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RECOMMENDATIONS FOR QUALIFICATIONS OF ENGINEERING PERSONNEL OF NUCLEAR-POWERED SHIPS.

BY:

PERRY HALL, ROBERT E. LEWIS,
DAVID R. ROTH, AND BARBARA PARAMORE

OPERATIONS RESEARCH, INC.
1400 SPRING STREET
SILVER SPRING, MARYLAND 20910

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P. Hall, R. Lewis, D. Roth, B. Paramore

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16. Abstract
The report presents summary recommendations, based on task analysis, concerning training and other qualification requirements appropriate for personnel to serve on future new commercial nuclear ships. Training content and type (classroom, shoreside practical/simulation, onboard) are recommended for 12 personnel functional areas.

The study described in this report is seen as an initial step in the process of developing marine nuclear personnel requirements. Pertinent existing standards and legal requirements are taken into account in the recommendations; however, the need for regulatory guidelines specific to the Merchant Marine environment is identified. The task data presented offer a basis for specific training curriculum development once the regulatory guidelines are defined.

In addition to the task data and summary recommendations, the report is a compendium of reference materials including description of the design proposals for new nuclear commercial ships; discussion of nuclear hazards; description of existing standards and legal requirements; and summaries of nuclear personnel requirements for the utilities, the U.S. Navy, and on the prototype NS SAVANNAH.

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PREFACE

The study which led to the recommendations made in this report was performed by Operations Research, Inc. (ORI), and General Physics Corporation. General Physics, with special expertise in nuclear power technology and training performed the analysis, using information from experience in the utilities industry, the NS SAVANNAH prototype nuclear commercial ship, and the U. S. Navy nuclear program. Representatives of the U. S. Maritime Administration and the Merchant Marine Academy assisted by providing information from the Preliminary Safety Analysis for the proposed new nuclear commercial ships. The Academy and other maritime training organizations provided feedback on analysis results. Contributing organizations and individuals outside of the study team are specifically acknowledged in Appendix B. ORI provided administrative support, assisted with review and refinement of the task data developed in the analysis, and prepared the final report.

The method of task analysis used was Functional Job Analysis (FJA), developed by Dr. Sidney A. Fine, industrial psychologist. Dr. Fine acted as a consultant to the study team on the application of the method. His expertise, practical advice, and personal interest in the progress of the analysis are acknowledged with appreciation.

EXECUTIVE SUMMARY

This report presents the results of a demonstration of the application of Functional Job Analysis (FJA) techniques to engine department activities on nuclear commercial ships. The demonstration study was based on the use of the Draft Handbook for the Development of Qualifications for Personnel in New Technology Systems, which was submitted as an interim report in September 1975. Based on the experience gained in the nuclear ship engineering study, and one other (to develop recommendations concerning qualification requirements for liquefied natural gas cargo vessel personnel), the draft handbook was revised and submitted in final form for U.S. Coast Guard use in future projects. The final handbook (ORI Technical Report No. 1012, February 1976), is a companion report to both demonstration study reports. It describes the methodology in detail. The entire research effort was performed for the Department of Transportation, U.S. Coast Guard, under contract DOT-CG-41903-A.

Although nuclear power generation is not new, its use for commercial ship propulsion is a relatively new development. The one operating example under U.S. flag registry was the prototype NS SAVANNAH. The SAVANNAH experiment ended more than five years ago. The experience of the nuclear utilities and the U.S. Navy is relevant, but different. Access to and use of information about the Navy's program is restricted.

Thus the nuclear power task analysis provided a case in the intermediate range of data availability, between virtually no operating experience to go by (as in the LNG demonstration study), and operating organizations which can be surveyed and observed as a basis for task analysis.

PURPOSE OF THE ANALYSIS

The purpose of the nuclear ship engineering task analysis was to provide a basis for developing qualifications requirements for engineering personnel to serve on nuclear commercial ships in the event they operate under U.S. flag registry, as has been proposed.

LIMITATIONS

The task analysis was limited to functions that have a direct relationship to the technical aspects, operation, or maintenance of a nuclear power plant. Ship control functions were considered only as they interface with the power plant -- i.e., change in power requirements or exposure to radiation hazard. The reference system for this analysis would not allow power changes to be made directly from the bridge. Given the prospective design features, ship control personnel could not directly affect the status of the nuclear power plant. Thus no tasks of these personnel were described. The requirement for them is to understand the capabilities, limitations, hazards and emergency conditions of the power system so that effective interaction can be maintained and emergencies responded to appropriately. The introduction of centralized automated control from the bridge would make it necessary for conning officers to receive substantially more nuclear propulsion training than is required with the presently anticipated system.

SCOPE OF THE REPORT AND ITS PLACE IN THE PROCESS OF QUALIFICATIONS DEVELOPMENT

This report presents conclusions and recommendations for summary qualifications based on the analysis, as well as the task data bank that was developed. The summary qualifications reflect the requirements of American National Standards Institute (ANSI) Standard N.18-1, and experience with land plants, naval vessels, and the SAVANNAH. The next step in the process, recommended in the report, should be development of a Regulatory Guide specifically for nuclear merchant ships, followed by development of more detailed qualifications. The extent to which responsibility for the licensing of ship personnel in this case would be shared by the Nuclear Regulatory Commission is not defined. The third step would be for training activities to develop detailed curricula for evaluation and approval by the appropriate agency or agencies. The recommendations concerning training that are presented in this report, including training content associated with each task, provide a foundation for the more detailed curricula.

CONCLUSIONS

- Distinct clusters of operating tasks can be defined, based on the operational characteristics, locations, and functions of the constituent systems (or subsystems) of the ship nuclear power plant.

- Maintenance and radiation protection tasks are not subsystem specific.

- Some tasks in the engine department are not directly affected by the fact of nuclear power generation and therefore no special <u>technical</u> training or other qualification requirement is needed.

- All ship personnel, however, in and out of the engine department, need training in at least the hazards of nuclear power, measures for protection against radiation, and emergency procedures.

- The Master and bridge officers require additional training concerning the nature and limitations of the system and certain administrative procedures.

- Some ship functions, including some related to the nuclear aspects of the system, are not adequately covered by existing regulations and standards for personnel qualifications. (In fact, only the nuclear reactor operations and supervision functions are adequately covered.) The cognizant organizations should develop comprehensive regulations and standards for nuclear commercial ships qualification requirements.

- The hazards of nuclear ship operations, and the relative isolation of a ship at sea indicate that the personnel must be particularly capable and conscientious in their work, and able to accept the requirements and conditions of this type of work.

- Procedures manuals are of critical importance, both in work and in training; it may be desirable that they be mandated and subject to approval by the cognizant regulatory agency, or agencies.

- Existing training programs and materials can provide at least a strong foundation for training of nuclear commercial ship personnel.

TRAINING RECOMMENDATIONS

- Twelve categories of training are recommended. They involve overlapping content. Thus a comprehensive, integrated common core module approach is recommended that could facilitate and reduce the cost of the total program. (See Section IV, especially Table 4.1.)

- The training format is recommended to allow for maximum flexibility in the program. Some modules permit self-paced, individualized instruction using programmed materials, whereas others require uniform classroom instruction using lectures and practical demonstrations. These features are recommended to accommodate differing training requirements and learning characteristics and to make it possible to use training materials on the ship as well as in a school setting.

- The type of training suitable for each training topic is recommended. Three general types are specified:

-- presailing shoreside in a school/classroom setting

-- presailing practical application/experience (which will involve use of simulators in some instances)

-- onboard indoctrination to assure adequate knowledge of ship-specific features.

- System drawings or diagrams, parts of procedures manuals, and certain other training materials should be prepared during ship construction in order to illustrate equipment and processes that might not be accessible when the ship is in operation.

QUALIFICATION RECOMMENDATIONS

Qualification of all personnel directly involved in the system operations is recommended to be based primarily on

- Satisfactory completion of training
- Demonstration of specific performance capabilities by simulation
- Demonstration of specific performance capabilities on the actual ship systems.

Personnel responsible for nuclear reactor operations must of course be licensed by NRC. The proposed qualifications would enable the personnel to obtain the necessary license (RO in the case of operators; SRO in the case of supervisors).

- Similar qualification requirements are recommended for the other categories directly involved with nuclear aspects of the work. No NRC license is required in these cases, which include maintenance/repair and plant chemistry control/radiation protection.
- All other personnel would be qualified on the basis of satisfactory completion of the training designed for them.
- A two-year period for renewal of the nuclear qualification is recommended. This is the period of renewal for NRC licenses. Change in the other marine license renewal requirements is not considered necessary.
- Renewal is recommended to depend on documented completion of approved refresher/update training plus documented performance proficiency in specific operations. This approach is compatible with requirements

for the NRC-licensed personnel and desirable to maintain crews with up-to-date skills. Others could renew on the basis of completion of refresher training only.

- Renewal requirements could be met while sailing or at training centers ashore.

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I. INTRODUCTION

This report presents recommendations concerning qualification requirements for engineering personnel to serve on nuclear-powered merchant ships. In addition, qualification requirements are recommended for other ship personnel, because of the nuclear hazard, although their work would not involve them directly in nuclear operations.

The recommendations address training and other requirements for initial qualification and renewal, including time frame of renewal. The recommendations were developed in a study for the U.S. Coast Guard, which has the responsibility to license, certify, and endorse personnel for Merchant Marine service, so as to avoid unsafe performance at sea, on U.S. navigable waters, and at waterfront facilities.

No U.S. nuclear merchant ship has operated since the 10-year pilot effort of the NS SAVANNAH ended in 1970, and no construction is underway. However, the U.S. Maritime Administration (MarAd) has proposed the construction of at least three. It was proposed that the first be delivered in mid-1980, with the others to follow at one-year intervals. A Preliminary Safety Analysis Report (PSAR) for this proposal was issued in April 1974.[1] Analysis of the plans for and merits of nuclear merchant ship operations has continued, involving the Coast Guard and the Nuclear Regulatory Commission (NRC), as well as MarAd. Thus the Coast Guard called for the study reported herein to examine personnel qualification requirements associated with nuclear ship operations.

The study used task analysis to establish the basis for recommending personnel qualification requirements. The detailed task data provide informa-

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[1] Babcock and Wilcox, Competitive Nuclear Merchant Ship Program Preliminary Safety Analysis Report, prepared for the U.S. Maritime Administration. Lynchburg, Virginia: Babcock and Wilcox, April 1974, 5 vols.

mation that can be used for development of training programs and measures of performance as well.

The method of task analysis used was Sidney A. Fine's Functional Job Analysis (FJA). The nuclear power qualifications study, and another, addressing qualifications of cargo handling personnel on liquefied natural gas carriers, served to demonstrate how FJA might be applied to the problem of establishing qualification requirements for new technology ship occupations with limited or no operating examples upon which to base the task analysis and conclusions about the qualifications. From the experience gained in the development and application of the method in these two studies, ORI has prepared a Handbook for the Development of Qualifications for Personnel in New Technology Systems (ORI Technical Report 1012), for use by the Coast Guard in future projects. The Handbook, which explains the methodology in detail, is a companion volume to this report. A summary of the methodology is provided as an appendix hereto, with the task data, for reading convenience.

ORGANIZATION OF THE REPORT

An effort has been made to present the results of this study as clearly and succinctly as possible so that they may be easily evaluated and applied. Sections II-IV comprise the main body of the report. Section II provides a framework for the conclusions and recommendations. It includes a description of the reference ship, an overview of the nuclear power plant system, a summary of the associated hazards, and an overview of the analysis structure. The limits of the analysis are also stated. General conclusions are presented in Section III. The specific recommendations for personnel qualification are presented in Section IV. Description of the methodology, analysis documentation, and other supporting information are referenced or summarized as necessary to make clear the reasons for various conclusions and recommendations. We have tried to avoid diffusing those study results into a large body of supporting materials. The latter are presented in appendices (and, as previously stated, the methodology is treated in a separate report as well).

Appendix A contains the summary of the information along with the task analysis documentation. Sources of information for the analysis and participants in its review are credited in Appendix B. Appendix C contains a detailed description of the hazards associated with nuclear power. Appendix D presents excerpts from the previously cited PSAR, describing the probable nature of future nuclear ships. Appendix E covers standards and legal requirements pertinent to nuclear ship personnel qualifications. Appendix F contains reviews of nuclear power plant operations on the NS SAVANNAH, on the U.S. Navy ships, and in the utilities.

II. FRAME OF REFERENCE

DESCRIPTION OF THE REFERENCE NUCLEAR SHIP

It was assumed for this analysis that any future nuclear merchant ship will be similar to that proposed by the Maritime Administration (MarAd), U.S. Department of Commerce, and described in the Competitive Nuclear Merchant Ship Program Preliminary Safety Analysis Report (PSAR), (Babcock and Wilcox, April 1974). A very brief description of the power plant and ship follows, excerpted from the PSAR.

The Maritime Administration has proposed the construction of at least three similar nuclear power plants to supply propulsion power for three merchant ships. The nuclear ships will be operated from the United States to ports of call identified by the owner/operator.

The reference nuclear ship is a 600,000 dead-weight-ton (DWT) tanker, denoted as the Very Large Crude Carrier (VLCC), designed for long-distance oil transport. It is designed and arranged to carry approximately 4,701,000 barrels of cargo oil.

The ship is fitted with navigation and collision/grounding avoidance systems to direct the movement of the ship in response to manual bridge commands and to data accumulated automatically from the various electronic systems. The systems provide data on ship position, heading, speed, sea depth, heel and trim. In addition, the systems provide the position and track of other vessels in the area and warn of necessary course changes.

The reference ship power plant has a pressurized water reactor nuclear steam system utilizing the steel-shell, pressure-suppression containment concept (hereafter referred to as Consolidated Steam Generator or CNSG). The reactor unit operates at a rated core power level of 312.0 Mwt, resulting in a new power output of 120,000 shp and an average ship speed of 18.8 knots.

As required by the U.S. Coast Guard and the American Bureau of Shipping, the two-compartment standard of subdivision has been incorporated in the ship design. The reactor compartment is aft of amidship and above and aft of the machinery space. The auxiliary propulsion boilers are located forward of the reactor compartment. The reactor compartment houses the reactor vessel, the containment features, and the reactor-associated auxiliaries. The compartment is bounded on either side by longitidinal structural bulkheads; the spaces outboard of the bulkheads are designated as collision resistance areas. Propulsion is provided by twin screws, each having a rating of 60,000 shp. The screws are driven by cross-compound steam turbines through locked-train, double helical reduction gearing. The propulsion machinery is located below the reactor compartment.

The automatic control system for the reactor/propulsion plant comprises two redundant channels. Each channel contains a digital "minicomputer," which calculates coordinated control signals for the plant using modern control techniques. Although both channels receive information from the plant and calculate control signals, only one is closed with the plant at any given time. The controllers are self-checking and control is transferred automatically to the alternate channel when a fault is detected. In addition, the control channels are monitored by a digital-based operator information system. Semiautomatic control is also provided; it consists of reactor-following (turbine control on manual) and turbine-following (reactor control on manual) modes. Finally, manual controls are provided for all control devices.

The auxiliary service requirements and engineered safety features of the CNSG plant have been evaluated and combined for maximum system reduction and simplification consistent with reliability, operability, safety, and function. All auxiliary systems are based on current pressurized water reactor technology coupled with consideration of shipboard duty and environment. All systems and components are designed and fabricated in accordance with nuclear service codes and standards, or their equivalent, in combination with appropriate consideration of the functional importance of said system and/or component. Components are selected and systems are arranged so as to afford high operational safety assurance and the appropriate degree of functional combination.

SUMMARY OF NUCLEAR HAZARDS

The hazards of nuclear power production may be divided into four categories:

- Chronic exposure by ship's personnel to low-level radiation
- Acute exposure to radiation associated with maintenance and repair activities
- Improper disposal of radioactive wastes
- Release of radioactivity to the environment due to a breach of the containment systems.

A detailed description of the hazards is provided in Appendix C.

It is noted that system/reactor accidents are generally considered improbable, based on operating experience with nuclear power production to date. However, the probability is judged greater for ship nuclear power production than for land-based operations because the ship is mobile. Avoidance of collisions, rammings, and groundings becomes even more critical than on conventionally-powered ships, despite the fact that the proposed ship design includes features to protect the nuclear power plant system in the event of such a casualty. For this reason, attention was given to special qualification requirements for deck personnel to serve aboard nuclear ships, although to do so was beyond the requirements of this study.

SCHEMATIC VIEW OF A SHIP NUCLEAR POWER SYSTEM

Figure 2.1 represents the major nuclear power plant hardware configurations—the reactor-steam generator and auxiliaries, and the steam propulsion plant and auxiliaries. The figure also indicates the general work functions of the nuclear power plant system: reactor operations and maintenance, steam propulsion plant operations and maintenance, and plant chemistry control and radiation protection. The connection to ship operations and control (most significantly, to the bridge) is represented, as is the role of health and safety standards and legal requirements.

The structuring of the analysis began with the system perspective illustrated in Figure 2.1. As the analysis progressed, the major hardware configurations were defined more specifically, as follows.

SYSTEM DEFINITIONS USED IN THE ANALYSIS

Nuclear Power Plant Systems includes all systems (actually subsystems within the framework of this analysis) in the ship's propulsion plant associated with the generation of power in the nuclear reactor, the control of the reactor, and the supply of power to the ship's propulsion equipment. For purposes of this analysis, the nuclear power plant system is subdivided, specifically, into the nuclear reactor subsystem, the steam propulsion subsystem, and the reactor auxiliary subsystem.

