____

10088-1 QC-03-2

QC

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.

Remarks:

ITION 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.

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 / WILL NOT ☐ be Incorporated ☐ 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	Designee for ACTION / Contractor Review / Date 10 ☐ DC ☐ SC ☐ SI ☐ . ☐ Other
	S & W Resident Eng. Date 6	
	SQC Approval Date 7	Inspector ☐SAT ☐UNSAT Date 11
	ASME QA Mgr. Date 8	N & D Closed Date 12
	ANI Review Date 9	New N & D

Remarks:

4.45

[B.42]

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)

Exhibit 4.5.--Project H Nonconformance Report

NONCONFORMANCE REPORT

NO. 1523 REV. 4-76

LINE NO.						
1	NCR NO.	REV. SHT. 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 ENGINEER	DATE	DECISION: ☐ ACCEPT ☐ REJECT QA/QC	DATE	
13	DISPOSITION VERIFIED	NAME	TITLE	DATE		

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.)		

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

1 Shop ☐ Field ☐ Other ☐

2 JOB ORDER NUMBER

3 N&D NUMBER № 1023

SITE OR SHOP

4 SYSTEM OR PART NAME

5 MATERIAL LOCATION

6 DATE— MONTH / DAY / YEAR

7 RELATED I.R. NUMBER

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

19 INITIATOR — 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

DISPOSITION

PROJECT

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. MAT'L'S ENG — DATE

29 EQUIP. SPECIALIST — DATE

30 PROJECT ENGINEER — DATE

REVIEW

31 CHIEF ENG. OSD — DATE

32 QUALITY ASSURANCE — DATE

33 CONSTRUCTION — DATE

REWORK

34 PLANNED COMPLETION DATE

35 REWORK COMPLETE — SIGNATURE — DATE COMPLETE

INSPECTION

36 REWORK INSPECTION ACCEPTABLE — Q.C. SIGNATURE

37 REWORK INSP UNACCEPTABLE — Q.C. SIGNATURE

38 NEW N&D REPORT NO ISSUE

39 Q.C. INSPECTION DEVICE ID. NO. & DESCRIPTION

40 NONCONFORMANCE CLOSED — Q.C. SIGNATURE — DATE

REMARKS (ADDITIONAL SUPPLEMENTS, ETC.)

N&D NUMBER № 1023

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		

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

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:

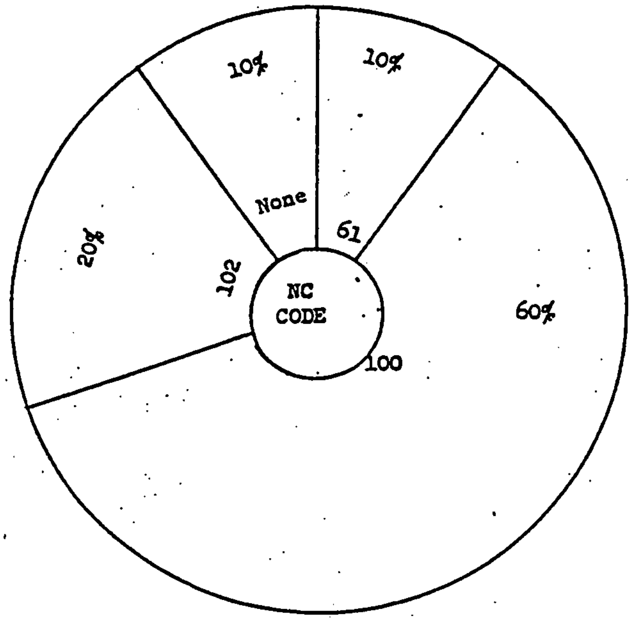
1. Nonconformance Reports

   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

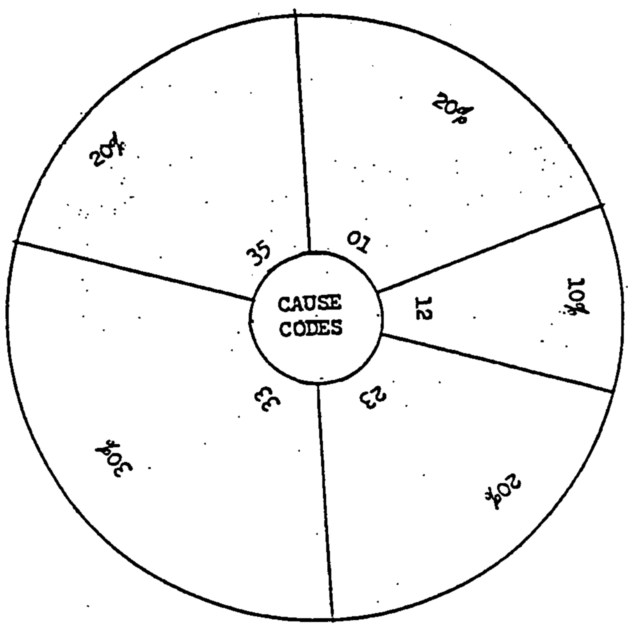
A. Nonconformance Codes



NC CODES

61—Instrument/ Certification/ Calibration
100—Testing
102—Calibration

B. Cause Codes

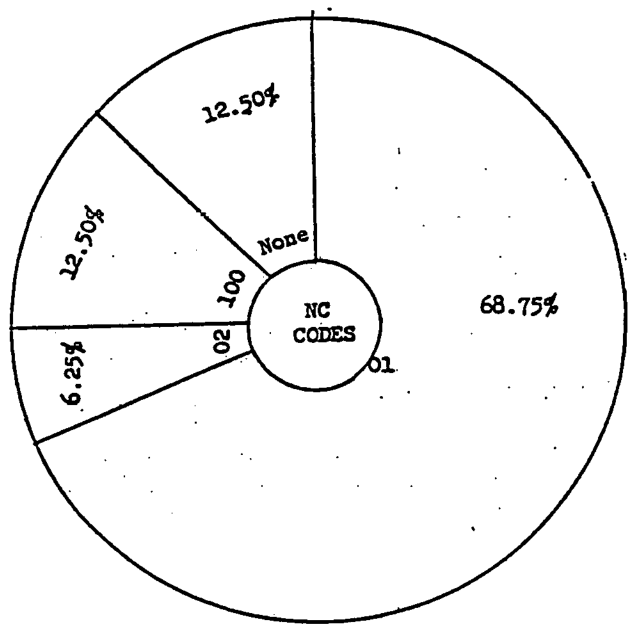


CAUSE CODES

01—Operator Error
12—Specification-Misinterpretation
23—Malfunction-Failure of Construction, Inspection and Test Equipment
33—Equipment
35—Violation of Procedure

Exhibit 4.10r–1977 Project H Trend Analysis of NR's Against CBP

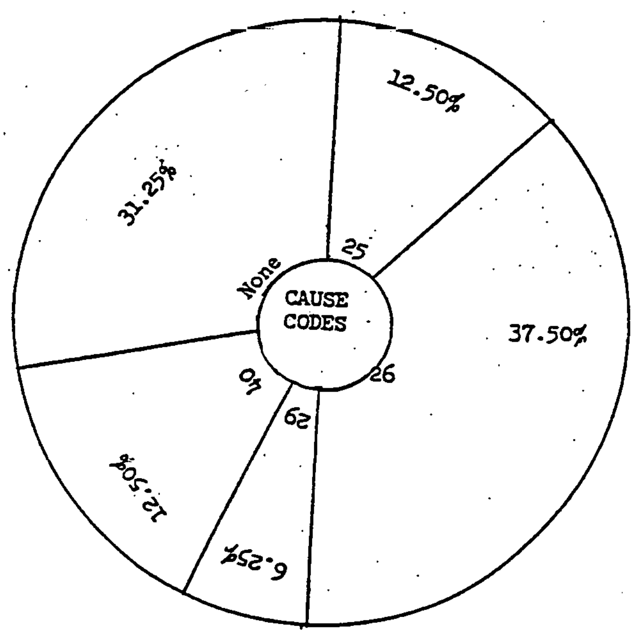
A. Nonconformance Codes



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

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

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: ____________

Exhibit 4.13.--Typical Project F Audit Checklist Page

ORGANIZATION AUDITED:	LOCATION:	PREPARED BY:	AUDIT NO. 2-77-8
Project F Concrete Batch Plant (C.B.P.)	Project F	AUDITORS:	PAGE 13 OF 18 PAGES
DATE: April 25, 1977			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 meltimg, 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.						

Exhibit 4.14.--Project F Audit Follow-Up Report

QUALITY ASSURANCE DEPARTMENT
AUDIT FOLLOW-UP REPORT

AFR NO. (d)

NIZATION 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. ________

SECTION 4

ABRIDGEMENT OF CHAPTER 5 OF REPORT COO/4120-1

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.

SUMMARY OF CHAPTER 5

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 major components of concrete. The contents of this chapter are summarized below according to these 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 of aggregates 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, a lack of application of statistical concepts for describing the natural variability of materials was indicated. 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 Reports" 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 might 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 placement temperature down. The testing requirements for ice on all of the projects were generally the same as the ones specified for mixing water.

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 might not be 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 might be considered for congested rebar areas 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.

PRESENTATION OF FIGURES, TABLES AND EXHIBITS

The figures, tables and exhibits which appear in Chapter 5 of the original report are presented below. They are presented without explanation in the order in which they appeared in the original report (the original page numbers have been retained). The interested reader is referred to the original report for a supportive detailed explanation.

