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Central Heating Plant Site Characterization Report, Marine Corps Combat Development Command, Quantico, Virginia

August 1990

Prepared for the United States Marine Corps Research, Development, and Acquisition Command, Project 16439, under a Related Services Agreement with the U.S. Department of Energy under Contract DE-AC06-76RLO 1830

Pacific Northwest Laboratory
Operated for the U.S. Department of Energy
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CENTRAL HEATING PLANT SITE CHARACTERIZATION REPORT, MARINE CORPS COMBAT DEVELOPMENT COMMAND, QUANTICO, VIRGINIA

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Pacific Northwest Laboratory
Richland, Washington 99352

EXECUTIVE SUMMARY

This report presents the methodology and results of a characterization of the operation and maintenance (O&M) environment at the U.S. Marine Corps (USMC) Quantico, Virginia, Central Heating Plant (CHP). This characterization is part of a program intended to provide the O&M staff with a computerized artificial intelligence (AI) decision support system that will assist the plant staff in more efficient operation of their plant.

An extensive upgrade of the CHP systems was recently made to allow the use of coal as a primary fuel as well as number six oil, which is more expensive and has a less reliable source of supply. The upgrade replaced most of the existing plant components and included a new coal handling system, boiler internal refurbishment, water treatment and chemical addition system, stack emission precipitators, and ash handling systems. As part of this upgrade, a digital, integrated boiler control system was also installed. With the anticipated increase in efficiency resulting from the upgrade, other less efficient units on the site were decommissioned, and the operating staff was reduced and consolidated.

These events significantly increased the need for safe, reliable, and efficient operation of the CHP. As part of the effort to provide the AI decision support system, a team of six scientists and engineers from the Pacific Northwest Laboratory[a] (PNL) visited the plant to characterize the conditions and environment for operating and maintaining the CHP. The PNL team used accepted industry practices for these characterizations. This assessment resulted in a list of potential performance improvement opportunities for the administrative as well as the plant O&M organizations.

The PNL team observations included the following:

- Since the upgrade, installation and/or system design problems have commanded a large fraction of available manpower resources.

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- The plant O&M staff have not been provided with sufficient training or adequate equipment information to allow effective operation and maintenance of newer systems.

- The plant O&M staff has not been adequately trained or provided with sufficient information to meet the operation and maintenance requirements of the new equipment.

- As a result of the previous observations, the plant is operated and maintained in a reactive manner; i.e., it is not possible for the staff to anticipate and avoid trips or component failures but only to react to the events after they happen.

- Adequate engineering support is not available to the plant operations staff to solve design or operating problems, to establish and control O&M programs and procedures, to monitor the adequacy of contractor modification and documentation, and to measure and ensure the maintenance of a high level of plant efficiency.

Based on contacts with other USMC power plant personnel and multi-plant instrument crews, the operations and maintenance environment at Quantico are, in general, typical of similar applications. Improving information acquisition retrieval, accuracy, analysis, and display capabilities available to the plant O&M staff would be a desirable and significant part of a coordinated program to improve the efficiency, reliability, and safety of the Quantico CHP.

ACKNOWLEDGMENTS

The PNL team would like to acknowledge the outstanding support provided to them by the Quantico Facilities Staff, from the head of the Facilities Maintenance Branch, Colonel Cucina and his deputy Lawrence Bailey, through the entire crew of Central Heating Plant personnel. Repeatedly, time was made available in an already hectic schedule to candidly share information and insights into the working environment of the power plant. Our choice of Quantico as the lead site for a demonstration of this Artificial Intelligence application was based to a large extent on the attitude displayed by the staff and their willingness to honestly assist our team in making their team and their plant better performers. Their positive attitude and up-front answers to many difficult questions have provided both teams with the proper direction for achieving that goal.

Don Jarrell
Rex Stratton
Mike Brambley
Mark Hoza
Jon Anderson
Shawn Bohn

CONTENTS

DEFINITIONS

Availability	A function of reliability and maintainability expressed as the probability that a system, when used under predetermined conditions, will operate satisfactorily at any point in time.
Artificial Intelligence	A method of computer programming that manipulates logical concepts as well as numerical operations.
Forced Outage	An outage that is required to be initiated no later than the weekend following discovery of an off-normal condition. The forced outage hours are the clock hours that the unit is unavailable because of that initiating event.
Maintainability	A characteristic of design and installation expressed as the probability that an item of equipment will be restored to specified conditions within a given period of time when maintenance action is performed in accordance with prescribed procedures and resources.
Maintenance	The aggregate of those functions required to preserve or restore safety, reliability, and availability of plant structures, systems, and components. Maintenance includes not only activities traditionally associated with identifying and correcting actual or potential degraded conditions, i.e., repair, surveillance, diagnostic examinations, and preventive measures but extends to all supporting functions for the conduct of such activities.
Metric	A reference standard or sample used for the quantitative comparison of properties; an evaluation or basis of comparison.
Operable - Operability	A system, subsystem, train, component, or device shall be OPERABLE or have OPERABILITY when it is capable of performing its specified function(s) and when all necessary attendant instrumentation, controls, electrical power, cooling or seal water, lubrication, or other auxiliary equipment that are required for the system, subsystem, train, component, or device to perform its function(s) are also capable of performing their related support function(s).
Predictive Maintenance	Techniques and activities used to predict onset of equipment malfunction or failure, e.g., vibration monitoring, acoustic monitoring, and oil analysis.
Preventive Maintenance	Regularly scheduled tasks (e.g., inspection, servicing, adjustment, calibration, replacement) intended to keep equipment in condition for operational or emergency use.

Reliability	The probability that a system will perform a required function under specified conditions without failure for a specified period of time.
Root Cause Analysis	An analysis performed to determine the cause of component or part failures.
Trending Analysis	An analysis of a component or part history to determine programmatic failure causes. Consideration should be given to part, component, system, and manufacturer.

1.0 INTRODUCTION

This report presents the methodology and results of a characterization of the operation and maintenance (O&M) environment at the U.S. Marine Corps (USMC) Quantico, Virginia, Central Heating Plant (CHP). This characterization is part of a program intended to provide the O&M staff with a computerized artificial intelligence (AI) decision support system that will assist the plant staff in more efficient operation of their plant.

1.1 CENTRAL HEATING PLANT BACKGROUND

The background of United States Marine Corps (USMC) utility plants and of the Quantico plant specifically are helpful in understanding this site characterization report. This background information is presented in Sections 1.1.1 and 1.1.2.

1.1.1 General Considerations

The USMC depends upon USMC-managed utility plants for heating needs at many of its installations. These plants are generally old and are operated and maintained under minimum budgets. As a result, effective operation and maintenance of these plants is difficult. The situation is exacerbated by several factors:

- There have been significant reductions in manpower available to utility engineers for base operations and maintenance. If the USMC is to employ its scarce operations and maintenance resources effectively, it must know what activities are most important for efficient plant operation and for ensuring plant reliability.

- USMC plants generally lack the real-time data acquisition systems necessary for efficient operation and for detecting operating problems and anticipating catastrophic equipment failures. The plants must be adequately monitored before they can be adequately controlled and maintained.

- Many USMC-experienced heating plant operators are nearing retirement. Often their replacements will have neither the experience nor training to master the skills necessary for operation and maintenance of the plant. The heating plant operator/maintainer needs access to expertise that can recommend courses of action under specific circumstances.

- The rising cost of energy (including demand charges) makes efficient and reliable operation of these plants more important economically.
- An additional impetus for increased plant reliability is found in the changing nature of the demand-supply picture at USMC sites. A clear trend toward shutting down smaller, less efficient boiler units results in a dramatic increase in the need for large-unit reliability. This trend gives a high return in financial gain, but it significantly reduces the site's supply side flexibility.

1.1.2 The Quantico Central Heating Plant

The purpose of the Central Heating Plant (CHP) boiler complex is to provide sufficient steam at the correct pressure for all the users connected to the Quantico heating system. The Quantico site has a daytime population of over 14,000 people, who work in the site's 1384 buildings. Through 22 miles of steam lines, the CHP supplies the heating requirements of most of the Quantico site, including administrative buildings, training facilities, private living quarters, hospital facilities, and an air facility. To achieve this purpose, a yearly operating budget in excess of $12M is required. An interruption of steam service would have a major impact on the site training mission, facility operations, and personnel safety, as well as a potential for freezing damage to buildings and other property.

The total steam load varies with the time of year, but for an average year an estimated range is from 40,000 (summer) to 125,000 (winter) pounds mass per hour. At least three serviceable boilers are required to meet the winter load demand. In the event of the loss of more than two boilers, a viable back-up steam source would not be available for a one- to two-week duration.

The plant staff consists of approximately 29 members, including administration, operations, and maintenance. This staff interacts with the central facilities maintenance section, who assist in some of the larger maintenance tasks. A detailed manpower discussion is found in Section 4.2.

The active boilers were built between 1938 and 1947 and were originally fired with coal. For approximately 10 years (from 1973 until 1983), all boilers were fired with number six fuel oil to meet environmental restrictions. Beginning in 1980, the plant and its steam distribution network underwent an extensive overhaul. The major renovation work, which is nearing completion, represents approximately a $24M investment.

The CHP represents a vital component of the Quantico site mission and a significant fraction of the yearly operating and capital revenue budget; it is necessary for the safety and comfort of site personnel and the protection of the facility.

1.2 DECISION SUPPORT SYSTEM PROJECT

Artificial intelligence (AI)-based decision support systems have the potential for significantly improving the operation of heating plants, power plants, and other utility operations. Such improvement can be manifested in many ways, including greater efficiency, improved reliability, and extended longevity. Successful integration of an AI decision support system project requires a careful, engineering-based approach to understanding and modeling the physical system; monitoring the system's operating environment; and the needs, practices, and resources of the plant operators. Once a successful decision support system has been developed, the effort required to replicate it at other installations and for other related uses will be substantially reduced.

In this project, an integrated AI decision support system will be developed and coupled to a data acquisition system in the CHP at the USMC training base at Quantico. The decision support system will be designed to provide the base operations and maintenance (O&M) staff with a computer system that will assist them in operating their heating plant efficiently and reliably. The system will serve as a decision support tool for assisting personnel with plant operations, predictive maintenance, and preventive maintenance. Each of these plant functions will be augmented by computer systems that will assist plant personnel by providing information necessary to enhance the performance of their tasks.

The project is organized in four phases:

Phase I: Project Definition. Selects and characterizes the test site from among the USMC power plants available. Documentation includes a characterization of the physical condition and operation of the plant, an evaluation of the potential benefit from decision support system implementation, and a plan for the development of the Phase II work. This site characterization report (SCR) is part of Phase I.

Phase II: Conceptual Design. Assesses the current information processing technology in relation to the needs of the CHP and defines the computer system necessary for design implementation.

Phase III: Development and Implementation. The design, construction, and implementation of the decision support system at the selected test site.

Phase IV: Evaluation, Modification, and Documentation. The system designers will complete development and implementation of the decision support systems and test, evaluate, and modify these systems to the extent of the funding available.

The following are the goals of the Phase I effort:

- Understand and characterize the challenges to O&M at the Quantico CHP. The SCR will provide insights into the impediments that preclude safe, reliable, and efficient O&M at the CHP.

- Evaluate the project potential for realizable cost savings. This function will be served by the value/impact report, which will discuss the problems characterized by the SCR in terms of their effects on economics, safety, and reliability.

- Produce a description of the tasks to be performed during the second phase of the project. A Phase II description which provides the task descriptions for completion of Phase-II. The principal product of the second phase will be the DSSDM conceptual design.

1.3 REPORT ORGANIZATION

This SCR provides the documentation required to satisfy the first goal of the Phase I effort and is organized as follows:

- Section 2 explains the objectives of the site characterization task.

- Section 3 provides a description of the analytical methods used to characterize the physical plant, and the performance criteria used to evaluate the existing operations and maintenance environment. The basic improvement opportunities are also identified in Section 3.

- Section 4 provides a discussion of

- the general plant operation
- a comparison of the Quantico plant with the O&M performance criteria developed in Section 3.

• Section 5 presents the study conclusions.

• The appendices provide additional information:

Appendix A: Plant Systems Description; provides a more detailed review of each of the plant's major systems, their function, flowpath, components, and observed material condition.

Appendix B: Plant Metric Standard; presents an ideal standard against which a fossil power plant may be systematically measured for the achievement of performance goals.

Appendix C: Observations and Events; gives a description of what the team members observed during their two site visits. The pertinent issues identified from each observation are listed and numbered for easy reference.

2.0 SITE CHARACTERIZATION TASK OBJECTIVES

To design and construct a decision support system that increases the efficiency of operations and maintenance at the CHP, it is necessary to fully understand the needs, constraints, and operating environment of the plant work force. Without this understanding, we are bound to construct the wrong tool (one they don't really need) or to produce a tool that plant personnel cannot readily interact with (one they can't use). In either case, the result will be the same: the system will not be used, and the desired O&M efficiency and reliability increase, will not be achieved. In general terms, then, our objective is to understand the needs of the plant personnel and respond by building a tool which fulfills those needs.

The following objectives are intended to be accomplished by the site characterization task:

- To understand the plant physical systems, the as-built system configuration, the system material condition, and the structure and flow of O&M as performed at the plant. To build a decision support system that is designed to support the specific needs of the plant's operations and maintenance staff, it is necessary that we, the system's designers, fully understand the processes required to perform the O&M function and the environment in which these processes must operate.

- To provide a comparison of the Quantico site to the O&M requirements of an idealized standard plant, and thereby to generate a potential list of improvement opportunities. These opportunities are improvement areas grouped by recognizable functional categories (e.g., coal handling, ash handling, instrument accuracy). This comparison provides a summary of the improvement opportunities identified at the site.

3.0 ANALYTICAL APPROACH

This section describes the approach used to obtain the data necessary to characterize the physical plant, to develop a method of evaluating the operating and maintenance environment at the CHP, and to show how the evaluation was used to produce opportunities to improve the plant performance.

3.1 A SITE DATA ACQUISITION METHODOLOGY

Before beginning the site characterization task, a carefully weighted survey of six potential USMC sites was evaluated for suitability for the lead site role. The selection was based on an evaluation of each candidate site's ability to provide attributes that would be desirable for development of an AI decision support system. Through a telephone question interview protocol, which was directed to each of the sites' Deputy Facilities Managers and Plant Foremen, the initial list of six sites was reduced to three. Representatives of the USMC and Pacific Northwest Laboratory (PNL) then visited the top three sites to determine suitability firsthand. The visits showed that Quantico provided the optimum conditions for developing the decision support system approach.

An overall plan for identifying and analyzing the problems that exist at the Quantico CHP was outlined in the project management plan (PMP). The elements of this plan were to

- develop an initial site data acquisition plan including system familiarization, condition inspection guide, and a questionnaire protocol for interviewing plant personnel
- perform the first site visit with the accent on learning basic system components and arrangements, previewing the plant O&M records, and learning the organization and manner of interaction between the plant and its administrative body
- debrief the information garnered from the first visit into a computerized text, and modify the original site visit plan to include any directions suggested to be particularly productive by the first visit

- perform a second site visit with particular emphasis on
  - interaction with plant O&M personnel
  - review of specific systems with plant personnel
  - in-depth inspection of plant systems which might prove to be suitable Decision Support for Operations and Maintenance (DSOM) implementation systems
  - conduct of administration, O&M, and training functions
- conduct a second debriefing to capture all relevant observations and document event scenarios
- write this SCR to document this process and characterize the "problems" in a structured set.

3.2 DATA ANALYSIS METHODOLOGY

To analyze the data gathered during the site visit, the plant was characterized according to accepted industry practice. The O&M functions were evaluated using standard power plant functions as a frame of reference.

3.2.1 Plant Characterization

In producing this SCR, three fundamental aspects of accepted industry practice were followed:

1. A planned protocol (a data gathering outline) was prepared and used to obtain the specific range and type of data required to perform a meaningful plant environment characterization. The experience gained by PNL in similar work performed under the Nuclear Plant Aging Research (NPAR) Program for the Nuclear Regulatory Commission's (NRC's) Office of Nuclear Regulatory Research (Jarrell et al. 1989) indicates that a protocol minimizes the impact on utility personnel while promoting a more complete documentation of the data.

2. Accepted methods of plant characterization and data analysis were utilized. The approach taken to isolating the characteristics of the information obtained from the lead site and the analysis of that data from a functional adequacy standpoint is based on 1) the PNL team operations and maintenance experience, 2) work found in commercial fossil-fired power production (Boiler Efficiency Institute 1985), and 3) guidance produced for the nuclear power industry by the U.S. Nuclear Regulatory Commission (NRC 1988).

3. Plant experienced researchers performed the investigation. The approach, method and manner of implementation were carried out by PNL engineers with an extensive background in O&M of both nuclear and fossil

power plants. Recognizing operating and maintenance limitations is much easier for those who have attempted to overcome similar obstacles first-hand.

A general description of the physical plant is found in Section 4.1. Specific system functional descriptions, flowpaths, major components, and material conditions are contained in Appendix A.

3.2.2 Operating and Maintenance Evaluation

Despite a wide variation in appearance, construction, and equipment, the functions necessary to operate and maintain all power plants are remarkably similar. These functions can be broken down into five basic categories which are found to varying degrees in all power producing plants whether they are nuclear or fossil-fueled. In most utilities, these functional categories are the basis for departmental organization within the energy generation division. Our approach to analyzing observations made at Quantico was to create a reference frame similar to the functional structure of all plant O&M activities.

It is the goal of a well-run, well-maintained power plant to perform as efficiently, safely, and reliably as possible. To accomplish this goal, the following set of functions must be performed in an efficient and well-coordinated manner:

- organization and administration
- operations
- maintenance
- engineering
- training.

Our goal in the O&M evaluation is to present the functional criteria that are necessary to efficiently and effectively accomplish the tasks found in each of these categories. Plant personnel can achieve the intent of each of these criteria in a variety of acceptable ways. When these criteria cannot be met, however, experience has shown that difficulties frequently arise. By presenting the criteria in terms of the function they must perform, the results of not fulfilling a specific criterion can be more easily tied to observations made by the team.

In Appendix B we present the proposed criteria for each area of the following outline:

1.0 ORGANIZATION AND ADMINISTRATION

- 1.1 Station Organization and Administration
- 1.2 Management Objectives
- 1.3 Management Assessment
- 1.4 Personnel Planning and Qualification
- 1.5 Industrial Safety

2.0 OPERATIONS

- 2.1 Administration
- 2.2 Conduct of Operations
- 2.3 Plant Status Control
- 2.4 Operator Knowledge and Performance
- 2.5 Operations Procedures and Documentation

3.0 MAINTENANCE

- 3.1 Administration
- 3.2 Work Control System
- 3.3 Plant Control System
- 3.4 Conduct of Maintenance
- 3.5 Preventive Maintenance
- 3.6 Maintenance Procedures and Documentation
- 3.7 Maintenance History
- 3.8 Facilities
- 3.9 Materials Management
- 3.10 Maintenance Personnel Knowledge and Performance

4.0 ENGINEERING SUPPORT

- 4.1 Engineering Support Organization and Administration
- 4.2 Plant Modifications
- 4.3 Plant Performance Monitoring
- 4.4 Engineering Support Procedures and Documentation
- 4.5 Document Control

5.0 TRAINING

- 5.1 Administration
- 5.2 General Employee Training
- 5.3 Training Facilities and Equipment
- 5.4 Operator Training
- 5.5 Maintenance Training
- 5.6 Chemistry Training
- 5.7 Emergency Response Training

For each of these areas, the following questions are addressed in this evaluation:

FUNCTION:	WHAT is the goal to be achieved?
RESPONSIBILITY:	WHO is responsible for achieving it?
CRITERIA:	HOW can goal achievement be measured?

These criteria can form the basis for an accurate comparison of functions between operating power plants and are presented in Appendix B of this report.

3.3 METHODOLOGY FOR IDENTIFYING IMPROVEMENT OPPORTUNITIES

To form a supportable impression of the CHP functional needs, the entire team's observations were assembled in a computerized text (included as Appendix C). After the observations were assembled, PNL team sessions were held to review and discuss each of the events and observations to identify the pertinent issues from each event. The issues were then attributed to specific functional categories and criteria, defined above, to direct the study toward areas that could be viewed as possible impediments to efficient plant operation.