Nuclear Reactor Subsystem consists of mechanical, electrical, and electronic systems directly associated with the generation of power in the nuclear reactor and the transmission of that power to the steam generators. These systems are principally located within the radiation containment boundary and are normally controlled remotely from the reactor console in the control room. Examples of these systems are the primary coolant system and the rod control system.

Steam Propulsion Subsystem consists of systems (primarily mechanical) associated with the transmission of steam from the steam generators to the ship's propulsion turbines, the condensation of the steam exhausted from these turbines, and the supply of feedwater to the steam generators. These systems are principally located in the engineroom and are controlled either locally, by manual or semiautomatic means, or remotely from a steam plant console in the control room. Examples of these systems are the main steam system, condensate system, and feedwater system.

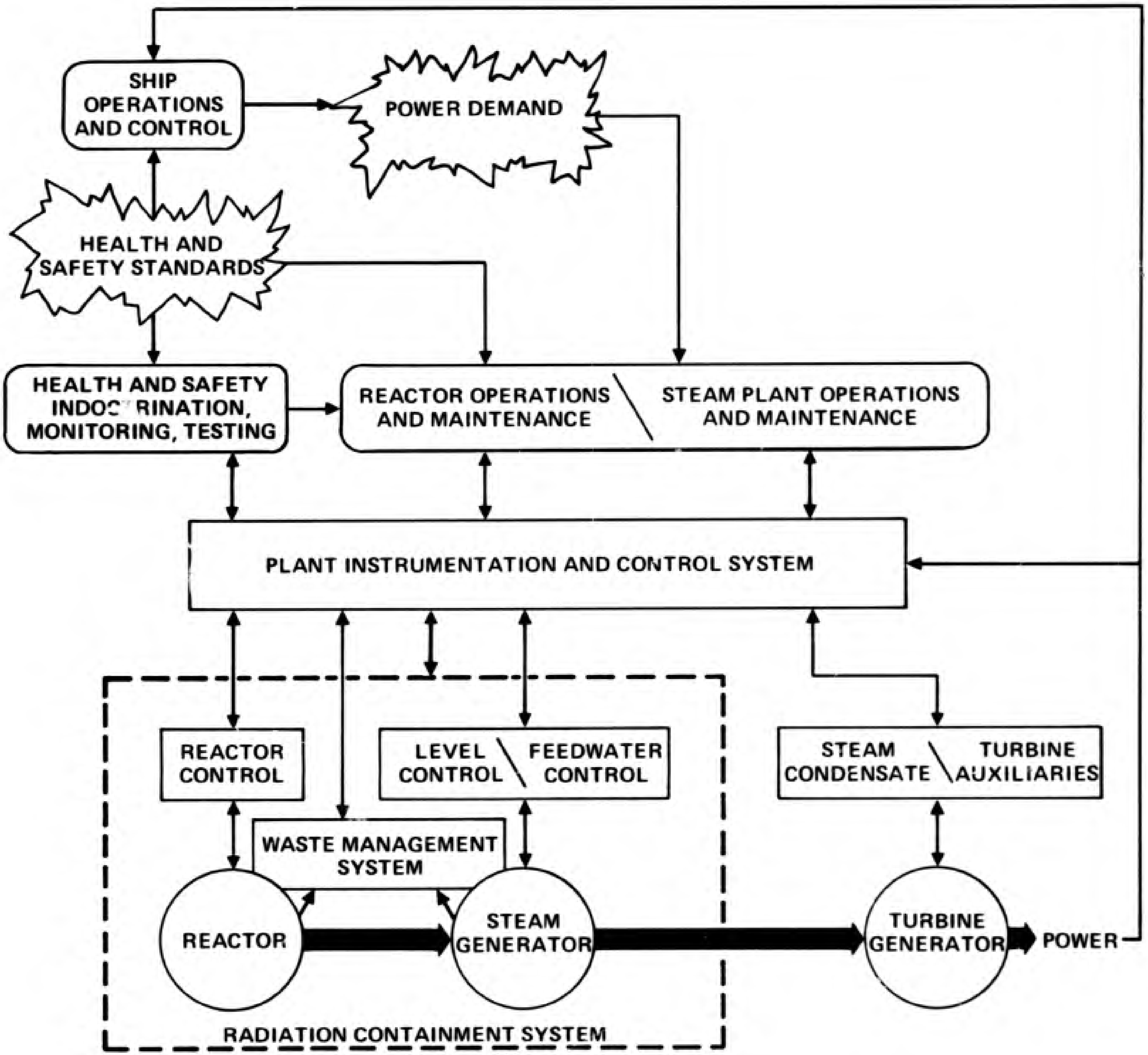


FIGURE 2.1 NUCLEAR POWER PLANT SYSTEM PERSPECTIVE

Reactor Auxiliary Subsystem consists of mechanical, electrical, and electronic systems which support the operation of the reactor, but which are not involved directly with the generation of power in the nuclear reactor. These systems are principally located in the auxiliary space and are controlled either locally, by manual or semiautomatic means, or remotely from the reactor console in the control room. Examples of these systems are the fresh water cooling system, which supplies cooling water to the main coolant pumps, and the waste disposal system.

The steam propulsion auxiliaries are not defined. Their operations and maintenance are no different on a nuclear ship than on a conventionally-powered ship and thus those tasks were not delineated in the analysis.

OVERVIEW OF THE TASK ANALYSIS STRUCTURE AND CONTENT

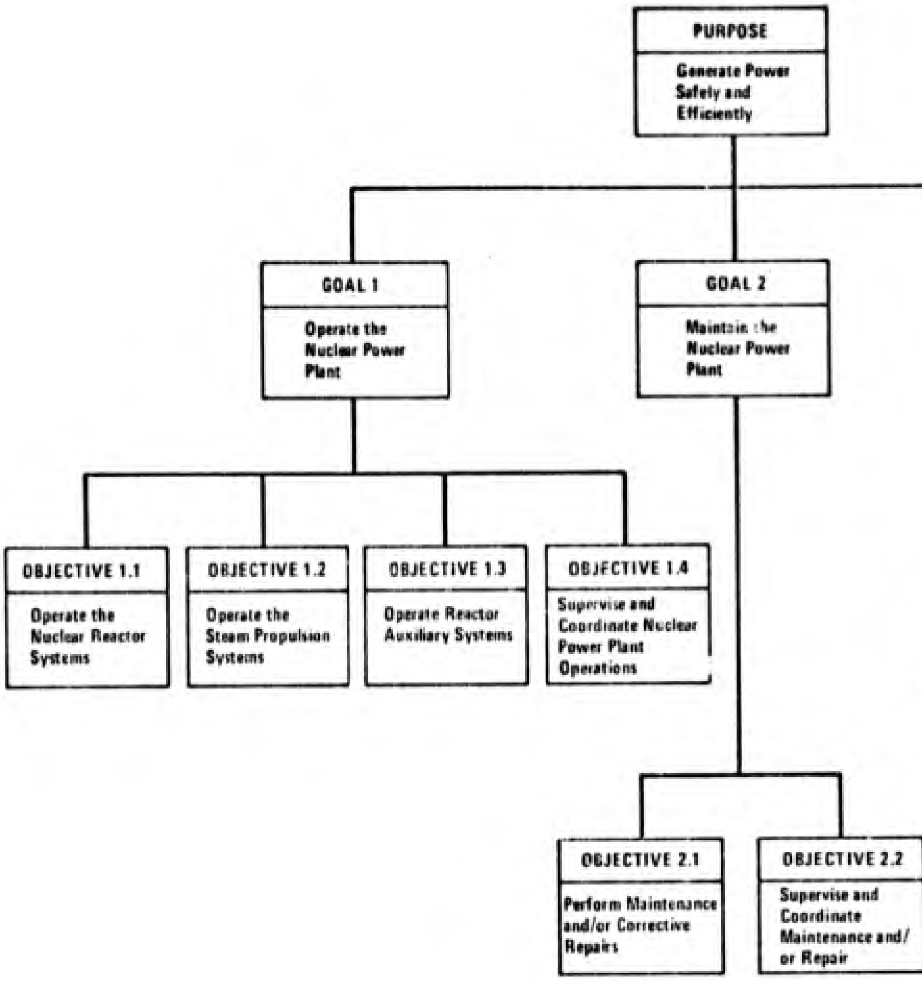
As previously stated, the analysis began with the system view represented in Figure 2.1; that view was made more detailed by the further definition of the system hardware configurations--the three subsystems. Those three subsystems are the focus of the operations and maintenance activities that comprise most of the work of this system, with health and safety assurance being a separate work area, or category of functioning, that spans the entire system. The three categories of functioning--operate, maintain, assure health and safety (or protect), although closely interrelated, involve distinct clusters of tasks.

Figure 2.2 illustrates how those functional categories were used to structure the analysis. The complete structure is presented in Appendix A, including the resulting task statements. Figure 2.2 is intended to provide an overview of the analysis that formed the basis for the conclusions and recommendations in the next two report sections.

LIMITS OF THE ANALYSIS

The analysis delineated tasks directly related to nuclear (as opposed to fossil) plant operations. Certain tasks that occur in the Engineering Department (the operations and maintenance of steam plant auxiliaries, for example) are not included because they do not represent requirements associated with nuclear power in particular.

Merchant Marine rates were not considered in the analysis. The task requirements are presented and it is left to the appropriate government agencies, the unions, and the owners/operators to decide who shall perform the tasks.



NOTE: The maintenance (and repair) function could have been broken out into objectives by hardware subsystem, as was the operate function. That was not done because it was found to result in a very large number of statements of tasks that do not differ from maintenance/repair tasks on conventionally-powered ships of similar size and automation. The difference in maintenance/repair on a nuclear ship will be in the special analysis of the system impact of repair activities and in precautions to assure radiation protection during certain repairs. Major repairs to reactor systems will require the ship to go to a repair facility, where the work is done by special technicians, not ship personnel. The complete set of diagrams of the analysis structure and the maintenance/repair task statements show how this function was handled. See Appendix A.

FIGURE 2.2. OVERVIEW OF TASK ANALYSIS STRUCTURE: PURPOSE, GOALS, AND OBJECTIVES OF SHIP NUCLEAR POWER PLANT SYSTEM

III. GENERAL STUDY CONCLUSIONS

The conclusions are divided into four parts. The first deals with the categories of work identified in the analysis. The second has to do with standards and legal requirements pertinent to nuclear ship personnel qualifications. The third has to do with implications of the hazard for personnel attributes and for the written procedures that will guide nuclear power plant system operations. The last has to do with the applicability of existing training programs.

CATEGORIES OF WORK

The operating organization of the ship nuclear power plant system is the engine department. It will consist of personnel concerned with operations, with maintenance/repair, and with health and safety assurance (including radiation protection and plant chemistry control).

The operations functional category may be subdivided by the types of hardware systems involved--i.e., nuclear reactor systems, reactor auxiliary systems, and steam propulsion systems. Steam propulsion auxiliary operations are not included because they are the same as on a conventionally-powered ship.

The maintenance functional category can be subdivided on the same basis as the operations category, but this was considered to be unnecessary in this study for the following reasons. The task analysis and experience in the utilities industry and the U.S. Navy indicates that the actual work of maintenance and repair of the nuclear power plant system is not different in kind from the usual electronic, mechanical, and hydraulic maintenance and repair work that goes on in the Engine Department of any large modern ship, although the reactor control instrumentation is more complex. The significant difference vis-a-vis the fact of nuclear power is in the analysis and precautions required to assure that the work will not negatively affect the integrity of the system and in special radiation protection requirements that might be associated with certain repairs. These types of special requirements may apply regardless of whether the work is performed on the nuclear reactor subsystem, the reactor auxiliary subsystem, of the steam propulsion subsystem. In addition, since all three are basically electromechanical systems, their maintenance and repair involve similar tasks. Major maintenance and repair work that differs significantly from the normal (e.g., refueling, core replacement) can be expected to be performed at repair facilities because of requirements for special equipment, safety precautions, and specially-trained technicians. Ship personnel are not expected to perform such work.

The functional category of health and safety assurance serves the entire system (indeed the entire ship, the public and the environment). Except for plant chemistry control tasks, this work goes on in all spaces.

The training and qualification of personnel directly involved in the nuclear aspects of the ship power plant system operations can be conveniently organized on the basis of the foregoing functional categories and system subdivisions. The task statements in Appendix A provide details about the work in each cluster and associated performance standards, general education requirements, and training requirements.

The following is a summary of the general content of work in each functional category.

Operation of Nuclear Reactor Systems

This function is to work the control panel for the reactor and associated systems during watches (generally for four hours, eight hours in port), in coordination with other watch operations (bridge, steam propulsion, reactor auxiliary) as required. The nuclear control function might also include performance of minor, routine, control system maintenance tasks during the watch.

Operation of Steam Propulsion Systems

This function involves monitoring and control of the steam propulsion equipment (including supervision of auxiliary operations), during watches, in coordination with other watch operations as required. The steam propulsion function might also involve performance of routine maintenance and repair tasks during watches.

Operation of Reactor Auxiliary Systems

This function involves operation of the reactor auxiliary equipment in the machinery spaces during watches. This involves interaction with the nuclear control operations. Checks and actions at equipment locations may be required when automated control panel indicators are ambiguous, indicate a problem in the equipment, or indicate a failure of automated control. The reactor auxiliary function might also include performance of routine maintenance and repair tasks during watches.

Supervision of Nuclear Power Plant System Operations

A watch supervisory function is called for by the system hazard potential and the fact that the total system operation involves a number of personnel in different locations. This function is to take responsibility for all aspects of the total system operations--nuclear control systems operation; steam plant systems, and reactor auxiliary systems during watches, assuring that the ship's power requirements are safely provided. Personnel fulfilling this function would move throughout the engineering spaces--which include the reactor control area, the engineroom, and the auxiliary machinery spaces--monitoring the systems and the performance of the other operator watchstanding personnel and providing assistance, direction, and coordination as needed. During normal operations, the supervision function would be mainly to double check and back up other watch personnel and to assure that alertness is maintained.

Watchstanding Requirements. As is evident from the descriptions of the first four personnel functional categories, above, the analysis indicated that four watchstanders would be needed. This conclusion was reached based on the spaces in which the various kinds of work are performed and on safety considerations. Four watchstanders were employed on the NS SAVANNAH; land-based facilities use five. The U.S. Navy uses a larger number, in part because of the need for additional personnel in combat situations. On the other hand, preliminary plans for the new merchant nuclear ship proposed by MarAd suggested the possibility of three watchstanders--one senior licensed (SRO) watch officer, one licensed (RO) control operator, and one operator in the engineroom and auxiliary spaces. The arrangement could suffice for normal operations; however, in a critical situation or casualty, the additional person should be available.

Instrumentation and Control Maintenance and Repair

This function is to perform maintenance and repair on the instrumentation and controls, electrical components, and mechanical components of the nuclear power plant systems. This work would normally be performed on a regular day basis, but the personnel for it would be on call 24 hours.

Supervision of Maintenance and Repairs

A maintenance and repair supervisory function is indicated by the complexity and quantity of equipment. The responsibility would span all systems of the nuclear power plant: electrical, electronic, mechanical, and hydraulic. This function would involve directing and checking on all maintenance and repair activities and performance, or assistance in the performance of such activities as required. This function would normally involve day work, but personnel in this category would be on call 24 hours.

Plant Chemistry Control and Radiation Protection

The primary responsibility in this case is to provide protection from radiation hazard. The work would involve monitoring radiation levels in engineering spaces and amounts absorbed by personnel. It would also involve testing reactor water to assure that chemical balance remains within standards. It also appears reasonable to include in this function responsibility for training ship personnel in radiation protection and for checking on compliance with procedures for radiation protection and emergency response. The latter activities are grouped with the monitoring and testing activities in the task data presented in Appendix A.

Overall Supervision

An overall supervisory function is indicated by the complexity of the total system, the number of personnel involved (including QMEDs, wipers, utilities, etc., whose work is not directly related to the nuclear aspects of the system), the hazard potential, the fact of 24-hour operations, and the administrative requirements of the engine department of any large ship. All watchstanding and other engine department personnel would be under the ultimate authority of this supervisor. (No task statements were developed for this function because, with regard to the technical aspects of the work, it would require the same capabilities as delineated for the watch supervisory function, and, with regard to leadership and administrative aspects, it would require the capabilities usually associated with the position of Chief Engineer. Recommendations concerning qualifications for this function are included in Section IV.

Other Engine Department Activities

Some of the work that goes on in the engine department of a nuclear ship (e.g., that associated with the steam plant auxiliaries) is no different that on a conventionally-powered ship. Thus some engine department personnel may have no tasks that call for qualifications beyond those already established for them by the Coast Guard. However, it is concluded that, because of the hazards associated with nuclear power and the necessity for engine department personnel to observe safety precautions and to know emergency procedures, they all should receive basic training in those areas. In addition, it is believed that all department personnel should have at least a general understanding of how the nuclear power plant system operates. A qualification requirement for training to meet these needs is recommended in Section IV, although no task statements were developed for the "other" personnel.

Other Ship Personnel

It is further concluded, based on the hazards and the fact that all personnel will be required to observe certain precautions, that all ship personnel need a basic understanding of the hazards, protective measures, and emergency procedures. This is recommended as a qualification requirement in Section IV.