Table 5.1.--Testing Requirements for Portland Cement

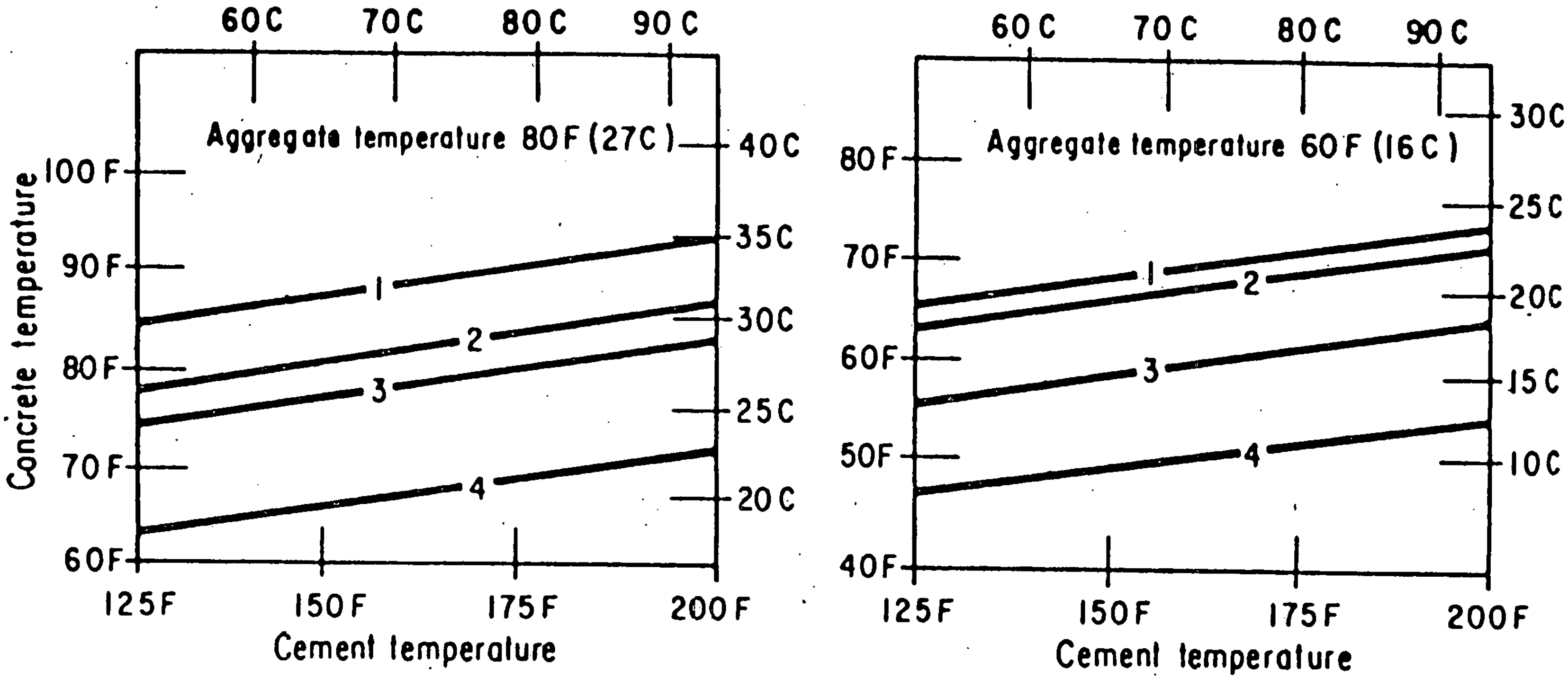
Project	A	B	C	D	E	F	G	H	I	ANSI	ASME
Cement Type	II	II	II	II	I[a]	II	II	II	II		
Reference ASTM C150	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Optional Tests	-[d]	chemical	-	chemical	chemical physical	chemical	chemical	chemical	-		
Additional Requirements	-	mortar cubes 1250 @ 3 2250 @ 7 4375 @ 28	-	-	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.



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)

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	C 128	✓	✓	✓	✓	✓	✓	✓	✓	✓	-
Absorbtion	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.

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: Test	ASTM #	A	B	C	D	E	F	G	H	I	ANSI	ASME
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

Table 5.4.--Test for Flat and Elongated Particles

Project	Reference CRD-C119	Frequency	Definition Flat (w/t)	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

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

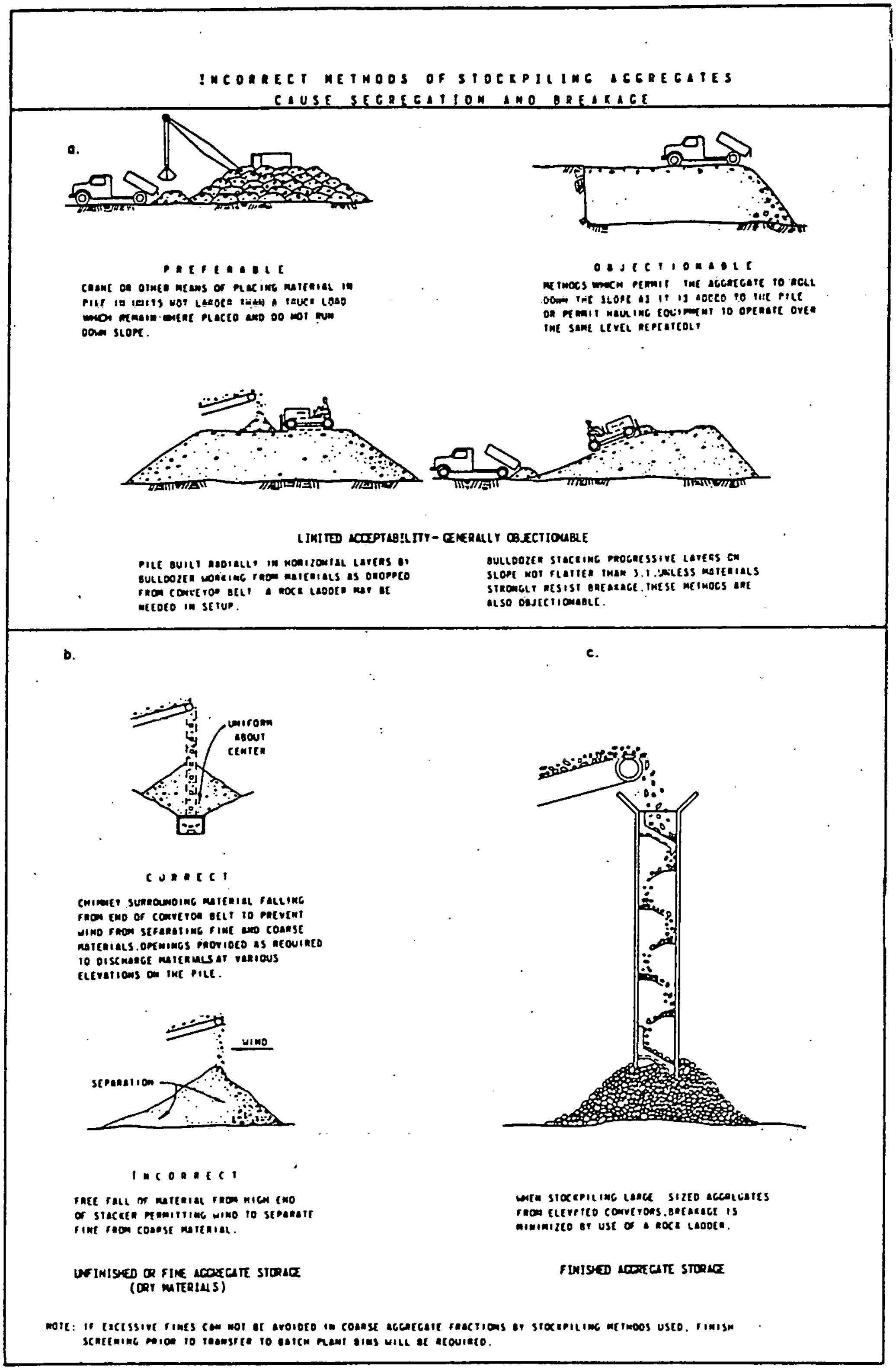


Figure 5.2.--Correct and Incorrect Methods of Handling and Storing Aggregates (Source ACI 304-73)

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 $\geq$ 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

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)

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.

Table 5.9. Use of Admixtures on the Projects Studied

Project / Admixture	A	B	C	D	E	F	G	H	I
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.

Table 5.10.—Fly Ash Requirements

Project	A	D	E			F	G	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.

SECTION 5

ABRIDGEMENT OF CHAPTER 6 OF REPORT COO/4120-1

PRODUCTION AND EVALUATION OF FRESH CONCRETE

INTRODUCTION

The very large volumes of concrete which are required on major projects such as nuclear power plants have resulted in the development of very sophisticated equipment for the batching and mixing of concrete. This chapter begins, therefore, with a comparison of the specification requirements for the concrete batch plants on each of the projects in the study. The role of the Quality Control group at each of these batch plants is then examined. The procedures related to concrete mix design on each of the projects are also discussed. The chapter is concluded with a presentation of the testing requirements for plastic concrete which have been established on each of the projects in the study.

SUMMARY OF CHAPTER 6

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 batch plants were equipped for automated batching, automated recordation and were capable of automatically compensating for varying moisture content in the aggregate. Most of the projects also placed additional production requirements on the batch plants that were used; 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 of mixing requirements, it was noted 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; it was pointed out that on some projects the batch plant inspector has so much responsibility that it appears 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 might not be the best approach since the procedures on one of the projects state 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 noted that concrete strengths may be set higher than necessary on 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 established correlation testing programs to try to predict changes of material properties between the batch plant and the forms. It was pointed out that such correlation testing 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 may 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 greatly exceeded the required strengths. There were a 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 concrete is being placed on a nuclear power plant project.