As expected, a complex interactive pattern emerged because the functional categories themselves are interdependent. Thus, a functional group or subgroup which performs well may be less effective because it must assist another functional group with major difficulties.

This point is perhaps best illustrated by a hypothetical but realistic example: the in-plant administrative team is responsible for a monthly consumable report, but the report is delivered late to the facilities engineer because the administrative team must help the maintenance crew keep coal delivered to the bunkers via a conveyer system which is only partially operative. In this case, the inability of the maintenance crew to cope with the conveyer problem kept the in-plant administrative team from carrying out its responsibility. The root cause of the difficulty may, in fact, not be attributable to either of these in-plant functions, since the conveyer disfunction could be the result of inadequate design at the belt transfer points. As this example shows, tracing the thread of cause and effect to its source is often a long and convoluted process. Nevertheless, an effort was made to sift through each event or observation and identify its root cause and to assign the functional failure to the most basic category.

The results of this categorical assessment are presented in Section 4.2, Improvement Opportunities.

4.0 PLANT CHARACTERIZATION

4.1 PLANT PHYSICAL DESCRIPTION

As stated in Section 1.0, the purpose of the CHP boiler complex is to provide sufficient steam at the correct pressure for all the users connected to the Quantico heating system. To accomplish this goal, four boilers are located in the CHP.

The active boilers were built between 1938 and 1947 and were originally fired with coal. For approximately 10 years (from 1973 until 1983), all boilers were fired with Number 6 fuel oil to meet environmental restrictions. Beginning in 1980, the plant underwent an extensive overhaul. The major renovation work, which is nearing completion, represents approximately a $24M investment. The following major components were replaced:

- Boilers No. 1 and 2 were retubed and new forced and induced draft fans were installed on all units.
- New burners and refractory bricking were added.
- Electrostatic precipitators (ESPs) were installed on all boilers, and a new ash handling system was installed to serve the ESPs and the original ash hoppers under the boilers.
- New coal conveyors and ball mills were installed.
- A new control room with modern instruments and controls, including a Forney Engineering AFS-1000® combustion control and burner management system, were installed.
- Extensive upgrading of in-plant and steam distribution piping insulation and a new deaerating feed system were added.

Following this renovation, all plant boilers are capable of burning either coal or Number 6 fuel oil.

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The following paragraphs describe the steam production process at the CHP. The process is broken into two parts. The first part consists of fuel(s) transportation and heat generation. The second part consists of water treatment and steam generation.

The process begins by transporting coal from either the north or south coal yards (see Figure 4.1) to six hoppers inside the plant building using a system of conveyers. Since several conveyers must be used to move the coal to the desired location, transfer operations from one conveyer to the next must occur. The coal is next moved from the hopper to the desired ball mill (coal pulverizer) on the carousel conveyor located beneath the hoppers. The coal is weighed and pulverized in the ball mill and blown into the windbox, where it is burned. Oil, the alternate fuel of the CHP, may also be used to create the needed heat. The transportation of the oil to burners on the furnace face begins in the oil storage tank located next to the north coal pile. Oil is pumped from the storage tank to a heat exchanger where it is preheated to a set temperature and then pumped to the burner. At the burner the oil is atomized with steam from the main steam header. The air from the forced and induced draft fans creates the appropriate fuel-to-air ratio for efficient combustion to occur. The combustion product exhaust is vented through an air preheat heat exchanger and passed through the ESPs to remove combustion particulate. The combustion gases are finally released to the atmosphere. The heat from the combustion process is partially transferred to the tubes in the boiler where steam is created.

The steam generation process begins with the heat exchange between the hot combustion gases in the windbox and the water in the boiler tubes. The water is heated to nearly saturation temperature in the downcomer tubes, and additional heat is absorbed in the riser tubes, creating a two-phase mixture of water and steam. The steam-water mixture rises into the steam drum where it is separated into phases; the liquid recirculates to the bottom of the drum, while the steam enters the main header and is utilized either in the north or south loads. After the steam is utilized, it is returned to the CHP through the condensate return system.

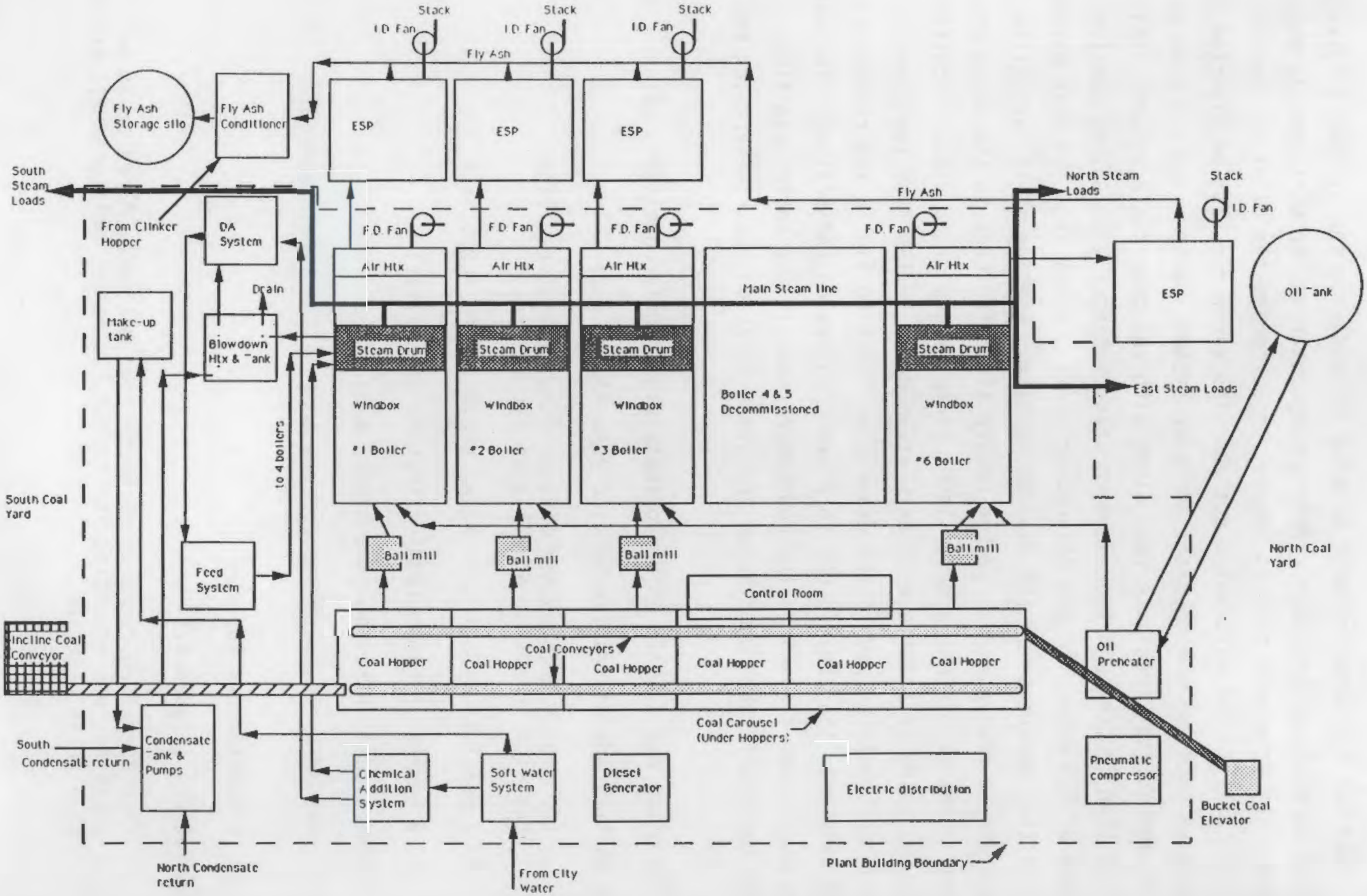

FIGURE 4.1. Plant Schematic

Since not all water returns because of losses in the system, city water is added to make up this loss. Before city water can be utilized, it must be treated. The treatment process consist of softening the water in the ion exchange tanks in the soft-water system. The water can then be diverted to the make up tank and the chemical addition system. Water from the make up tank is fed to the condensate tank along with the condensate return. This water is then fed through the blowdown heat exchanger, increasing the temperature of the water, to the deaerating tanks. Steam from the main header is added to the condensate in the deaerating tanks, heating it to saturation temperature to remove excess oxygen before it is fed back to the steam drum. The feed pumps maintain the water level in the steam drums via a feedwater regulating valve associated with each steam drum. Water from the chemical addition system is pumped to the deaerating tanks to aid in the removal of oxygen, and into the steam drums to prevent corrosion and scaling. The water in the steam drum flows into the downcomer tubes in the boiler and flows through the riser tubes completing the steam creation and regenerating cycle.

The plant has a staff of approximately 30 people consisting of:

- a central administrative section (see Figure 4.2)
  - the Deputy Maintenance Officer (the highest civilian position in charge of all site facilities),
  - a Facilities Engineer (responsible for the CHP), and
  - a General Foreman (administrative specialist)
- in-plant administration (see Figure 4.3)
  - headed by an Operating Foreman (operations & maintenance) and,
  - a Maintenance Foreman
- operations (Figure 4.3)
  - five operating crews of three or four men each, three crews on rotation, one scheduled for repair (to assist maintenance), and one as a relief section

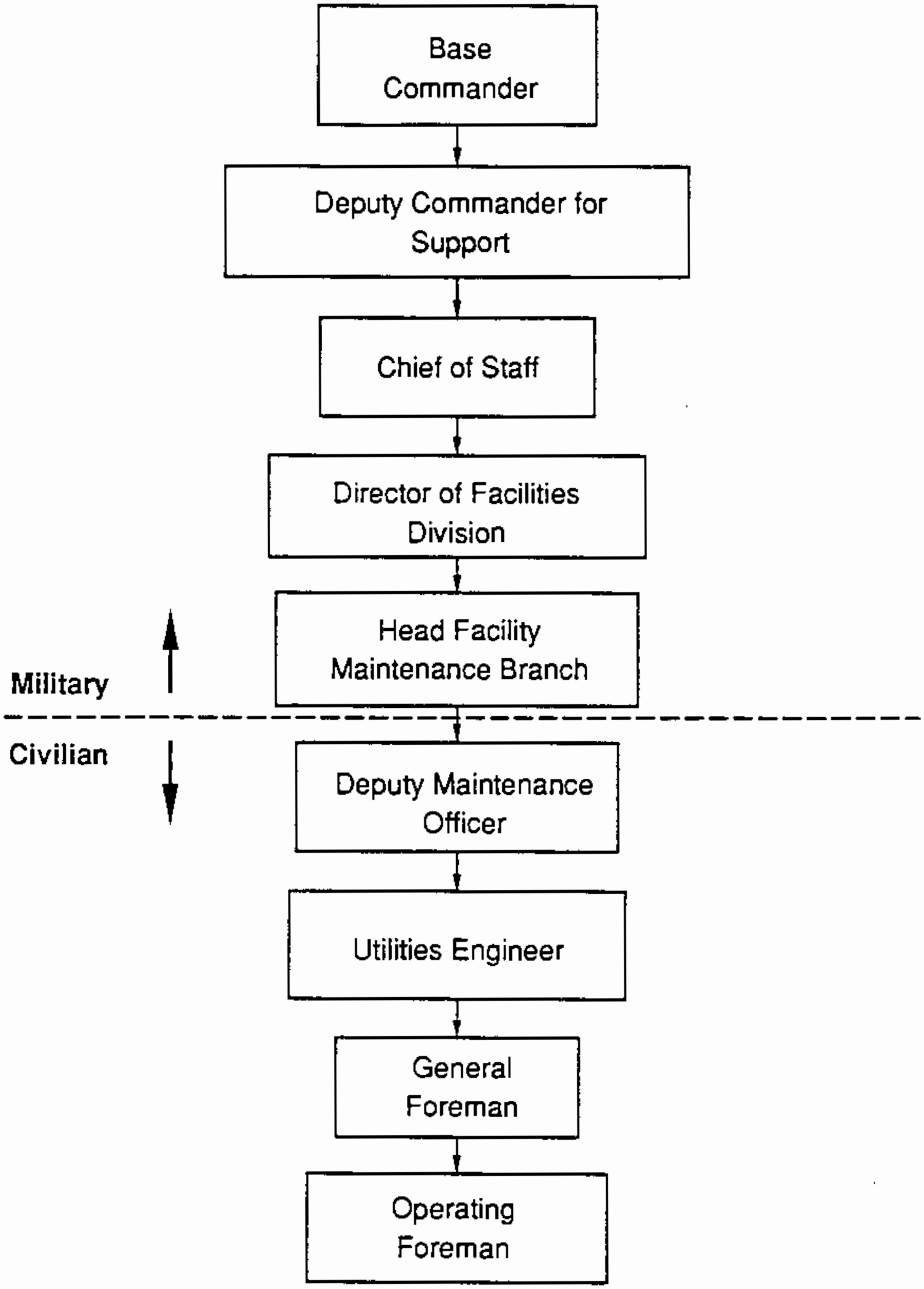

FIGURE 4.2. Quantico Base Organization for the Central Heating Plant

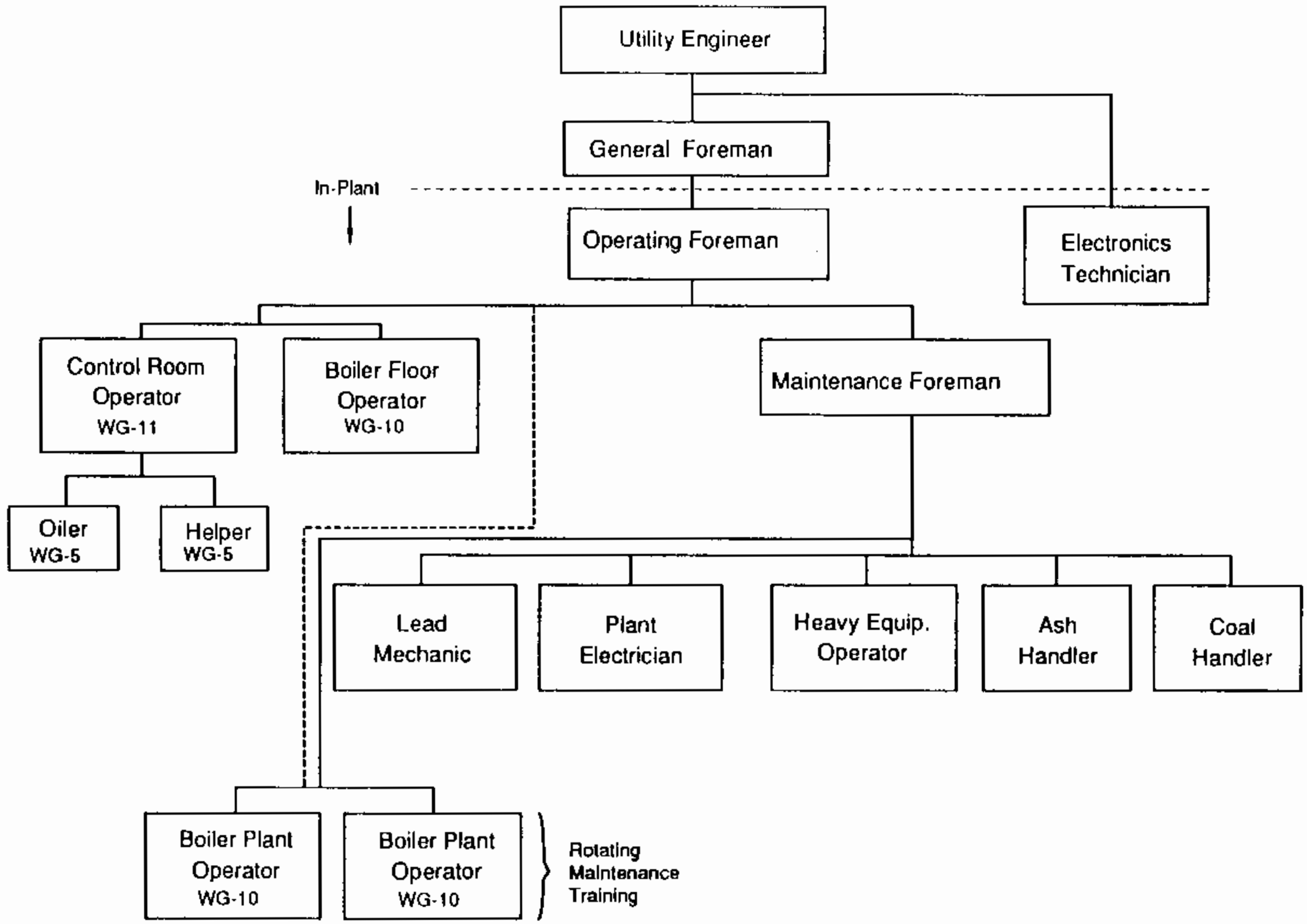

FIGURE 4.3. In-Plant Organization

- maintenance (Figure 4.3)
  - a Maintenance Foreman (administrative)
  - a Lead Mechanic (preventive maintenance and materials inventory)
  - an Electronics Technician
  - a six-man maintenance crew (one shift only)
  - two men from the operations crew (training/assistance).

4.2 PLANT OPERATION AND MAINENANCE CHARACTERIZATION

This section deals with the collection and distillation of identified plant issues into sets, which will serve to direct the focus of the investigation. This step in the information analysis is presented here to best document the operator perspective of the O&M process detractors. The organization follows the metric presented in Section 3.2.2 and Appendix B.

4.2.1 Plant Organization

The plant civilian administrative and managerial structure was observed to be somewhat narrow; i.e., responsibility was concentrated in only a few people in a direct reporting chain (see Figure 4.3). The Utilities Engineer position was vacant at the time of our visits.

Compared with the same position in a typical commercial organization, the Deputy Maintenance Officer position seemed to be equivalent to a utility site manager (Figure 4.4) at a multiple-unit site. His responsibilities included not only the heating plant but all of the other facilities at the base (waste water treatment, buildings and grounds, and others).