In addition, it is concluded that Masters and bridge watch officers should be required to complete some special training beyond the minimum for all personnel to assure that they understand the capabilities and hazards of the power plant system. This conclusion is based on the communication between the engineering and ship control functions; on the special hazard of collision, ramming, or grounding of a nuclear ship; and, in the case of the Master, on his ultimate responsibility for the safety of the ship. Such training is recommended as a qualification requirement in Section IV.

It is understood that some consideration is being given to a nuclear-powered Ultra-Large Crude Carrier (ULCC) with a centralized control system. The nuclear plant would respond automatically to throttle control without the intervention of engineering watch personnel. Conning officers would require substantial nuclear propulsion training in cases of automated marine nuclear propulsion plants.

STANDARDS AND LEGAL REQUIREMENTS

No existing law or standards specifically address qualifications for personnel on nuclear-powered ships. Two sets of existing requirements are applicable under existing law. They are the U.S. Coast Guard requirements for licensing/certification of merchant vessel personnel and the Nuclear Regulatory Commission (NRC) requirements for the licensing of reactor operators and senior reactor operators.

The Coast Guard criteria cover all pertinent categories of personnel, but only with regard to their usual maritime functions. The NRC requirements pertain to nuclear power functions, but would only apply to ship personnel who were to be designated ROs or SROs. Supervisors and lower level personnel responsible for reactor control operations on a nuclear ship would have to be so designated. The nuclear-related functions of ship personnel who do not need to be designated ROs or SROs are totally uncovered under the current regulations. Reactor auxiliary operators and steam propulsion system operators would be in this category, although their interfaces with reactor control would be critical. NRC does in fact review the qualifications of such non-licensed personnel in the utilities, but specific criteria and training guidelines have not been set forth.[2]

The task analysis suggests that the two sets of existing requirements could provide an adequate basis for qualifying personnel to perform reactor control functions on ships (i.e., the ship ROs and SROs). A comparison of Task Statements 1.1.1-1.1.7 with the summary training recommendations in Table 4.1 of Section IV and with the NRC licensing requirements described in Appendix E supports this conclusion. In addition, the existing sets of requirements might provide some of the criteria needed for other personnel functions, particularly reactor auxiliary operations.

However, an integrated set of standards is needed, which would provide comprehensive guidelines tailored for the ship environment and covering all functional categories delineated in this task analysis. A cooperative effort

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[2] The Code of Federal Regulations, Title 10, Part 55 (10CFR55) establishes NRC licensing applicability and requirements. In addition, NRC generally endorses the criteria of the American National Standards Institute (ANSI) Standard N18.1-1971. See Appendix E for details.

is required to establish such standards, involving, as appropriate, the Coast Guard, NRC, the Maritime Administration, the maritime unions, operators, and other interested organizations. The task analysis results presented in this report were designed to facilitate such an effort.

IMPLICATIONS OF THE HAZARD FOR PERSONNEL ATTRIBUTES AND WRITTEN PROCEDURES

The conclusions about the need for special qualification requirements for all nuclear ship personnel (under the heading "Categories of Work," at the beginning of this section), resulted from consideration of the hazards. Other implications are addressed here.

All personnel involved in nuclear power plant system operations and maintenance have to participate in assuring personnel and system safety, even if only by wearing their film badges and observing area access restrictions. Certainly all tasks associated with the nuclear aspects of system operations have safety implications. For analysis purposes, the tasks were clustered by goal and objective, and there is a separate goal to "Provide Protection from Nuclear Hazards," which encompasses plant chemistry control and radiation protection. In practice, however, all tasks must serve the protection goal.

The task analysis demonstrates that high-level functioning in relation to technical data (e.g., analysis, synthesis), high-level reasoning skills, and a high degree of discretion, or decision-making capability, may be required in the tasks of the nuclear power plant system, in ship control, and indeed in all aspects of nuclear ship operations. This is the case despite the existence of detailed procedures in use in current plant operations and anticipated for use on any new nuclear merchant ship. Capacity for high-level functioning by key personnel is required because of (a) the complexity of the equipment, and (b) the potential hazards associated with abnormal events and the possibility that an emergency could occur which could not be handled adequately solely by following procedures.

The task analysis also points up a potential problem area in the criticality of maintaining alertness and keeping task performance up to standards in a situation of uneventful routine operation of an automated system. Such a situation requires mature, reliable, careful personnel, with thorough knowledge of the system as appropriate to their tasks. These attributes are perhaps most needed in supervisors, but they are suitable and reasonable requirements for all personnel whose work affects nuclear power system safety. The problem of maintaining alertness may be particularly acute for highly trained personnel with high level decision-making capabilities. Innovative practices may be needed to help personnel maintain vigilance.

It is clear from the task statements that operations and maintenance procedures manuals will have a very important role in ship nuclear power plant work. In all past and current nuclear plant operations and maintenance, the work is done according to highly detailed procedures that are intended to cover all reasonable contingencies. The procedures for different operations vary in degree of detail, allowing more or less worker discretion; but the trend and goal is for the procedures to eliminate the need for discretion, thus hopefully to eliminate or minimize human error as a source of casualties. The technology is such that error can be tolerated only within narrowly-defined limits. Recommendations concerning procedures manuals are made in Section IV.

RELEVANCE OF EXISTING TRAINING PROGRAMS

Experience in working with the utilities and in the U.S. Navy indicates that existing training programs could provide a solid basis for the development of a program or programs suitable for nuclear ship personnel. The curriculum needs would have to be evaluated and modified based on further analysis of the task data developed in this study, in light of more certain knowledge of the specific ship systems and of the manning to be employed.

IV. RECOMMENDED QUALIFICATIONS FOR NUCLEAR SHIP PERSONNEL

INTRODUCTION

Recommendations are made concerning the qualifications for nuclear ship service needed by personnel in each of the functional categories defined in the General Study Conclusions (Section III). Although the purpose of the study was to recommend qualifications for engineering personnel, needs were identified for some special training for all ship personnel, as explained in the conclusions. The scope of the recommendations was expanded accordingly.

The requirements recommendations reflect the degree to which the various functional categories are involved with the nuclear aspects of the system. Overall, the recommendations call for the qualifications to include satisfactory completion of specified training, demonstration of performance capabilities, and experience--as appropriate to the responsibility and complexity of the particular work assignments.

No recommendations are made concerning qualifications for the non-nuclear aspects of work. Those qualifications are provided for in the Coast Guard's established program for the licensing, certification, and endorsement of personnel to serve in the U.S. Merchant Marine.

It is noted that the design proposals for future commercial nuclear ships do not feature a fully automated bridge; nuclear power plant system control would be retained in the Engine Department. Thus no nuclear-specific tasks were delineated for ship control personnel. General qualifications were recommended for those personnel, however, reflecting their need to understand the capabilities, operating states, hazards and emergency states of the nuclear system, and also reflecting their need to understand radiation protection and emergency response requirements. In the event that a fully automated marine nuclear propulsion plant were implemented, ship control personnel would need to fulfill more extensive qualification requirements.

The rules, regulations, and practices by which the Nuclear Regulatory Commission licenses nuclear power facilities and nuclear reactor operators and senior reactor operators were taken into account in developing the recommendations for nuclear-related qualifications. Under existing law, personnel in two of the functional categories defined in this study would have to be licensed by the NRC: namely, those in the nuclear reactor systems operations category (RO license), and those in the total system operations supervisory category, including watch supervision and overall supervision (SRO license). The analysis indicated that the current NRC requirements for ROs and SROs are applicable to assure the adequacy of the nuclear-specific skills and knowledge of ROs and SROs in the particular case of ship nuclear power plant operations. In addition, the analysis indicated that some of the RO and SRO licensing provisions (specifically, training content and license renewal processes) would have applicability to other personnel functions for which an RO or SRO license is not required by law or by the nature of the work.

FORMAT OF THE RECOMMENDATIONS

Each task statement prepared in this analysis contains recommendations concerning the training and general educational development (level of skills in reasoning, math, and language) requirements for each task. Thus, each task statement is in itself a detailed recommendation. The task statements are presented in Appendix A.

In this section, the individual task statement recommendations are synthesized into an overall recommendation of qualification requirements for each category of work. Existing practice pertinent to these qualification requirements is brought into the synthesis.

Training is discussed first. Then overall requirements for initial qualification are recommended for each category of personnel, and distinctions necessary for personnel of the first ships are identified. Renewal of qualifications is discussed next. The last recommendation has to do with procedures manuals and their role in training and actual operations.

TRAINING RECOMMENDATIONS

It is assumed that all ship's personnel would come into nuclear power training having already met the requirements for the non-nuclear aspects of their work.

<u>Training Content</u>

The task analysis indicated that there is enough overlap in the nuclear-related training requirements for the various categories of work that a "common core module approach" can be adopted, and that is recommended.

As the name implies, the modules would contain information common to all categories of work. This recommendation is based on the overlap in training content requirements identified in the task analysis. The integrated module approach also facilitates training program administration, including update and upgrade training, and allows more economical use of simulators, which are essential for the training in several categories.

Table 4.1 gives a comprehensive view of the training recommended for each personnel category, at the module level. It shows the personnel categories that require training in each module, which represents a subject area or type of work procedure. It also shows the area of module application for the different categories of personnel, which is one way in which module lessons would be differentiated. For example, modules 14-18, 19-23, and 24-28 have the same titles. (They were separated and numbered this way for clarity in the table and in discussion.) They deal with types of system operations. The training involved would differ for people involved with different constituent systems of the total system. Thus all operations personnel would learn about, say, Maneuvering Watch and Mooring (nos. 16, 21, and 26), but in relation to particular application areas or constituent systems.

A reference key is provided on the page following Table 4.1, giving the number of the task statements applicable to the personnel categories in the table. The task statements indicate the appropriateness of the modules for the categories.

Obviously there would be various combinations of the depth of content and duration of training within a module for different categories of personnel, reflecting the degree of involvement with and responsibility for the system which their particular work assignments require. The task statements indicate the appropriate levels of training in the worker function and instructional level ratings, and performance standards. Trainees would be required to complete the lessons in each module applicable to their particular job assignments. The curricula can be developed from further analysis of the task data in relation to the particular power plant system designs that will be built.

Types of Training

Different experience, background knowledge, and learning skills can be expected among the trainees. Thus it is further recommended that the lessons be developed to accommodate self-paced, individualized training insofar as practical. A self-paced approach will facilitate the qualifications renewal process, which, as discussed later, is recommended to include update/refresher training. Of course there must be classroom training also.

Preliminary screening is advisable to maximize timely, successful completions. The task analysis data, particularly the functional and GED ratings associated with each task, in conjunction with the functional training and content, could be used to maximize timely, successful completions of training.

The following combination of types of training is proposed:

- School/classroom training (including lectures, demonstrations, practical exercises, and programmed materials for individual study)
- Practical experience through the use of simulators
- Onboard indoctrination.

Table 4.2 shows the types of training recommended as generally appropriate for each module.

TABLE 4.1

RECOMMENDED REQUIREMENTS FOR NUCLEAR TRAINING OF SHIP PERSONNEL, BY FUNCTIONAL CATEGORY

Personnel Functional Category

Application Area	Module No.	Module Title (Topic/Type of Procedure)	1 Operation, Nuclear Reactor Systems (Watchstanding)	2 Operation, Steam Propulsion Systems (Watchstanding)	3 Operation, Reactor Auxiliary Systems (Watchstanding)	4 Supervision, Total System Operations (Watchstanding)	5 Electronics Maintenance and Repair	6 Mechanical Maintenance and Repair	7 Electrical Maintenance and Repair	8 Supervision, Maintenance and Repair	9 Plant Chemistry Control, Radiation Protection	10 Other Engineering	11 Ship Control	12 Other Non-Engineering
General System Knowledge	1	Principles of Reactor Operation	•		•	•	•			•	•			
	2	System Design (the specific system to be installed aboard the ship)	•		•	•	•	•	•	•	•	•		
	3	General and Specific Plant Operating Characteristics	•		•	•	•	•	•	•	•	•	•	
	4	Nuclear Power Plant System Operation	•	•	•	•	•	•	•	•	•	•	•	
	5	Nuclear Instrumentation & Controls	•		•	•	•			•	•			
	6	Safety and Emergency Systems	•	•	•	•	•	•	•	•	•	•	•	•
	7	Normal, Abnormal and Emergency Operating Procedures	•	•	•	•	•			•	•		•	
	8	Radiation Control and Safety	•	•	•	•	•	•	•	•	•	•	•	
	9	Nuclear Theory				•				•				
	10	Radioactive Material Handling				•				•				
	11	Administrative Procedures, Conditions and Limitations				•				•				
	12	Health Physics and Radiation Protection	•	•	•	•	•	•	•	•	•	•	•	•
	13	Power Plant Chemistry				•					•			
Nuclear Reactor Subsystem Mechanical, electrical, and electronic systems directly associated with generation of power in the nuclear reactor and transmission of power to the steam generators. Systems principally located within the radiation containment boundary and are normally controlled remotely from the reactor console in the control room.	14	Nuclear Plant Startup from Subcritical to Escalating Power to Normal Steaming Mode	•			•								
	15	Making Major Power Changes of Greater than 10%	•			•								
	16	Maneuvering Watch and Mooring	•			•								
	17	Nuclear Plant Shutdown from At-Sea Mode to Reactor Subcritical Mode with the Plant Operating on the Auxiliary Power Source	•			•								
	18	Simulation of Emergency or Abnormal Conditions	•			•								
Steam Propulsion Subsystem Systems (primarily mechanical) associated with the transmission of steam from generators to propulsion turbines, condensation of the steam exhausted from the turbines, and supply of feedwater to generators. Systems principally located in engineroom and controlled either locally, by manual or semi-automatic means, or remotely.	19	Nuclear Plant Startup from Subcritical to Escalating Power to Normal Steaming Mode		•		•								
	20	Making Major Power Changes of Greater than 10%		•		•								
	21	Maneuvering Watch and Mooring		•		•								
	22	Nuclear Plant Shutdown from At-Sea Mode to Reactor Subcritical Mode with the Plant Operating on the Auxiliary Power Source		•		•								
	23	Simulation of Emergency or Abnormal Conditions		•		•								
Reactor Auxiliary Subsystem Mechanical, electrical, and electronic systems which support the operation of the reactor but are not involved directly with the generation of power in the reactor. Systems principally located in auxiliary space and controlled either locally, by manual or semi-automatic means, or remotely from the control room.	24	Nuclear Plant Startup from Subcritical to Escalating Power to Normal Steaming Mode			•	•								
	25	Making Major Power Changes of Greater than 10%			•	•								
	26	Maneuvering Watch and Mooring				•								
	27	Nuclear Plant Shutdown from At-Sea Mode to Reactor Subcritical Mode with the Plant Operating on the Auxiliary Power Source			•	•								
	28	Simulation of Emergency or Abnormal Conditions			•	•								
All Subsystems of Nuclear Power Plant	29	Maintenance Manuals and Operating Procedures Manuals	•	•	•	•	•	•	•					
	30	Preventive Maintenance Checklists	•	•	•	•	•	•	•					
	31	Fault-finding Techniques and Allowable Repairs	•	•	•	•	•	•	•					
	32	Systems Specifications & Drawings	•	•	•	•	•	•	•					
	33	Maintenance Radiation Protection					•	•	•					

TABLE 4.1. (Cont)

REFERENCE TO TASK ANALYSIS RESULTS:

Functional Category	Task Statement No. (Appendix A)
Operation, Nuclear Reactor Systems	1.1.1-1.1.7
Operation, Steam Propulsion Systems	1.2.1-1.2.5
Operation, Reactor Auxiliary Systems	1.3.1-1.3.5
Supervision, Total System Operations	1.4.1-1.4.5
Electronics Maintenance and Repair	2.1.1
Mechanical Maintenance and Repair	2.1.2
Electrical Maintenance and Repair	2.1.3
Supervision, Maintenance and Repair	2.2.1-2.2.3
Plant Chemistry Control, Radiation Protection	3.1.1-3.2.3
Other Engineering Ship Control Other Non-Engineering	Task statements not developed. Functions not specific to nuclear power.

TABLE 4.2

PROPOSED TRAINING SCHEDULE FOR NUCLEAR ENGINEERING FUNCTIONS

Module No.	Module Title	Pre-Sailing Shoreside/School Classroom	Pre-Sailing Shoreside Practical Application/ Experience Through Simulators	Onboard Indoctrination[3]
1	Principles of Reactor Operation	•[1]		
2	System Design	•[1]		•
3	General and Specific Plant Operating Characteristics	•[1]		•
4	Nuclear Power Plant System Operation	•[1]		•
5	Nuclear Instrumentation & Controls	•[1]		•
6	Safety and Emergency Situations	•[1,2]		•
7	Normal, Abnormal and Emergency Operating Procedures	•[1,2]		•
8	Radiation Control and Safety	•[1]		•
9	Nuclear Theory	•[1]		
10	Radioactive Material Handling	•[1]		
11	Administrative Procedures, Conditions and Limitations	•[1,2]		
12	Health Physics and Radiation Protection	•[1,2]		•
13	Power Plant Chemistry	•[1,2]		•
14, 19, 24	Nuclear Plant Startup from Subcritical to Escalating Power to Normal Steaming Mode		•	•
15, 20, 25	Making Major Power Changes of Greater than 10 Percent		•	•
16, 21, 26	Maneuvering Watch and Mooring		•	•
17, 22, 27	Nuclear Reactor Plant Shutdown from At-Sea Mode to Reactor Subcritical Mode with the Plant Operating on the Auxiliary Power Source		•	•
18, 23, 28	Simulation of Emergency or Abnormal Conditions		•	
29	Maintenance Manuals and Operating Procedures Manuals	•[1,2]	•	•
30	Preventive Maintenance Checklists	•[1,2]	•	•
31	Fault-finding Techniques and Allowable Repairs	•[1,2]		•
32	Systems Specifications and Drawings	•[1,2]		•
33	Maintenance Radiation Protection	•[1,2]		•

[1] Instructor presentation/demonstration; text/other individual study.