PRESENTATION OF FIGURES, TABLES AND EXHIBITS

The figures, tables and exhibits which appear in the main body of the original report are presented below. They are presented without explanation in the order in which they appeared in the original report (the original page numbers have been retained). The interested reader is referred to the original report for a supportive detailed explanation.

It should be noted that Chapter 6 included two appendices. Appendix 6.A provided examples of "Concrete Batch Plant Reports" which are used on six of the projects. Appendix 6.B presented statistical data related to the compressive strength cylinder results which were obtained on five of the projects. The Table of Contents for both of these appendices is included after the figures, tables and exhibits of Chapter 6 are presented.

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

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%

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.

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	LEFT JOB	UNIT	CODE	TOTAL YARDS INCLUDING THIS LOAD
	(1)	(2)	(32)	(34)	(3)

AGGREGATE	N/A
CEMENT	N/A
TIME	(35)
DATE	(5)
YEAR	N/A
FORMULA NUMBER	Mix
BATCH CODE	N/A
YARDAGE	N/A
MOISTURE COMPENSATION	N/A
TRUCK NUMBER	(36)
A1	(27)
A2	(28)
	(29)
	(30)
	(33)

(4)
Placement No. ________
Location ________

(6) - BC
(7) - YD
(8) - 3WA
(9) - TA
(10) - 2AG
(11) - 1AG
(12) - 3AG
(13) - 1 or 2CM
(14) - 3CM
(15) - 2WA
(16) - 1WA
(17) - 1AD
(18) - 2AD
(19) - TN
(20) - TI
(21) - TA

Show reason for rejection
due to code no. 9 only

(31)

2

(24)
John Doe

A3	N/A
A4	N/A
C1	N/A
C2	N/A
AD1	N/A
AD2	N/A
AD3	N/A
W	N/A
ICE	N/A
FLY ASH	N/A
OTHER AD	(22)
OTHER INGREDIENTS	(23)
	N/A
	N/A
	N/A

READY MIX SYMBOLS

A - AGGREGATE
C/A - CEMENT
TI - TIME
DT - DATE
YR - YEAR
F - FORMULA NUMBER
BC - BATCH CODE
YD - YARDAGE

MC - MOISTURE COMPENSATION
TR - TRUCK NUMBER
A1 - AGGREGATE
A2 - AGGREGATE
A3 - AGGREGATE
A4 - AGGREGATE
C1 - CEMENT
C2 - CEMENT

AD1 - ADMIX
AD2 - ADMIX
AD3 - ADMIX
WA - WATER
WF - ICE
FLY ASH
OTHER AD
OTHER INGREDIENTS

WATER ADDED (25) GALS. X (26) AUTHORIZED SIGNATURE

	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: ________________________

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.

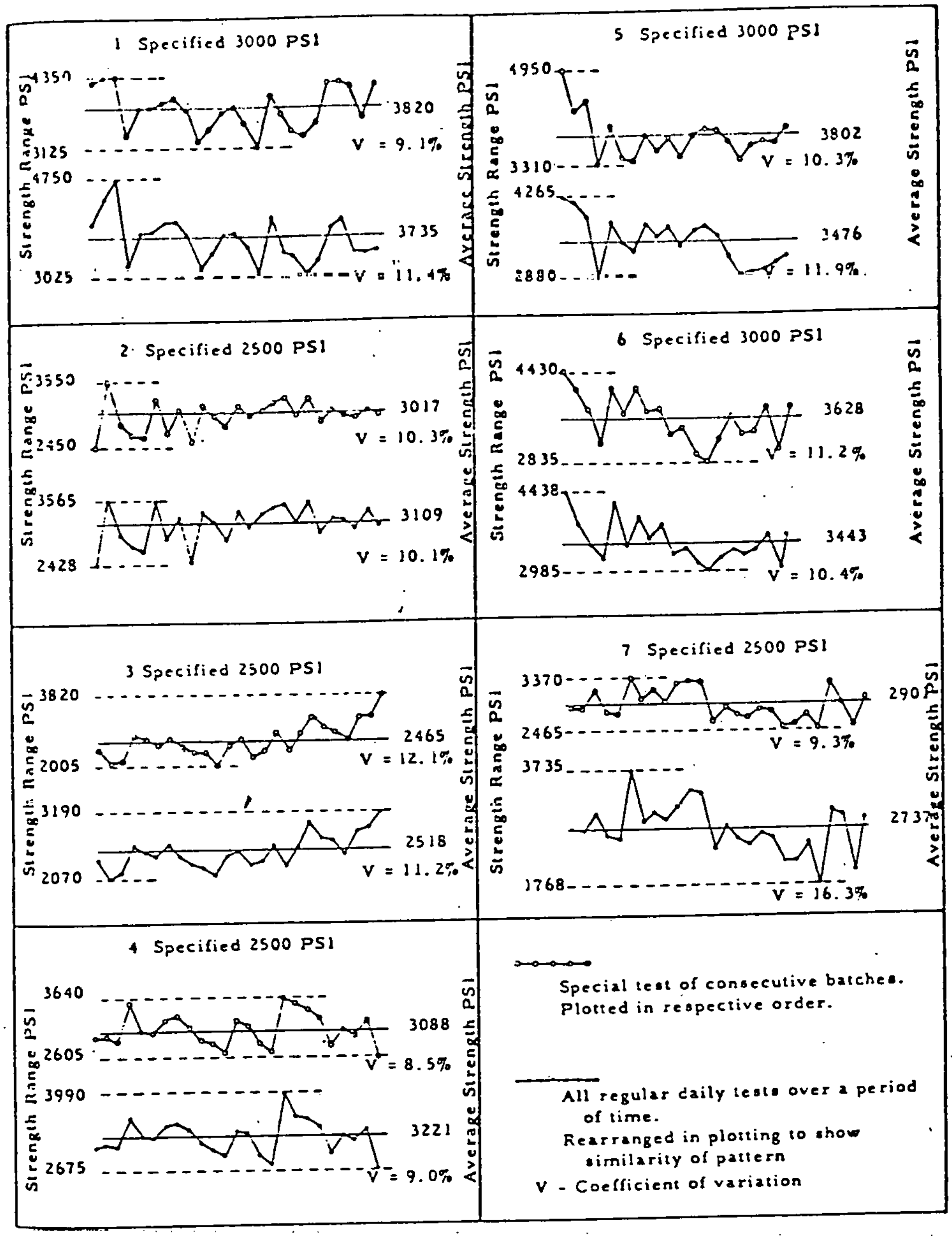


Figure 6.1.--Comparison of Strength Variations of Consecutive Batches During One Shift Compared to Variation Over a Concomitant Period

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 ≤ 3000 psi concrete: the average of any five consecutive strength tests must be ≥ f'c, and ≤ 20% of the strength tests are ≤ f'c. --for ≥ 3000 psi concrete: the average of any three consecutive strength tests must be ≥ f'c, and ≤ 10% of the strength tests are ≤ f'c. --Coefficient of variation ≤ 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

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.

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.

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

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.

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.

Table 6.13.--Method of Slump Requirement Specification on Projects C, D, and G

Type of Concrete	Working Limit[a]	Inadvertency Margin[a]	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)

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

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)

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)

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

SECTION 6

ABRIDGEMENT OF CHAPTER 7 OF REPORT COO/4120-1

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., project 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.

SUMMARY OF CHAPTER 7

A number of aspects which were not related specifically to concrete preplacement, placement or post placement activities were presented in this chapter. They were a) Project Control Systems, b) Mass Concrete, c) Attributes of Fresh Concrete, and d) Cold and Hot Weather Concreting. A summary of the findings is presented below.

The Project Control System for each project was discussed. The primary emphasis was placed on the involvement of the Quality Control group 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 it appeared that Quality Control was not 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 noted that the Quality Control group 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, two examples which indicated that such systems had not functioned as intended were presented. The hypothesis was therefore presented that increased involvement of QC beyond a certain level of intensity probably does not improve quality and in fact may have a directly opposite effect.

Mass concrete was discussed with a major emphasis being placed on how mass placements were defined on each of the projects in the study. 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 provisions result 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 the nine projects use a critical dimension to define mass placements although the critical size varies from 30 to 48 inches. Occasionally exceptions are made for fill concrete and isolated footings. One project evaluates each placement to determine if the heat of hydration will cause a problem, and therefore, if 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" approach 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 maximum or minimum temperature limits. At these discontinuities in temperature requirements an inadvertency 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; on a few projects 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.

PRESENTATIONS OF FIGURES, TABLES AND EXHIBITS

The figures, tables and exhibits which appear in Chapter 7 of the original report are presented below. They are presented without explanation in the order in which they appeared in the original report (the original page numbers have been retained). The interested reader is referred to the original report for a supportive detailed explanation.

Exhibit 7.1.--Standard Work Plan and Inspection Record for Concrete Operations For 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

7.6 [B.111]

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

B.112
7.7

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

[B.113] 7.8

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

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.

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

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

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.

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 80	Max: 80 Min: 45	Max: 75 Min: 45	Max: 65 Min: 45
	70 60 50	Max: 85 Min: 45	Max: 75 Min: 45	Max: 70 Min: 45
	40 30 20	Max: 85 Min: 55	Max: 80 Min: 50	Max: 75 Min: 45
	10 0	Max: 85 Min: 60	Max: 80 Min: 55	Max: 75 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.