Within this arrangement, the Utilities Engineer is equivalent to the Plant Manager of a commercial unit, and the General Foreman fills the role of the planning, administration, technical, and chemistry managers. While some combination of positions such as administration and planning may well be possible, the situation at Quantico creates considerable voids. In fact, the Operating Foreman shown in Figure 4.3 actually performs the day-to-day duties normally done by a commercial plant manager. Operations and Maintenance both report to the Operations Foreman as is common in commercial practice. Without

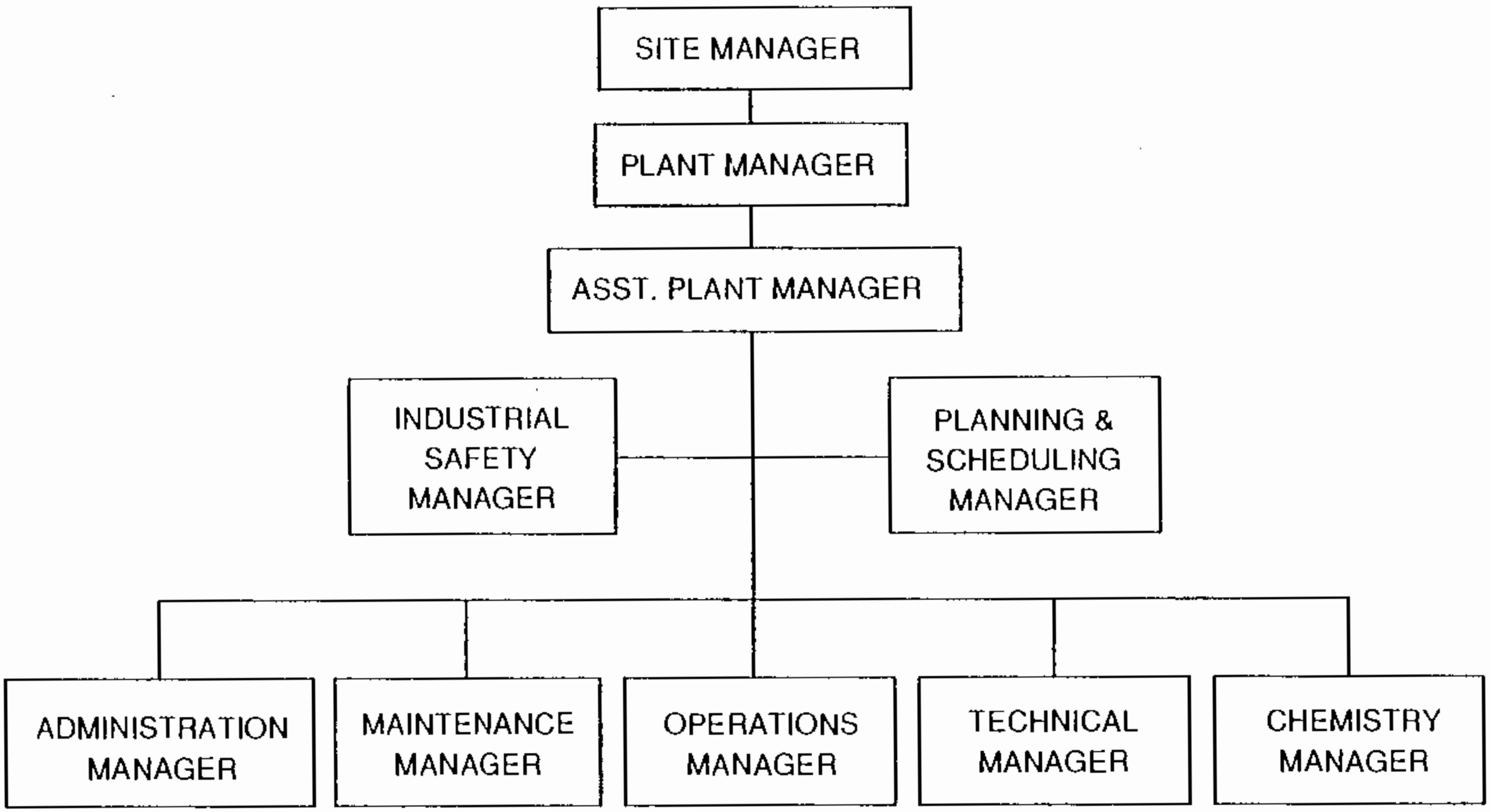

FIGURE 4.4. Typical Commercial Plant Organization

an operations manager position, however, the operations managerial duties are performed by the Operating Foreman. This seems to remove him from a coordination/oversight position. By contrast, the on-shift operators have similar role in the Control Room and as the Boiler Floor Operators. The maintenance structure has a commercial appearance, but its staff does nothave the knowledge required to maintain the plant following the upgrade. Additional resources in these areas as well as skills inventory building will be necessary to add efficiency and reliability to system operations.

Typical function and responsibility assignments seen in commercial practice are presented in Appendix B for all plant levels.

4.2.2 Plant Operation

Brief summaries of issues in plant operations are presented in this section.

Procedures for O&M Functions

Operation of the plant before the control system revamping was relatively simple. By observing the operation of the older systems, operators could master the basic principles of plant operation, particularly, burner control. With the addition of a much higher level interactive system control, it was not as easy to understand the effect a change in one system might have on another. Without procedures in place to calibrate, align, and operate these more complex systems, operators frequently place the controls in manual because they only understand the manual, independent operation of the controls. Without accurate drawings and maintenance procedures, even an experienced electrical technician is hard pressed to restore the complex automatic control functions to a fully operative condition.

Communications

There are few written guidelines or procedures regarding administrative matters. Communication between the in-plant administration and operations groups is nearly all verbal, and the watch turnover between shifts was not demonstrated to be complete. No medium such as a night order book, equipment status log, or status board is used to track chronic plant problems. The operating foreman read the watch log, but major plant occurrences (such as a boiler trip) were observed to have occurred without being entered into that log.

Coal Handling

Coal spillage at conveyer belt transfer points requires a large investment of manpower. An inoperative underbunker transfer device compounds this situation because it requires more frequent and difficult individual hopper transfers. This task at times has been an "all hands" process and represents a serious dilution of manpower needed for other maintenance/operation/administration duties.

Ash Handling

Frequent flooding of the ash hopper vacuum transfer line requires diversion of manpower to disassemble and clean the resultant hardened water/ash slurry from the transfer pipe. Again, this diversion has results similar to the coal handling situation described above. The root cause of the ash handling difficulty appears to be partially design (excessive water run-off goes into ash pipe trench) and partially a material/parts ordering snag (sump pit pump rotors eroded in the abrasive ash environment and incorrect replacement rotors were ordered because of an incorrect or unavailable replacement part number).

Steam Drum Water Level Control

The water level control on the steam drum is one of the primary operator concerns. The system is frequently operated in a manual control mode because the automatic system does not maintain a satisfactory steam drum water level operating band. Severe water level swings were also observed during manual control. The staff operators who were interviewed understood the dangers of extreme high- and low-level operation and expressed dismay over not knowing which of the level instruments in the control room was reliable. All level instrumentation, with the exception of the sight glass, which is not located in the control room, were dismissed as inoperative on some boilers.

Plant Malfunction Diagnosis

As a corollary to the discussion on instrumentation, many operators attempting to diagnose the cause of a plant trip found that in addition to digital instrument inaccuracy, hard copy recording instruments (circle charts) were equally ineffective at providing a reliable (or resolvable) record for diagnosis. A "first in" feature on the boiler annunciator status panel which was designed to indicate the trip initiation signal did not function correctly during either of the PNL team visits.

Instrument Accuracy

The situation described for the drum level indication was found to be endemic to many if not most of the instrumentation available to the operators in the control room. Several pertinent points should be made regarding this general mistrust of instrument reliability in some instances:

- It is, in general, well-founded. Unacceptable (outside manufacturer's stated tolerance bands) error was clearly evident in redundant and correlated instrumentation.

- Attempts to calibrate critical instruments with the unit on the line have resulted in unit trips. As a result, efforts to improve reliability have been thwarted. Follow-up discussions revealed a lack of as-built piping and instrumentation diagrams (P&IDs) or control algorithms which would allow control circuitry to be understood and possibly tested. No procedure for trip and calibration tests was available from the installation contractor.

- The control room concept is new to the CHP. Operators previously serviced the plant and took readings from an operating floor which ran nearly the full length of the plant. The unfamiliar environment of the enclosed control room, the unavailability of operating procedures or uniform guidelines for operation, digital (and often conflicting) instrumentation, and the more stringent calibration requirements of the newer instruments reinforce the opinion that the instruments are not adequate to operate the plant.

The end result of these points is that operation is almost completely reactive. This mode of operation is, in our experience, typical for noncommercial heating plants where economy is not the primary concern. The team observed only isolated attempts to proactively control even critical parameters. Explanations for observed abnormal parameters varied from one shift to the next as did the process variables used to control the plant. The variables chosen often reflected the different operating experiences incurred by each shift. Training on the new control system was described by operators as ineffective. Given these observations, the operators were prone to react to an alarm rather than to optimize a variable when that attempt might well result in a plant trip.

4.2.3 Maintenance

Summaries of maintenance issues are provided in this section.

Maintenance Control and Follow System

To effectively maintain the plant, certain basic processes must take place. These processes are depicted in Figure 4.5, Typical Work Control System. Each of the steps shown in the diagram is considered by most power plant maintenance managers to be essential to controlling a corrective maintenance task. Many of these steps are performed ad hoc or informally (without documentation) at the CHP. Following the diagram in Figure 4.5 from the EQUIPMENT MALFUNCTION box in the upper right corner of the figure, several observations are noteworthy:

- Malfunction Recognition. The plant staff does not routinely report equipment discrepancies to maintenance. While major malfunctions of critical gear were reported, degraded or partially functioning components were not. Some operations staff felt that maintenance already "had its hands full" because of high manpower drains such as the coal handling system and did not wish to burden them further. This attitude pervaded the operational ranks as well, and numerous out-of-normal band readings were not reported.

- Work Requests. Plant maintenance work requests are followed verbally for the most part, without any documentation of observed symptoms, trouble-shooting efforts (causal diagnostics), or job status (such as parts unavailability) concerning performance of the necessary repair. Because of the enormity of maintaining such a large block of information and the pressure exerted by the previously described manpower sinks, some of the repair tasks are bound to "slip through the cracks."

- Planning. Routine job planning and preparation are also handled in an ad hoc fashion. An inventory of specialized parts used for power plant repairs is maintained in several storage locations in the plant. The contents of these repositories have been developed through repair demand, are not inventoried, and are known only to a few individuals. Job priority is established on the basis of

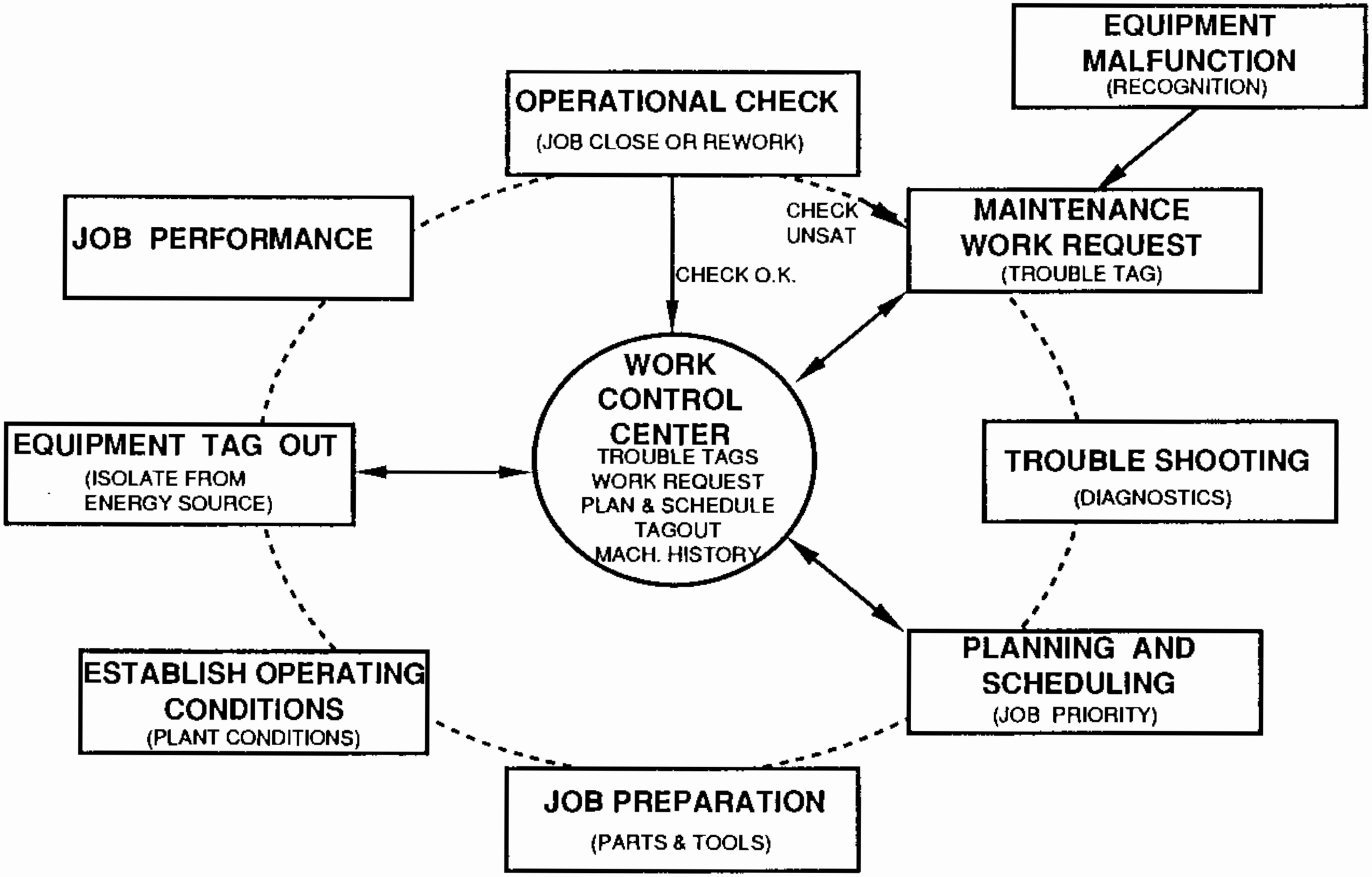

FIGURE 4.5. Typical Work Control System

perceived need by the O&M foremen (a commonly accepted practice). Planning is performed for plant controlling jobs, because it dictates the operational constraints of the system.

- Plant Conditions. The operating conditions necessary to perform a job are frequently established by the maintenance crew. While this has the benefit of making the worker responsible for his own safety, it does not always ensure that he is aware of all plant operational limitations or that operation of certain components does not endanger fellow workers.

- Tag Out. Formal isolation (tag out) of a component does not appear to be used effectively at the plant. In truth, the requirements of such a system are hard to meet because of the lack of as-built P&IDs to determine that all energy sources are isolated. Electrical breaker locking switches are used whenever possible to isolate major electrical loads.

- Operational Check. Following the completion of a job, little post-repair testing is done to ensure proper re-energization and function of the fixed component. Normal post-repair testing is done when equipment service is next required. Maintenance work history is not systematically documented in a single place; rather, each mechanic keeps his own notebook, and he sometimes shares information verbally with his co-workers. Possible root causes of failure, difficulties in job performance, and information about the degree of component degradation are often lost.

4.2.4 Engineering Support

Engineering support issues are described in this section.

Technology Transfer for Systems Modifications

A recent revamping of the burner system and the installation of a Forney Engineering AFS-1000® burner management and combustion control system provided the CHP with high tech electronic control. Unfortunately, adequate operator and maintenance staff training was not part of that improvement. Minimal training of the operators, which was not commensurate with their previous technical education, left them uncertain as to the function or operating principles of the system. A lack of operating procedures for the new system,

® AFS-1000 is a registered trademark of the Forney Engineering Company, Carrollton, Texas

Conceptual rather than as-built drawings, and the lack of instrument maintenance compounded their uncertainty, and completes the formula for reactive O&M.

Technical Support

Chronic or unresolved technical problems are typically referred to the engineering support group in large-scale power production. As was pointed out previously, this might not have been a major concern at the CHP prior to its control system revision. However, with the addition of complex interactive system controls and a large number of system modifications, the ability to resolve technical difficulties or overcome poor design features is required.

Component Trending

The plant does very little degradation monitoring or trending. Some operators were observed to correlate high stack temperatures with a need for soot or slag removal, while others dismissed the same indications as instrument inaccuracy. Other monitoring schemes such as oil analysis, vibration measurement, or thermography are not used.

4.2.5 Training

There is no formal plant technology training group at the site. Most instruction is done on the job. Prior to the plant modernization this method worked adequately, providing sufficient training in day-to-day experiences to cope with the variety of operating situations encountered.

With the addition of more complex plant systems, the necessity for a changed work force cross-section is evident. The ability of the current personnel to maintain a high degree of system reliability is severely limited by their lack of technological education. The efforts at training the operators in the care and feeding of the control system were probably ineffective because of what can best be described as a mismatch between the level of instruction done by the contractor Forney engineers and the educational needs of the operators.

4.2.6 Summary

Several of the functional areas normally found in efficient power plants are marginal or missing at the CHP. The following summary suggests areas for performance criteria improvements:

- Management objectives and administrative policies are in need of review and revision to reflect current plant status and to maintain efficient plant operations and maintenance (e.g., organizational structure, stated performance objectives, contractor modification turnover controls).
- Programs to produce many of the necessary plant functional requirements are not established (training, industrial safety, engineering support, materials management, and work control).
- Plant performance monitoring is not being effectively performed; consequently, data analysis, trending, and plant performance optimization do not reflect current plant status (e.g., engineering support needs to be more involved in setting the performance standards or measuring the performance levels of systems and equipment).
- A method for the plant to obtain timely engineering support for chronic problem areas does not exist.
- Plant system modification impacts on operations and maintenance are not well-controlled, documented, or communicated to plant personnel.
- Operator knowledge level and conduct standards need to be revised to better support the plant.
- An improved system to make operators more aware of plant system and component status needs to be developed.
- Current procedures for operations (and maintenance) need revision to reflect the various upgrades of the plant.
- Training programs which would effectively equip the plant staff to cope with the new level of technological sophistication at the CHP should be established (e.g., controls and electronics).
- Maintenance programs to keep plant equipment, control systems, and instrumentation in good working order are in need of revision (e.g., preventive maintenance, performance monitoring).
- Maintenance work history and parts inventories procedures need revision.

- Training for a coordinated plant emergency response team needs to be updated.
- Human factors received little consideration in the control room design.

5.0 STUDY CONCLUSIONS

This study has established and identified areas for improving the performance, reliability, and safety of the Quantico CHP. Based on observations of plant operations and maintenance, the study revealed many opportunities to implement performance upgrades with improved resource and information management.

In general, the plant physical systems are, except as noted, in good condition following the CHP upgrade and modifications. Several chronic problems requiring engineering solutions are noted in this report.

A severe handicap to operations is a lack of as-built drawings of systems and control circuitry. This deficiency, coupled with minimal operator training on the new control systems and the lack of an effective preventive maintenance program for the control system instrumentation, results in reactive rather than anticipatory operation at the plant.

The maintenance team is not trained in the methods necessary to establish and implement an effective maintenance program for critical components and instruments. Corrective work is performed with an adhoc work control system which may have contributed to some malfunctions.

Significant plant upgrade modifications were performed by contractors who were not effectively controlled by the plant management, did not provide adequate system or operations training to the O&M personnel, and did not provide as-built drawings of installed systems or turn over maintenance spares and history records from the installation. As a result, plant personnel have an insufficient understanding of the O&M requirements of the modified systems to allow cost-effective operations and maintenance.

Adequate engineering support is not available to the plant staff to solve design or operating problems, to establish and control O&M programs and procedures, to monitor the adequacy of contractor modification and documentation, and to measure and ensure the maintenance of a high level of plant efficiency.

Based on the preceding observations, a balanced plant upgrade program encompassing all five functional areas (administration, operations, maintenance, engineering, and training) will be required to significantly improve the efficiency, reliability, and safety of the Quantico CHP. A framework for the requirements and performance criteria of a suggested upgrade program is provided by Appendix B of this report.

Given that the commitment to such an upgrade can be made, the DSSOM project could be a key contributor to improving information accuracy, acquisition, analysis, and display capabilities available to the CHP O&M staff at Quantico.

6.0 REFERENCES

Boiler Efficiency Institute. 1985. Heating Plant Optimization Survey at the MCDEC, Quantico, Virginia. Boiler Efficiency Institute, Auburn, Alabama.

Jarrell, D.B. et al. 1989. Nuclear Plant Service Water Aging Degradation Assessment. NUREG/CR-5379V1, PNL-6506, prepared by Pacific Northwest Laboratory for the U.S. Nuclear Regulatory Commission, Washington, D.C.

U.S. Nuclear Regulatory Commission (NRC). 1988. NRC Maintenance Inspection Guidance. Washington, D.C.

APPENDIX A

SYSTEM DESCRIPTIONS

APPENDIX A

SYSTEM DESCRIPTIONS

The following paragraphs describe the major systems of the Central Heating Plant (CHP) for the United States Marine Corp (USMC) at Quantico, Virginia. Describing these systems will give the reader a better understanding of the importance of each system and its contribution to the plant. Figure A.1 is an overview of the major systems located in the CHP and is used to illustrate the flow of interactions between systems (refer to the discussion in Section 4.2.2). Each system discussed in the overview will be described in greater detail in this appendix. The description will include the system purpose, its major components and configuration, inputs and outputs for the system, and the normal operating mode. The system boundary is generally considered to be defined by the associated figure.

A.1 FEEDWATER SYSTEM

The feedwater system provides makeup feedwater to the boiler's steam drums. The system consists of five centrifugal pumps and five header pressure regulators in parallel (shown in Figure A.2.) The pumps are normally supplied from a common header which has three inlets. Two of the inlets come from each of the two tanks of the deaerating system. These two inlets are the normal flow path into the system. The third inlet is a backup system and comes directly from the soft-water system. Two pumps are normally used to move water from the input header to the output header. Water is then piped from the outlet header to steam drums through each of the boiler's individual feedwater regulation valves. Note: The feedwater regulation valves are part of boiler systems operation and are addressed in that section. The feedwater system is one of the simplest but most crucial elements in the steam plant since almost all water flows through this system.