[2] Should involve student participation in exercises/drills using models/mockups, actual demonstration units of equipment/materials/gear.

[3] In the continuing system, onboard indoctrination can include actual performance of tasks under the supervision of experienced personnel.

REQUIREMENTS FOR INITIAL QUALIFICATION, BY PERSONNEL FUNCTIONAL CATEGORY

The following paragraphs discuss the recommendations for the initial qualification of the nuclear ship personnel in each of the twelve functional categories delineated by the analysis. As previously stated, the qualifications address only the nuclear aspects of ship operations. The qualifications reflect existing legal requirements that would apply, as well as the task data.

By "initial qualification" is meant the first issue of a license, certificate or document endorsement to an individual. Requirements for renewal of the license, certificate, or endorsement are recommended in the following subsection. Special conditions exist for initial qualifications of personnel to serve on the first of any new commercial nuclear ships. It is recognized that experience requirements may be inapplicable until there has been sufficient time for the personnel pool to become established. First crew exceptions are suggested in the discussion of recommended initial qualifications.

Training recommendations, treated separately in the preceding subsection, are incorporated into the total qualification recommendations by reference.

Operation of Nuclear Reactor Systems

The following recommendations reflect NRC requirements and practice:

- Education - a minimum of high school diploma or equivalent (current practice in the utilities, shown to be appropriate in the analysis)
- Experience - two years of power plant experience; minimum of one year in nuclear (current practice in the utilities, shown to be appropriate by the complexity and hazards of the work; also desirable to facilitate training)
- Additional training - must meet the necessary requirements to qualify as a licensed reactor operator, through the NRC's Operator Licensing Program, as defined in 10CFR55.

It will not be possible for ship personnel to meet the existing requirement for one year of nuclear power plant experience, unless they are recruited from former Navy nuclear personnel, former NS SAVANNAH personnel, or utilities operators. (Such personnel would of course have to be able to meet the Coast Guard requirements for licensing/certification in their ratings.) Most likely, it will be necessary to waive the nuclear experience requirement until there is time for personnel to develop the experience. It is recommended, however, that the experience requirement should apply as soon as it is feasible; personnel should have to have served in the engine department of a nuclear-powered ship for at least 12 months in order to be eligible for training for the function of nuclear reactor systems operator. This overall recommendation is based on safety considerations and compliance with existing law and practice. In addition, it should facilitate training success. Furthermore, it is recommended that a limit be set on time that may elapse between last nuclear service and application. This probably should not exceed one year, if the experience is to be of value.

The training modules recommended for these personnel categories in Tables 4.1 and 4.2 would satisfy the NRC requirement for "Additional training" necessary to qualify through the NRC's Operator Licensing Program, provided that the modules are properly developed and administered for the particular type of nuclear power plant.

After completion of training, candidates can be given a provisional qualification based on their knowledge of the nuclear reactor system characteristics and operation. They should be required to

- Describe system operation and operating parameters, with emphasis on system limitations and precautions
- Locate and identify all instrumentation and controls in the control room
- Demonstrate on a simulator their ability to operate the reactor under normal and abnormal conditions.

For conversion of a provisional qualification to a standard qualification, it is recommended that the operators be required to demonstrate the following capabilities with an actual ship nuclear reactor:

- Nuclear plant startup from subcritical and escalating power to the normal steaming condition
- Making major power changes
- Maneuvering watch and answering engine order telegraph bells for mooring
- Shutdown from at-sea condition to subcritical to plant operating on the auxiliary power source.

The foregoing are the normal operations through which the nuclear reactor will be taken. Obviously, no actual demonstration of operations under abnormal or emergency operations can be included as a requirement.

In addition, to convert a provisional qualification to a standard for nuclear reactor operations, personnel should complete a written comprehensive examination on the overall nuclear power plant. This recommendation is based on existing NRC requirements, on the interface that occurs with other constituent systems (i.e., reactor auxiliary and steam propulsion), and on the amount and technicality of the information that these operators must be able to apply (see task statements 1.1.1-1.1.7 in Appendix A, particularly the training content and data, reasoning and language level ratings).

The final step to standard qualification is an interview with key personnel in the qualification program. This requirement is based on the hazards, the amount of discretion the operators would be called upon to apply (see task statements 1.1.1-1.1.7, worker instructions ratings), and the need for personnel who can and will maintain vigilance during uneventful, routine operations.

Successful candidates are now ready for licensing by the NRC. (See Appendix E.)

Operation of Steam Propulsion Systems

The requirements for personnel to serve in this category almost exactly parallel the requirements for the nuclear reactor operations category. The following is a summary indicating the distinctions:

- It is not necessary for the training to be designed to enable candidates to qualify as NRC licensed reactor operators. Training needs are as defined for this functional category in Tables 4.1 and 4.2.

- The steps to provisional qualification, after successful completion of training, are the same but the content of the tests is as appropriate to the system (e.g., should be required to locate and identify all steam propulsion equipment and controls and to demonstrate steam propulsion operations in coordination with reactor control under normal and abnormal conditions).

- The steps for conversion from provisional to standard qualification also involve demonstration of the previously listed, specific normal cycles in actual operations, but of the steam propulsion systems.

- A written test and interview are recommended for conversion from provisional to standard qualification, but, again, as appropriate to steam propulsion operations.

- An NRC license is not required.

The rationales for the recommended requirements for the function of steam propulsion system operations is similar to those for the nuclear reactor operations function. The recommendations were derived from task statements 1.2.1-1.2.5 (in Appendix A) and reflect consideration of the hazards of nuclear power, the complexity of the reference system, current practice in the utilities industry and the U.S. Navy, and the desirability of an integrated approach for the training and licensing of nuclear ship engineering personnel.

Operation of Reactor Auxiliary Systems

The requirements for personnel to serve in this category parallel the requirements for the steam propulsion category. Training content, demonstrations of knowledge including simulator demonstrations, written test and interview, should of course be based on the particular requirements of this function.

The rationales for these recommendations are as described for the preceding categories. The relevant task statements are 1.3.1-1.3.5 in Appendix A.

Supervision of Nuclear Power Plant System Operations: Watch Supervision and Overall Supervision

Personnel in these supervisory categories must be NRC-licensed senior reactor operators. The following is required by law or practice for that license.

- Education - minimum of high school diploma or equivalent.
- Experience - four years of power plant experience; minimum of one nuclear.
- Two years experience may be fulfilled by academic or related technical training. Related technical training is formal training beyond the high school level in technical subjects associated with steam propulsion plants. The training can be acquired in training schools conducted by the military, utilities, plant vendors, merchant marine associations or unions, or others.
- Additional training - must meet the necessary requirements to qualify as a licensed senior operator through the NRC's Operator Licensing Program, as defined in 10CFR55.

Basically to get an SRO license, candidates must meet the RO requirements but must pass a more demanding written test, which includes (in summary) reactor theory; radioactive material handling; disposal and hazards; specific operating characteristics of the nuclear power plant; fuel handling and core parameters; and administrative procedures, conditions, and limitations.

The recommended requirements for provisional qualification of personnel to serve in a supervisory capacity over ship nuclear power plant system operations include:

- The foregoing general education and experience prerequisites to eligibility for training (except that the prerequisite one year of nuclear power plant experience could be waived for first-crew personnel).
- Training as defined in Tables 4.1 and 4.2 for the operations supervisory category.

- Demonstration of ability to locate and identify all instrumentation and controls for all three constituent systems of the total nuclear power plant system.

- Demonstration of ability to describe the total system operation, including operating parameters, limitations, and precautions.

- Demonstration on a simulator of the ability to operate all three constituent systems in the normal cycles listed in the recommendations for nuclear reactor operations personnel (demonstration of proficiency in modules 14-28 of Table 4.1).

For conversion from provisional to standard qualification, the following is recommended:

- Demonstration of ability to operate all three constituent systems in the foregoing normal cycles on the actual ship equipment.

- A written test as previously described.

- An interview as previously described.

The candidates for supervisory functions would then be prepared for licensing by the NRC.

The rationales for these recommendations are as stated for preceding categories. The supervisory function requires personnel capable of performing as operators of all constituent systems. They must have thorough understanding of the total, integrated workings of the system. They have particular responsibility for response to abnormal and emergency situations. Each ship will have emergency plans to protect the health and safety of the crew and the civilian populace in the event of an accident involving the ship and/or the nuclear power plant. The spectrum of accidents ranges from minor accidental releases of radioactive material within the confines of the nuclear power unit, to the design basis accident such as loss of coolant, to non-nuclear emergencies such as collision, fire, etc., which could threaten the nuclear power plant. Effective implementation of emergency procedures is the main responsiblity of the watch supervisor. Thus he must be extremely knowledgeable and proficient in task performance. The supervisory task statements (in Appendix A) are nos. 1.4.1-1.4.5. All other task statements under Goal 1 are relevant as well.

Maintenance and Repair Functions

As previously discussed, the maintenance and repair of ship nuclear power plant systems are like those functions for conventional systems except for the following:

- The nuclear reactor instrumentation and controls (electronic maintenance and repair) are more complex than the engineering instrumentation and controls on a conventionally powered ship.

- Certain repair activities of all three kinds (electronic, mechanical, and electrical) would require precautions beyond the usual for radiation protection.

- Analysis to determine whether, when, and how to perform maintenance and repair actions (which may require isolation of system elements or shutdown, for example) may be more critical and more complex than with a non-nuclear propulsion system.

The program is largely aimed at preventive maintenance, but it allows for corrective repairs when within the capabilities of the ship's personnel. Special or major repairs would not be done by ship personnel; they would be accomplished at shore-based repair facilities by personnel with specialized craft skills. Nevertheless, the isolation of a ship at sea requires that nuclear engineering maintenance and repair personnel be highly proficient in their tasks, and the supervisor at least must know all constituent systems and be able to exercise a high degree of discretion as well. Persons fulfilling the maintenance supervisory function on a merchant nuclear ship would have heavier responsibility than their counterparts in a land-based plant because the ship supervisors would not have the option of calling in other specialists for advice.

Despite their importance, the maintenance and repair tasks were not delineated in great detail because they correspond to those tasks in large, modern non-nuclear ship power plants. Moreover, they could not be delineated in detail, even if that were desirable, until more is known about specific hardware that will be used. The task statements (nos. 2.1.1-2.2.3) were developed to reflect the unique aspects of the functions aboard ship.

The recommended qualification requirements for the maintainance/repair function are as follows:

- Satisfactory completion of training as defined in Tables 4.1 and 4.2, with "satisfactory completion" involving diagnosis and maintenance/repair actions on mock-ups or prototypes as feasible, and also involving "walk-through" exams in which the trainee responds to questions about hypothetical conditions, demonstrating knowledge of how to use schematics, manuals and checklists.

Maintenance/repair training for first crews should be provided by the equipment manufacturers at their facilities and continuing while the ship is fitted. Training in the continuing system can be based on the manufacturers' training.

Plant Chemistry Control and Radiation Protection

This function requires specialized training emphasizing the basic aspects of atomic and nuclear physics, interaction of radiation with matter, radiation detection and measurements, radiation hazards, calibration and surveillance, waste disposal, laws and regulations, and personnel monitoring and recordkeeping. The initial training should also include a water chemistry course which covers nuclear power water requirements, radiochemistry, and cold water chemistry. Practical water chemistry laboratory training and experience are also required for the ship's laboratory to be operated effectively. These requirements must be covered in the modules identified for this function in Tables 4.1 and 4.2.

It is recommended that personnel be qualified for this function based on satisfactory completion of the training defined in Tables 4.1 and 4.2. "Satisfactory completion" must involve walk-through examinations and practical tests to assure that candidates thoroughly know the equipment and procedures they must use on the specific ship and that they can in fact assure that the radiation standards are met.

The task of providing onboard indoctrination/training in health and safety measures was included in the plant chemistry/radiation protection category in the task analysis (task statement 3.2.3). (It might be allocated to some other category.) This task involves skills in interaction with people, and organization and presentation of materials, as shown in the task statement. Thus it is recommended that demonstration of such skills be required as a qualification for the task.

All Other Functions

The study defined three other functional areas not directly involved with the nuclear aspects of the system. These are "Other Engineering," "Ship Control" (Master and deck officers) and "Other Non-engineering" (categories 10-12 in Table 4.1).

It is recommended that personnel in each of these categories be required to complete training as defined for them in Tables 4.1 and 4.2 in order to qualify for nuclear service. The rationale for these requirements was stated earlier in this section and in Section III.

RENEWAL OF QUALIFICATIONS

The Code of Federal Regulations, Title 10, requires license renewal by reactor operators and senior reactor operators every two years. The renewal requirements as currently implemented by NRC include completion of refresher and update training and documentation of proficiency in the performance of specified operations. The power plant operating facility is required to provide a continuing requalification program (as well as the initial training) that enables its personnel to meet the requirements for NRC license renewal. The facility must maintain records documenting the fulfillment of program requirements by ROs and SROs. License renewal is granted on the basis of program inspection and review of the records of participation of applicants for renewal. The outcome of such a program, with its two-year time limit for completion of training units and performance demonstrations, is to create personnel whose qualifications are maintained and continuously updated. This requirement will also apply for nuclear merchant ships.

While it is certainly desirable to expand the two-year renewal requirement to include the personnel in all operations/maintenance categories and in the plant chemistry control/radiation protection categories (1-9 in Table 4.1), such a regulation would cause an unjustified increase for the marine engineering license renewal system. It is therefore recommended that such personnel renew their qualifications for nuclear merchant ships in the same time frame now required for marine licensing.

It is also recommended that all other personnel (categories 10-12 in Table 4.1) be required to renew their nuclear qualifications within the same time frame now required for marine licensing.

The training modules required for initial qualification provide a basis for the training aspects of the requalification program. This training could be conducted either on the ship or ashore at approved training centers. Various instructional media could be used to develop the modules as on-board training packages enabling the personnel to participate in the requalification training program at sea. Types of instructional media that could be used include: (1) narratives -- in-depth written presentations in text book format; (2) programmed instruction -- step-by-step written presentations in discrete limits or frames followed by test frames; (3) summaries -- quick written overview or reviews; (4) progress checks -- self-administered tests consisting of matching, true-false, work fill-in or multiple-choice questions and exercises; (5) job programs -- workshop or laboratory projects; and (6) videotapes on closed circuit television using recorded lectures.

Requirement for demonstrated task proficiency could normally be met in the course of actual work. The requirements for operators would be like those listed as simulation and actual demonstration requirements for initial qualification. Maintenance/repair requirements for demonstration of on-the-job proficiency should involve implementation of preventive maintenance checklists and certain types of diagnosis and repair tasks as feasible. Personnel working in the plant chemistry/radiation protection area should be required to have proven satisfactory performance of ship laboratory tasks, radiation radiation exposure recordkeeping (and personnel indoctrination activities, if responsibility for them is allocated to that functional category).

Compliance with existing law would require the owner/operator of the ship to establish the requalification program. This could be done within the operating framework of the company by the establishment of a training manager with the responsibility to requalify all personnel. A department member on each ship would have to be designated ship's training coordinator.

It might also be practical to send off-duty crews to a training center where they could complete their refresher training (and possibly their practical requirements, by means of simulation). Such an approach would centralize the training activities and facilitate the access to records. It would also alleviate the requirement for each ship to have a training coordinator.

The operating company might also meet the requalification requirements by using an alternate program established and maintained by an organization or company that is approved by NRC.

If personnel fail to meet the requirements for renewal of their qualifications, it is recommended that they be required to make special application for renewal. Such applications should be evaluated by the examining agency on an individual basis; some applicants might be issued provisional qualifications and have to go through written and/or proficiency testing to regain their qualifications, while others might need to repeat parts of the initial qualification training, and others might need only to complete some units of refresher training.

REQUIREMENTS FOR OPERATIONS AND MAINTENANCE MANUALS

As stated in the General Study Conclusions (Section III), the task analysis pointed up the very great importance of the operations and maintenance/repair manuals. The manuals provide a standard code of practice, and they are the foundation for training and shipboard indoctrination.

Basically, these manuals fall into two categories:

- Operating and maintenance instructions provided by equipment vendors

- Ship operating manuals, compiled by the shipbuilder or ship owner and related to the particular ship, its specific systems and flexibility.

The first category, manufacturers' technical manuals, are generally provided to the ship. In most cases they are written for the particular marine application of the equipment; in some cases, however, this type of document may not be particularly relevant to the situation at hand. Thus the second category, the ship's operating manuals, must not only provide operating instructions that consolidate all of the various aspects of each system, they must also complement the manufacturers' technical manuals.

In general, ship manuals for nuclear power plant operations and maintenance will need to cover the topics listed in Table 4.1 of Section IV.

In view of the detail of nuclear power plant system procedures, and their importance to the safety of the ship, its personnel, and the environment and general population, it would seem that their presence aboard should be mandated and their content reviewed by the appropriate regulatory agency or agencies.