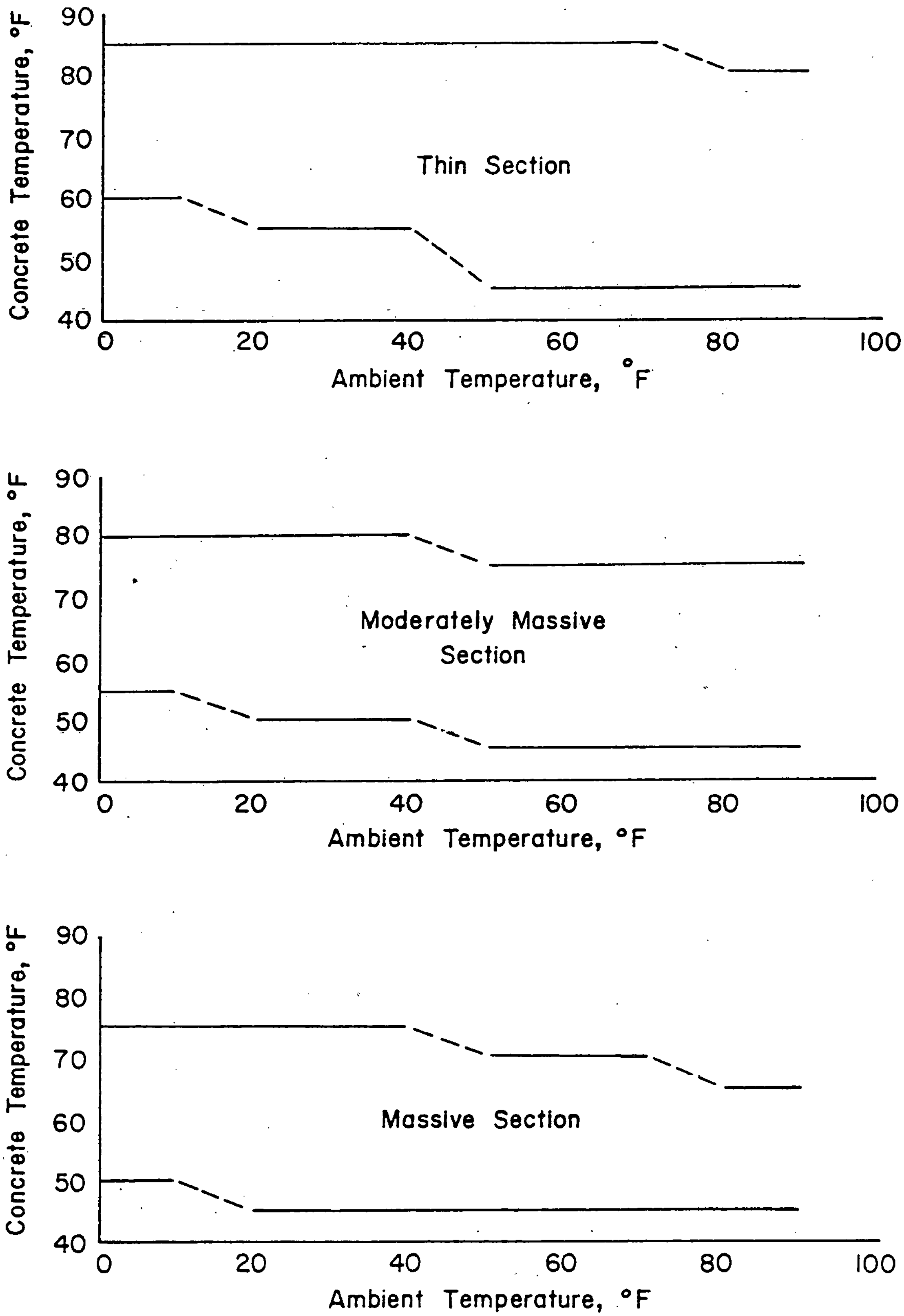


Figure 7.1. - Placing Temperatures for Project H

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)

Line			Very thin sections				Thin sections				Moderately massive sections				Massive sections			
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)

Line		Very thin sections	Thin sections	Moderately massive sections	Massive sections
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

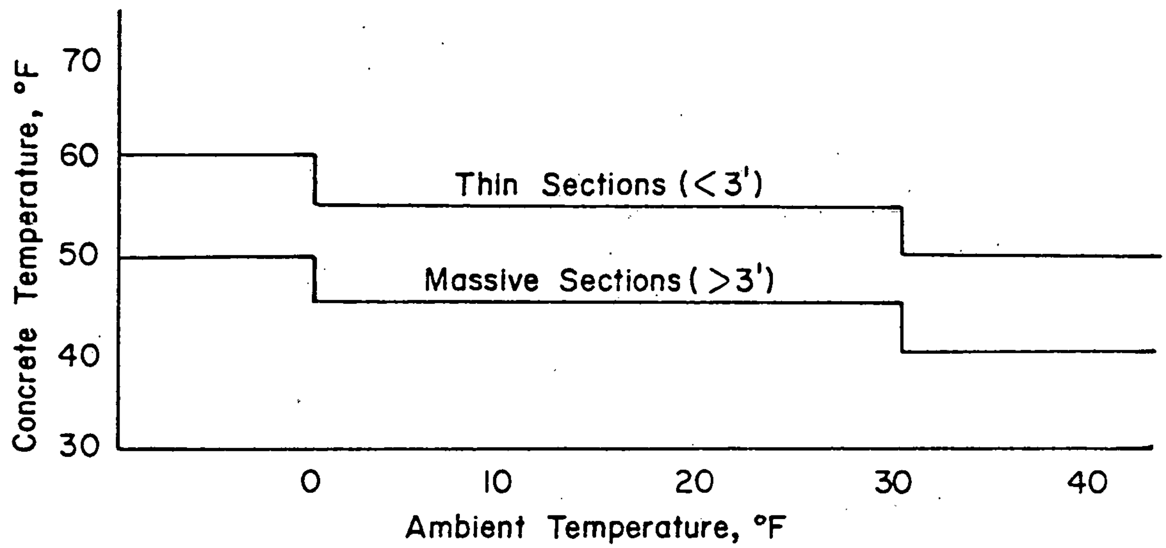


Figure 7.2. Minimum Placing Temperatures for Placing Concrete on Project G

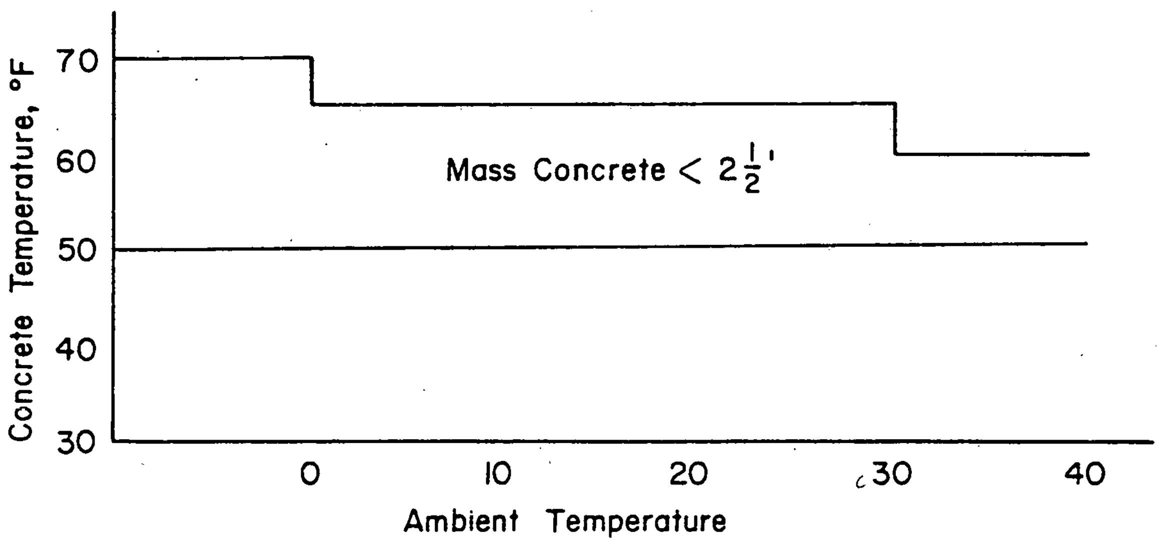


Figure 7.3. Range of Batching Temperatures for Placing Mass Concrete on Project D