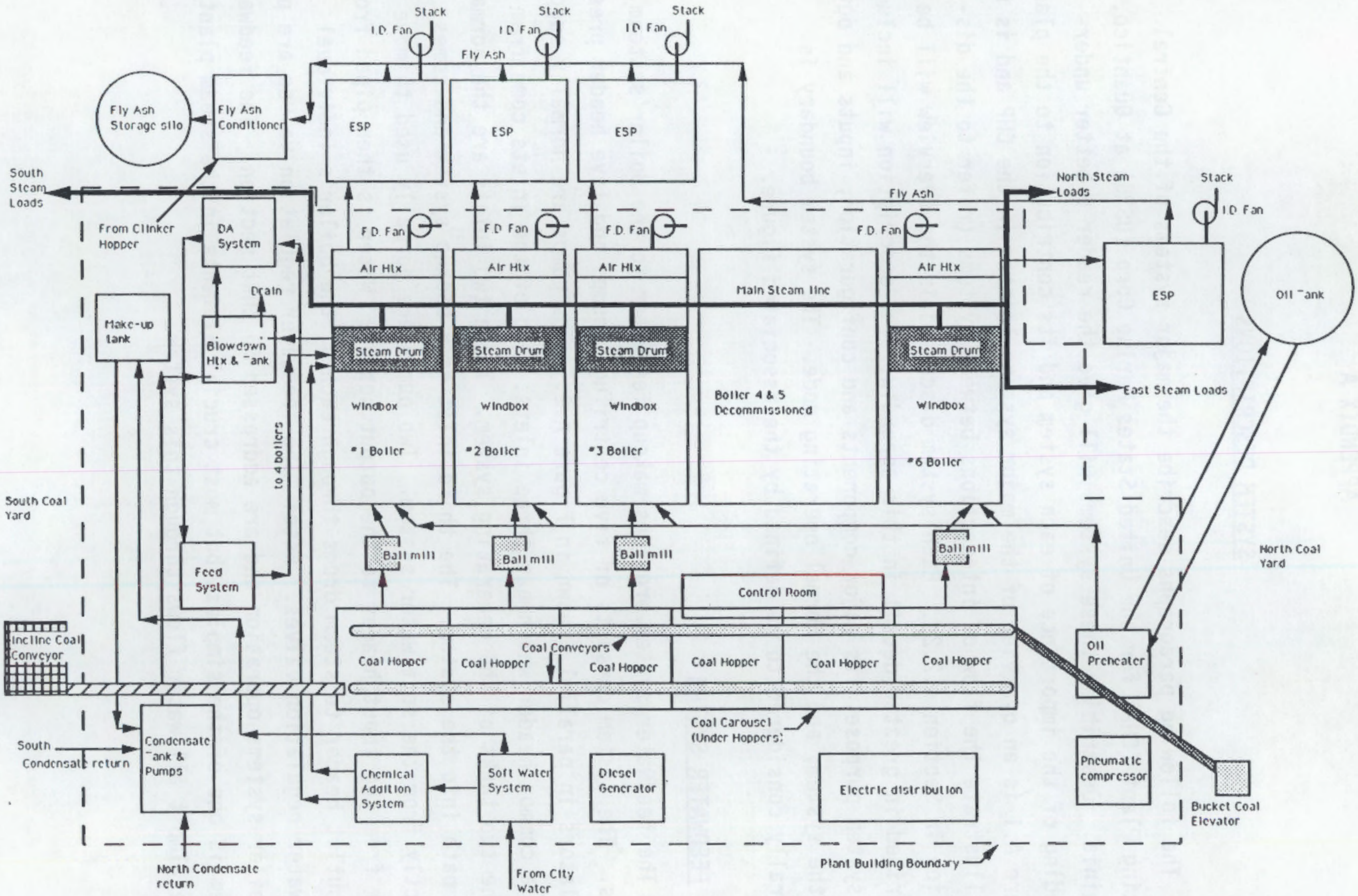

FIGURE A.1. Plant Schematic

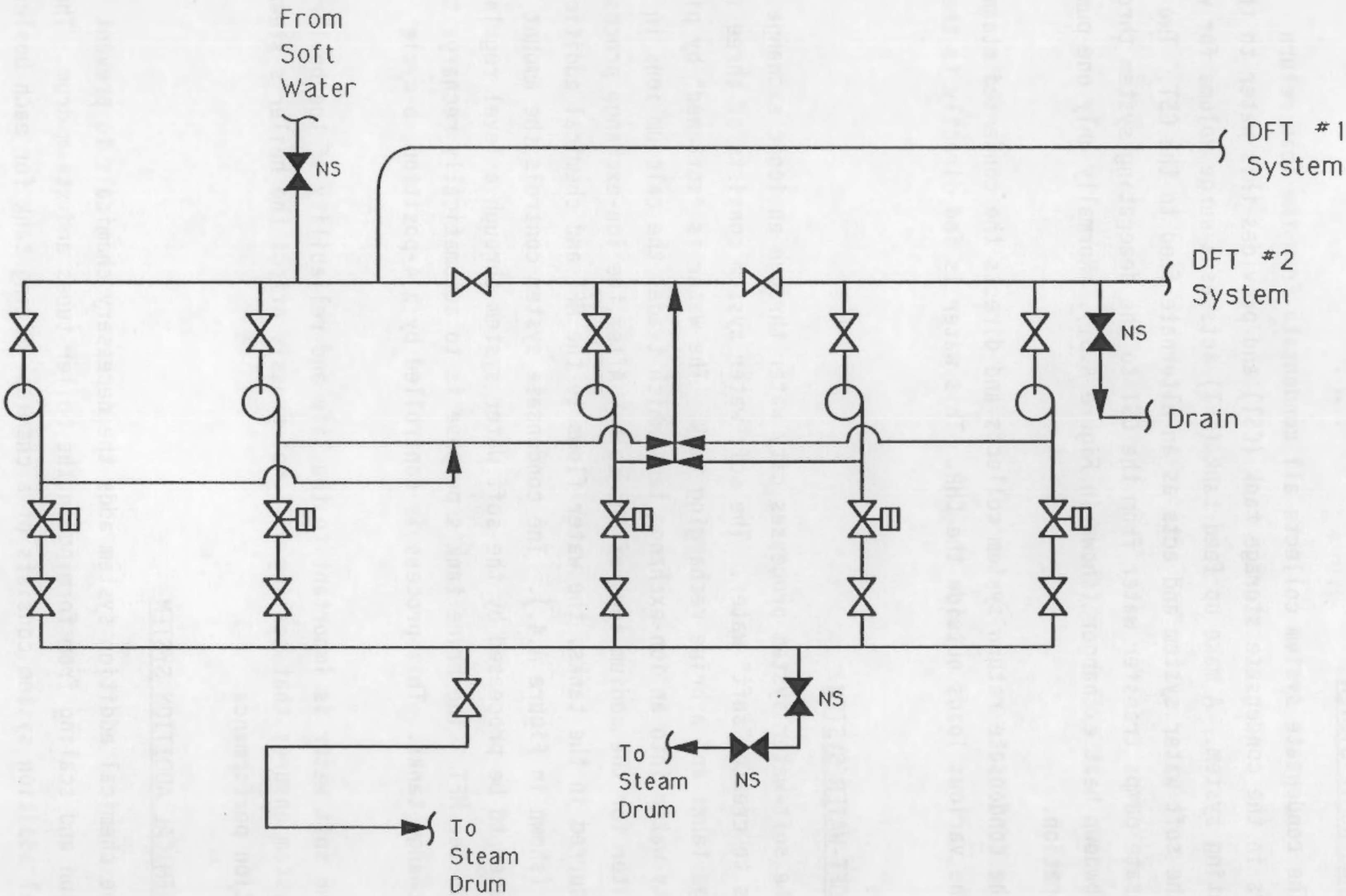

FIGURE A.2. Feed-Water System

A.2 CONDENSATE SYSTEM

The condensate system collects all condensate from the load return headers in the condensate storage tank (CST) and provides this water to the deaerating system. A make up feed tank (MFT) acts as a surge volume for water from the soft water system and acts as an alternate feed to the CST. Two condensate pumps transfer water from the CST to the deaerating system through the blowdown heat exchanger (shown in Figure A.3.). Normally only one pump is in operation.

The condensate return system collects and directs the condensed steam from the various loads outside the CHP. This water is fed directly to the CST.

A.3 SOFT-WATER SYSTEM

The soft-water system processes city water through an ionic exchange process to create "soft" water. The soft-water system consists of three ion-exchange tanks and a brine recharging tank. The water is "softened" by piping the city water into an ion-exchange tank which trades the calcium ions in the city water for the sodium ions of the salt. After the ion-exchange process has occurred in the tanks, the water flows to the MFT and chemical addition system (shown in Figure A.4.). The condensate system controls the amount of city water to be processed by the soft water system through a level regulation valve in the MFT. The brine tank's purpose is to automatically recharge the ion-exchange tanks. This process is controlled by a 4-position, 5-cycle valve.

The soft water is important to the life and reliability of the boiler. This system ensures that scaling will not grossly affect the boiler's steam generation performance.

A.4 CHEMICAL ADDITION SYSTEM

The chemical addition system adds the necessary chemicals to prevent corrosion and scaling from forming in the boiler tubes and steam drum. The chemical addition system consists of a chemical mixing tank for each boiler

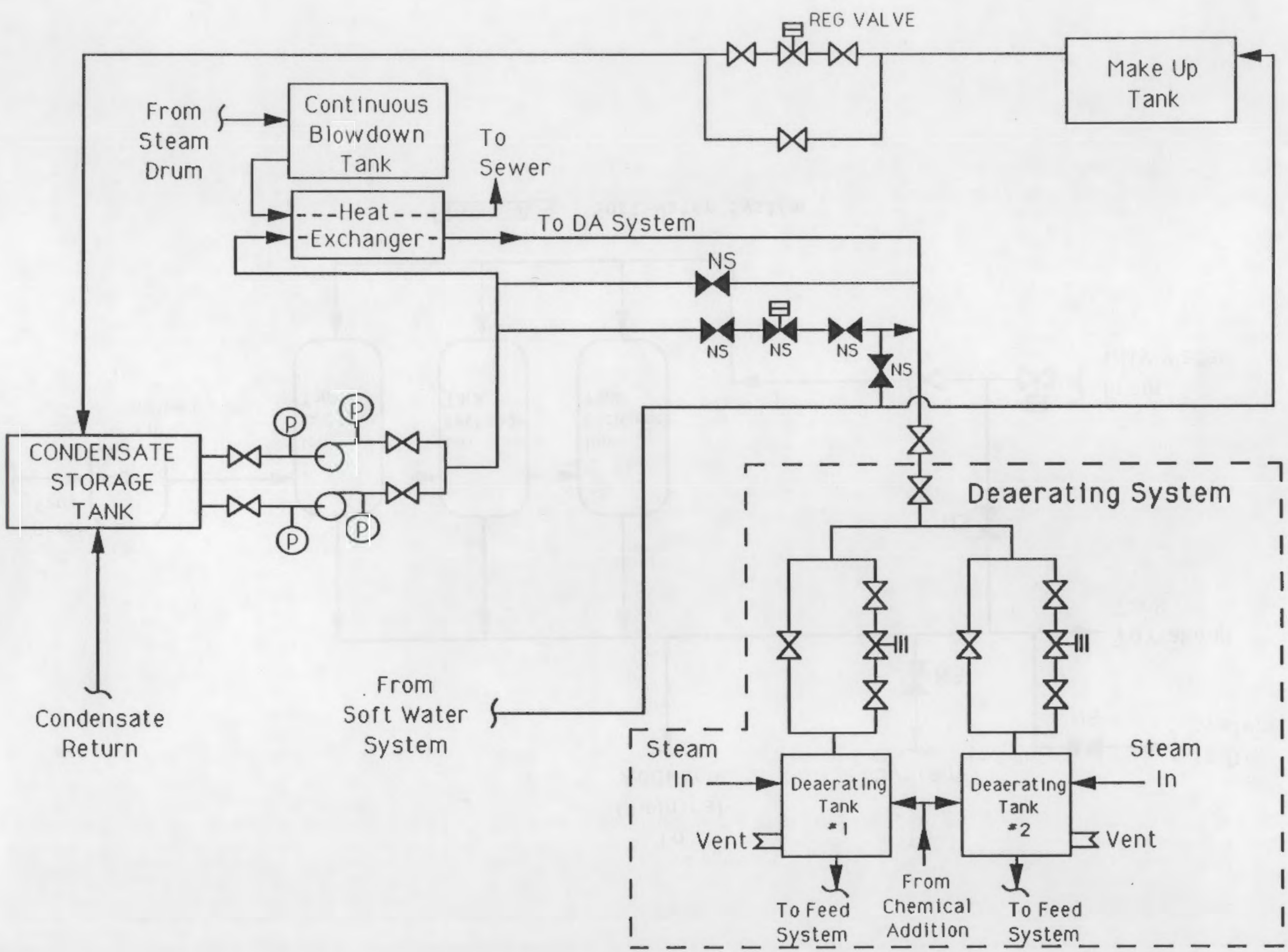

FIGURE A.3. Condensate System

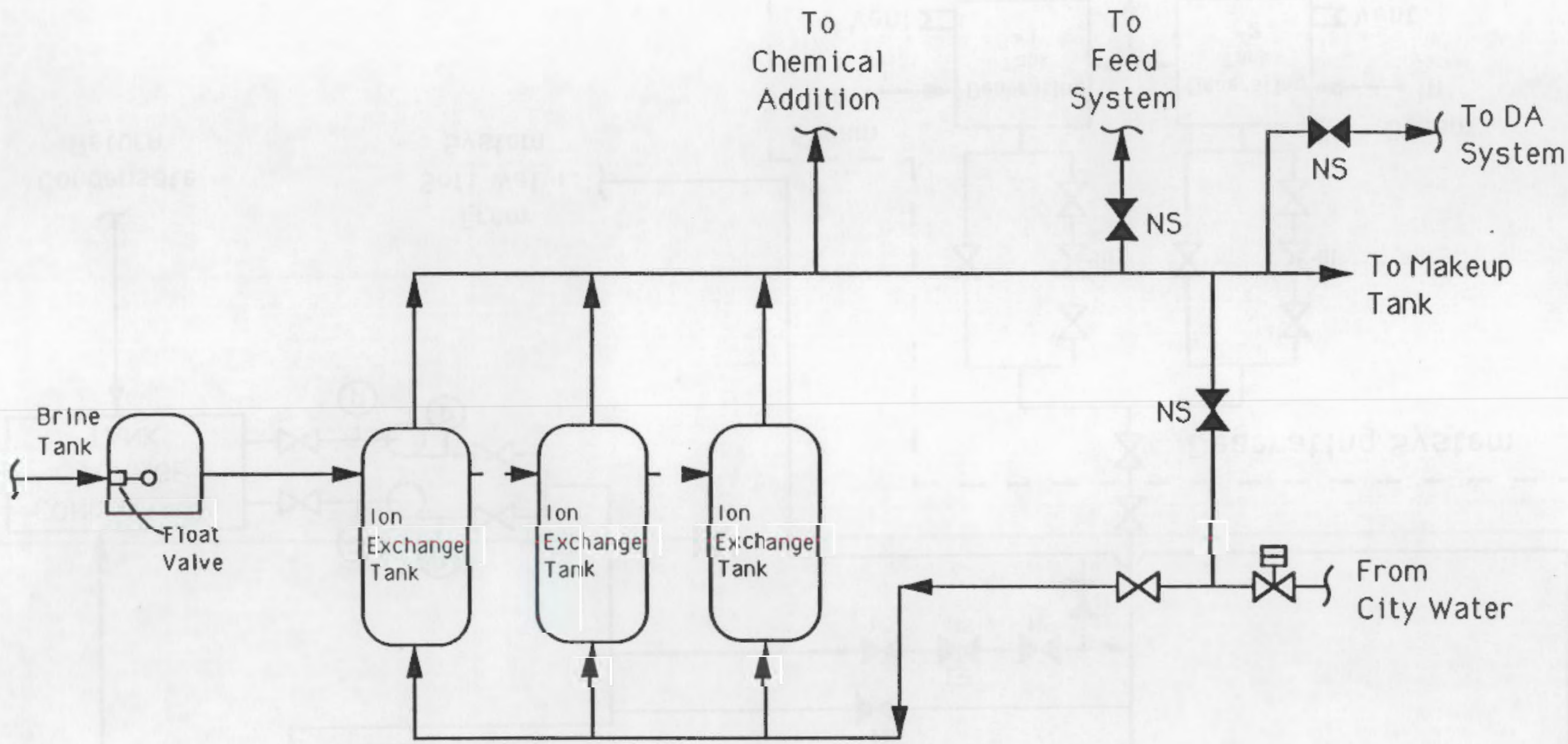

FIGURE A.4. Soft-Water System

and a sulfite tank (shown in Figure A.5). Water comes from the soft water system and is fed into the appropriate tank. The complete boiler chemistry is measured daily, and water conductivity is measured on each shift. Needed chemicals are manually placed in the mixing tank, and a positive displacement pump transfers this mixture directly to the boiler steam drum. The sulfite solution from the sulfite tank is pumped to the deaerating system to aid in removing oxygen from the feedwater. Each tank is regulated by a control valve which monitors the tank's level.

A.5 DEAERATING SYSTEM

The deaerating system removes oxygen from water to slow the corrosion process in the boiler. The major components of this system are the two deaerating tanks (shown in Figure A.3). These tanks, using steam supplied from the main steam header, deaerate the water by heating it to the saturation temperature. The deaerating tanks normally receive water from the condensate tank. Water from the chemical system is added to aid in the deaerating process. Steam used for heating enters the tank and moves through a ring header perforated with small holes. A vent is located at the top of each tank to release excess steam. The deaerated water is piped out of the bottom of the tank and fed into the feedwater system.

A.6 STEAM GENERATION SYSTEM

The steam generation or boiler system creates steam by heat transfer from burning either oil or coal to heat pressurized water. Steam generation is directly linked to the combustion control system, which regulates the fuel/air ratio and the emission control system, which disposes of combustion particulate.