APPENDIX A

DESCRIPTION OF THE TASK ANALYSIS BY WHICH RECOMMENDATIONS CONCERNING NUCLEAR SHIP PERSONNEL QUALIFICATIONS WERE DEVELOPED

INTRODUCTION

Task analysis is a process of defining the duties, requirements, and conditions of a given work system in a systematic way. Such analysis seeks to state the tasks that must be performed and the skills and knowledge required to perform them. Materials, equipment, and information used in doing the work are commonly cited. Other information about the work may be included, depending on the purpose of the analysis.

The task analysis in this case was performed to develop recommendations for qualifications, including training requirements, of nuclear ship personnel. It was a prototype effort in two respects. No U.S. flag nuclear merchant ship has operated since an experimental ship, the NS SAVANNAH, ceased operation more than 5 years ago. Thus there were no actual work situations upon which to base the analysis. The task of nuclear ship engineering had not been delineated. Even for the SAVANNAH, no detailed task analysis had been performed.

The analysis of nuclear ship engineering operations was a prototype in another sense as well. It was intended to demonstrate a method of task analysis appropriate for determination of the qualifications needed by merchant marine personnel in new technology occupations. Another demonstration project, to develop qualifications for liquefied natural gas cargo handling personnel was conducted simultaneously. The method selected was Functional Job Analysis (FJA). Its application is described in a companion report to this recommendations report.[1]

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[1] Operations Research, Inc., Handbook for the Development of Qualifications for Personnel in New Technology Systems (Review Draft), Technical Report No. 1012. Silver Spring, Maryland: Operations Research, Inc., February 1976.

Thus the methodology is not treated in detail here. Basic concepts of FJA are stated, and the main steps of the analytic procedure are shown in flow diagram form, to indicate how the recommendations in the main body of the report, and the detailed task data (which are presented at the end of this section) were developed. The FJA scales for assessing the functional and instructional levels of the tasks and the general educational development required by them are provided at the end of this appendix.

OVERVIEW OF THE FJA APPROACH TO TASK ANALYSIS

Conceptual Framework

FJA takes a systems approach to task analysis. The term "systems approach" refers to systems analysis theory, not just to being systematic, or orderly and thorough, in performing the work.

- In FJA, task analysis begins with delineation of the requirements of the system, or "work organization" (in this case, nuclear power plant system of a VLCC). Those requirements are termed the purpose, goals, and objectives of the operation.

- It requires identification of the resources and constraints (such as equipment and material), operating conditions, hazards and regulations) that affect how the system requirements can be fulfilled.

- It then describes the actions (tasks) through which requirements are fulfilled in light of the resources and constraints. Performance standards are established for each task that reflect the criticality of its contribution to the system objective.

The worker action, or task, is the fundamental unit of work to which the analysis is directed. The task arises from and must be examined in relation to system requirements, resources, and constraints. This system view of each individual task is represented in the FJA task statement, which is the basic output format for FJA projects.

The capacities, skills, and knowledge needed by the worker are deduced from and expressed in relation to the requirements and characteristics of the system and the behavioral demands of the tasks. Thus worker qualifications are securely tied to what actually must go on inthe work situation when it operates effectively.

Figure A.1 is an example of an FJA task statement prepared in the analysis of nuclear ship engineering operations. As the figure shows, the statement includes the goal and objective to which the task contributes and a description of the task which specified the action, the expected result of the action, the equipment, materials, and/or information used, and an indication of the source(s) of prescription and/or the degree of discretion in the task.

TASK CODE: 1.2.4

WORKER FUNCTION LEVEL AND ORIENTATION						WORKER INSTRUCTIONS	GENERAL EDUCATIONAL DEVELOPMENT		
DATA	%	PEOPLE	%	THINGS	%		REASONING	MATH	LANGUAGE
4	90	2	5	1	5	4	3	3	3

TASK CODE: 1.2.4

GOAL: Operate the Nuclear Power Plant.

TO DO THIS TASK

OBJECTIVE: Operate the Steam Propulsion Systems.

TASK: Examines and evaluates operating procedures ordered by control room with reference to actual status of Steam Propulsion Systems equipment, drawing on knowledge and experience, to determine whether effects of implementing procedures may cause or result in out-of-limit conditions.

PERFORMANCE STANDARDS	TRAINING CONTENT
DESCRIPTIVE: - Safely implements steam propulsion systems operating procedures. - Clear and accurate in determination of out-of-limits conditions. NUMERICAL: - 100% accurate in following procedures. - Zero failure in detecting inappropriate procedures. TO THESE STANDARDS	FUNCTIONAL: - Knowledge of interrelationships of Steam Propulsion Systems to Nuclear Reactor Systems. - How to use engineering procedures. SPECIFIC: - Knowledge of Steam Propulsion Systems equipment characteristics. - Knowledge of steam propulsion Systems operating procedures and how to use them. THE WORKER NEEDS THIS TRAINING

FIGURE A.1. EXAMPLE OF AN FJA TASK STATEMENT

Written on the figure is the FJA paradigm, which points up the relationship of the descriptive parts of the task statement.

It should be noted that the systems view tends to be obscured when the job becomes either the framework for analysis (i.e., the tasks in a specific job are studied) or the unit of analysis (i.e., an attempt is made to determine personnel qualifications or to accomplish some other purpose based on a summary of duties, requirements, conditions at the job level). It is preferable for purposes of this task analysis to consider "job" in its older meaning as a piece of work to be done. In that sense, a job is something equivalent to a work system objective rather than a title or a position in an organizational structure or a fixed allocation of duties that may contribute to a number of "jobs." This approach is more than appropriate in the case of the analysis of nuclear power operations on merchant ships; it is essential. The jobs do not exist, and manning requirements and task allocations remain to be determined. Task analysis as performed in this study provides the needed bases for sound decisions, considering the dictates of safety, on such matters.

Tools Provided by FJA

FJA is a way of looking at work that provides a structure for task analysis, as described in the foregoing subsection. In addition, FJA provides the following tools:

- Definition of the elements of information needed for complete delineation of a task.
- Scaled definitions of worker functions in task performance, task instructional levels, and levels of reasoning, language, and math skills required for task performance. Use of scales results in task delineation reliability and contributes to a consistency of analysis from task to task. In addition, the scales provide measures of task complexity.
- A format for organization and presentation of task data.

Figure A.1 showed the task statement format. Figure A.2 describes the elements of information needed for each task. Figure A.3 provides an overview of the worker function scales--the taxonomy of what people do in relation to data, to people, and to things, which helps the analyst separate tasks and see the essence of the actions. A copy of the complete scales is provided at the end of this appendix.

FJA Approach to Validation of the Data That Result from the Analysis

FJA calls for personnel in the field to validate the task statements by editing them. This procedure was devised for an organization conducting an in-house analysis of its own operations. The editing involves several reviewers, preferably the workers whose tasks are being studied and/or their supervisors, who read the task statements, evaluate levels of task complexity in terms of the FJA scales, and apply other FJA criteria. The editing takes

1. Who? (Subject)

   The subject of a task description is understood to be simply "worker". The description contains no subject since it is always assumed to be "worker".

2. Performs what action? (Action Verb and Object)

   A task description requires a concrete, explicit action verb. Verbs which point to a process (such as develops, prepares, interviews, counsels, evaluates and assesses) should be avoided or used only to designate broad processes, methods, or techniques which are then broken down into explicit, discrete action verbs.

3. To accomplish what immediate results?

   The purpose of the action performed must be explicit so that (1) its relation to a system objective is clear and (2) performance standards for the worker can be set.

4. With what tools, equipment, or work aids?

   A task description should identify the tangible instruments a worker uses as he performs a task; for example, telephone, pencil/pater, checklists, written guides, wrench, etc.

5. Upon what instructions?

   A task desctiption should reflect the nature and source of instructions the worker receives. It should indicate what in the task is prescribed by a superior and what is left to the worker's discretion or choice.

FIGURE A.2. INFORMATION NEEDED TO DESCRIBE A TASK

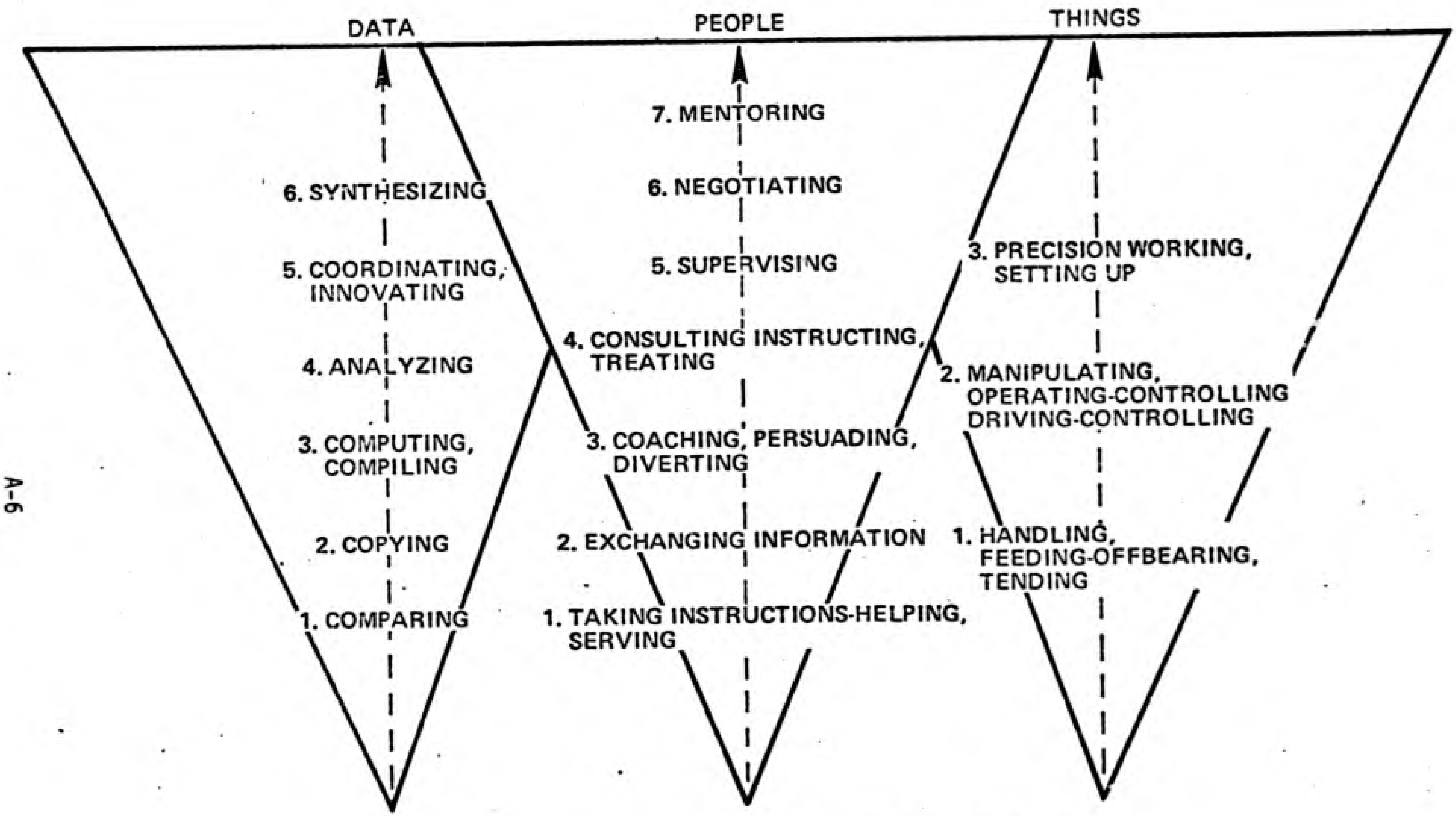

FIGURE A.3. OVERVIEW OF WORKER FUNCTION SCALES considerable time, and the editors must be trained in FJA. Modification to the FJA approach was made for this study. Task editing was performed by study team members to take advantage of their combination of nuclear power expertise, sea experience, and knowledge of FJA. Other General Physics Corporation personnel (the company which performed the task analysis) with expertise in nuclear power operations and training, and reviewers in the field were asked to assess the tasks for accuracy and completeness, without having to consider the workings of the analytic method.

OVERVIEW OF THE STEPS IN THE ANALYSIS

Figure A.4 provides an overview of the analysis in diagram form. The steps are shown in their general sequence, but, as the dashed lines indicate, the process involves a good deal of looping back for revision and refinement of the task data as their development proceeds.

Information Sources

Study team members already possessed expertise in ship operations and in nuclear power. Other information sources are listed in Appendix B.

One of the prerequisites for analysis of a hazardous work system is to understand the hazards involved. A detailed review of nuclear power is presented in Appendix C.

System Configuration

The work system must also be understood in terms of its equipment. This is particularly important with a high technology system such as nuclear power operations. Figure A.5 provides a generalized overview of the equipment components, their functions, and relationships.

Specification of the Work System for Task Analysis

As previously stated, specification of the work system for task analysis using FJA requires that its functional requirements be broken out as a taxonomy of purpose, goals, and objectives; then the tasks required to accomplish each objective are designated for analysis. Figure A.6 illustrates the system specification results. The complete breakout developed in this analysis appears on page A-23, where each functional goal is listed with the objectives it involves, followed by designators of the associated tasks; statements follow.

Reviewers checked the purpose, goals, objectives, and tasks designated in this study, as well as the completed task statements.

Development of Task Statements

This is a detailed, painstaking process in which (1) the elements of information described in Figure A.2 are obtained from available information sources, if not already known to the analyst, (2) the FJA scales are applied, and (3) performance standards and training content appropriate for the task are stated. These processes are described in the previously cited Handbook.