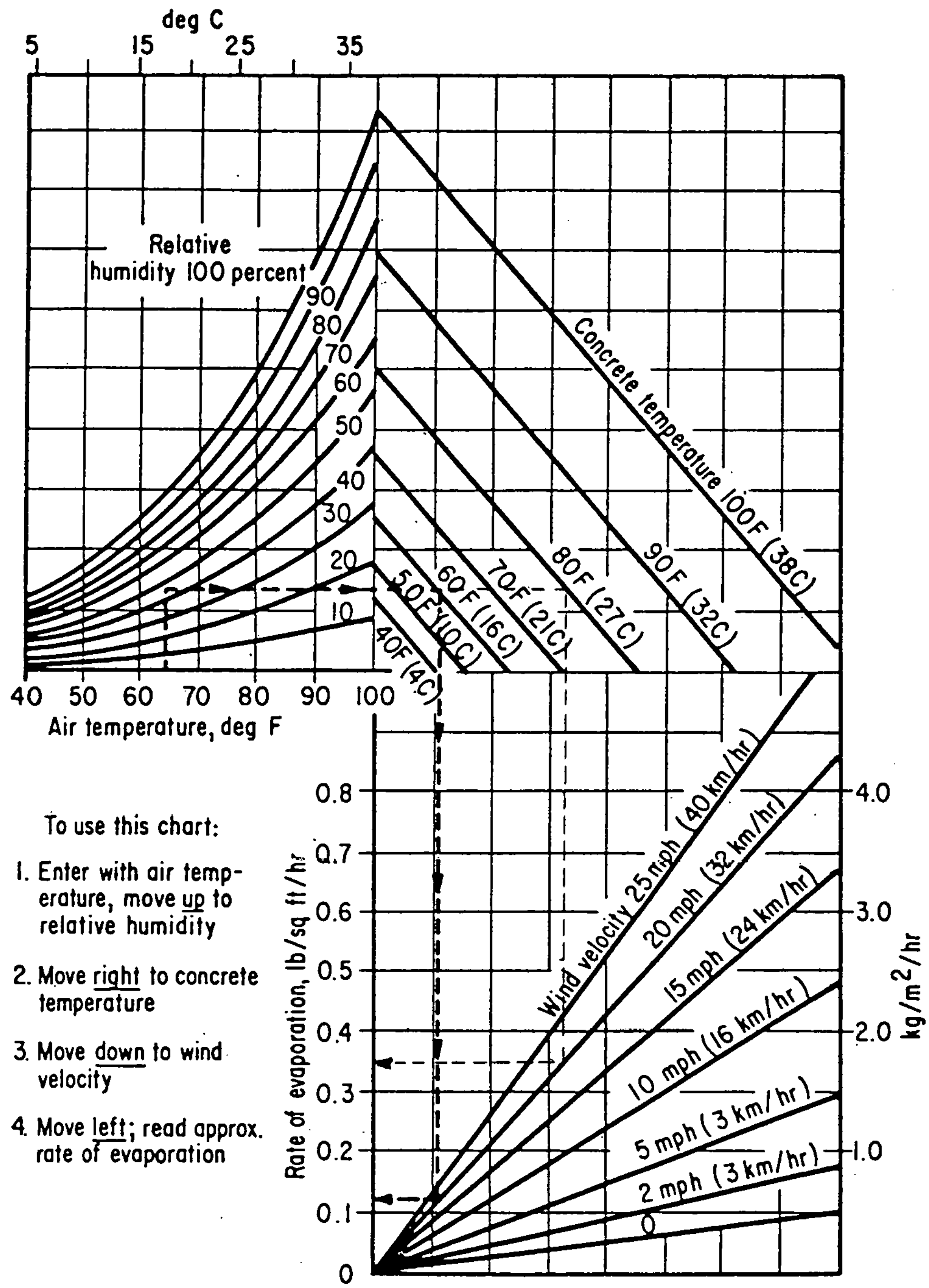


Figure 7.4.-- Effect of concrete and air temperatures, relative humidity, and wind velocity on the rate of evaporation of surface moisture from concrete. This chart provides a graphic method of estimating the loss of surface moisture for various weather conditions.

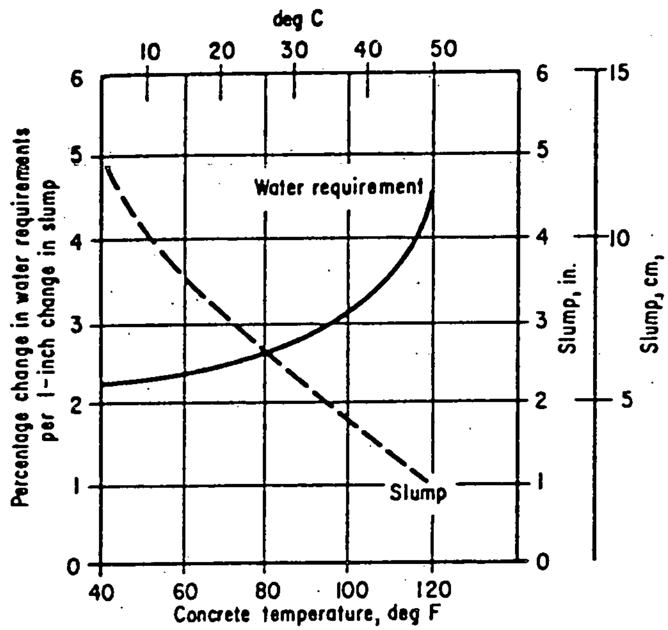


Fig. 7.5 — Effect of concrete temperature on slump and on water required to change slump. Cement content: 517 lb per cu yd (307 kg/m³); 4½ ± ½ percent air; maximum size of aggregate, 1½ in. (3.8 cm); average of data for Types I and II cements.

SECTION 7

ABRIDGEMENT OF CHAPTER 8 OF REPORT COO/4120-1

PREPLACEMENT ACTIVITIES

INTRODUCTION

This chapter discusses those activities which can collectively be defined as preplacement activities. The discussion will concentrate on the four major areas of: (1) formwork, (2) reinforcement, (3) cadwelding, and (4) delivery systems. These topics are preceded by an overview of the involvement of the Quality Control group 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.

SUMMARY OF CHAPTER 8

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. It appears that these changes have resulted in an ever increasing emphasis on written communication rather than on verbal communication. The documents on each of the projects 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 appear to be particularly acute around embedments. Several projects have received approval to relax the ACI tolerances for vertical and horizontal surfaces and grooves. The justifications for these changes were presented. The method of obtaining relief from formwork tolerances on a case by case basis by requesting an engineering design change was discussed. On several projects the frequent use of this approach would indicate that the project site organization was using this as a convenient mechanism for modifying certain specification requirements without requesting a major change in either the project specification or the industry standards.

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 previously published 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 reinforcment. 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 later vintage plants generally comply with the Reg Guide provisions. With respect to testing, it appeared that the testing frequencies were excessive since the visual inspection and tensile test data from several projects indicates that virtually all the defective cadwelds were identified by 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 it was noted that the primary concerns appeared to be focused on insuring 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 specification requirements on the projects in the study. 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 appeared to be 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 appears that cadwelds may be overtested and overinspected.

There also seemed to be room for improvement in the paper management aspects of the cadwelding process.

PRESENTATION OF FIGURES, TABLES AND EXHIBITS

The figures, tables and exhibits which appear in the main body of Chapter 8 of the original report are presented below. They are presented without explanation in the order in which they appeared in the original report (the original page numbers have been retained). The interested reader is referred to the original report for a supportive detailed explanation.

It should be noted that Chapter 8 included two Appendices. Appendix 8.A provided examples of the "Concrete Preplacement Inspection Documents and Attribute Lists" which were used on the nine projects in the study. Appendix 8.B provided examples of the "Cadweld Surveillance and Inspection Reports" which are used on the nine projects. The Table of Contents for both of these appendices is included after the figures, tables and exhibits of Chapter 8 are presented.

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

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						
Variation 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
Misplacement 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

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 1	2	3	4	NOTES: Depth & Direction of passes. Delays, unusual conditions, etc.
	Start Placement	0'-0"					
	Liquid Head						

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.

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	+½ / −¼	±⅜	±¼
Members 8" to 24" deep	±½	±½		±½	±½	±⅜	±½	±½	+¾ / −⅜	±½	±½
Members greater than 24"	±1	±½		±½	±½	±½	±½	±1	+1 / −½	±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.

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

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.

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						

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 hown 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 owder bags from which the original ample 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 sting, 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 tes 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

CB-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.

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.

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

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

SECTION 8

ABRIDGEMENT OF CHAPTER 9 OF REPORT COO/4120-1

PLACEMENT AND POST PLACEMENT ACTIVITIES

INTRODUCTION

This chapter will discuss those aspects relating to concrete placement and post placement activities. In a number of cases the emphasis will be on the time delays involved and the effect which these interruptions have on the quality of the structure. The involvement of Quality Control in these activities will be presented prior to a discussion of these aspects.

SUMMARY OF CHAPTER 9

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 which is often found in the QC procedures may tend to draw attention away from the broader aspects of concrete practice which are necessary to insure the necessary quality of the final product. Also presented was the fact that several projects have chosen to stress those practices which are not desirable rather than those practices which should be encouraged.

In discussing delivery systems the emphasis was placed on the effect which various practices had on delivering, conveying, and placing the concrete 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 felt to be important. It appears that the elimination of routine testing at the point of placement requires the completion of a correlation testing program. It was noted that most of the correlation testing programs which were studied did not appear to be well conceived and thus were very lengthy and costly. It was also suggested that the addition of supplemental water at the placement location should perhaps be prohibited because of the additional testing requirements and delays encountered. On several projects it was felt by site personnel that the provision which allowed the addition of water encouraged the production of low slump concrete at the concrete batch plant.

Construction joints were discussed, and it was noted that both starter mixes and grout were used on the projects in the study. 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. It was found that two methods of cleaning the joint were used. From an economic standpoint, sandblasting appears to be preferred over "green cutting". A number of projects reflect this in their specifications. The requirement that aggregate be exposed during the cleaning operation was also discussed. It was noted that data from previously performed research has shown the exposure of that aggregate to a specified amplitude offers no increased advantage in water-tightness or bonding characteristics.

Placement practices were also discussed with a particular emphasis being placed on consolidation. The level of detail in several project specifications and QC procedures with respect to consolidation was presented. 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. It is felt that this type of a requirement will force the vibrator operators to become timid and more concerned about contact rather than good consolidation. 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 also discussed, and the projects on which this technique was not allowed or discouraged were noted. It appeared that revibration was contrary to accepted 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 which was used. With regard to documentation it appeared that on several projects there were opportunities to consolidate the documents that were required.

Form removal and curing aspects were also presented and these were compared with the industry standards. It was noted that most projects comply with the ACI provisions. There appears to be some confusion, however, with regard to the ACI 306 Cold Weather requirements regarding the curing period that is required.