The boiler consists of the feedwater regulation valve, the steam drum, the downcomer/riser tubes, and the blowdown system. Figures A.6 and A.7 show the configuration of the components. The steam drum receives a continual source of subcooled water from the feed system. The drum level is regulated by the feedwater regulation valve, which maintains the level within a programmed band in the drum. This water then flows down the downcomer tubes

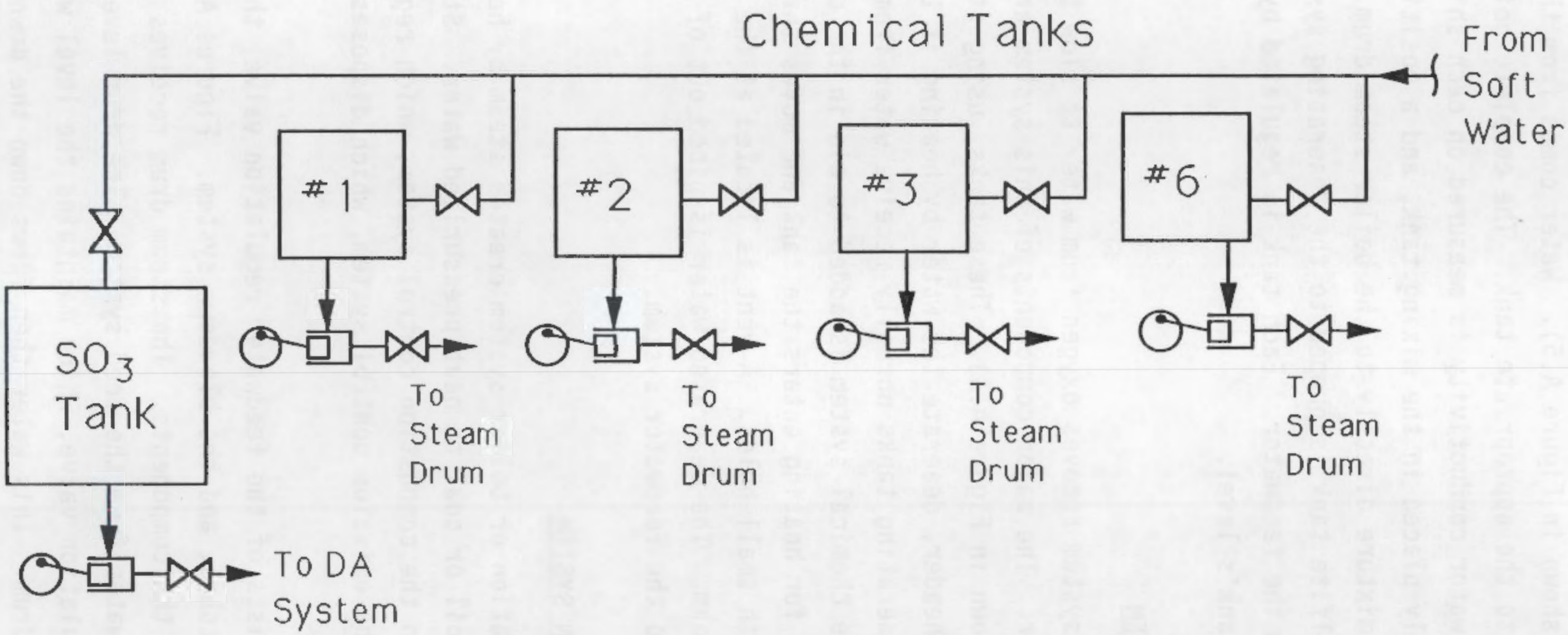

FIGURE A.5. **Chemical Addition System**

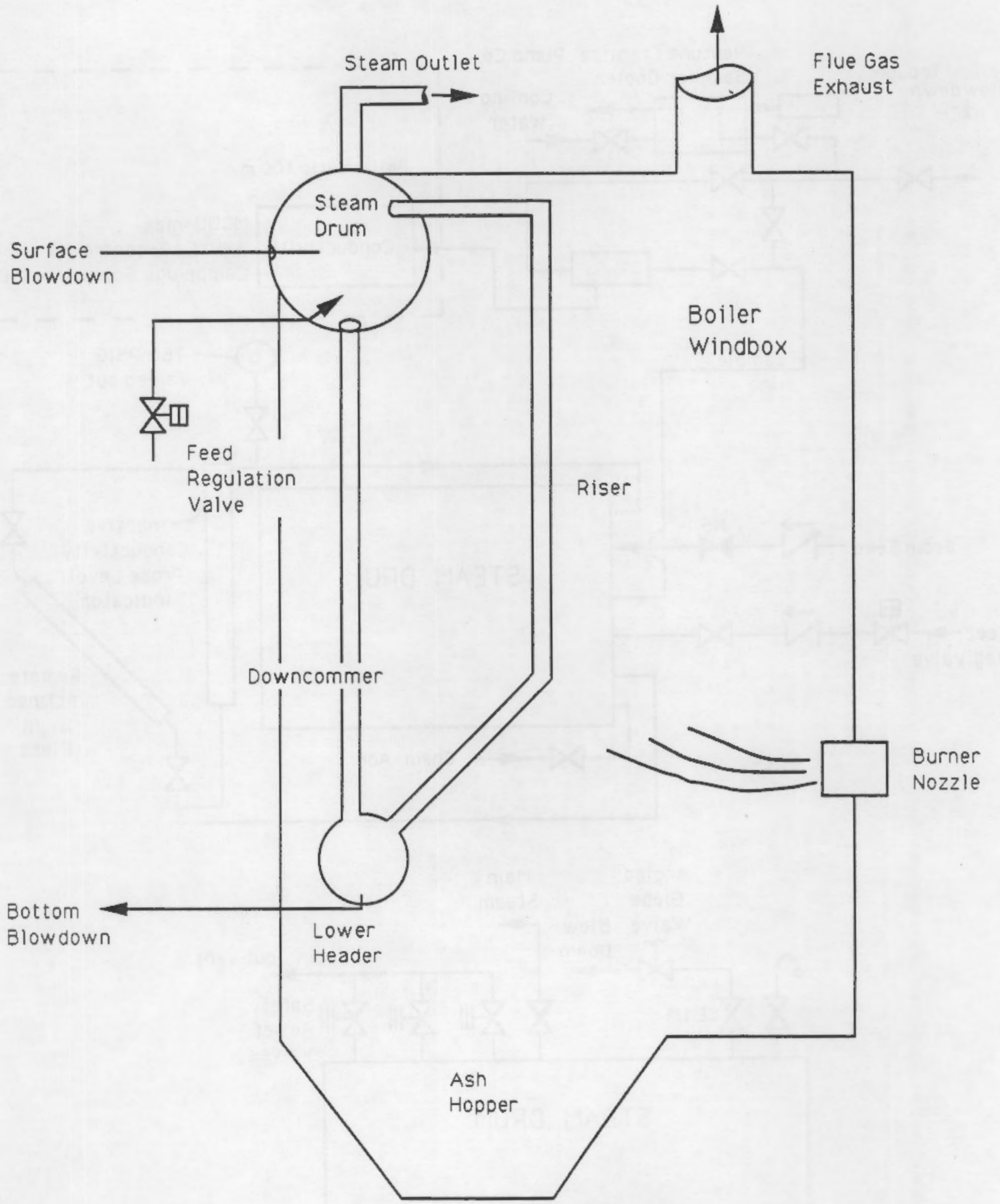

FIGURE A.6. Boiler Schematic

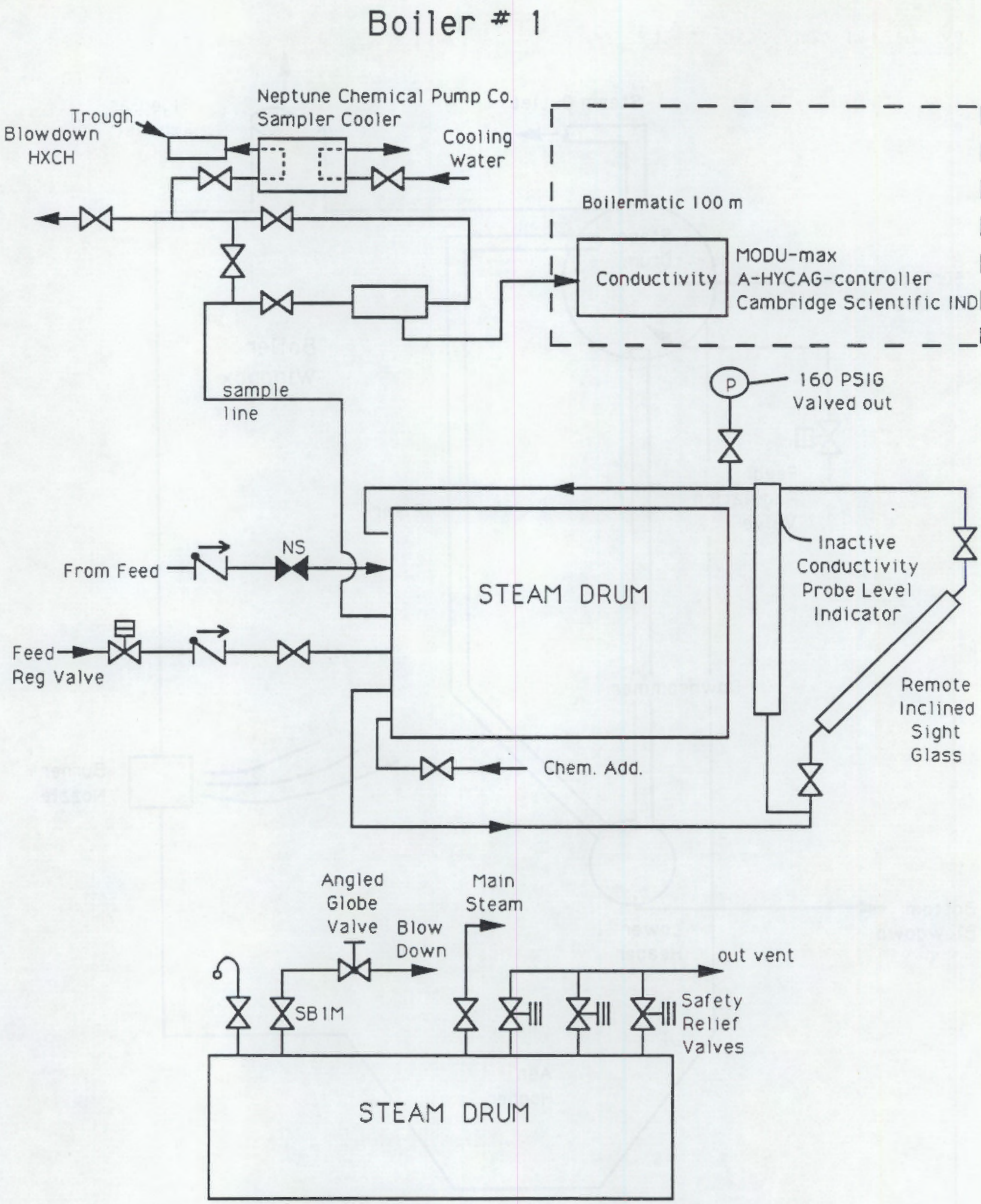

FIGURE A.7. Steam Drum Configuration

by natural convection to the lower header. From the lower header, the water flows to the riser tubes, where it absorbs further heat and is converted to a steam/water mixture. This mixture from the boiler riser tubes is then returned to the drum. The steam in the drum exits through the top of the drum, passing through a series of baffles to maintain steam quality, to the main steam header.

Water quality is generally maintained by the chemical addition system; however, certain solids and waste products may still remain in the water. These products are removed by the blowdown system. The blowdown system consists of two pipes: the continuous blow pipe and the bottom blow header. Continuous blowdown is provided by a perforated pipe which extends into the drum just below the surface of the water. Flow through this pipe removes floating solids in the water. The continuous blowdown water is then fed to the blowdown heat exchanger, where the heat from the blowdown is transferred to the feedwater. After the heat exchange, the continuous blowdown goes to a drain. The bottom blowdown, located at the bottom of the lower header, removes the heavy particles from the water and pipes it to the drain.

Water also enters the steam drum from the chemical addition system. Although the quantity of water from the chemical addition system is small compared to the quantity from the feed system, it maintains the proper water chemistry in the steam drum.

The steam distribution system receives steam produced in the active drums and directs it to the various loads outside the CHP. This system distributes steam to heat the housing units on base, laundry facility, mess hall, hospital, and some aircraft hangers.

A.7 OIL HANDLING SYSTEM

The oil handling system provides warmed fuel oil at the proper pressure to the burners. It is composed of the oil storage tank, oil pumps, and the oil preheater. The storage tank contains number six grade fuel oil and is located next to the north coal yard. Normally, oil is constantly recirculated from the storage tank to the preheater and back to keep the oil lines free for the times when oil is needed. The oil is fed to the burner via a pressure regulation valve located next to the preheater. The burners have two requirements: 1) the oil must be above a certain temperature, and 2) the pressure in the line must be kept above a setpoint for the burner to function properly. Although the oil in the storage tank is heated when circulated through the preheater because it is located in the CHP, the oil in the storage tank is also heated by a steam heat exchanger in the fuel oil tank.

The oil handling system is one of two fuel handling systems for the CHP. It is, therefore, a crucial element in fuel delivery if the other fuel system is inoperable.

A.8 GAS PILOT SYSTEM

The gas pilot system provides ignition for the burner system, prevents thermal shock at boiler startup, and prevents condensation in an idle boiler. Natural gas enters the CHP through a metering system and is piped directly to the burner face of each boiler. A shutoff system and burner nozzle then complete its functions.

A.9 COAL HANDLING SYSTEM

The coal handling system weighs, pulverizes, and moves coal from the north and south coal yards to the burner. Three subsystems make up the coal handling system: 1) conveyors, 2) coal scales, and 3) ball mills (pulverizers). There are four conveyor systems that transport the coal to the individual ball mill coal scales. The north coal yard uses a bucket elevator system (vertical conveyer) to transport the coal to an elevation slightly above the top of the coal hoppers. Once the coal reaches this location, a horizontal conveyor moves it to a (third) transfer conveyer, which then deposits the coal in the hopper of the operator's choice. The south coal yard has an inclined two-belt conveyor system to transport coal to the top of the hopper. Again, a transfer conveyer located at the top of the hoppers moves the coal to the hopper of the operator's choice. A fourth conveyor is referred to as the carousel and is located under the hoppers. The carousel moves coal from any hopper to any coal scale. The coal weighing system measures an appropriate amount of coal and feeds it to the ball mill. The ball mill pulverizes and feeds coal to the burner through a centrifugal fan and duct arrangement.

A.10 EMISSION CONTROL SYSTEM

The emission control system removes the particulate combustion by-products of the boiler from the flue gas and prepares those by-products for transportation to an appropriate dump site. The subsystems of the emission control system are the electrostatic precipitators (ESPs) and the ash handling system.

The ESPs remove particulate combustion by-products from the burner exhaust by charging the particles with a negative charge as the flue gases pass by electrodes. The charged particles then become attached to a positively charged series of plates, which then are periodically vibrated, causing the particles to drop down into a hopper. Those particulates are then processed by the ash handling system. Flue gases that have passed through the ESPs flow through ducting to the induced draft fan, and, finally, are vented out through the stack.

The ash handling system conveys bottom ash from the boiler and fly ash from the precipitator hoppers to the ash storage silo. The system conditions the ash with a water spray in a rotary conditioner and uses steam from the main steam header to dry the fly ash. The fly ash is then ducted to the storage silo. Bottom ash (larger ash particles and slag) from the boiler falls from the boiler tubes into the boiler ash hoppers. Slag is suctioned using a steam venturi into a common header under all the boiler ash hoppers and through ducting to the storage silo. Both the bottom ash and the fly ash are discharged from the storage silo to a truck for offsite disposal.

A.11 COMPRESSED AIR SYSTEM

The compressed air system consists of three air compressors and various receivers, dryers, regulators, and reducers. This system provides air pressure for controlling various valves, dampers, and other pneumatic loads.

Since the CHP has many automatic controls and most of them are pneumatically operated, the compressed air system is crucial to the automatic operation of the CHP.

A.12 ELECTRICAL SYSTEM

Power for the CHP is supplied by Virginia Power Company transmission lines to a substation which reduces the voltage to 13,200 V and provides two feeders to the Butler Stadium Substation busses A and B. The CHP is supplied by two older feeders through circuit breakers and step-down transformers.

Back-up emergency power for the CHP is supplied by a General Motors Detroit diesel-driven 300 kW DELCO® generator at 2400 V. This emergency generator can be connected to a section of the 2400 V bus by a transfer switch and an oil circuit breaker and can be connected to the new 480 V bus A through a step-down transformer.

A.13 CONTROL SYSTEMS

Various control systems are used to manage plant processes in the systems mentioned above. The three major control systems, which interface with numerous systems, are the burner management system, the combustion control system, and the feedwater system.

A.13.1 Burner Management

The primary purpose of the burner management system is to safely place oil and coal burners in and out of service from a remote master control panel. The burner management system protects against the unsafe admission of fuel into the furnace of each unit.

The secondary purpose of the burner management system is to aid the operator. It provides the operator with a consistent method for starting and stopping the flow of fuel into the furnace.

The burner management system comprises a number of subsystems, each responsible for a portion of the overall control of the system. Each subsystem communicates information to the other subsystems and provides the operator with indications of the operations being performed within that subsystem.

A.13.2 Combustion Control

The combustion control system automatically fires the boiler at the correct fuel/air ratio for any given steam load.

The combustion control system uses instruments such as pressure or flow transmitters to send control signals to the final control devices such as oil valves, dampers, and coal feeders. Based on information provided by the primary sensing elements, the system regulates fuel and air to the furnace to maintain the correct steady steam pressure at varying loads.

The manual/automatic control stations allow the operator to take manual control of the system to block all automatic signals and provide signals to the final control devices (valves, dampers, coal feeders, etc.) for complete operator control.

A.13.3 Feedwater Control

The feedwater control system is a three-element system that maintains the desired steam drum level by balancing signals from the steam drum level, feedwater flow, and steam flow.

These three signals are summed in the feedwater-flow controller to produce a control signal that opens or shuts the feedwater regulation valve (FRV). A positive signal will open the FRV, admitting more water to the steam drum; a negative signal will decrease the flow; and a zero control signal causes the valve to remain in the same position.

APPENDIX B

A STANDARD PLANT METRIC

APPENDIX B

A STANDARD PLANT METRIC

A characterization such as the one in this report requires a systematic yardstick by which to measure, relative to an agreed upon standard or metric, the degree to which these performance expectations are achieved by the plant in question.

This appendix explains the plant metric used by the PNL team to make its observations during our two Quantico site visits. It is the goal of a well-run, well-maintained power plant to perform as efficiently, safely, and reliably as possible. To accomplish this goal, certain functions must be performed in an efficient and well-coordinated manner. These functions are centered around the categories of

- administration
- operations
- maintenance
- engineering
- training.

The following text states the functional criteria that are necessary to efficiently and effectively accomplish the tasks found in each of these categories. Plant personnel can achieve the intent of each of these criteria in a variety of acceptable ways. When these criteria cannot be met, however, experience has shown that difficulties frequently arise. By presenting the criteria in terms of the function they must perform, the results of not fulfilling a specific criterion can be more easily tied to observations made by the team.

1.0 ADMINISTRATION

1.1 PLANT ADMINISTRATION
1.2 MANAGEMENT OBJECTIVES
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For each of these areas, the following questions are addressed in this evaluation:

FUNCTION: WHAT is the goal to be achieved?

RESPONSIBILITY: WHO is responsible for achieving it?

CRITERIA: HOW can goal achievement be measured?

These criteria can form the basis for an accurate comparison of functions between operating power plants and are presented in the following appendix.

B.1.0 ADMINISTRATION

B.1.1 PLANT ADMINISTRATION

FUNCTION: To establish and ensure effective implementation of policies and the planning and control of station activities.

RESPONSIBILITY: Plant management and administration

FUNCTIONAL CRITERIA:

1. The organizational structure is clearly defined.

2. Staffing and resources are sufficient to accomplish all tasks.

3. The responsibility and authority of each position are clearly defined and understood.

4. Interfaces with supporting groups, including the military staff, are clearly defined and understood.

5. Contractor tasks, responsibilities, and interfaces are clearly defined and understood.

6. Administrative controls are employed for activities that affect efficient, safe, and reliable plant operation.

7. Communications are effective within the station organization and with supporting organizations, including the military staff.

8. Commitments are routinely met. Open commitment status is tracked and up to date.

9. Controls are established for protecting the material condition of permanent equipment during construction and modification.

10. During construction and modification, the operations (plant) manager has sufficient control to ensure coordination of system/equipment/document turnovers to support the test program and future plant operation.

B.1.2 MANAGEMENT OBJECTIVES

FUNCTION: To formulate and utilize formal management objectives to improve station performance.

RESPONSIBILITY: Power plant management

FUNCTIONAL CRITERIA:

1. Specific objectives for each plant and support group organizational unit down through the functional group (operations, maintenance, etc.) leader level are published and kept current.

2. Objectives address areas where improvement is needed. Objectives are challenging and set at the level of performance desired by management. Objectives are stated in measurable terms.

3. Where appropriate, action plans with specific milestones are used to help achieve objectives and improve the level of performance.

4. Responsibilities are assigned for achieving specific objectives. Assignments reflect actions needed by each contributing functional group to achieve common objectives.

5. Personnel understand the actions necessary, within the scope of their duties and responsibilities, to achieve the objectives.

6. Managers and supervisors are held accountable for the achievement of assigned objectives.

7. Management reviews are periodically conducted to assess progress toward achieving objectives and to determine changes in planned actions necessary to achieve them.

B.1.3 MANAGEMENT ASSESSMENT

FUNCTION: To monitor and assess station activities to improve all aspects of station performance.

RESPONSIBILITY: Station management and supervisory personnel

FUNCTIONAL CRITERIA:

1. Line managers and supervisors are responsible for and personally take part in monitoring and assessing heating plant activities. Assessments by other independent groups are used by line managers and supervisors as a management tool to assist them in assessing heating plant performance.

2. Managers and supervisors frequently tour the plant and observe ongoing work. Effective corrective actions are taken for noted problems.

3. Senior managers monitor the assessment activities of their subordinate managers and supervisors.

4. Management and supervisory assessment and improvement effects are performance oriented. Line managers and supervisors are responsible for determining and implementing corrective actions.

5. Selected operational data reflecting plant performance are analyzed and trended, and the results are forwarded to appropriate levels of management.

6. Root causes are determined for problems identified during monitoring of station activities and by analysis of trends. Corrective actions are initiated and tracked to completion.