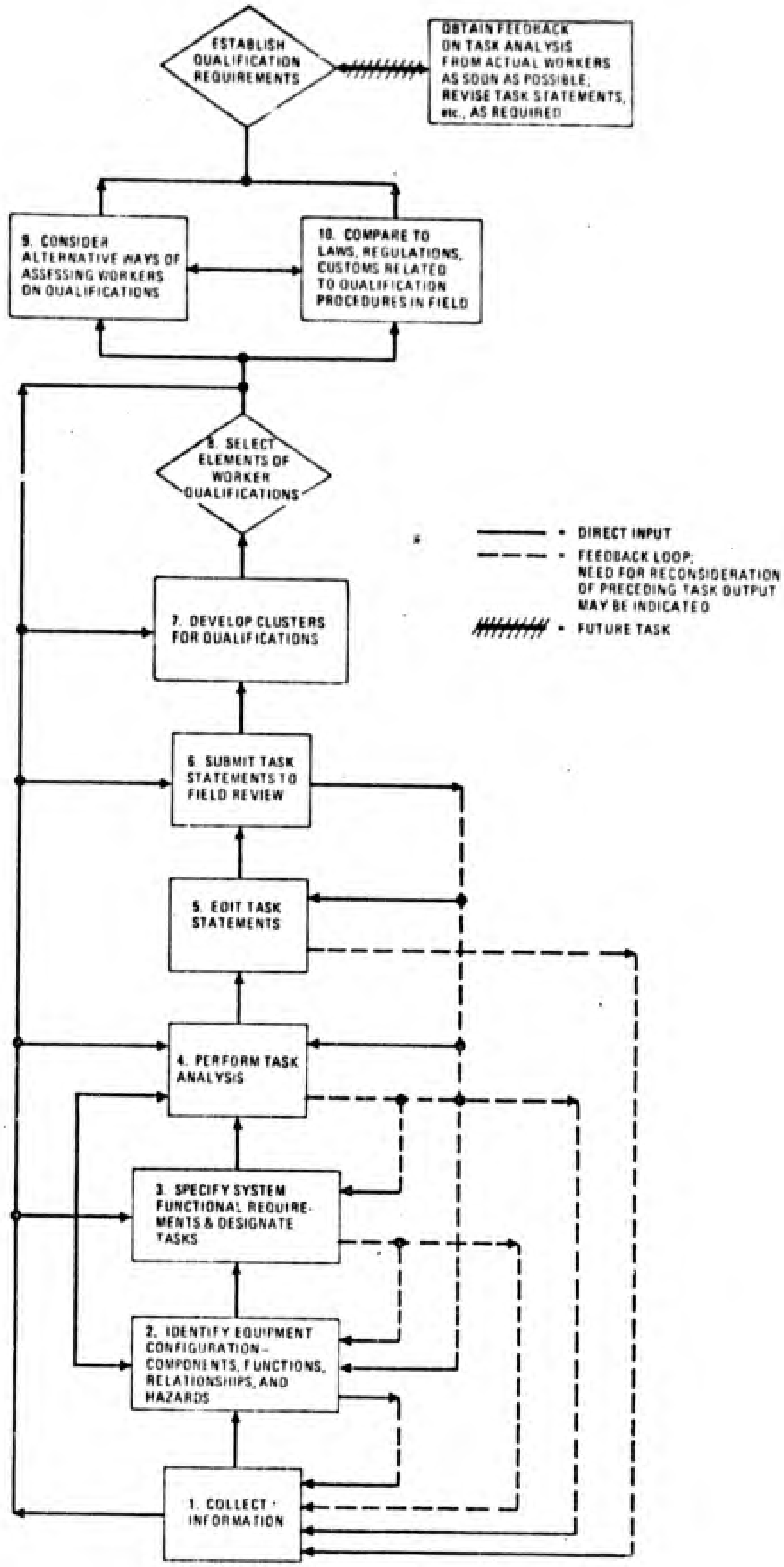

FIGURE A.4. PROCESS FLOW CHART

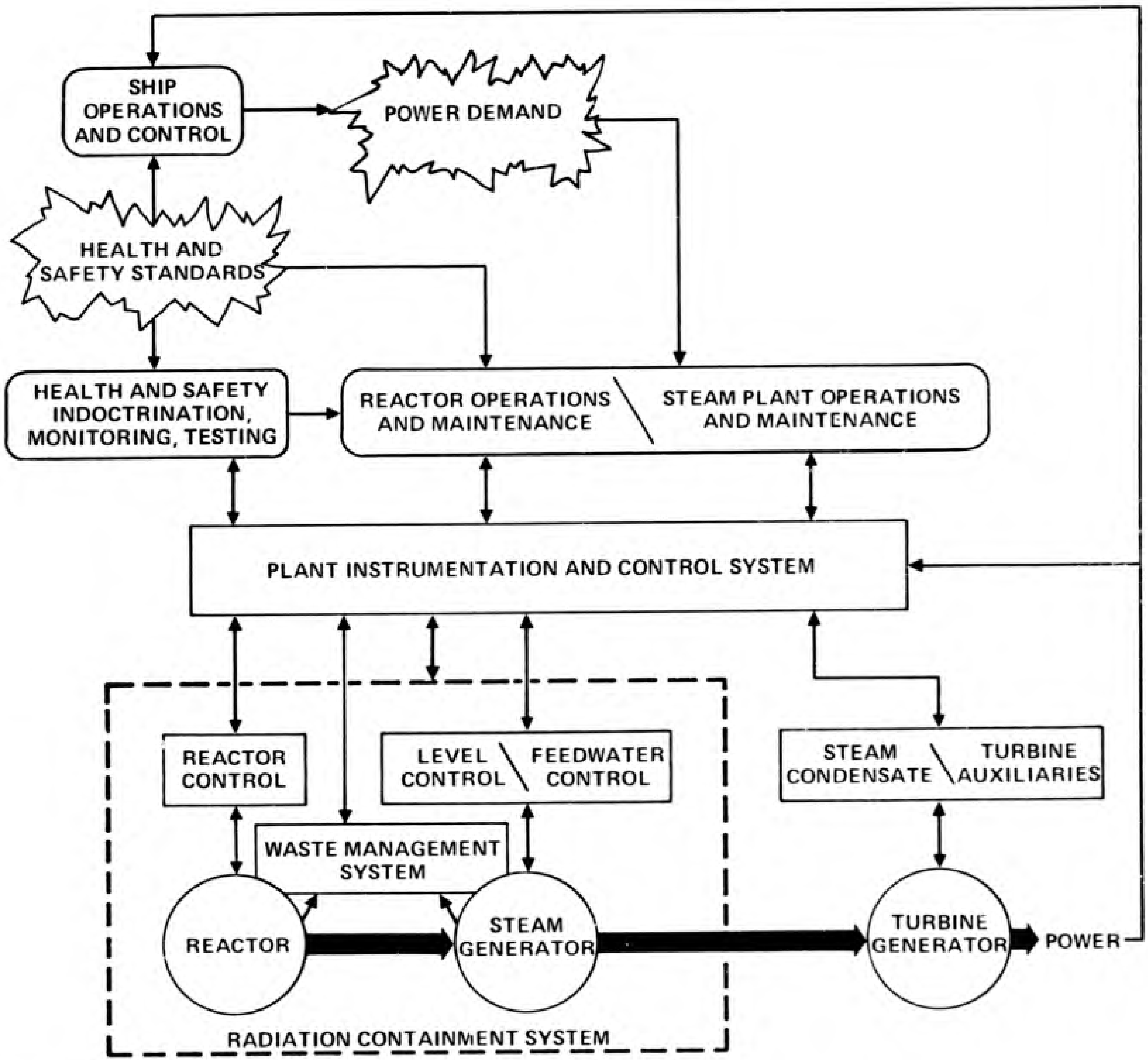

FIGURE A.5. NUCLEAR POWER PLANT SYSTEM PERSPECTIVE

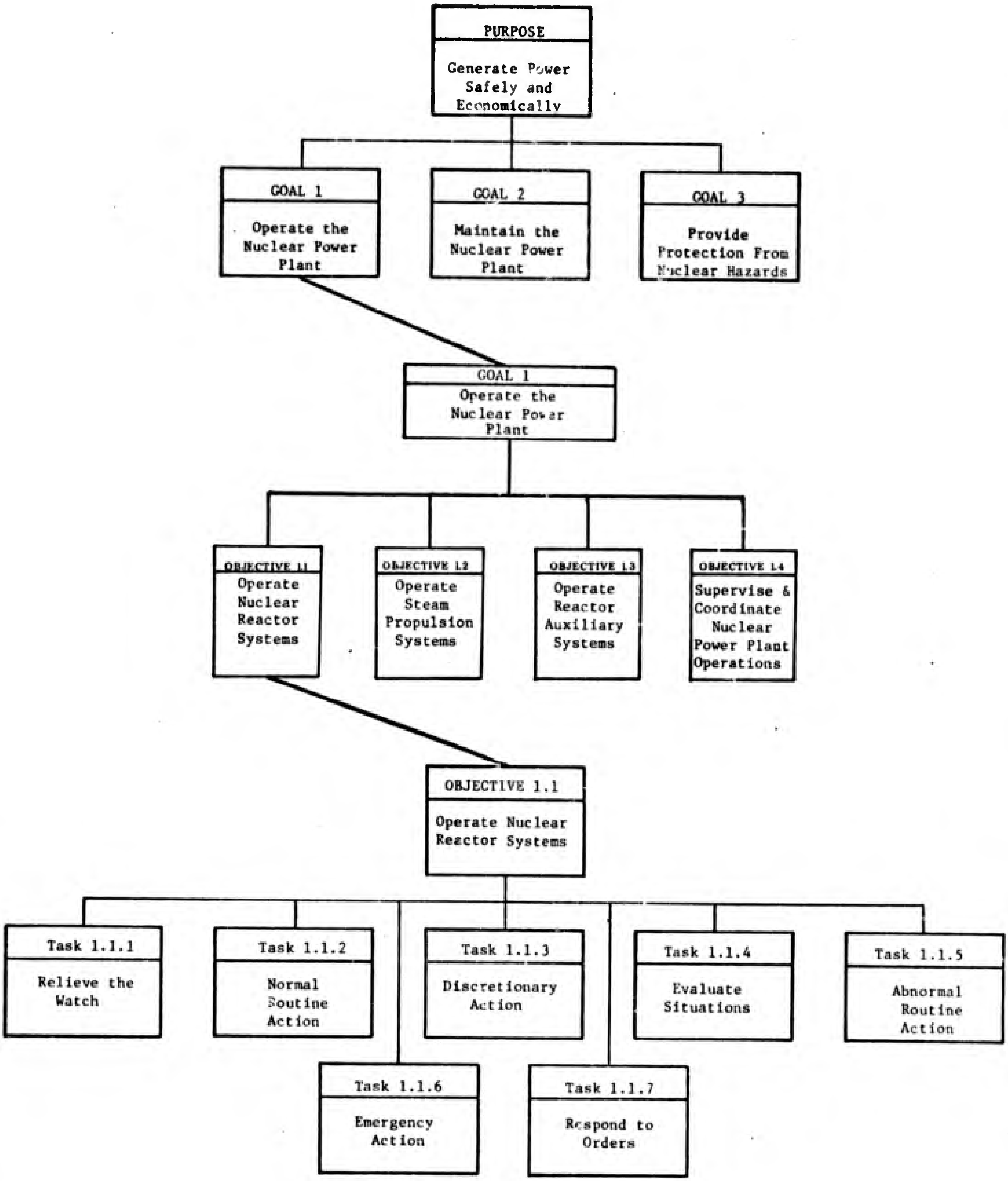

FIGURE A.6. SPECIFICATION OF SYSTEM PURPOSE, GOALS, AND OBJECTIVES, WITH EXAMPLE TASK DESIGNATORS

Review of Task Statements

Review of the task statements by people knowledgeable in the field was given high priority in this study. The review provides validation of the analysis. Appendix B describes the participation in the review process.

Recommendations

The recommendations took into account task requirements, safety, established regulatory practice, the nature of the merchant vessel personnel population, the problem of vessel-specific conditions, and the likelihood of changing technology. An effort was made to achieve a good balance of training and experience in the qualification requirements and to define a program that would be compatible with existing legal requirements, and as easy and economical to implement as possible.

FJA SCALES

Data Function Scale

The arabic numbers assigned to definitions represent the successive levels of this ordinal scale. The *A*, *B*, and *C* definitions are variations on the same level. There is no ordinal difference between *A*, *B*, and *C* definitions on a given level.

LEVEL	DEFINITION
1	COMPARING Selects, sorts, or arranges data, people, or things, judging whether their readily observable functional, structural, or compositional characteristics are similar to or different from prescribed standards.
2	COPYING Transcribes, enters, and/or posts data, following a schema or plan to assemble or make things and using a variety of work aids.
3A	COMPUTING Performs arithmetic operations and makes reports and/or carries out a prescribed action in relation to them.
3B	COMPILING Gathers, collates, or classifies information about data, people, or things, following a schema or system but using discretion in application.
4	ANALYZING Examines and evaluates data (about things, data, or people) with reference to the criteria, standards, and/or requirements of a particular discipline, art, technique, or craft to determine interaction effects (consequences) and to consider alternatives.
5A	INNOVATING Modifies, alters, and/or adapts existing designs, procedures, or methods to meet unique specifications, unusual conditions, or specific standards of effectiveness within the overall framework of operating theories, principles, and/or organizational contexts.
5B	COORDINATING Decides time, place, and sequence of operations of a process, system, or organization, and/or the need for revision of goals, policies (boundary conditions), or procedures on the basis of analysis of data and of performance review of pertinent objectives and requirements. Includes overseeing and/or executing decisions and/or reporting on events.
6	SYNTHESIZING *Takes off in new directions* on the basis of personal intuitions, feelings, and ideas (with or without regard for tradition, experience, and existing parameters) *to conceive new approaches* to or statements of problems and the development of system, operational, or aesthetic "solutions" or "resolutions" of them, typically outside of existing theoretical, stylistic, or organizational context.

People Function Scale

The arabic numbers assigned to definitions represent the successive levels of this ordinal scale. The *A*, *B*, and *C* definitions are variations on the same level. There is no ordinal difference between *A*, *B*, and *C* definitions on a given level.

LEVEL	DEFINITION
1A	TAKING INSTRUCTIONS-HELPING Attends to the work assignment, instructions, or orders of supervisor. No immediate response or verbal exchange is required unless clarification of instruction is needed.
1B	SERVING Attends to the needs or requests of people or animals, or to the expressed or implicit wishes of people. Immediate response is involved.
2	EXCHANGING INFORMATION Talks to, converses with, and/or signals people to convey or obtain information, or to clarify and work out details of an assignment within the framework of well-established procedures.
3A	COACHING Befriends and encourages individuals on a personal, caring basis by approximating a peer or family-type relationship either in a one-to-one or small group situation; gives instruction, advice, and personal assistance concerning activities of daily living, the use of various institutional services, and participation in groups.
3B	PERSUADING Influences others in favor of a product, service, or point of view by talks or demonstrations.
3C	DIVERTING Amuses to entertain or distract individuals and/or audiences or to lighten a situation.

LEVEL	DEFINITION
4A	CONSULTING Serves as a source of technical information and gives such information or provides ideas to define, clarify, enlarge upon, or sharpen procedures, capabilities, or product specifications (e.g., informs individuals/families about details of working out objectives such as adoption, school selection, and vocational rehabilitation; assists them in working out plans and guides implementation of plans).
4B	INSTRUCTING Teaches subject matter to others or trains others, including animals, through explanation, demonstration, and test.
4C	TREATING Acts on or interacts with individuals or small groups of people or animals who need help (as in sickness) to carry out specialized therapeutic or adjustment procedures. Systematically observes results of treatment within the framework of total personal behavior because unique individual reactions to prescriptions (chemical, physical, or behavioral) may not fall within the range of prediction. Motivates, supports, and instructs individuals to accept or cooperate with therapeutic adjustment procedures when necessary.
5	SUPERVISING Determines and/or interprets work procedure for a group of workers; assigns specific duties to them (delineating prescribed and discretionary content); maintains harmonious relations among them; evaluates performance (both prescribed and discretionary) and promotes efficiency and other organizational values; makes decisions on procedural and technical levels.
6	NEGOTIATING Bargains and discusses on a formal basis as a representative of one side of a transaction for advantages in resources, rights, privileges, and/or contractual obligations, "giving and taking" within the limits provided by authority or within the framework of the perceived requirements and integrity of a program.
7	MENTORING Works with individuals having problems affecting their life adjustment in order to advise, counsel, and/or guide them according to legal, scientific, clinical, spiritual, and/or other professional principles. Advises clients on implications of analyses or diagnoses made of problems, courses of action open to deal with them, and merits of one strategy over another.

Things Function Scale

The arabic numbers assigned to definitions represent the successive levels of this ordinal scale. The *A*, *B*, and *C* definitions are variations on the same level. There is no ordinal difference between *A*, *B*, and *C* definitions on a given level.

LEVEL	DEFINITION
	HANDLING
1A	Works (cuts, shapes, assembles, etc.), digs, moves, or carries objects or materials where objects, materials, tools, etc., are one or few in number and are the primary involvement of the worker. Precision requirements are relatively gross. Includes the use of dollies, handtrucks, and the like. (Use this rating for situations involving casual use of tangibles.)
	FEEDING-OFFBEARING
1B	Inserts, throws, dumps, or places materials into, or removes them from, machines or equipment which are automatic or tended/operated by other workers. Precision requirements are built in, largely out of control of worker.
	TENDING
1C	Starts, stops, and monitors the functioning of machines and equipment set up by other workers where the precision of output depends on keeping one to several controls in adjustment, in response to automatic signals according to specifications. Includes all machine situations where there is no significant setup or change of setup, where cycles are very short, alternatives to nonstandard performance are few, and adjustments are highly prescribed. (Includes electrostatic and wet-copying machines and PBX switchboards.)
	MANIPULATING
2A	Works (cuts, shapes, assembles, etc.), digs, moves, guides, or places objects or materials where objects, tools, controls, etc., are *several* in number. Precision requirements range from gross to fine. Includes waiting on tables and the use of ordinary portable power tools with interchangeable parts and ordinary tools around the home, such as kitchen and garden tools.

LEVEL	DEFINITION
	OPERATING-CONTROLLING
2B	Starts, stops, controls, and adjusts a machine or equipment designed to fabricate and/or process data, people, or things. The worker may be involved in activating the machine, as in typing or turning wood, or the involvement may occur primarily at startup and stop as with a semiautomatic machine. *Operating a machine* involves readying and adjusting the machine and/or material as work progresses. *Controlling equipment* involves monitoring gauges, dials, etc., and turning valves and other devices to control such items as temperature, pressure, flow of liquids, speed of pumps, and reactions of materials. *Includes the operation of typewriters, mimeograph machines, and other office equipment where readying or adjusting the machine requires more than cursory demonstration and checkout.* (This rating is to be used only for operations of one machine or one unit of equipment.)
	DRIVING-CONTROLLING
2C	Starts, stops, and controls the actions of machines for which a course must be steered or guided in order to fabricate, process, and/or move things or people. Actions regulating controls require continuous attention and readiness of response. (Use this rating if use of vehicle is required in job, even if job is concerned with people or data primarily.)
	PRECISION WORKING
3A	Works, moves, guides, or places objects or materials according to standard practical procedures where the number of objects, materials, tools, etc., embraces an entire craft and accuracy expected is within final finished tolerances established for the craft. (Use this rating where work primarily involves manual or power hand-tools.)
	SETTING UP
3B	Installs machines or equipment; inserts tools; alters jigs, fixtures, and attachments; and/or repairs machines or equipment to ready and/or restore them to their proper functioning according to job order or blueprint specifications. Involves primary responsibility for accuracy. May involve one or a number of machines for other workers or for worker's own operation.

Scale of Worker Instructions

LEVEL	DEFINITION
1	Inputs, outputs, tools, equipment, and procedures are all specified. Almost everything the worker needs to know is contained in his assignment. He is supposed to turn out a specified amount of work or a standard number of units per hour or day.
2	Inputs, outputs, tools, and equipment are all specified, but the worker has some leeway in the procedures and methods he can use to get the job done. Almost all the information he needs is in his assignment. His production is measured on a daily or weekly basis.
3	Inputs and outputs are specified, but the worker has considerable freedom as to procedures and timing, including the use of tools and equipment. He has to refer to several standard sources for information (handbooks, catalogs, wall charts). Time to complete a particular product or service is specified, but this varies up to several hours.
4	Output (product or service) is specified in the assignment, which may be in the form of a memorandum or of a schematic (sketch or blueprint). The worker must work out his own ways of getting the job done, including selection of tools and equipment, sequence of operations (tasks), and obtaining important information (handbooks, etc.). He may either carry out work himself or set up standards and procedures for others.
5	Same as (4) above, but in addition the worker is expected to know and employ theory so that he understands the whys and wherefores of the various options that are available for dealing with a problem and can independently select from among them. He may have to do some reading in the professional and/or trade literature in order to gain this understanding.
6	Various possible outputs are described that can meet stated technical or administrative needs. The worker must investigate the various possible outputs and evaluate them in regard to performance characteristics and input demands. This usually requires his creative use of theory well beyond referring to standard sources. There is no specification of inputs, methods, sequences, sources, or the like.
7	There is some question as to what the need or problem really is or what directions should be pursued in dealing with it. In order to define it, to control and explore the behavior of the variables, and to formulate possible outputs and their performance characteristics, the worker must consult largely unspecified sources of information and devise investigations, surveys, or data analysis studies.
8	Information and/or direction comes to the worker in terms of needs (tactical, organizational, strategic, financial). He must call for staff reports and recommendations concerning methods of dealing with them. He coordinates both organizational and technical data in order to make decisions and determinations regarding courses of action (outputs) for major sections (divisions, groups) of his organization.