PRESENTATION OF FIGURES, TABLES AND EXHIBITS

The figures, tables and exhibits which appear in the main body of Chapter 9 of the original report are presented below. They are presented without explanation in the order in which they appeared in the original report (the original page numbers have been retained). The interested reader is referred to the original report for a supportive detailed explanation.

It should be noted that Chapter 9 included two Appendices. Appendix 9.A provided examples of the "Concrete Placement Inspection Documents and Attribute Lists" which were used on the nine projects in the study. Appendix 9.B provided examples of the "Concrete Postplacement Inspection Documents and Attribute Lists" which were used on six of the projects. The Table of Contents for both of these appendices is included after the figures, tables and exhibits of Chapter 9 are presented.

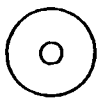
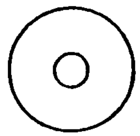
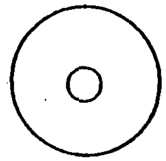
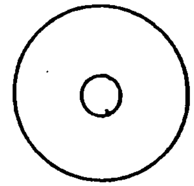
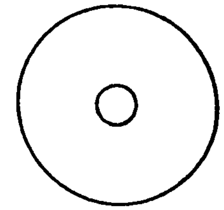
1" Vibrator	2" Vibrator		3" Vibrator	
				
Radius of action 4"-6" in 4" to 6" slump concrete.	Radius of action 12" to 16" in 2" to 3" slump concrete.	Radius of action 14" to 18" in 3" to 4" slump concrete.	Radius of action 20" to 25" in 2" to 3" slump concrete.	Radius of action 22" to 28" in 3" to 4" 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

9.16

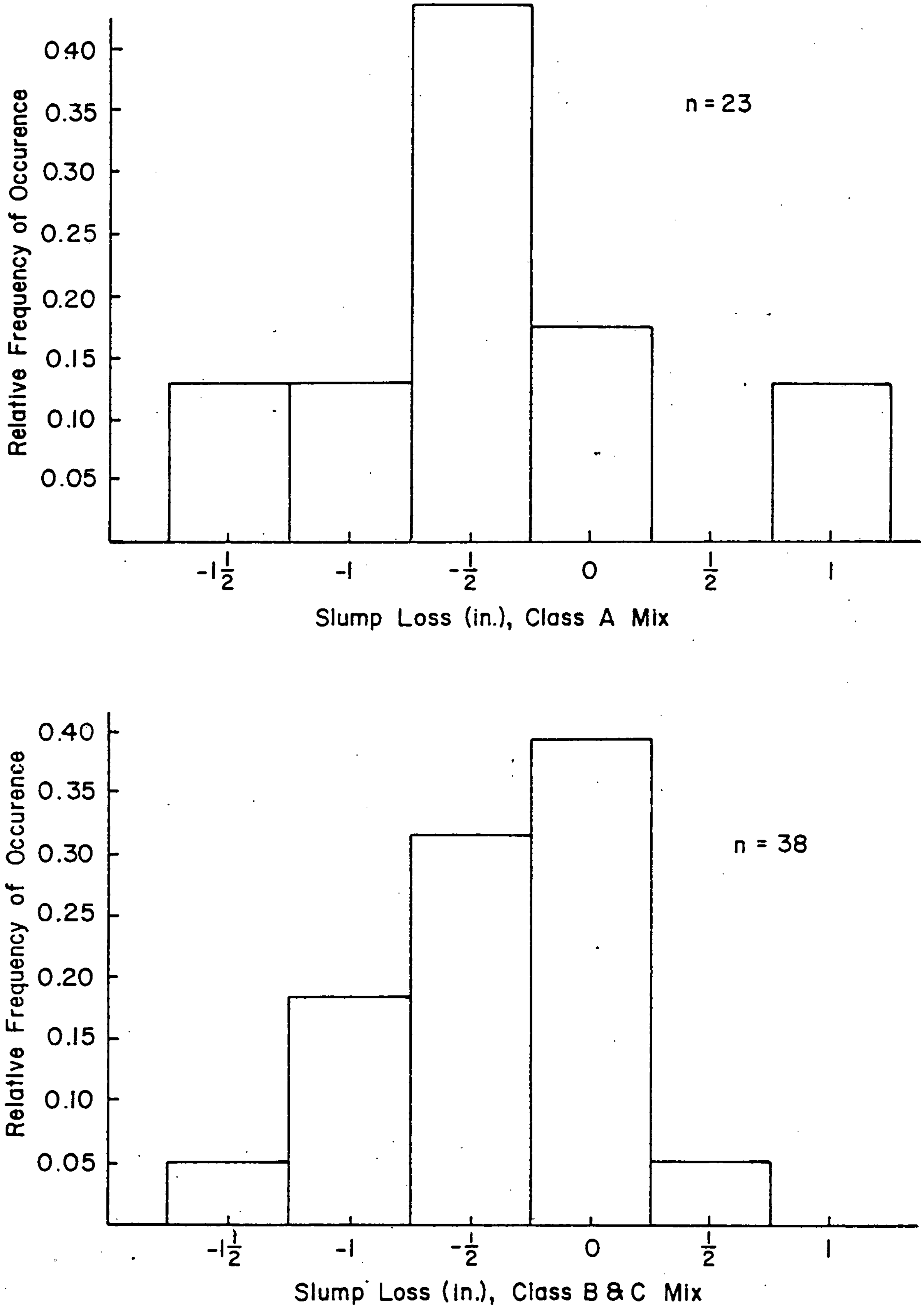
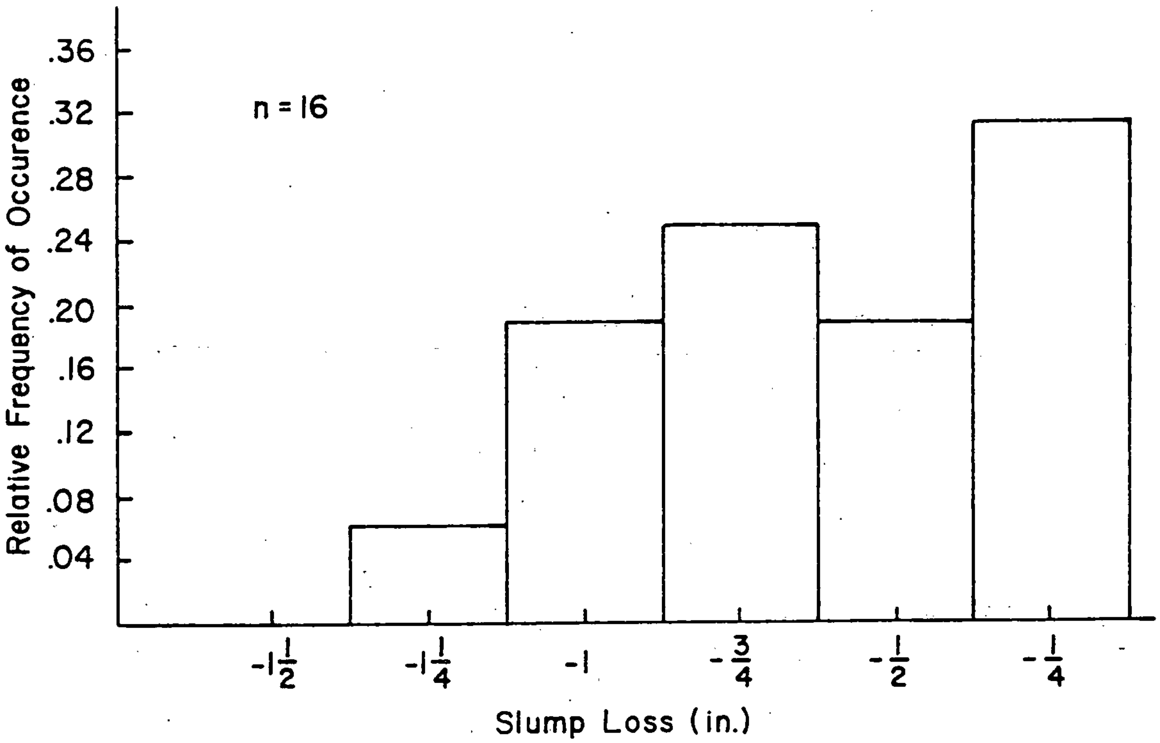