7. Management assessments are conducted to determine the reasons for success or failure in achievement of objectives. Results are incorporated into future objectives.

B.1.4 PERSONNEL PLANNING AND QUALIFICATION

FUNCTION: To ensure that station positions are filled with highly qualified individuals.

RESPONSIBILITY: Station management and administration

FUNCTIONAL CRITERIA:

1. A personnel management and acquisition program is effectively implemented.

2. Timely action is taken to anticipate and fill vacancies.

3. Selection of personnel to fill vacancies is based on merit and ability.

4. Appropriate job qualification requirements are established for all station positions that affect plant operational efficiency, safety, and reliability.

5. Position incumbents meet the prescribed job qualification requirements.

6. Appropriate career advancement programs are used to develop the management, supervisory, and technical expertise of personnel. Potential candidates are selected and developed for management positions.

7. The employee performance appraisal program is effectively used to enhance individual performance.

8. Plant personnel are provided job-related operational experience through coordinated involvement with vendors, the architect/engineer, and other utilities.

B.1.5 INDUSTRIAL SAFETY

FUNCTION: To achieve a high degree of personnel safety.

RESPONSIBILITY: Plant management

FUNCTIONAL CRITERIA:

1. An effective industrial safety program with clearly defined policies, procedures, and responsibilities is implemented.

2. Initial and continuing training are conducted for all station personnel on the industrial safety program requirements and safe work practices.

3. Managers and supervisors actively support and enforce the industrial safety program.

4. Managers and supervisors are held accountable for achieving a high level of industrial safety performance in their work groups.

5. Personnel at all levels, including contractors, consistently adhere to station industrial safety program requirements.

6. A safe and orderly working environment exists. Safety hazards are identified and corrected in a timely manner.

7. The effectiveness of the industrial safety program is periodically evaluated, and the results are used to make program improvements.

B.2.0 OPERATIONS

B.2.1 ADMINISTRATION

FUNCTION: To ensure effective implementation and control of operation activities.

RESPONSIBILITY: Plant managerial staff

FUNCTIONAL CRITERIA:

1. There is a clearly defined organizational structure.

2. Staffing and resources are sufficient to accomplish assigned tasks.

3. Responsibility and authority of each supervisory and operator position are clearly defined and understood.

4. Interface with supporting groups is clearly defined and understood.

5. Administrative controls are employed for operations activities that affect safe and reliable plant operations. Examples include equipment isolation, posted operator aids, status boards, and shift turnovers.

6. Performance appraisals are used effectively to enhance individual performance.

B.2.2 CONDUCT OF OPERATIONS

FUNCTION: To ensure efficient, safe, and reliable plant operations.

RESPONSIBILITY: Plant operations and management staff

FUNCTIONAL CRITERIA:

1. Operators are attentive and responsive to plant parameters and conditions.

2. Operating conditions of plant equipment are effectively monitored, and appropriate corrective action is initiated when required.

3. Operator shift duties are limited to activities that support safe and reliable operation.

4. Control room activities are conducted in a businesslike and professional manner.

5. Oral communications regarding operational activities are conducted in a professional manner so that information is transmitted accurately and reliably.

6. Plant evolutions and testing are properly authorized by management and are controlled by operations personnel.

7. Operational and testing activities are conducted in accordance with approved procedures.

B.2.3 PLANT STATUS CONTROL

FUNCTION: To be cognizant of the status of plant systems and equipment. Operations personnel should ensure that systems and equipment are controlled in a manner that supports economical, safe, and reliable operation.

RESPONSIBILITY: Operations personnel

FUNCTIONAL CRITERIA:

1. Policies and procedures defining plant status controls are written and implemented.

2. Checksheets are used to ensure that proper conditions are established for each mode of plant operation and for mode shifts.

3. Equipment status changes are appropriately documented and communicated to appropriate shift personnel in a timely manner.

4. Activities affecting the status of installed systems and equipment are authorized by appropriate personnel.

5. The number of alarms that are normally light-sounded during power operation is minimized. Operators are able to differentiate between annunciator lights providing status information and those providing indication of an alarm condition.

6. Defective or out-of-tolerance instrumentation, alarms, and controls are identified and properly labeled. Corrective measures to repair instrumentation are taken in a timely manner.

7. Positions of valves important to safe and reliable operation are known and accurately recorded.

8. Logkeeping is timely, accurate, and adequately reflects plant activities and status.

9. Turnovers conducted for each shift station effectively and accurately transfer information between shift personnel.

10. Procedures are implemented to effectively control the placement and removal of tags used for the protection of personnel or equipment.

11. Tagouts and tags are periodically reviewed for accuracy and continued application.

B.2.4 OPERATOR KNOWLEDGE AND PERFORMANCE

FUNCTION: To ensure that operator knowledge and performance will support safe and reliable plant operation.

RESPONSIBILITY: Operations staff and management

FUNCTIONAL CRITERIA:

1. Operators are knowledgeable in the following areas:

   a. plant systems and components
   b. plant procedures and operating practices
   c. applicable in-plant and industry operating experience.

2. An operations good practices standard is written and is followed in conducting plant operations, including industrial safety.

3. Operators are cognizant of all recent procedure changes and plant modifications.

4. Operators are knowledgeable in appropriate lessons learned from industry and in-plant operating experiences.

5. Operators are capable of diagnosing plant conditions and performing required tasks.

6. Operators exhibit an attitude and approach that reflect an awareness of abnormalities, unusual conditions or trends, and a determination to inquire into and follow up on indications of abnormalities and unusual conditions and trends.

7. Each operating shift functions effectively as a team in handling routine and emergency situations and evolutions.

B.2.5 OPERATIONS PROCEDURES AND DOCUMENTATION

FUNCTION: To provide appropriate procedural direction that can be used effectively to support efficient, safe, and reliable operation of the plant.

RESPONSIBILITY: Plant administrative staff

FUNCTIONAL CRITERIA:

1. Preparation, review, approval, and revision of procedures and documents are properly controlled.

2. Emergency and abnormal operating procedures effectively guide the operators in responding to casualties.

3. Procedures are clear and concise, and contain adequate information for users to understand and perform their activities effectively.

4. Procedures are verified and validated prior to use.

5. A policy governing the use of procedures is implemented.

6. Procedures are readily available and clearly identified.

B.3.0 MAINTENANCE

B.3.1 ADMINISTRATION

FUNCTION: To ensure effective implementation and control of maintenance activities.

RESPONSIBILITY: Maintenance management (Facilities Manager, Facilities Engineer, Maintenance Manager)

FUNCTIONAL CRITERIA:

1. There is a clearly defined organizational structure.

2. Staffing is sufficient to accomplish assigned tasks.

3. Responsibility and authority of each staff position are clearly defined and understood.

4. Interfaces with other plant groups are clearly defined and understood.

5. Procedures exist to conduct maintenance such that components and systems are capable of efficient, safe, and reliable operation. Examples include procedures for preventive maintenance and the use of measuring and test equipment.

6. Performance appraisals are effectively used to enhance individual performance and advance personnel position through a clearly defined career path.

B.3.2 WORK CONTROL SYSTEM

FUNCTION: To control the performance of maintenance in an efficient and safe manner such that economical, safe, and reliable plant operation is optimized.

RESPONSIBILITY: Plant management, Maintenance Manager

FUNCTIONAL CRITERIA:

1. The work control system provides plant management with accurate feedback on the status of maintenance.

2. An effective work priority system is established; the work backlog is monitored and managed.

3. Work planning includes material and tool availability, manpower requirements, and safety considerations. Maintenance history records are considered where appropriate.

4. An applicable work document defining the problem, authorizing specific trouble shooting, and describing the work to be done is written for all jobs which are potentially dangerous or require more than one-half hour to perform.

5. Advance planning for large jobs (those that require boiler shutdown or are more than one man day) consider: work priority, work procedures, plant/system conditions required, length of outage required, prestaging of material, and any contractor support activities.

6. Post-maintenance testing is written as part of the work package as appropriate (critical components or major work), and include test instructions and acceptance criteria.

7. Work documentation is reviewed to ensure proper completion of work to support efficient operation.

B.3.3 PLANT MATERIAL CONDITION

FUNCTION: To maintain the plant in a condition that supports efficient and reliable operation.

RESPONSIBILITY: Maintenance Manager, all plant personnel

FUNCTIONAL CRITERIA:

1. Systems and equipment are in good condition and fully operable. The following are important examples of this criteria:

   - Fluid leaks are minimized.

   - Equipment is protected from adverse environmental conditions.

   - Instruments, controls, and associated indicators are calibrated as required.

   - Good lubrication practices are evident.

   - Equipment, structures, and systems are properly preserved and insulated.

2. Material deficiencies are identified and entered in the work control system.

3. Temporary environmental protection (from dust, debris, freezing, etc.) is provided when necessary to support construction, outages, or maintenance.

4. Newly installed or modified systems/equipment are verified to be in good working order by the plant staff prior to operational acceptance.

B.3.4 CONDUCT OF MAINTENANCE

FUNCTION: To conduct maintenance in a safe and efficient manner.

RESPONSIBILITY: Plant management, engineering, operations, and maintenance personnel

FUNCTIONAL CRITERIA:

1. Maintenance personnel are attentive to identifying and correcting plant deficiencies.

2. Managers and supervisors routinely observe maintenance activities to identify and correct problems and monitor policy adherence and industrial safety practices.

3. Operations and engineering are appropriately involved in maintenance activities.

4. Maintenance work is properly authorized, controlled, and documented.

5. Work activities are carried out in accordance with work request documents, instructions, and drawings.

6. Good maintenance practices are followed, for example,

    - proper equipment and tools are used

    - good industrial safety practices are followed

    - work sites are clean and orderly.

7. Appropriate post-maintenance testing is performed.

8. Contract personnel are properly supervised and work under the same controls, procedures, and standards as plant maintenance personnel.

9. Direction and control are maintained over contractor maintenance activities on plant-accepted equipment.

B.3.5 PREVENTIVE MAINTENANCE

FUNCTION: To contribute to optimum performance and reliability of plant systems and equipment.

RESPONSIBILITY: Maintenance Manager and staff

FUNCTIONAL CRITERIA:

1. A preventive maintenance program is effectively implemented and includes all equipment that affects safe an efficient plant operation.

2. For new or renovated systems, the plant staff preventive maintenance system is implemented at operational turnover.

3. Preventive maintenance tasks are performed at appropriate intervals. These intervals are established to maximize equipment efficiency and reliability, and are based on operational experience, vendor recommendations, engineering recommendations, and cost/benefit analysis.

4. Preventive maintenance is performed as scheduled; deferment is by managerial approval only.

5. Preventive maintenance documentation provides a record of preventive maintenance activities, data collected, and condition of equipment.

6. Documentation of pre-operational turnover preventive maintenance data provides assurance that unanticipated component degradation has not occurred.

7. Preventive maintenance is used to assess equipment performance as well as to provide feedback for preventive maintenance adjustments and corrective action.

B.3.6 MAINTENANCE PROCEDURES AND DOCUMENTATION

FUNCTION: To provide directions when appropriate for the performance of work and to ensure that maintenance is performed safely and efficiently.

RESPONSIBILITY: Engineering support, Maintenance Manager

FUNCTIONAL CRITERIA:

1. Procedures, vendor manuals, and other work-related documents are technically accurate and reflect the actual as-built plant configuration.

2. Procedures are readily available and clearly defined.

3. New and revised procedures are reviewed for technical accuracy prior to or during initial use to ensure usability.

4. Procedures contain enough information for users to understand and perform their activities effectively.

5. A policy is implemented governing the use of procedures, which contains actions to be taken when procedures conflict, are not usable, are inadequate, or when unexpected results occur.

6. Lessons learned from installation testing are incorporated into maintenance procedures.

7. Calibration test procedures are validated during installation testing. Adequate information is provided to users to understand and perform these activities effectively.

B.3.7 MAINTENANCE HISTORY

FUNCTION: To support maintenance activities, adjust maintenance programs, optimize equipment performance, and improve equipment reliability.

RESPONSIBILITY: Maintenance Manager and staff

FUNCTIONAL CRITERIA:

1. Maintenance history records are maintained for components and systems that affect the efficiency, safety, or reliability of plant operations.

2. Pertinent component failures or other installation difficulties should be documented prior to operational turnover from the contractor.

3. All maintenance work requiring a Maintenance Work Request is documented to job completion.

4. Maintenance history records are appropriately considered in planning for corrective maintenance, modifications, and preventive maintenance.

5. Maintenance history information is readily available and easy to use.

6. Maintenance history is used to identify equipment trends and recurring maintenance problems and to assess their impacts on plant efficiency and reliability.

7. Appropriate construction and installation repairs and modifications are documented and transferred to the plant maintenance staff upon equipment turnover.

B.3.8 MAINTENANCE FACILITIES AND EQUIPMENT

FUNCTION: To effectively support the performance of maintenance activities by providing adequate facilities and equipment.

RESPONSIBILITY: Maintenance Manager

FUNCTIONAL CRITERIA:

1. Maintenance facilities' sizes and arrangements promote safe and effective work.

2. Work areas are well-lighted and maintained in a clean and orderly condition.

3. Tools, equipment, and consumables are available to support work requirements.

4. Loading, lifting, and transport equipment is available for movement of large equipment. Adequate room is available, particularly around large equipment needing frequent servicing, for lift and lay down maneuvering.

5. Suitable storage is provided for tools, supplies, and equipment.

6. Measuring and test equipment is calibrated and controlled to provide accuracy and traceability. Out-of-tolerance test equipment is tagged and removed from service.

B.3.9 MATERIALS MANAGEMENT

FUNCTION: To ensure that necessary parts and materials meeting quality and design requirements are available when needed.

RESPONSIBILITY: Maintenance Manager, Inventory Specialist.

FUNCTIONAL CRITERIA:

1. Programs are implemented to order, receive, and issue proper parts and materials for work activities. Stock levels are adjusted to meet plant needs.

2. Procurement programs are established to assume responsibility for procurement of parts when systems are turned over to the plant.

3. Storage, preventive maintenance, and shelf-life requirements for replacement parts are addressed. Engineering approval is required for any deviation from design specifications for critical parts and materials.

4. Mechanisms are in place for the expeditious procurement of parts and material on a high-priority basis when needed.

5. Critical material is inspected to ensure conformance to purchasing requirements prior to storage or release for use. Nonconforming items are identified and controlled to prevent use.

6. Material status is provided by having accurate stock records and tracking of purchase orders.

7. Material is identified and stored in a manner that allows timely retrieval.

8. The quality of stored equipment, parts, and equipment is maintained by appropriate means such as environmental and shelf-life controls and preventive maintenance.

9. Lessons learned from experience, such as lead times, parts usage, and supplier reliability, are factored into materials management.

B.3.10 MAINTENANCE PERSONNEL KNOWLEDGE AND PERFORMANCE

FUNCTION: To keep maintenance personnel knowledge and performance at a level which effectively supports efficient, safe, and reliable operation.

RESPONSIBILITY: Maintenance Manager and staff, training

FUNCTIONAL CRITERIA:

1. Critical maintenance is performed by or under the direct supervision of personnel who have demonstrated competence in performing the task at hand.

2. Maintenance staff knowledge is demonstrated by understanding in the areas of

   - maintenance policies and procedures
   - general plant layout
   - purpose and importance of plant systems and components
   - effect of work on plant systems
   - safety hazards associated with work on specific systems
   - job-specific work practices
   - cleanliness and housekeeping practices.

3. Maintenance personnel are capable of effective equipment troubleshooting.

B.4.0 ENGINEERING SUPPORT

B.4.1 ENGINEERING SUPPORT ORGANIZATION AND ADMINISTRATION

FUNCTION: To ensure effective implementation and control of technical support.

RESPONSIBILITY: Engineering staff manager

FUNCTIONAL CRITERIA:

1. The organizational structure is clearly defined.

2. Staffing and resources are sufficient to accomplish assigned tasks.

3. Responsibilities and authority for each management, supervisory, and professional position are clearly defined and understood.

4. Interfaces with supporting groups, including military groups and contract services, are clearly defined and understood.

5. Technical support personnel have sufficient expertise in plant systems, components, and operations to effectively investigate and resolve plant problems.

6. Performance appraisals are effectively used to enhance individual performance.

7. Technical support personnel are actively encouraged to develop improved methods of meeting safety, quality, and efficiency goals.

8. Technical support personnel coordinate and monitor technical services provided by outside organizations and contractors in cognizant areas.

9. Administrative controls are used as necessary to ensure the proper conduct of technical support activities that affect safe, efficient, and reliable plant operation.

10. Performance indicators are established and used to improve technical support performance.

11. Engineering support personnel effectively implement lessons learned and recommendations resulting from in-house and industry operating experience pertinent to their activities.

12. Sufficient permanent engineering support personnel are involved in system installation and start-up activities to obtain the experience and skills necessary to support future plant operations.

B.4.2 PLANT MODIFICATIONS

FUNCTION: To ensure proper design, review, control, implementation, and documentation of plant design changes in a timely manner.

RESPONSIBILITY: Engineering support personnel

FUNCTIONAL CRITERIA:

1. Approved procedures and knowledgeable personnel are used to design, review, and implement permanent and temporary modifications.

2. All modification requests are reviewed for inclusion in the modification program. Appropriate cost/benefit criteria are used to screen proposed modifications. Approved requests are identified, prioritized, scheduled, and tracked. Plant management monitors the modification schedule and takes appropriate action to ensure timely completion of modifications.

3. Activities related to modifications, including design, procurement of original and spare parts, installation, testing, document update, and closeout are effectively coordinated by engineering support among responsible groups.

4. Appropriate codes and standards are addressed in designing plant modifications.

5. Modifications receive an effective review for constructibility, testability, operability, and maintainability, with input from appropriate plant personnel.

6. Requirements for installing, verifying installation, inspecting, and testing modifications are specified as part of the design review process.

7. Modifications undergo a formal, interdisciplinary, technical review and approval. The bases for review results are clearly documented. Formal guidance is provided delineating the requirements for performing and documenting technical reviews.

8. Work required for installing and testing modifications is coordinated with and controlled by plant personnel.

9. Modification testing is completed and accepted before putting modified systems in service.

10. Documents affected by plant modifications such as drawings and procedures commonly used for system operation, tagouts, and maintenance are updated before the system or equipment is operated.

11. Plant personnel are aware of the effects of modifications before operating and maintaining modified systems and equipment.

12. Temporary modifications are minimized as much as possible. Temporary modifications that are necessary are controlled in the same manner as permanent modifications. As a minimum, the modification program should include the following:

    - Technical reviews are performed and documented prior to operating modified systems.

    - Necessary training and document updates (i.e., procedures and critical operation drawings) are done before operating modified systems.

    - Temporary modifications are periodically reviewed to be sure they are still needed. Those needed on a permanent basis are converted to permanent modifications in a timely manner.

13. Final documents (i.e., drawings, procedures) are completed and issued in a timely manner to support closeout of the modification package.

14. The as-built configuration of modified systems is verified by comparisons with approved design documents before they are accepted for operation by the plant staff. In addition, design, testing, and installation records are reviewed for completeness and accuracy prior to final acceptance of the modification.

15. Field changes receive a technical review and approval equivalent to the original design change package.

16. Changes to plant process and alarm setpoints and computer software are controlled in a manner similar to other plant modifications.

B.4.3 PLANT PERFORMANCE MONITORING

FUNCTION: To perform monitoring activities that optimize plant reliability and efficiency.

RESPONSIBILITY: Engineering support organization

FUNCTIONAL CRITERIA:

1. Programs are implemented to routinely monitor, collect, trend, and analyze performance data for equipment, systems, and components important to plant reliability and efficiency.

2. Approved procedures or guidelines and knowledgeable personnel are used to conduct performance monitoring functions. Tests are conducted consistently to help analyze results.

3. Instrumentation used for performance monitoring is calibrated as necessary and is sensitive and accurate enough to provide reliable results.

4. Optimum performance levels are defined through baseline data, design parameters, and/or modeling. These levels are adjusted when performance improvement modifications are made.

5. For modified systems, plans are made for collecting data during start-up testing and initial power operation. The data are used for defining baselines, verifying design parameters, and validating models.

6. Performance data are analyzed, and the results are used to optimize plant reliability and efficiency.

7. The effectiveness of the performance monitoring program is periodically evaluated and the results are used to make program improvements.