Reasoning Development Scale

The Reasoning Development Scale is concerned with knowledge and ability to deal with theory versus pra ice, abstract versus concrete, and many versus few variables.

LEVEL	DEFINITION
1	• Have the common sense understanding to carry out simple one- or two-step instructions in the context of highly standardized situations. • Recognize unacceptable variations from the standard and take emergency action to reject inputs or stop operations.
2	• Have the common sense understanding to carry out detailed but uninvolved written or oral instructions. • Deal with problems involving a few concrete variables in or from standardized situations.
3	• Have the common sense understanding to carry out instructions furnished in written, oral, or diagrammatic form. • Deal with problems involving several concrete variables in or from standardized situations.
4	• Have knowledge of a system or interrelated procedures, such as bookkeeping, internal combustion engines, electric wiring systems, nursing, farm management, ship sailing, or machining. • Apply principles to solve practical, everyday problems and deal with a variety of concrete variables in situations where only limited standardization exists. • Interpret a variety of instructions furnished in written, oral, diagrammatic, or schedule form.
5	• Have knowledge of a field of study (engineering, literature, history, business administration) having immediate applicability to the affairs of the world. • Define problems, collect data, establish facts, and draw valid conclusions. • Interpret an extensive variety of technical material in books, manuals, texts, etc. • Deal with some abstract but mostly concrete variables.
6	• Have knowledge of a field of study of the highest abstractive order (e.g., mathematics, physics, chemistry, logic, philosophy, art criticism). • Deal with nonverbal symbols in formulas, equations, or graphs. • Understand the most difficult classes of concepts. • Deal with a large number of variables and determine a specific course of action (e.g., research, production) on the basis of need.

Mathematical Development Scale

The Mathematical Development Scale is concerned with knowledge and ability to deal with mathematical problems and operations from counting and simple addition to higher mathematics.

LEVEL	DEFINITION
1	• Counting to simple addition and subtraction; reading, copying, and/or recording of figures.
2	• Use arithmetic to add, subtract, multiply, and divide whole numbers.
3	• Make arithmetic calculations involving fractions, decimals, and percentages.
4	• Perform ordinary arithmetic, algebraic, and geometric procedures in standard practical applications.
5-6	• Have knowledge of advanced mathematical and statistical techniques such as differential and integral calculus, factor analysis, and probability determination. • Work with a wide variety of theoretical mathematical concepts. • Make original applications of mathematical procedures, as in empirical and differential equations.

Language Development Scale

The Language Development Scale is concerned with knowledge and ability to deal with oral or written language materials from simple instructions to complex sources of information and ideas.

LEVEL	DEFINITION
1	• Cannot read or write but can follow simple oral, "pointing-out" instructions. • Sign name and understand ordinary, routine agreements when explained, such as those relevant to leasing a house; employment (hours, wages, etc.); procuring a driver's license. • Read lists, addresses, safety warnings.
2	• Read comic books, "true confession" or "mystery" type magazines (short sentences; simple, concrete vocabulary; words that avoid complex Latin derivations). • Converse with service personnel (waiters, ushers, cashiers). • Copy verbal records precisely without error. • Keep taxi driver's trip record.
3	• Read material on level of the *Reader's Digest* and straight news reporting in popular "mass" newspapers. • Comprehend ordinary newscasting (uninvolved sentences and vocabulary with focus on events rather than on their analysis). • Copy verbal material from one record to another, catching gross errors in grammar. • Fill in report forms, such as Medicare forms, employment applications, and card form for income tax. • Conduct house-to-house surveys to obtain common census-type information or market data, such as preferences for commercial products in everyday use.

LEVEL	DEFINITION
4	• Have language ability to take and transcribe dictation, make appointments, and sort, route, and file the mail according to subject. • Write routine business correspondence reflecting standard procedures. • Interview job applicants to determine work best suited for their abilities and experience; contact employers to interest them in services of agency. • Understand technical manuals and verbal instructions, as well as drawings and specifications, associated with practicing a craft. • Guide people on tours through historical or public buildings, tell relevant anecdotes, etc. • Conduct opinion research surveys involving stratified samples of the population.
5	• Write instructions for assembly of prefabricated parts into units. • Write instructions and specifications concerning proper use of machinery. • Write copy for advertising. • Report news for the newspapers, radio, or TV. • Prepare and deliver lectures for audiences that seek information about the arts, sciences, and humanities in an informal way. • Report, write, or edit articles for magazines which, while popular, are of a highly literate nature (e.g., *New Yorker, Saturday Review, Scientific American*).
6	• Report, write, or edit articles for technical and scientific journals or journals of advanced literary criticism (e.g., *Journal of Educational Sociology, Science, Physical Review, Daedalus*). • Prepare and draw up deeds, leases, wills, mortgages, and contracts. • Prepare and deliver lectures on politics, economics, education, or science to specialized students and/or professional societies. • Comprehend and apply technical engineering data for designing buildings and bridges. • Comprehend and discuss literary works of a highly symbolic nature, such as works in logic and philosophy (e.g., Kant, Whitehead, Russell).

TASK ANALYSIS DATA

A list showing the complete task analysis structure is provided on the next page. The tasks statements follow. They are coded in accordance with the list. The pertinent goal and objective are recorded on each task statement form.

OVERVIEW OF TASK ANALYSIS STRUCTURE

GOAL 1. OPERATE THE NUCLEAR POWER PLANT

Objective	1.1	Operates the Nuclear Reactor Systems
Task	1.1.1	Relieves the Watch
	1.1.2	Normal Routine Action
	1.1.3	Discretionary Action
	1.1.4	Evaluates Situations
	1.1.5	Abnormal Routine Action
	1.1.6	Emergency Action
	1.1.7	Responds to Orders
Objective	1.2	Operates the Steam Propulsion Systems
Task	1.2.1	Relieves the Watch
	1.2.2	Normal Routine Action
	1.2.3	Discretionary Action
	1.2.4	Abnormal Routine Action
	1.2.5	Emergency Action
Objective	1.3	Operates Reactor Auxiliary Systems
Task	1.3.1	Relieves the Watch
	1.3.2	Normal Routine Action
	1.3.3	Discretionary Action
	1.3.4	Abnormal Routine Action
	1.3.5	Emergency Action
Objective	1.4	Supervises and Coordinates Nuclear Power Plant Operations
Task	1.4.1	Relieves the Watch
	1.4.2	Supervises Operator Actions in Normal Routine
	1.4.3	Coordinates and Directs Operator Actions in Abnormal Routine
	1.4.4	Directs Operators Actions in Emergency Situations
	1.4.5	Informs Higher Authority of Plant Conditions

GOAL 2. MAINTAIN THE POWER PLANT

Objective	2.1	Performs Maintenance and/or Corrective Repairs
Task	2.1.1	Instrumentation and Controls
	2.1.2	Mechanical Components
	2.1.3	Electrical Components
Objective	2.2	Supervises and Coordinates Maintenance and Repairs
Task	2.2.1	Routine Maintenance
	2.2.2	Evaluates Failures
	2.2.3	Directs Corrective Repairs

GOAL 3. PROVIDE PROTECTION FROM NUCLEAR HAZARDS

Objective	3.1	Monitors Level of Shipboard Radiation
Task	3.1.1	Performs Airborne Particulate and Smear Surveys
	3.1.2	Analyzes Samples to Determine Level of Airborne and Surface Radiation
	3.1.3	Draws Samples of Radioactive Liquid Effluent
	3.1.4	Analyzes Samples to Determine Effluent Radioactivity Concentration
Objective	3.2	Monitors Level of Personnel Exposure
Task	3.2.1	Checks Personnel Exposure Rate
	3.2.2	Issues Monitoring Equipment to Crew
	3.2.3	Conducts Training in Radiation Protection

TASK CODE: 1.1.1

WORKER FUNCTION LEVEL AND ORIENTATION						WORKER INSTRUCTIONS	GENERAL EDUCATIONAL DEVELOPMENT		
DATA	%	PEOPLE	%	THINGS	%		REASONING	MATH	LANGUAGE
4	65	2	30	1	5	5	4	3	4

TASK CODE: 1.1.1

GOAL: Operate the Nuclear Power Plant

OBJECTIVE: Operate nuclear reactor systems

TASK: Tours reactor control space observing engineering equipment and indicators (gages, annunciator lights, meters, CRT's, switch positions), examines and evaluates control room logs and status boards (some data in decimals) and converses with off-going worker to obtain briefing, and draws on knowledge and experience with the system in order to determine the actual nuclear power plant conditions before assuming the responsibilities of the watch.

PERFORMANCE STANDARDS

DESCRIPTIVE:

- Tours reactor control space alert to system detail.
- Relieves watch carefully attending to all safety checks.

NUMERICAL:

- Is 100% accurate in recognition of contradictions between logs, status boards and actual plant status.
- Completes task and relieves the watch at the proper time without exception.

TRAINING CONTENT

FUNCTIONAL:

- How to maintain control room logs and status boards (some data in decimals) and interpret trends.
- How to tour reactor control space and observe equipment.
- Understanding of nuclear power plant systems.

SPECIFIC:

- Knowledge of control room logs and status boards.
- Knowledge of control room and equipment layout.
- Knowledge of ship's nuclear reactor systems.
- Knowledge of ship's steam propulsion systems.
- Knowledge of ship's reactor auxiliary systems.

TASK CODE: 1.1.2

WORKER FUNCTION LEVEL AND ORIENTATION						WORKER INSTRUCTIONS	GENERAL EDUCATIONAL DEVELOPMENT		
DATA	%	PEOPLE	%	THINGS	%		REASONING	MATH	LANGUAGE
4	90	1A	5	1C	5	5	4	3	4

TASK CODE: 1.1.2

GOAL: Operate the Nuclear Power Plant

OBJECTIVE: Operate nuclear reactor systems

TASK: Scans, examines and evaluates control panel indications (gages, annunciator lights, meters, CRT's, switch positions) with reference to plant operating procedures for normal evolutions in order to determine that all systems under his control are operating within prescribed limits.

PERFORMANCE STANDARDS	TRAINING CONTENT
DESCRIPTIVE: - Monitors nuclear power plant systems operation, alert to system detail. **NUMERICAL:** - Is present in front of the panel 100% of the time. - Is apprised of nuclear power plant operating conditions at all times.	**FUNCTIONAL:** - How to scan an instrument panel. - How to integrate nuclear power plant indications and interpret trends. - Knowledge of nuclear power plant systems, functions and theory. **SPECIFIC:** - Knowledge of instrument panel layout. - Knowledge of power plant components and limits. - Knowledge of ship's nuclear reactor systems. - Knowledge of ship's steam propulsion systems. - Knowledge of ship's auxiliary systems.

TASK CODE: 1.1.3

WORKER FUNCTION LEVEL AND ORIENTATION						WORKER INSTRUCTIONS	GENERAL EDUCATIONAL DEVELOPMENT		
DATA	%	PEOPLE	%	THINGS	%		REASONING	MATH	LANGUAGE
3B	50	2	20	2B	30	2	3	3	4

TASK CODE: 1.1.3

GOAL: Operate the Nuclear Power Plant

OBJECTIVE: Operate nuclear reactor systems

TASK: Checks initial indications (gages, lights, switches) on control room panels, manipulates the appropriate controls (levers, push buttons, switches) relevant to ordered plant procedures (startup, shutdown, maneuvering, chemical injection) signals (via face to face, telephone and P.A. Communications) other engineering personnel, and checks resultant indications (gages, lights, switches) on control room panels so that procedures ordered from the bridge and/or by the Chief Engineer are implemented.

PERFORMANCE STANDARDS

DESCRIPTIVE:

- Implements plant procedures accurately and expeditiously.

NUMERICAL:

- 100% accuracy in implementing procedures.

TRAINING CONTENT

FUNCTIONAL:

- How to check indications.
- How to manipulate nuclear power plant controls.
- How to use communications equipment.

SPECIFIC:

- Knowledge of instrument panel layout.
- Knowledge of nuclear power plant controls.
- Knowledge of all nuclear power plant operating procedures in Ship's Standard Operating Procedures Manual.

TASK CODE: 1.1.4

WORKER FUNCTION LEVEL AND ORIENTATION						WORKER INSTRUCTIONS	GENERAL EDUCATIONAL DEVELOPMENT		
DATA	%	PEOPLE	%	THINGS	%		REASONING	MATH	LANGUAGE
3B	40	2	20	1C	40	4	4	3	3

TASK CODE: 1.1.4

GOAL: Onerate the Nuclear Power Plant

OBJECTIVE: **Operate nuclear reactor systems**

TASK: Seeks further information in order to respond to inconsistent indications on control room indicators, (gages. meters, instrument panels); selects alternate inputs to control room indicators using switches, interrogates the plant computer (push buttons) and communicates with engineering watchstanders, drawing on knowledge and experience of power plant systems.

PERFORMANCE STANDARDS

DESCRIPTIVE:

- Uses good judgement in determining what secondary sources of information are appropriate.

NUMERICAL:

- 100% accurate in clarifying inconsistent control room indications.

TRAINING CONTENT

FUNCTIONAL:

- How to interrogate a computer.
- How to use communication equipment.
- How to use peripheral equipment.
- Knowledge of secondary sources of information (redundant gages and indicators, alternate inputs to control room indicators outside of control room).

SPECIFIC:

- How to use plant computer.
- How to use plant communications equipment.
- Knowledge of secondary sources of information for ship's nuclear power plant systems.

TASK CODE: 1.1.5

WORKER FUNCTION LEVEL AND ORIENTATION						WORKER INSTRUCTIONS	GENERAL EDUCATIONAL DEVELOPMENT		
DATA	%	PEOPLE	%	THINGS	%		REASONING	MATH	LANGUAGE
4	90	2	5	1	5	5	5	3	4

TASK CODE: 1.1.5

GOAL: Operate the Nuclear Power Plant

OBJECTIVE: Operate nuclear reactor systems

TASK: Evaluates plant procedures ordered by bridge and/or by Chief Engineer with reference to actual plant status and ship's safety requirements, drawing on knowledge and experience, to determine whether effects of implementing procedures may cause or result in out-of-limit conditions for the nuclear power plant.

PERFORMANCE STANDARDS

DESCRIPTIVE:

- Safely implements plant operating procedures.
- Clear and accurate in determination of out-of-limits conditions.

NUMERICAL:

- 100% accurate in following procedures.
- Zero failures in detecting inappropriate procedures.

TRAINING CONTENT

FUNCTIONAL:

- Knowledge of nuclear power plant systems and functional inter-relationships.
- How to use engineering procedures.

SPECIFIC:

- Knowledge of ship's nuclear power plant system operational characteristics.
- Be familiar with plant operating procedures and out-of-limits conditions.

TASK CODE: 1.1.6

WORKER FUNCTION LEVEL AND ORIENTATION						WORKER INSTRUCTIONS	GENERAL EDUCATIONAL DEVELOPMENT		
DATA	%	PEOPLE	%	THINGS	%		REASONING	MATH	LANGUAGE
5B	30	2	10	2B	60	5	4	3	4

TASK CODE: 1.1.6

GOAL: Operate the Nuclear Power Plant

OBJECTIVE: Operate nuclear reactor systems

TASK: When continuity of power cannot be maintained, evaluates indications (gages, annunciator lights, meters, CRT's, switch positions), identifies casuality, performs "Immediate Operator Actions" from memory (checking indications, manipulating controls), and carries out "Subsequent Operator Actions" using the appropriate emergency checklists, (notifies personnel, checks indications and manipulates controls) in order to place and/or maintain the nuclear power plant in a safe condition.

PERFORMANCE STANDARDS

DESCRIPTIVE:

- Recognizes the symptoms of casualties and carries out emergency procedures from memory in an expeditious manner.

NUMERICAL:

- Zero defect in recognition of symptoms of casualties and malfunctions.
- 100% accurate in implementing immediate operator actions from memory.
- 100% accurate in implementing subsequent operator actions using the appropriate emergency checklist.

TRAINING CONTENT

FUNCTIONAL:

- Knowledge of common power plant casualities and nuclear power plant systems malfunctions.
- How to scan and integrate panel indications.
- How to manipulate controls.
- Knowledge of nuclear power plant systems and functions.

SPECIFIC:

- Knowledge of instrument panel layout.
- Knowledge of nuclear power plant limits and components.
- How to use communications equipment.
- Knowledge from memory of casualty symptoms, and required immediate actions.
- How to implement "Subsequent Operator Actions" using emergency procedures.