Figure 9.1. Correlation Study Results, Project C



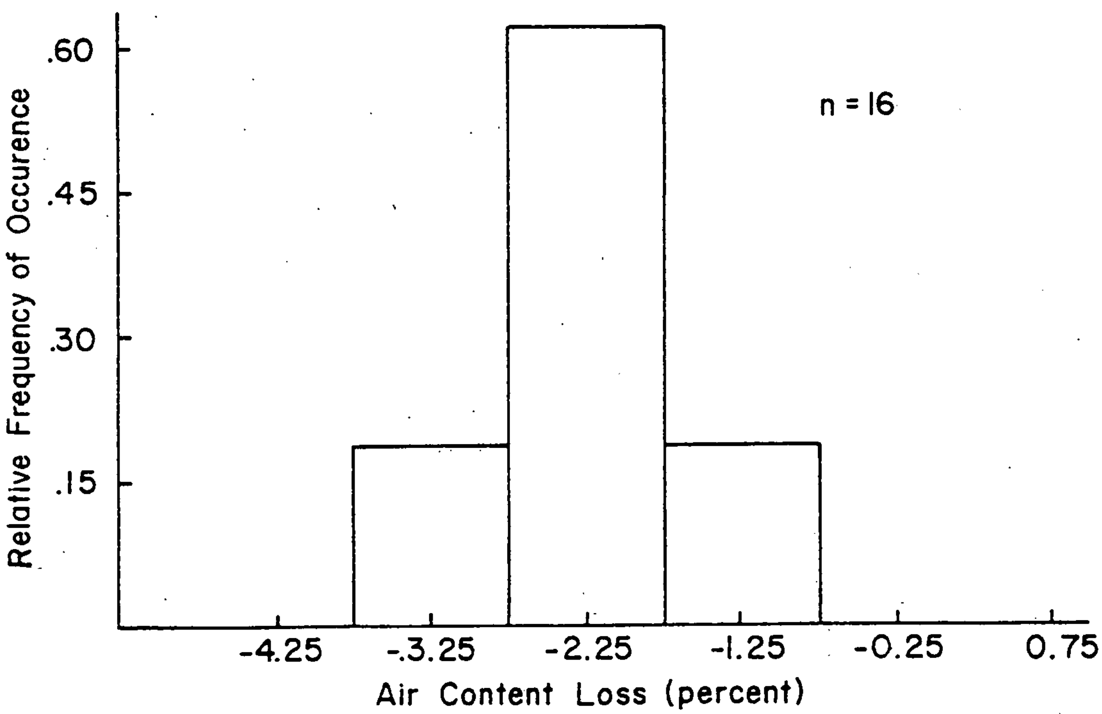


Figure 9.2. Correlation Study Results, Project F

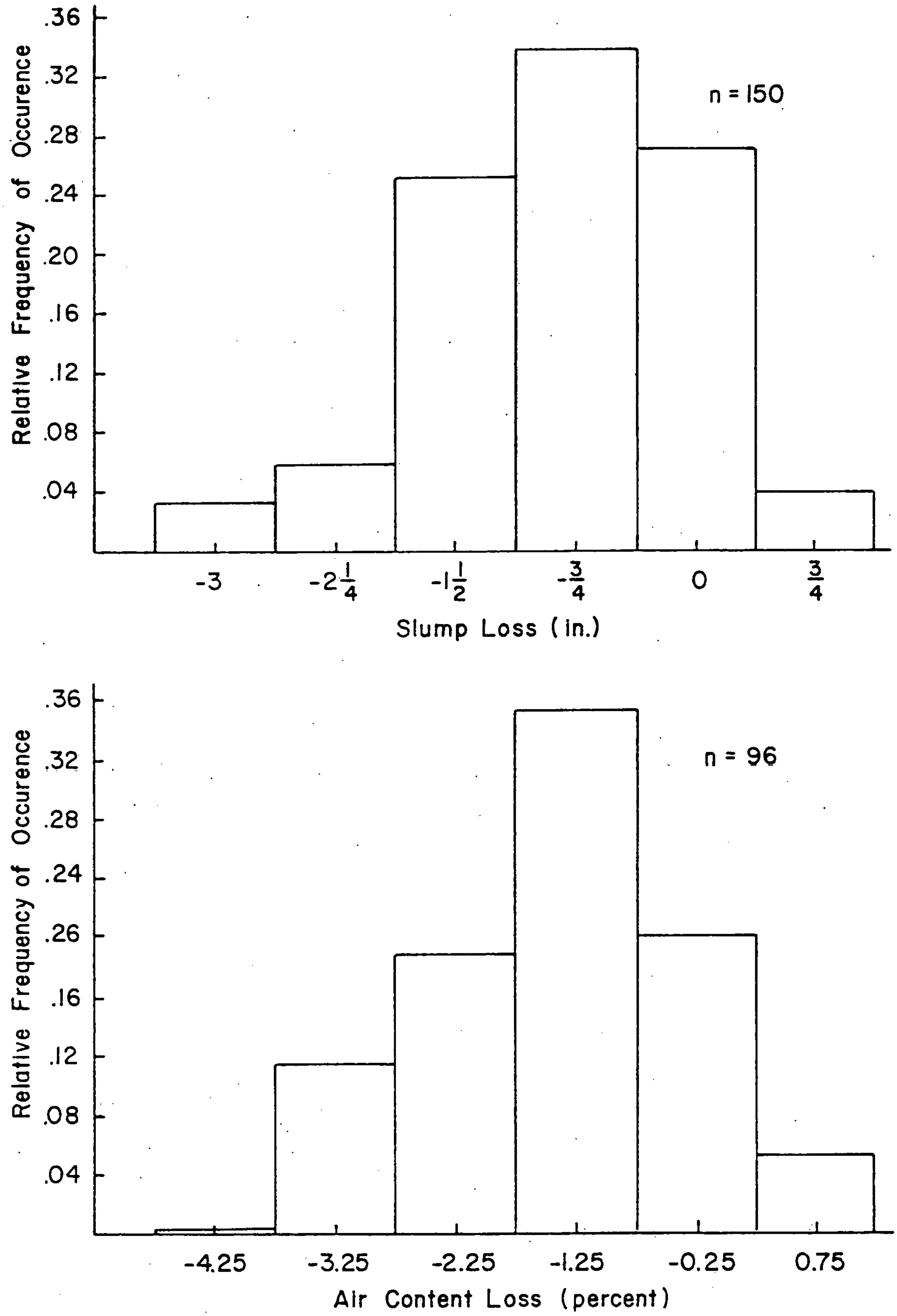


Figure 9.3. Correlation Study Results, Project H

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	

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.

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 representative
[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

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.

Table 9.5. - Timetable for Project E[a]

Type of Form-work	Minimum Strength at Form Removal, (psi)	Average Mean Daily Temperature[b] Concrete in Forms, (°F)	Ambient Air, (°F)	Time Required to Assure Minimum Strength of Classes A, B, and C Concrete at Form Removal: f'c = 2000 PSI, C (Days)	f'c = 2000 PSI, B (Days)	f'c = 3000 PSI, B (Days)	f'c = 3000 PSI, A (Days)	f'c = 4000 PSI, 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.

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.

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^{o}/24hr			3%/hr[d] 30^{o}/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^{o}F and steel forms must be wetted when the ambient temperature exceeds 70^{o}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

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

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

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

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

SECTION 9

ABRIDGEMENT OF APPENDIX A OF REPORT COO/4120-1

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 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: Instruction, 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 10CFR 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.

EXAMPLE OF CASE STUDIES: PROJECT C

The Case Study for Project C is presented below to indicate the depth of detail which was presented in the 9 Case Studies which appeared in Appendix A of the original report. It will be noted that the page numbers used in the original report have been retained.

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.

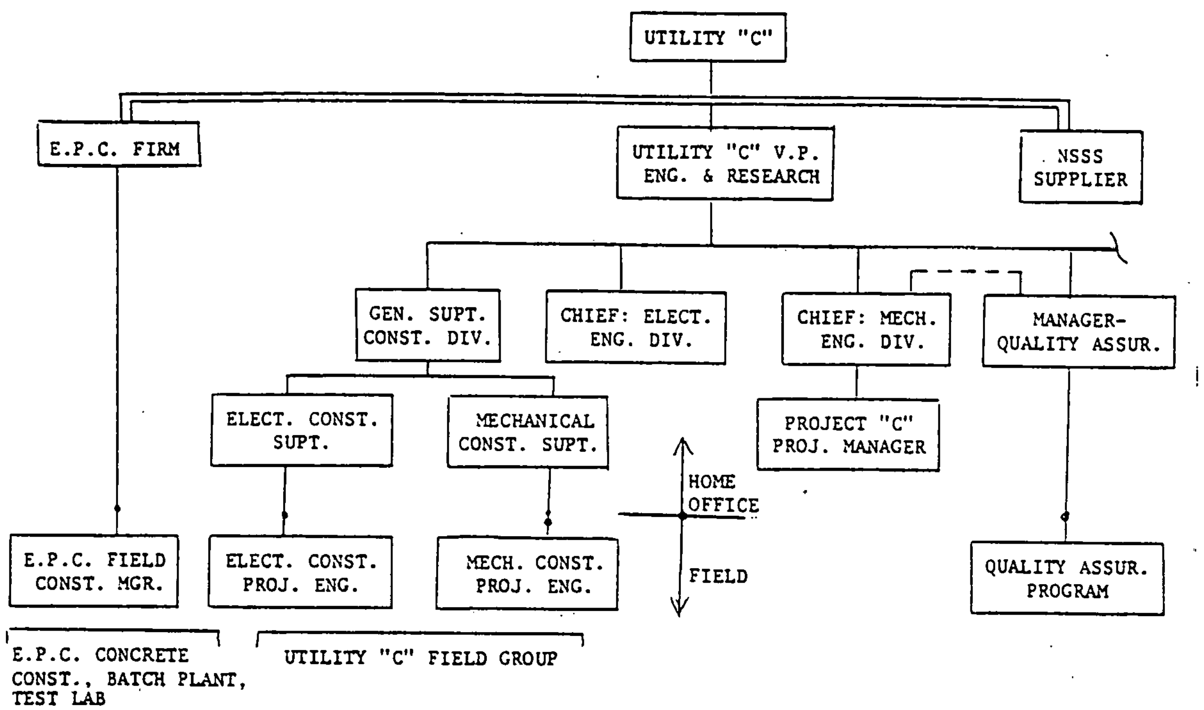


Figure A.9.--Project C: Interrelationship of Parties Involved In the Concrete Phase

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 A10, 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