B.4.4 ENGINEERING SUPPORT PROCEDURES AND DOCUMENTATION

FUNCTION: To ensure that engineering support procedures and documents provide appropriate direction and that they support the efficiency and safe operation of the plant.

RESPONSIBILITY: Engineering support organization

FUNCTIONAL CRITERIA:

1. The preparation, review, approval, and revision of procedures and documents are properly controlled and timely.

2. Procedures are clear, concise, and contain adequate information for users to understand and perform their activities effectively.

3. Procedures are readily available and clearly identified.

4. Procedures are approved and validated prior to use.

5. Procedures, manuals, and reference materials are technically accurate and up-to-date.

6. A policy governing the use of procedures is implemented and includes directions for

   - when procedures are to be used as general guidance, are to be followed step-by-step, or require sign-off for each step

   - actions to be taken when procedures conflict, are inadequate for the intended tasks, or when unexpected results occur.

7. Documents, drawings, and other technical data are readily accessible, authorized, and properly controlled.

B.4.5 DOCUMENT CONTROL

FUNCTION: Document control systems should provide accurate, legible, and readily accessible information to support station requirements.

RESPONSIBILITY: Engineering support organization.

FUNCTIONAL CRITERIA:

1. Documents in the system include drawings, vendor manuals, and procedures for use in activities such as operations, maintenance, testing, and modifications.

2. Receipt, review, and approval of documents from sources outside the station are properly controlled. These documents are distributed in a timely manner.

3. Preparation, review, approval, and distribution of documents originated at the station are properly controlled and timely.

4. Documents are kept current and legible, and superseded or voided documents are removed from use.

5. Necessary documents are readily available to appropriate locations in the plant.

6. Permanent records are properly stored and readily retrievable.

7. The document control system supports system turnover and start-up. Start-up test program results are incorporated into the system.

B.5.0 TRAINING

B.5.1 ADMINISTRATION

FUNCTION: To ensure effective implementation and control of training activities.

RESPONSIBILITY: Administration

FUNCTIONAL CRITERIA:

1. There is a clearly defined organizational structure.
2. Staffing and resources are sufficient to accomplish assigned tasks.
3. The responsibility and authority of each supervisory and operator position are clearly defined and understood.
4. Interface with supporting groups is clearly defined and understood.
5. Performance appraisals are effectively used to enhance individual instructor performance.
6. Classroom and individualized instruction are effectively presented, and instructor performance is routinely evaluated.
7. A performance-based training system is defined and implemented for accomplishing the following:
   - assessing entry-level personnel's knowledge
   - identifying and documenting tasks to be included in training
   - developing and modifying training programs
   - planning and scheduling training activities
   - conducting on-the-job training
   - providing remedial training
   - including lessons learned from plant and industry operating experience.

B.5.2 GENERAL EMPLOYEE TRAINING

FUNCTION: To ensure that plant personnel have a basic understanding of their responsibilities and safe work practices and have the knowledge and practical abilities necessary to operate the plant safely and reliably.

RESPONSIBILITY: Plant personnel and training personnel

FUNCTIONAL CRITERIA:

1. Programs are established and implemented for initial and continuing training.

2. Initial training develops job-related knowledge and skills in the areas listed below.

   - plant organization and administration

   - plant description

   - industrial safety

   - plant and industry operating experience.

3. Continuing training maintains and improves job-related knowledge and skills and includes areas such as the following:

   - plant and industry experience

   - pertinent changes to the plant

   - selected items from Number 2 above, with emphasis on identified performance problems of workers.

4. Emphasis is placed on correcting plant-specific problems that require employee awareness in both initial and continuing training.

5. Knowledge and practical abilities are evaluated periodically.

B.5.3 TRAINING FACILITIES AND EQUIPMENT

FUNCTION: The training facilities, equipment, and materials effectively support training activities.

RESPONSIBILITY: Training Manager

FUNCTIONAL CRITERIA:

1. Classroom facilities are adequate for effective group instruction.

2. Reference material is adequate and readily accessible.

3. Training aids are adequate to support hands-on and practical demonstration training.

4. Training materials effectively support the training programs.

B.5.4 OPERATOR TRAINING

FUNCTION: To develop and improve the knowledge and skills necessary to perform assigned job functions.

FUNCTIONAL CRITERIA: Training manager, operations personnel.

1. Programs are established and implemented for initial and continuing training.

2. Initial training for control room operators consists of classroom and on-the-job training, develops job-related knowledge and skills, and includes the following areas:

   - technical subjects and applied sciences
   - power plant fundamentals
   - plant systems and components
   - procedures and operating practices
   - transient and accident analysis and control
   - practical factor demonstration
   - fundamental and practical teamwork and diagnostic skills
   - communications
   - industrial safety
   - in-house and industry operating experience (including actual events)
   - communicating and working with the construction organization.

3. Initial training for senior control room operators and shift supervisors develops necessary job-related knowledge and skills and includes the following areas:

   - supervisory techniques
   - emphasis on transient and accident analysis
   - application of teamwork skills
   - emergency responsibilities.

4. On-the-job training requirements are identified, completed, and documented before the employee is assigned to perform the tasks independently.

5. Continuing training maintains and improves job-related knowledge and skills in areas such as the following:

   - plant system and component changes

   - procedure changes

   - industry and in-house operating experience (including actual events).

6. Seldom-used knowledge and skills that affect the efficiency, safety, and reliability of plant operation.

7. Evaluation methods verify trainee competence.

B.5.5 MAINTENANCE TRAINING

FUNCTION: To develop and improve the knowledge and skills necessary to perform assigned job functions.

RESPONSIBILITY: Training, Maintenance Manager

FUNCTIONAL CRITERIA:

1. Programs are established and implemented for initial and continuing training.

2. Initial training consists of classroom and on-the-job training, develops necessary job-related knowledge and skills, and includes the following areas:

   - basic technical and applied science subjects
   - maintenance fundamentals and troubleshooting and repair techniques
   - plant systems and components
   - special maintenance craft skills
   - practical factor demonstration
   - work control procedures
   - industrial safety
   - maintenance procedures and practices
   - in-house and industry operating experience (including actual events)
   - emergency response
   - system turnover inspection, testing, and component maintenance history.

3. On-the-job training requirements are identified, completed, and documented before an employee performs the tasks independently.

4. Continuing training maintains and improves job-related knowledge and skills in areas such as the following:

   - plant system and component changes
   - procedure changes
   - industry and in-house operating experiences (including actual events)

- seldom-used knowledge and skills that affect safe and reliable plant operation

- selected topics from Number 2 above to correct identified weaknesses.

5. Evaluation methods verify trainee competence.

B.5.6 CHEMISTRY TRAINING

FUNCTION: To develop and improve the knowledge and skills necessary to perform assigned job functions.

RESPONSIBILITY: Maintenance Manager, Chemistry Technologist

FUNCTIONAL CRITERIA:

1. Programs are established and implemented for initial and continuing training.

2. Initial training consists of classroom and on-the-job training, develops job-related knowledge and skills and includes the following areas:

   - fundamentals of mathematics and science
   - plant systems and components
   - plant-specific chemistry
   - chemistry operations
   - chemistry specifications
   - restoration from chemistry upsets
   - industrial safety.

3. Continuing training maintains and improves job-related knowledge and skills in areas such as the following:

   - plant system and component changes
   - procedure changes
   - industry and in-house operating experience (including actual events)
   - weaknesses identified in the plant's chemistry program
   - seldom-used knowledge and skills that affect efficiency and reliable plant operation
   - selected topics from Number 2 above to correct identified weaknesses
   - on-the-job training requirements identified, completed, and documented before an employee performs the tasks independently.

5. Inexperienced personnel who are assigned responsibility for controlling chemistry have experience in those activities under conditions similar to those found in power plants.

B.5.7 EMERGENCY RESPONSE TRAINING

FUNCTION: To develop and improve the knowledge and skills of emergency response personnel, to respond to and mitigate an emergency.

RESPONSIBILITY: Training and plant management

FUNCTIONAL CRITERIA:

1. Programs are established and implemented for initial and continuing training.

2. Initial emergency response training consists of classroom and simulated emergency drills and exercises, develops job-related knowledge and skills for plant and management positions, and includes the following areas:

   - emergency implementation procedures

   - operating procedures used in an emergency

   - communications and flow of information.

3. Continuing training maintains and improves job-related knowledge and skills in areas such as the following:

   - emergency implementation procedure changes

   - weaknesses identified through simulated emergency drills and exercises

   - in-house and industry operating experience

   - selected topics from Number 2 above to correct identified weaknesses.

4. Skills that must be demonstrated are identified, completed, and documented before an employee performs the task independently.

5. Inexperienced personnel assigned to emergency response functions are given experience in applicable day-to-day responsibilities and simulated emergency drills and exercises.

APPENDIX C

EVENTS AND OBSERVATIONS

APPENDIX C

EVENTS AND OBSERVATIONS

This appendix is an abridged version of a listing which was compiled by the PNL team following two separate visits to the Quantico, Virginia, Central Heating Plant (CHP). The original observation list was culled to remove duplicate issues resulting from multiple observations, unless additional areas for study were identified in the event-to-issue resolution process. A second difference found in the presented list is the removal of the data information sources to preserve to some degree the sense of confidence in anonymity that the plant personnel entrusted to the research team.

As stated in the report, these observations are typical of operating environments found at most non-commercial heating plants, and reflect the conditions brought about by de-coupling the economics from the functional needs of plant operations. Some of the items identified in this appendix have been resolved since the site visits in November and December of 1989.

The format of each observation is:

EVENT/OBSERVATION: NO.## — A simple statement of the observation or event itself.

ISSUE: NO.** — An identified concern resulting from the observation or event. Issues are numbered sequentially by observation number. For example, Issue 1-1 is observation 1, Issue 1.

The issues identified in this appendix form the basis for both the plant functional improvement opportunities presented in Section 4.2 and the impact assessment that will follow in other work.

Events and Observations:

1. A leaking steam trap was observed by plant staff in March 1989. The steam trap was located in the steam line leading to the fuel oil tank heat exchanger. An isolation valve upstream of the trap was shut to stop the steam leak. The shut valve secured steam used to preheat fuel oil resulting in a drop in fuel oil temperature as cold weather set in this winter (December 1989). Fuel oil pressure to the oil burner nozzles then dropped because of the increase in fuel viscosity. The Number 3 boiler then tripped on (hypothesized) low fuel oil pressure. The event occurred 12-13-89 and was not put in the operator log.

Problem Isolation

1-1 Failure of steam trap not prevented (no preventive maintenance program).
1-2 No record of valve secured (status).
1-3 Did not know the status of failed components.
1-4 Data not available to diagnose what happened.
1-5 No warning prior to trip (annunciator).
1-6 Implication of temperature out of specification (desired was >90°F, indicated was 74°F).
1-7 Did not take corrective action when temperature was logged at 74°F (operating procedure).
1-8 Experience is not recorded (lessons learned from significant operating events).
1-9 Steam trap repair request not documented or completed (work control system).
1-10 Unrecorded trip leads to inaccurate assessment of boiler reliability.

2. Plant personnel explained that the boilers have been tripped several times because of tripped safety circuits during instrument calibration. Additionally, it has been determined that trip circuits do not provide a bypass to allow for on-line calibration.

   2-1 Circuitry not provided to calibrate some instruments while boiler is in service (turnover item).
   2-2 Instrumentation reliability/accuracy is not known.
   2-3 Plant condition is not known.

3. "First out" circuits appear to work improperly. Number 3 boiler tripped on 12-13-89 and did not have a first-out light indication. It was explained that sometimes the first-out works and sometimes it does not. The following are observed conditions by plant personnel: (A) While watching a trip the first-out light blinked and remained <u>unlit</u>, (B) After some trips <u>all</u> lights on the first-out light panel are lit, (C) After some trips <u>only one</u> light is lit.

   3-1 First-out feature does not work properly.
   3-2 Insufficient information to diagnose the boiler trip.
   3-3 First-out indicator is not being repaired (work control).
   3-4 Personnel do not know how to repair the circuit (training).

4. Plant personnel explained that sometimes after a major trip, i.e., all boilers off line, the boilers trip again when restarted. The boilers trip the second time due to clogged feed-water strainers and filters. Plant personnel believe that scale and debris that have settled out in low-flow areas are flushed back into the main flow when the system is run hard at restart.

   4-1 Boiler trip during plant restart because of clogged feed-water strainers (undetected degradation mechanism).

4-2 Boiler restart procedure <u>may</u> be part of the problem.
4-3 Personnel think the clogs are caused by corrosion products.
4-4 No traceability of degradation frequency.

5. Number 6 boiler tripped off and the operator did not have the data to diagnose the trip. Often operators diagnose the boiler by trying to restart the boiler and watch it trip off line again.

   5-1 Insufficient operator information.
   5-2 First-out light not working properly.
   5-3 The sensor system is not setup to provide data for automatic or manual diagnosis.

6. Plant personnel explained that the control system is not adequate. It does not provide the operator with enough response time to prevent a trip.

   6-1 Plant personnel do not believe indicator values, and therefore don't use them as warnings of impending trips.
   6-2 Operators don't believe that the control and indicator system provides them with sufficient warning of impending trips.
   6-3 Certain systems have no automatic warning system.

7. Analog recording shows indication of boiler trips; however, the operator's logs do not show the trip.

   7-1 Lack of administrative controls of what must be recorded in logs.
   7-2 Information loss on trip frequency (reliability).
   7-3 Does not give an accurate picture of the cyclic stress placed on the unit.

8. Soft water brine tank overflowed. Operators observed overflow but were instructed not to take corrective action to stop overflow. Plant personnel explained that the float valve mechanism malfunctioned. The system is still under warranty and will be fixed by vendor. Installation of brine tank is not complete, i.e., drain not connected properly.

   8-1 Responsibility: who is to take corrective action?
   8-2 Questionable operating practice.
   8-3 Control of plant modification, what is being done, when is modification complete, when components are in a condition that they can be operated by plant personnel.

9. Condensate tank overflowed. Plant personnel explained that the condensate tank overflowed because of pneumatic makeup regulator valve. Pneumatic line that controls the regulator valve has low spot that collects water. The water froze and blocked pneumatic control air to the regulator valve. The regulator valve was isolated and a light was placed on the freeze point to prevent freezing in the future.

9-1 Possibly the operator did not take the level reading or it was ignored.
9-2 Water in the air lines.
9-3 No interaction with engineering on modification/problem solution.
9-4 No warning prior to high level (remote indication).
9-5 Freezing occurs inside of building.

10. Plant personnel were called to investigate why the north conveyor system, which carries coal across the top of the bunkers, was not functioning. Using a volt meter, they detected that a fuse had blown in the motor power supply. Personnel then deenergized the fuse box and requested a fuse puller, but when none was available, a bare hand was used to extract the 208V fuse. After replacing the blown fuse with a new fuse, the conveyor was again restarted. The fuse blew again and was extracted as previously described. Another fuse was inserted and before the conveyor was turned on, other plant personnel began to remove coal at the conveyer junction transfer point. It was noted that coal fines were prohibiting motion of that part of the conveyor system. After a considerable amount of coal was removed from around and under the conveyor, plant personnel began to jump up and down on the conveyor as the conveyor was started. After approximately 15 minutes of repeating the jumping and removing coal around the conveyor the system was returned to operation. Plant personnel mentioned that the junction of the two conveyors must be vacuumed out monthly. Some plant personnel are not aware that there is a time delay when this conveyor is started.

10-1 Basic safety practices not followed.
10-2 No attempt was made to clear the coal fines around the conveyer transfer point prior to attempting restart.
10-3 Conveyor system designed or improperly operated; for example, fines and coal chunks drop off and buildup (stopping the system).
10-4 Conveyor system is run until a jam occurs instead of keeping system free to operate.
10-5 Repair procedure ad hoc.
10-6 The incident is not documented and passed to engineering for trending or resolution.

11. Number 3 and 6 boilers chemistry out of specification for long duration (days) while boilers are on line.

11-1 Continued to run boiler with out of specification chemistry.
11-2 Either tried to correct the problem and failed or ignored the problem.
11-3 Potential for very rapid tube wall degradation.

12. Several operators have expressed concern over the validity of sensor values; for example, the boiler top row indicators and the 24-hour circle charts.

Operators have opposite beliefs in the correctness of the sensor/meter readings such as 24-hour circle charts and boiler flue gas exit temperature. In conversations with plant personnel, some personnel explained that the flue gas was high because of heat transfer surface fouling on boiler tubes, while other personnel explained that this indication was wrong.

- 12-1 Operators do not know how to determine if the sensor readings are correct.
- 12-2 Operators do not believe actual correct readings and therefore do not take corrective actions as indicated by the sensor value.
- 12-3 Some of the sensors values are not correct.
- 12-4 Instrumentation is not being correctly maintained (calibration and repair of the complete sensor circuit).
- 12-5 No method available for coming to a common understanding of plant, component, and instrument condition (training).

13. Boilers Number 3 and 6 HI and LOW steam drum levels have alarmed several times (i.e., >5) during visit (12/11 to 12/15) while being operated in the manual mode. Alternately, filling the steam drum high and boiling the drum low is considered commonplace by operators.

    - 13-1 In manual mode, the operator doesn't control the water level within acceptable limits.
    - 13-2 The auto steam drum level control functions improperly.
    - 13-3 Some operators appear to be complacent about potentially damaging off-normal conditions.
    - 13-4 The high frequency of alarms is not recorded and is not assessed for potential boiler damage by engineering.

14. Some meters are working incorrectly. The Number 6 boiler level indicator moves high when the meter is tapped. Number 3 feed water flow analog meter has indicated constant feed flow for at least the past 3 days, even with a boiler trip.

    Signals to some meters are correct; however the value displayed is incorrect. This is illustrated by the Number 3 feed water flow indicator, where the analog meter is wrong and the digital (flag) display is correct.

    - 14-1 Instrumentation is not maintained.
    - 14-2 Instrumentation is not working correctly.

15. Various drum level indications are inconsistent. For example, Yarway indicator ≈ 0", site glass indicators ≈ 0", Forney meter indicates ≈ 10" high.

    Same problems as previous observation.

16. Number 3 boiler has two indications for wind box pressure, one installed by the contractor and one installed by the plant. It was determined

that the contractor's indication is incorrect. At indicated negative pressure, the pressure was actually positive as demonstrated by flames from opened view port.

16-1 Same problems as noted in number 16 with obvious potential for extreme personnel hazard as well as boiler reliability (explosion).

17. Some of the instrumentation turned over by contractors was allegedly not operating according to specifications at time of turnover. See previous discussion concerning wind box pressure.

17-1 Equipment may be accepted using inadequate or inappropriate acceptance criteria.
17-2 Same problems exist as noted in number 16.

18. Operator does not trust the steam drum level gauge on the control panel. He trusts the Yarway more and the sight glass most.

18-1 Same problems as noted in number 16.

19. There are no updated operating procedures: boiler, deaerator, softener, condensate system. Each operator develops his own procedure for operating systems.

19-1 Potential for system to be operated incorrectly.
19-2 Operating efficiency cannot be maintained at a high level from one operator to the next.

20. Percent capacity versus efficiency curves are not known or utilized to maximize efficiency of the individual boilers.

20-1 Cannot know optimum point at which to operate boiler.
20-2 Operator cannot know how to distribute load between boilers for maximum efficiency.

21. Operators have different levels of knowledge. Each operator has developed his own model of the plant based on his operating experience. Some models are incorrect and incomplete. Operators have different explanations why the Yarway was wrong. One operator does not know where O_2 monitors are located.

21-1 Training program is not consistent.
21-2 Operator qualification requirements are not consistent.

22. The control panels have problems with human factors and ergonomics. Noted various locations of the operator trip switches. Also, note that the burner permissives do not come on in an ordered sequence. Yarway data cannot be seen while looking at the panels. No schematic (mimic bus) layout in control room.

22-1 Layout contributes to confusion and lack of understanding of system.
22-2 Control room promotes operational errors.

23. Condensate return contributes corrosion products to the condensate storage tank.

    23-1 Engineering interface lacking on chronic problems.

24. The operating philosophy of most operators interviewed was to keep main header pressure near 120 psi and to avoid alarms and shutdowns.

    24-1 Coordinated approach to maintaining all appropriate parameters in a specific operating range for a well-understood reason is not a principal that is taught or an operator goal.