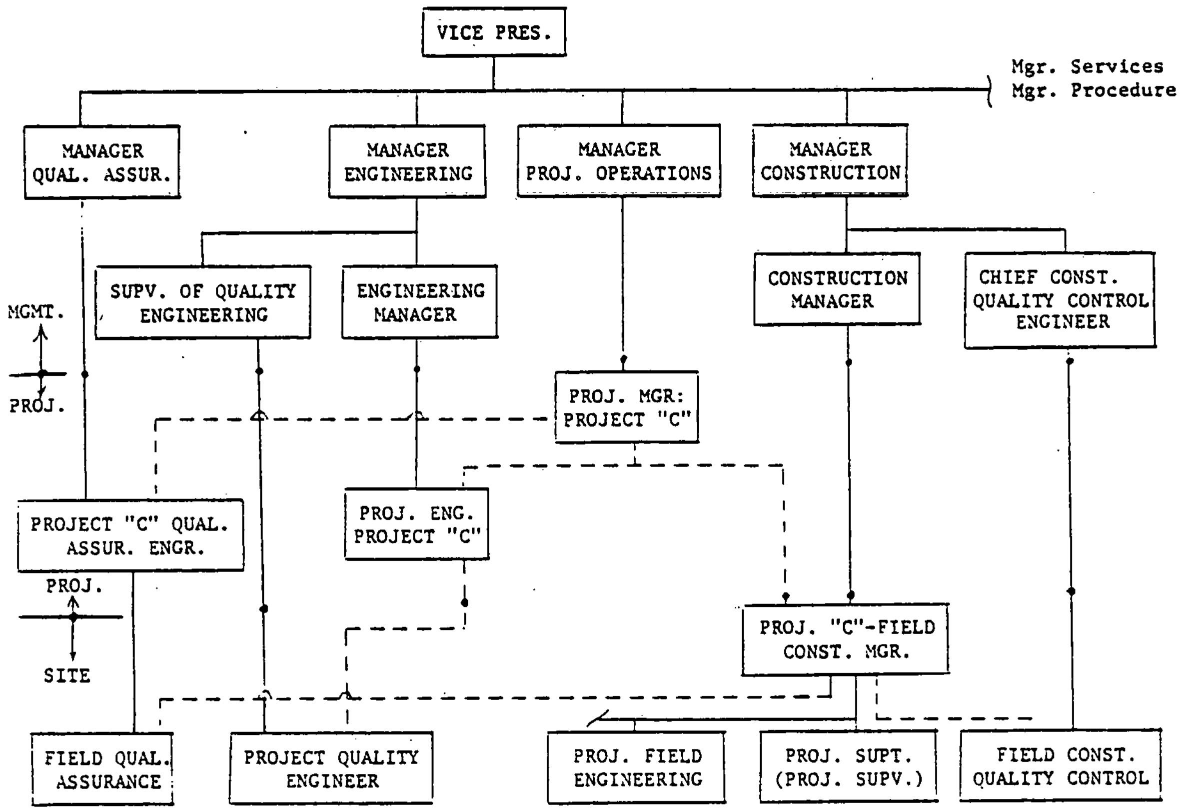


Figure A.10.--EPC Firm Organization ________ Technical and Administrative Direction

_ _ _ _ _ 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

<u>QUALITY ASSURANCE PROGRAM</u>

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 subcontractor'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.

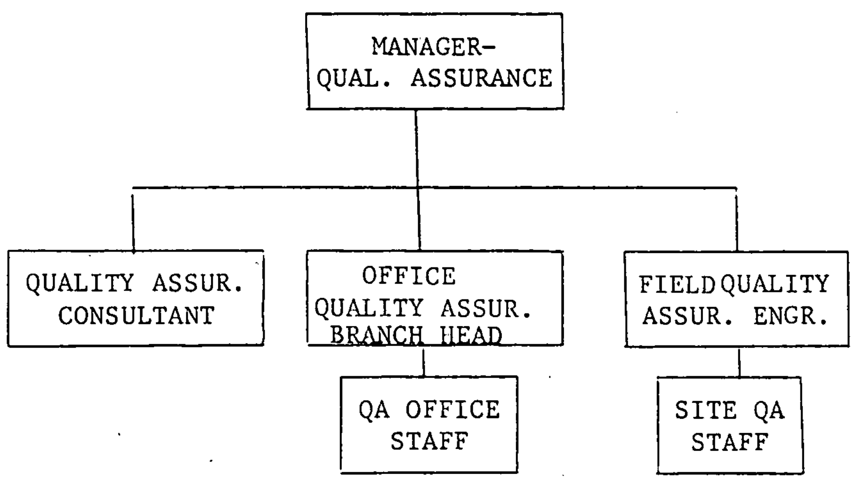


Figure A.11.--Utility C Quality Assurance Organization

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 <u>both</u> 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 A10) 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.

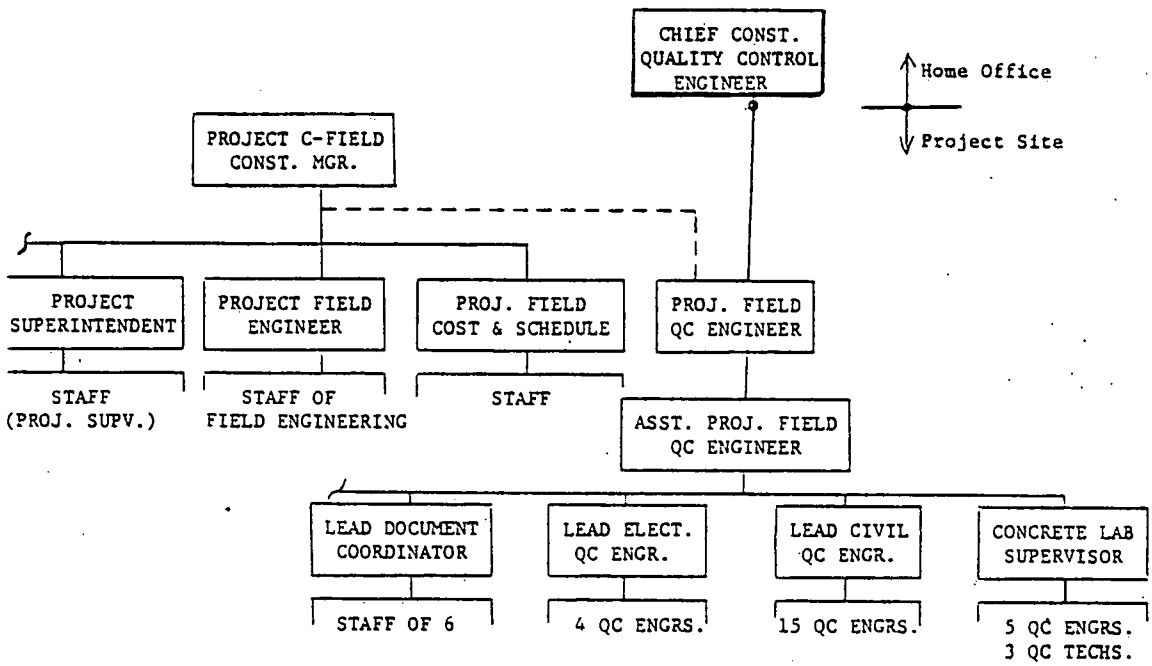


Figure A.12.--E.P.C. Firm Quality Control Organization

(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

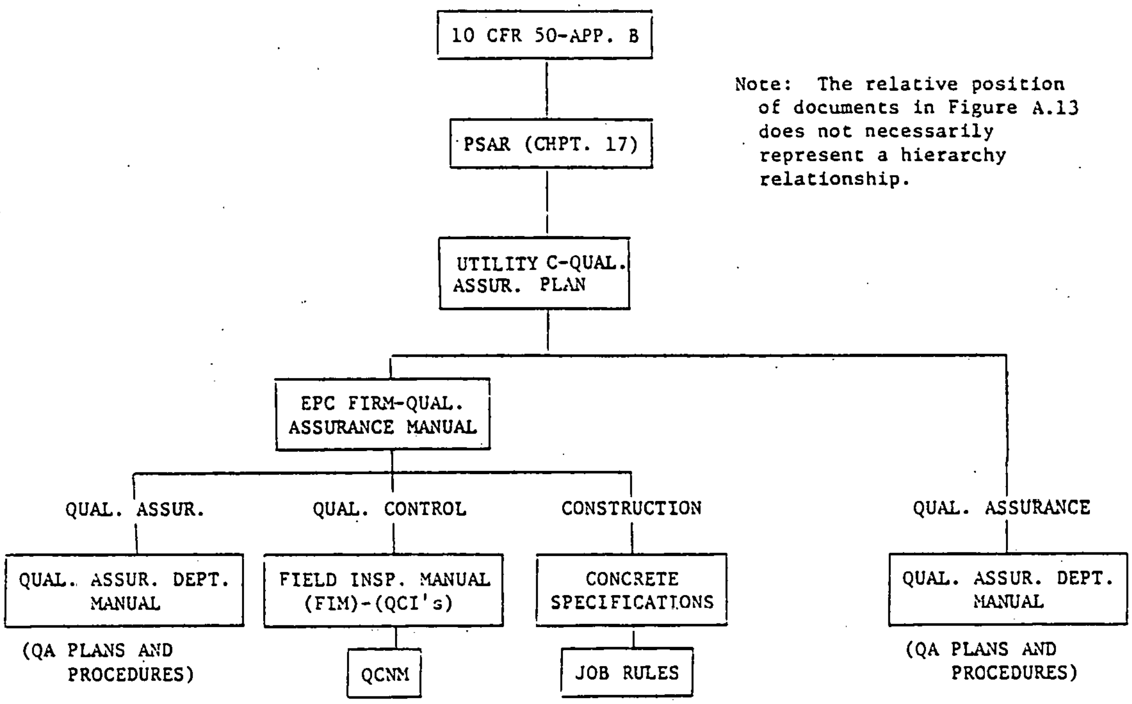


Figure A.13.--Project C Quality Assurance Documents

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.