25. Boiler Number 3 was burning oil, although operating objective was to burn coal. It was explained that oil was being used because the boiler's water tubes were very thin (it has been 25 years since the last retubing) and was expected to fail sooner if the boiler were burning coal because of the abrasive action of the coal ash. Boiler tube failure occurred during the second observation period. Boilers 1 and 2 were not available because of refractory modifications. Boiler Number 3 ran with the leaking tube until the modifications on the other two boilers were completed.

    25-1 Predictive maintenance was performed (eddy current testing) on boiler Number 3 during the summer shutdown, but instrumentation was not available to detect the failure on-line.
    25-2 Long-range planning efforts could be used to prevent this potentially threatening position by rescheduling the effort.
    25-3 This problem could be a direct result of the observed lack of steam generator chemistry control.

26. Less than 30% of the steam leaving the CHP is returned to the plant in the form of condensate. Condensate not returned must be made up by the soft water system. The soft water system gets its water from the water treatment plant. Condensate not returned and not dumped to the storm drains must be treated by the sewage treatment plant.

    26-1 Multiple penalties must be paid for condensate not returned to the plant:

    - More city water must be processed.
    - Energy is lost through unreturned warm condensate.
    - Additional waste water treatment is needed.

27. Plant personnel stated that each operator operates the boilers according to that operator's own procedure. One operator's procedure is to control the boilers by setting the required header pressure and waiting for

alarms. The operator watches the flue gas outlet temperature, and when the temperature reaches >700°F, he blows soot.

Several times throughout the visit, the operators waited for the alarm before initiating a control action. For example, 1) Number 6 drum level Hi and Low alarms, 2) steam relief on Number 3 boiler, 3) Number 3 trip on low fuel oil flow/pressure.

27-1 Operational efficiency variations are unavoidable.
27-2 Illustrates reactive stance of operators.

28. Obtained three different answers for why the Number 6 flue gas outlet temperature was 780°F.

    1. Some operators stated meter not working.
    2. Another operator stated slag on boiler tubes.
    3. Another operator stated fire box dampers set incorrectly. (Must run boiler hotter to get complete combustion.)

    28-1 Lack of interaction with engineering.
    28-2 Lack of uniform training and qualification.

29. Operator was asked questions about some of the instruments. He did not completely understand what information was being displayed and what it meant. He knew where the percent oxygen in the off-gas was indicated and that it is usually in the range of 2% to 4%, but he did not seem to understand why. The wind box damper readouts had additional functions and parameter readouts, but he did not know what all of them were.

    29-1 The operators appear to have a very limited plant process model of the new instrumentation/control system.

30. Oiler stated that one of the purposes of the plant tour was to identify leaks; he did not, however, look beyond the specific items he had to check on his rounds. He did not take any action on the leak in the feed pump room and did not even look at the boilers as he went past them.

    30-1 Plant material condition is not "owned" by the plant personnel.

31. Plant personnel prefer to burn coal because it is cheaper.

    31-1 This attitude shows that some plant goals are communicated.

32. Plant personnel could not explain the soft water and city water valve and piping where the system cross-connected below the blowdown heat exchanger.

    32-1 Modifications to plant systems must be understood by all personnel to ensure safety, reliability, and efficiency.

33. Fire in Number 1 boiler coal feeder after shifting from two burners to one-burner mode.

    33-1 All modes of operation must be verified to be satisfactory prior to system acceptance.

34. Plant personnel turned on unit Number 1 forced draft (FD) fan while men were working in the unit Number 1 wind box.

    34-1 No formal communications route is established to ensure the safety and coordination of needed work.

35. Multiple wires used for lighting with bare leads are inserted into an electrical outlet.

    35-1 Industrial safety practice violation.

36. Observed that there were no tags indicating danger or caution on defective or degraded components undergoing maintenance.

    36-1 Work control safety practices.

37. Vendor documentation is incomplete and in some cases incorrect. Also, drawing nomenclature is not given and panel meters are shown and are not present on actual panels. Electronics technician does not have as-built, complete, and readable drawings.

    Examined the Number 3 boiler control panel to determine what process parameters were indicated there and to compare it to the drawings. The contractor's drawing of the control panel was not entirely consistent with the actual panel. The key to the drawing, which identified the functions of the readouts, was not correct.

    37-1 As-built system diagrams and actual circuit information are not available.

38. Some valves do not have any labeling system. Different nomenclature was used to reference the same valve.

    38-1 A clear, standardized system of component labeling is necessary to provide unambiguous communication and to allow personnel safety while working on components.

39. There are no recorded position indication of valves that provide regulation or safety functions.

    39-1 Valve line-up sheets for normal operation are not evident; current valve status is not generally known.

40. Examined the information logged each shift and day. This information is inadequate to document status of operation and maintenance.

40-1 Administrative procedures to control the use of and proper recording of operator logs do not exist.

41. FD fan motor and pillow blocks appear not to be greased. A coating of coal dust is on all FD fan components.

    41-1 Potential preventive maintenance inadequacy.
    41-2 Plant cleanliness.

42. Very little or no preventive maintenance appeared to be practiced during the team visits. Nearly all maintenance personnel were totally engaged in ash or coal handling duties during these visits.

    42-1 Engineering problems are not being solved.
    42-2 A cascade effect on additional equipment failures is evident due to a lack of preventive maintenance manpower.

43. Noted the following maintenance practices: 1) tools left lying around, 2) no procedures followed, 3) operators don't know what maintenance is being conducted, and 4) proper spare parts are claimed to be a work holdup item.

    43-1 Lack of a work control system clearly evident.
    43-2 Poor or nonexistent plant status control.
    43-3 Maintenance cleanliness practices and tool inventory procedures are not used.
    43-4 No effective method of materials management.

44. Turbine driven oil pump had a large amount of steam escaping to atmosphere.

    44-1 High loss of steam energy.
    44-2 Possible personnel injury due to burns.
    44-3 Lack of preventive maintenance and material condition of equipment.

45. Noted many steam and water leaks during the site visit.

    45-1 Same remarks as number 76.
    45-2 Potential contamination of storm sewers.
    45-3 Contributor to efficiency and energy loss.
    45-4 Lack of timely corrective maintenance.

46. No way to determine amount of electrical power being used in the plant.

    46-1 Accurate heat rate not possible.
    46-2 Lack of knowledge of plant consumables.

47. It was noted that pop cans and miscellaneous garbage are left around the plant, including some garbage left on hot components. No trash cans were easily accessible.

47-1 Plant cleanliness and operator pride in the facility.
47-2 Indicates a lack of managerial monitoring.

48. Some plant efficiency calculations were determined for the boilers for different loads and fuels. The calculations provide some energy conversion efficiencies greater than 100% for coal-fired boilers, probably indicating incorrect steam flow rates.

    48-1 Calibration of instrumentation not adequate.
    48-2 A lack of engineering support for plant performance monitoring.

49. Technical manual written on a level that is incompatible with knowledge of plant personnel. Most plant personnel only went to high school, the manuals require at least a technician's school level.

    49-1 Additional basic training of operators will be necessary to utilize the minimal technical material that is available.
    49-2 Plant skills inventory is not adequate to run a modern facility.
    49-3 No training program is available for the operators to advance their level of knowledge.

50. South coal yard conveyor system requires three to four men to operate. Personnel stated that they need that many men since the coal spills off of the conveyor which causes the conveyor to bind up and eventually stop.

    50-1 Lack of engineering interaction on chronic problems.

51. No way to determine how much natural gas is being used per boiler.

    51-1 Prevents an accurate boiler heat rate (gas alone can provide about 20% of boiler-rated load).

52. Normal on-shift personnel lack diagnostic information, and do not know what to do in off-normal circumstances.

    52-1 Lack of operating, off-normal, and emergency operating procedures.
    52-2 Lack of diagnostic instrumentation and knowledge, based on current system.

53. Steam production recorded in monthly summaries for CHP are estimates obtained by multiplying measured fuel consumption by a constant (125 lbs steam/gallon of oil or 14 lbs steam/lb coal). They have no integrating recorder of cumulative total steam production, only instantaneous measurements of steam flow rate.

    53-1 Lack of engineering support for plant monitoring.
    53-2 Lack of steam production instrumentation necessary to understand plant efficiency.

54. Plant personnel have a fuel analysis for each shipment of coal received. This includes approximate analysis of the coal and the heating value per pound, plus percentage of sulfur. Additional information is also provided on ash fusion temperature. Plant personnel provided copies for the last three coal deliveries.

55. No fuel analysis is available for the Number 6 fuel oil used. Energy content is an approximate value provided by the USMC and is required for any calculations used for accounting purposes. A grab sample is taken for analysis each month.

    55-1 Possible inaccuracy in plant heat rate.

56. Oil quality does vary with shipment. High vanadium Venezuelan oil can cause deposition problems. Some oil requires more steam to atomize and more heat to reach normal pumping viscosity.

    56-1 Additional instrumentation may be needed to allow accurate control of oil parameters - engineering action.

57. Ash production is not measured, but ash handler records are available. The number of truck loads of ash removed is recorded. Dump truck with government driver takes the ash to a government landfill.

58. Major steam uses in production in order of demand: 1) ash silo probably 8,000 to 10,000 lbs steam/hour--based on watching steam demand go up when the silo is turned on, 2) steam atomization for oil burners (when oil is used), 3) plant heating system, 4) continuous blowdown, 5) soot blowers 6) steam driven oil service pumps, and 7) domestic hot water. The first three are probably worth monitoring.

    58-1 Plant parasitic losses are unknown (uninstrumented).

59. No records are available for ash disposal costs. Driver splits time with the sewage plant. A reasonable estimate of ash handling costs is probably 2 FTE salary + transportation cost for a 10-mile trip. Good records of number of loads are available. A solid waste management study is in progress now; it just started and will last 4 years.

60. Boiler Number 1 fire: Down for a couple of days. Took about 2 hours to replace gaskets and restore operation. Costs of this sort of occurrence are not tracked by incident or repair.

    60-1 Lack of maintenance history prevents tracking of design faults.
    60-1 Lack of engineering analysis of plant problems.

61. No consolidated formal records are kept on repairs completed except the notes kept by the mechanic.

61-1 Component failure frequency not available to provide information on spares, operating problems, maintainability of equipment, or poor installation.

62. New coal conveyor system in north yard is very difficult to operate. It takes three men to operate continuously. Previously they used a one-bucket elevator. Coal spills off the sides and at the ends where the conveyor changes direction. Sometimes several people (everyone except one operator) go out and shovel coal. This leaves the one operator at risk.

62-1 Same as number 84.

63. No monthly steam production records by boiler were available. Plant personnel would like to have this on the computer. An hourly history recorded on computer might save approximately 15 man-hours per week.

64. Cost ratio of burning oil versus coal is about 2.5 to 1.

65. There is no routine for cycling between the condensate pumps.

65-1 Engineering not available to set up for cyclic operation of redundant systems or components.

66. Plant personnel have suggested adding a "status board" for equipment in the control room. The suggestion has never been implemented.

66-1 Lack of plant status control
66-2 Communications feedback between plant operations and management is not adequate.

67. No formal or written procedure exists for identifying steam leaks in piping.

67-1 No plant deficiency identification scheme in place.

68. During a tour of the plant with an oiler, the oiler focused almost exclusively on things he is required to inspect or record; he seemed to neglect others such as steam leaks in lines and from the Number 3 boiler.

68-1 Attitude that accepts poor operating condition of equipment is prevalent.

69. Operators would like a video display of each of the sight glasses (one display for each) on the control panel.

70. Boilers operating at the same time on automatic seem to fight each other (particularly if the load changes), so the operators usually operate only one on auto.

    70-1 Engineering support interaction needed.

71. Boiler Number 6 "drum level low" light was flashing. Meter on control panel for Number 6 drum level indicated low also. Yarway indicated that the level was ok (right in the middle). Operator told the helper to inspect the sight glass. The helper found the level in the sight glass at the center of the bridge.

72. Coal fines around the conveyor in coal yards are vacuumed by a special truck. Cost is $150/hour. Last year the average cost per visit for three visits was about $2400.

73. Electricity use is an estimate. The Number 3 meter is for the old 2400 volt system, not the whole plant. The estimate is obtained by multiplying the meter reading by some estimated factor.

74. There is currently very little condensate return on the south side because of a bad line. The condensate return is on schedule for replacement (may be done in next 2 to 3 weeks).

75. Observed trip of boiler Number 6 when only Number 3 and Number 6 were operating. Boiler was down for approximately 15 minutes. Steam pressure dropped to about 60 psi and took about 1.5 hours to get back to line pressure of 120 psi. While Number 6 was down, operator indicated that Number 3 might trip if the steam pressure dropped below about 70 psi because the pressure would be insufficient for steam atomization of oil. Operator seemed surprised that Number 3 did not trip.

76. The CHP has experienced unscheduled outages of one-half day.

77. Impacts of boilers trips in the plant and on distribution system include:

    - need to reheat cooled water
    - boilers need to run near 100% capacity to catch up (build up pressure)
    - condensate return is colder
    - need to reheat the system that went down--causes wear on the system from expansion/contraction
    - water hammer occurs from condensate collecting in steam lines--may ultimately result in failure from stress
    - stress on pressure regulators--condensation stress on diaphragms

- steam galley in mess hall needs to be drained of water

- hospital: steam is used for sterilization and heat--could have to move patients

- corrosive scale loosens and plugs strainers for:
  - feed water
  - discharge side of condensate pumps

- more condensate but no demand for it by boilers--can overflow and flood coal galley (the pumps can't handle it)

- Flooding results in damage to motors, idlers, rollers, and pumps. If this happens during the day, men are sent out to dump condensate from the distribution system. The far end of the distribution system loses pressure faster, takes longer to come back up to pressure, more steam condenses in the lines, and it can freeze easier.

78. Frequency of trips:

    Major trips-- 1 hour or longer to get back up
    Average of about 1 per week

    Minor trips-- 3 or 4 per week
    If the small boiler trips, no one notices impact.
    When Number 6 trips, it has a distribution impact.

79. Consequences of plant outage or inability to meet load:

    Stress on distribution lines. Expansion joints can move 6 to 8 inches.

    Corrosion falls off and plugs strainers.

    Heating coils have frozen on mess hall when the south line was shut down.

80. Just got in a Bacharach test kit for flue gas analysis.

81. Acceptance of systems without adequate documentation, crew training, or proof testing.

    81-1 No procedures exist for installation and test acceptance criteria for new systems.
    81-2 No engineering support group.

82. Shift personnel consist of WG-10, WG-11, and WG-5.

    82-1 There is conflict in command chain.
    82-2 There is lack of a clear progression chain for entry level personnel.

83. No operations manager.

    83-1 The plant manager is responsible for shift management directly, which detracts from his ability to balance overall plant administration, operations, and maintenance functions.

84. Coal and ash handling occupied a vast majority of maintenance personnel time during our visit.

    84-1 The maintenance department operates submerged in operations problems.

85. Observed different plant operating parameters for critical indicators on each shift.

86. No formal method for plant manager to communicate directly with all operating shifts.

    86-1 Management to operator communication weak.
    86-2 Lack of plant efficiency control.

87. Observed that the level of plant knowledge varied widely from one operator to the next.

    87-1 Operator training and qualification standards are not established.

88. Observed that entries on boiler trips varied from a fairly complete documentation of all events and difficulties to no mention of the trip at all.

    88-1 Administrative requirements on log keeping do not exist.

89. There is no written procedure for the conduct of maintenance work in the plant.

    89-1 Lack of formal documentation requirements.

90. No plant problem identification/communication method exists, such as deficiency tags or a trouble log routinely kept by operations or read by maintenance.

    90-1 Maintenance is not aware of equipment problems until they actually impact operations (corrective reactions only).

    90-2 Operators have come to accept inoperative or deficient gear as normal, creating a negative attitude and a potentially dangerous operations philosophy.

    90-3 The operators or maintenance personnel do not have an accurate status of inoperative or degraded components at their disposal.

The ability to provide steam supply resiliency (ability to supply continuity of service under component malfunction conditions) is thereby severely limited.

90-4 No way for operations or maintenance personnel to know if a component deficiency has, or has not, been reported to maintenance for correction.

91. A maintenance work request (trouble ticket) that identifies the problem and the work required to fix it (solution) is not established. Additionally, the work planning and scheduling function appears to be done ad hoc (informally - i.e. "the hottest fire gets the water"). This maintenance responsibility belongs to an organization outside of the plant, so plant personnel do not have any control over which maintenance is performed when.

91-1 Deficiencies are reported to maintenance and sometimes forgotten by maintenance in the press of other more urgent demands. Trouble record books are kept by most maintenance personnel, but these are not always maintained or coordinated. Most of the deficiencies reported to maintenance are kept in a mental file by supervisory personnel.

91-2 The most urgent work in terms of maximum plant benefit is not systematically prioritized.

91-3 Multiple jobs on the same component are not scheduled to be done together. A more explicit formulation for work planning and scheduling will allow the existing work force to be more efficient.

92. Documented guidance on procurement, receipt acceptance, storage, and inventory control for tools and spare parts does not exist within the facility. The entire plant spares system is maintained through the experience and collective memories of the maintenance and operations supervisors.

92-1 A loss of any of several key individuals (operations foreman, maintenance foreman, electronics technician, lead mechanic) would result in a serious degradation in the plant's ability to respond to the need for corrective repairs.

93. Stores inventories have recently been separated to prevent thermal degradation of electronic equipment. This effectively separates the responsibility for spares maintenance as well.

93-1 Stores inventory coordination between different groups will now be needed.

94. All individuals who must order parts indicated that accurate part numbers are very hard to obtain or maintain.

94-1 Lack of engineering support for replacement parts.

95. Component and system turnover without adequate documentation from the installation contractor was frequently cited.

95-1 Plant modification and turnover procedures are not in place.

96. Older component manufacturers are sometimes defunct or they no longer make replacement parts for some installed components.

96-1 Engineering support is necessary for some replacement specifications.

97. The ash trench sump pumps are both currently inoperative because incorrect replacement rotors were received as a result of a part number problem.

97-1 Materials management system is no longer adequate.

98. Warehouse storage areas and inventory for the plant are informally maintained.

98-1 Included is the inability to demonstrate the need for certain critical spares (until plant performance results degrade), the quantity of spares needed, tracking long lead-time items, and a systematic approach to receipt inspection.

99. Storage of CHP specific new and used parts is followed almost entirely by mental notes.

99-1 During backshifts or in the event of unavailability of those individuals who know this "system," parts retrieval would be all but impossible.

100. The storage areas appear to be in disarray, but some plant personnel demonstrated an uncanny ability to retrieve requested items.

100-1 During backshifts or in the event of unavailability of those individuals who know this "system," parts retrieval would be all but impossible.

101. Advance planning to schedule maintenance is done only for outage related jobs. Re-bricking of the burner throats on units 1 and 2, which required a one-week shutdown of both units, is an example of such a job. Dismay over the timing of these jobs was expressed ("they should have been done last summer when the demand was low") by several of the plant personnel.

102. Job performance on potentially dangerous systems does not have a formal requirement for locking out high energy devices.

102-1 Maintenance Work Request system is not in place.
102-2 Lack of "lock and tag" procedures result in excessive personnel risk.

103. Plant schematics (P&IDs) are not accurate (as-built) enough to allow positive identification of all energy sources available to a specific component.

104. No procedures exist to provide for administration or execution of a component tag out system.

105. Technical manuals were found to be scarce for all old, and some new equipment. Manuals that were available were not consistent with as-built equipment, nor did they contain acceptance test information.

106. Maintenance instructions for even the most complex equipment are not instituted in the plant.

107. All maintenance training is of the on-the-job-training variety.

108. The completion of a job is usually communicated to the lead mechanic verbally. No documentation of job peculiarities or occurrences exist. Component condition or the root cause for the failure of the component are not recorded for future reference. Operational checks of the equipment following repair usually occur only when the equipment is energized for subsequent operation.

109. Systems critical to plant operation have not been formally defined. Experience with new systems is used to establish critical preventive maintenance. This approach requires repeated boiler trips to define critical components. This learning process is impeded by lack of trip diagnostic capability.

110. The underlying cause of most of the boiler trips does not appear to be known.

111. New equipment is added to the mental file of the lead mechanic as they are turned over following contractor completion of work. Tech manuals for the new gear have been very slow to be delivered to the plant personnel. In some cases, the tech manual is delivered after the equipment warrantee period has run out.

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