TASK CODE: 1.1.7

WORKER FUNCTION LEVEL AND ORIENTATION						WORKER INSTRUCTIONS	GENERAL EDUCATIONAL DEVELOPMENT		
DATA	%	PEOPLE	%	THINGS	%		REASONING	MATH	LANGUAGE
2	30	2	10	2B	60	3	3	3	4

TASK CODE: 1.1.7

GOAL: Operate the Nuclear Power Plant

OBJECTIVE: Operate nuclear reactor systems

TASK: In response to a casualty identified by another operator (e.g., Reactor Auxiliary Operator, Officer of the Deck) performs "Immediate Operator Actions" from memory (checking indications, manipulating controls), and carries out "Subsequent Operator Actions" using the appropriate emergency checklists, (notifies personnel, checks indications and manipulates controls) in order to place and/or maintain the nuclear power plant in a safe condition.

PERFORMANCE STANDARDS

DESCRIPTIVE:

- Carries out emergency procedures in an expeditious manner.

NUMERICAL:

- 100% accurate in implementing "Immediate Operator Actions" from memory.
- 100% accurate in implementing subsequent operator actions using the appropriate emergency checklist.

TRAINING CONTENT

FUNCTIONAL:
- Knowledge of common power plant casualities and nuclear power plant systems malfunctions.
- How to scan and integrate panel indications.
- How to manipulate controls.
- Knowledge of nuclear power plant systems and functions.

SPECIFIC:
- Knowledge of instrument panel layout.
- Knowledge of nuclear power plant limits and components.
- How to use communications equipment.
- Knowledge from memory of casualty symptoms, and required immediate actions.
- How to implement "Subsequent Operator Actions" using emergency procedures.

TASK CODE: 1.2.1

WORKER FUNCTION LEVEL AND ORIENTATION						WORKER INSTRUCTIONS	GENERAL EDUCATIONAL DEVELOPMENT		
DATA	%	PEOPLE	%	THINGS	%		REASONING	MATH	LANGUAGE
4	65	2	30	1	5	4	4	3	3

TASK CODE: 1.2.1

GOAL: Operate the Nuclear Power Plant

OBJECTIVE: Operate steam propulsion systems

TASK: Tours the engine room observing steam propulsion equipment (pumps, piping systems, valves, turbines, condensers) and indicators, (pressure, temp., level, flow, speed), examines and evaluates logs and status boards (some data in decimals), converses with off-going watchstander to obtain briefing, and draws on own experience with the System in order to determine the actual steam propulsion systems and nuclear reactor systems status before assuming the responsibilities of the watch.

PERFORMANCE STANDARDS

DESCRIPTIVE:

- Tours engine room space alert to system detail.
- Relieves the watch carefully attending to safety checks.

NUMERICAL:

- Is 100% accurate in recognition of contradictions between logs, status boards, and actual steam plant status.
- Completes task and relieves the watch at the proper time without exception.

TRAINING CONTENT

FUNCTIONAL: - How to interpolate data in decimals and trend analysis.
- Purpose and maintenance of engineering logs and status boards.
- How to tour engine room and observe equipment.
- How to relieve the watch.
- Operational understanding of steam plant systems.

SPECIFIC:

- Knowledge of engineering logs and status boards.
- Knowledge of engine room space and equipment layout.
- Knowledge of ships steam propulsion systems.
- Knowledge of effects of operation of ship's steam propulsion system on nuclear reactor systems.

TASK CODE: 1.2.2

WORKER FUNCTION LEVEL AND ORIENTATION						WORKER INSTRUCTIONS	GENERAL EDUCATIONAL DEVELOPMENT		
DATA	%	PEOPLE	%	THINGS	%		REASONING	MATH	LANGUAGE
4	90	1A	5	1C	5	4	4	3	3

TASK CODE: 1.2.2

GOAL: Operate the Nuclear Power Plant

OBJECTIVE: Operate steam propulsion systems

TASK: Scans and evaluates instrumentation (gages, meters) of machinery in engine room with reference to plant operating procedures for normal evolutions and personal knowledge and experience, and enters readings into engine room log hourly, in order to determine that all systems under his control are operating within prescribed limits.

PERFORMANCE STANDARDS

DESCRIPTIVE:

- Monitors Steam Propulsion Systems, alert to system detail.

NUMERICAL:

- Is present in engine room 100% of the time.
- Enters engine room log readings with 100% accuracy every hour or as prescribed.

TRAINING CONTENT

FUNCTIONAL:

- How to read meters and gages.
- Knowledge of steam propulsion systems, and their interactions with nuclear reactor systems.

SPECIFIC:

- Knowledge of ship's Steam Propulsion Systems operating limits.
- Knowledge of ship's steam propulsion systems effect on nuclear reactor systems.

TASK CODE: 1.2.3

WORKER FUNCTION LEVEL AND ORIENTATION						WORKER INSTRUCTIONS	GENERAL EDUCATIONAL DEVELOPMENT		
DATA	%	PEOPLE	%	THINGS	%		REASONING	MATH	LANGUAGE
3B	50	2	20	2B	30	2	3	3	3

TASK CODE: 1.2.3

GOAL: Operate the Nuclear Power Plant

OBJECTIVE: Operate steam propulsion systems

TASK: Checks initial indications on engine room machinery instrumentation, (readings on gages, meters), manipulates the appropriate controls, checks resultant indications on engine room machinery gages or meters, and communicates actions taken and results, in order to implement standard operating procedures (startup, shutdown, maneuvering) ordered by the control room.

PERFORMANCE STANDARDS	TRAINING CONTENT
DESCRIPTIVE: - Implements plant procedures expeditiously. NUMERICAL: - 100% accuracy in implementing procedures.	FUNCTIONAL: - How to check indications - How to manipulate engine room controls - How to use communication equipment - Knowledge Steam Propulsion Systems operating procedures. SPECIFIC: - Knowledge of ship's engine room spaces. - Knowledge of ship's steam propulsion systems operating procedures and how to use them.

TASK CODE: 1.2.4

WORKER FUNCTION LEVEL AND ORIENTATION						WORKER INSTRUCTIONS	GENERAL EDUCATIONAL DEVELOPMENT		
DATA	%	PEOPLE	%	THINGS	%		REASONING	MATH	LANGUAGE
4	90	2	5	1	5	4	4	3	3

TASK CODE: 1.2.4

GOAL: Operate the Nuclear Power Plant

OBJECTIVE: Operate steam propulsion systems

TASK: Examines and evaluates operating procedures ordered by control room with reference to actual status of Steam Propulsion Systems equipment, drawing on knowledge and experience, to determine whether effects of implementing procedures may cause or result in out-of-limit conditions.

PERFORMANCE STANDARDS	TRAINING CONTENT
DESCRIPTIVE: - Safely implements steam propulsion systems operating procedures. - Clear and accurate in determination of out-of-limits conditions. **NUMERICAL:** - 100% accurate in following procedures. - Zero failure in detecting inappropriate procedures.	**FUNCTIONAL:** - Knowledge of interrelationships of Steam Propulsion Systems to Nuclear Reactor Systems. - How to use engineering procedures. **SPECIFIC:** - Knowledge of Steam Propulsion Systems equipment characteristics. - Knowledge of steam propulsion Systems operating procedures and how to use them.

TASK CODE: 1.2.5

WORKER FUNCTION LEVEL AND ORIENTATION						WORKER INSTRUCTIONS	GENERAL EDUCATIONAL DEVELOPMENT		
DATA	%	PEOPLE	%	THINGS	%		REASONING	MATH	LANGUAGE
4	30	2	10	2B	60	4	4	3	3

TASK CODE: 1.2.5

GOAL: Operate the Nuclear Power Plant

OBJECTIVE: Operate the steam propulsion systems

TASK: Evaluates indications (gages, meters) identifies steam propulsion systems casualty, perform "Immediate Operator Actions" from memory, notifies control room personnel and carries out "Subsequent Operator Actions as required by appropriate Emergency Checklists by manipulating the necessary controls, in order to place or maintain the steam propulsion systems in a safe condition.

PERFORMANCE STANDARDS

DESCRIPTIVE:

- Recognizes the symptoms of steam propulsion systems casualties and carries out emergency procedure from memory in an expeditious manner.

NUMERICAL:

- Zero defect in recognition of symptoms of casualties and malfunctions.
- 100% accurate in implementing "immediate operator actions" from memory.
- 100% accurate in implementing "subsequent operator actions" using the appropriate emergency checlist.

TRAINING CONTENT

FUNCTIONAL:

- Knowledge of common Steam Propulsion System casualties.
- How to scan and integrate instrument indications.
- How to manipulate controls.
- Knowledge of Steam Propulsion Systems.

SPECIFIC:

- Knowledge of Ship's Steam Propulsion Systems equipment layout in engine room.
- Knowledge of ship's steam propulsion systems.
- Knowledge from memory of casualty symptoms and required immediate actions.
- How to implement "subsequent Operator actions" using emergency procedures.

TASK CODE: 1.3.1

WORKER FUNCTION LEVEL AND ORIENTATION						WORKER INSTRUCTIONS	GENERAL EDUCATIONAL DEVELOPMENT		
DATA	%	PEOPLE	%	THINGS	%		REASONING	MATH	LANGUAGE
4	50	3	20	2	30	4	4	3	4

TASK CODE: 1.3.1

GOAL: Operate the Nuclear Power Plant

OBJECTIVE: **Operate reactor auxiliary systems**

TASK: Tours engineering spaces observing reactor auxiliary systems and associated equipment (pumps, valves, motors, electric switch gear) and instrumentation (some data in decimals) (gages, meters) associated with the nuclear power plant, the electrical distribution system, motors and controls, examines logs and status boards (some data in decimals) in company with the off-going watchstander in order to determine the actual status of the reactor auxiliary and equipment.

PERFORMANCE STANDARDS	TRAINING CONTENT
DESCRIPTIVE: -Tours assigned engineering spaces alert to system detail. -Relieves watch carefully attending to all safety checks. **NUMERICAL:** - Is 100% accurate in recognition of contradictions between logs, status boards and actual equipment status. - Completes task and relieves the watch at the proper time without exception.	**FUNCTIONAL:** - Purpose and maintenance of logs and status boards (some data in decimals) and interpret trends. - How to tour engineering spaces and observe instrumentation and electrical equipment. - How to relieve the watch. **SPECIFIC:** - Knowledge of logs and status boards. - Knowledge of ship's reactor auxiliary systems. - Knowledge of effects of operation of ship's reactor auxiliary systems (e.g. Fresh water coolant system, Rad. waste disposal) on nuclear reactor systems.

TASK CODE: 1.3.2

WORKER FUNCTION LEVEL AND ORIENTATION						WORKER INSTRUCTIONS	GENERAL EDUCATIONAL DEVELOPMENT		
DATA	%	PEOPLE	%	THINGS	%		REASONING	MATH	LANGUAGE
4	75	1A	5	1C	20	4	3	3	3

TASK CODE: 1.3.2

GOAL: Operate the Nuclear Power Plant

OBJECTIVE: Operate reactor auxiliary systems

TASK: Examines and evaluates instrumentation (gages, annunciator lights, meters, CRT's, switches) in assigned engineering spaces with reference to plant operating procedures for normal evolutions and personal knowledge and experience in order to determine that all equipment (pumps, valves, motors, electric switch gear) under his control are operating within prescribed limits.

PERFORMANCE STANDARDS

DESCRIPTIVE:
- Stands a vigilant watch alert to system detail.

NUMERICAL:
- Is present in assigned engineering spaces 100% of the time.
- Is apprised of Reactor Auxiliary Systems operating conditions at all times.

TRAINING CONTENT

FUNCTIONAL:
- How to scan an instrument panel.
- How to read meters and gages.
- How to integrate power plant indications.
- Knowledge of power plant systems, functions and theory.

SPECIFIC:
- Knowledge of location of instrument panels, motors, and controls.
- Knowledge of nuclear power plant components and limits.
- Knowledge of ship's Reactor Auxiliary Systems.

TASK CODE: 1.3.3

WORKER FUNCTION LEVEL AND ORIENTATION						WORKER INSTRUCTIONS	GENERAL EDUCATIONAL DEVELOPMENT		
DATA	%	PEOPLE	%	THINGS	%		REASONING	MATH	LANGUAGE
3B	60	2	20	2B	20	2	3	3	3

TASK CODE: 1.3.3

GOAL: Operate the Nuclear Power Plant

OBJECTIVE: Operate reactor auxiliary systems

TASK: Monitors instrumentation (gages, meters) in assigned spaces during normal operating procedures (startup, shutdown, maneuvering), in order to signal via telephone or P.A., control room personnel when indications differ from standard operating limits.

PERFORMANCE STANDARDS	TRAINING CONTENT
DESCRIPTIVE: - Monitors Reactor Auxiliary Systems operation, alert to system detail. **NUMERICAL:** - 100% accuracy in recognizing contradictions in instrument readings. - Is apprised of Reactor Auxiliary Systems operating conditions at all times.	**FUNCTIONAL:** - How to check indications. - How to use communication equipment. - Knowledge of nuclear power plant systems, functions and theory. - Knowledge of Reactor Auxiliary Systems. **SPECIFIC:** - Knowledge of location of instrument panels, motors and controls in assigned engineering spaces. - Knowledge of ship's Reactor Auxiliary Systems. - Knowledge of the effects of the ship's Reactor Auxiliary Systems or other nuclear power plant systems.

TASK CODE: 1.3.4

WORKER FUNCTION LEVEL AND ORIENTATION						WORKER INSTRUCTIONS	GENERAL EDUCATIONAL DEVELOPMENT		
DATA	%	PEOPLE	%	THINGS	%		REASONING	MATH	LANGUAGE
3B	40	2	20	1C	40	3	3	3	3

TASK CODE: 1.3.4

GOAL: Operate the Nuclear Power Plant

OBJECTIVE: Operate reactor auxiliary systems

TASK: Makes adjustments (manipulates), operates equipment manually and provides readings from gages, meters, valve position indicators in response to orders from control room personnel in order to get auxiliary equipment under control.

PERFORMANCE STANDARDS	TRAINING CONTENT
DESCRIPTIVE: - Checks instrument readings expeditiously. **NUMERICAL:** - 100% accuracy in reading and communicating indications.	**FUNCTIONAL:** - How to check indications. - How to use communication equipment. - Knowledge of nuclear power plant systems. **SPECIFIC:** - Knowledge of location and use of instrument panels, motors, and controls in assigned engineering spaces. - Knowledge of ship's Reactor Auxiliary Systems.

TASK CODE: 1.3.5

WORKER FUNCTION LEVEL AND ORIENTATION						WORKER INSTRUCTIONS	GENERAL EDUCATIONAL DEVELOPMENT		
DATA	%	PEOPLE	%	THINGS	%		REASONING	MATH	LANGUAGE
4	20	2	20	2B	60	4	4	3	3

TASK CODE: 1.3.5

GOAL: Operate the Nuclear Power Plant

OBJECTIVE: Operate reactor auxiliary systems

TASK: Monitors assigned equipment (pumps, valves, motors, electric switch gear), evaluates indications (gages, meters) performs "Immediate Operator Actions" from memory (checking indications, manipulating controls), notifies control room personnel, and carries out "Subsequent Operator Actions" using appropriate emergency checklists or as ordered by control room, in order to place or maintain the nuclear power plant in a safe condition.

PERFORMANCE STANDARDS

DESCRIPTIVE:

- Recognizes symptoms of casualties and carries out emergency procedures expeditiously.

NUMERICAL:

- Zero defect in recognition of symptoms of casualties and malfunctions.
- 100% accurate in implementing immediate operator actions from memory.
- 100% accurate in implementing "subsequent operator actions" using the appropriate emergency checklist.

TRAINING CONTENT

FUNCTIONAL:

- Knowledge of common casualties and/or malfunctions in assigned spaces.
- Knowledge of equipment and functions.
- How to scan and integrate many indications.
- How to manipulate equipment controls.

SPECIFIC:

- Knowledge of location of instrumentation and equipment in assigned space.
- How to implement "Subsequent operator Actions" using emergency procedures.
- Knowledge of Reactor Auxiliary Systems.
- Knowledge from memory of casualty symptoms and required immediate actions.

TASK CODE: 1.4.1

WORKER FUNCTION LEVEL AND ORIENTATION						WORKER INSTRUCTIONS	GENERAL EDUCATIONAL DEVELOPMENT		
DATA	%	PEOPLE	%	THINGS	%		REASONING	MATH	LANGUAGE
4	55	5	40	1	5	5	4	3	4

TASK CODE: 1.4.1

GOAL: Operate the Nuclear Power Plant

OBJECTIVE: Supervise and coordinate nuclear power plant operations

TASK: Tours engineering spaces observing engineering equipment (e.g., pumps, motors, turbines, control room panels) and indicators (gages, meters, switch positions, CRT's, annunciator lights), examines and evaluates all engineering logs and status boards (some data in decimals) and converses with the off going watchstander, and other watchstanders if necessary, to obtain briefing, in order to determine the actual nuclear power plant conditions and to ensure that all on-coming watchstanders are alert and fully informed of nuclear power plant status before assuming the responsibilities of the watch.

PERFORMANCE STANDARDS

DESCRIPTIVE:

- -Tours engineering spaces, alert to system detail.
- -Relieves the watch, carefully attending to all safety checks, and demeanor of watchstanders.

NUMERICAL:

- -Checks and initials all engineering logs for completeness and accuracy.
- -Is 100% accurate in recognition of contradictions between all logs, status boards and actual nuclear power plant status.

TRAINING CONTENT

FUNCTIONAL:

- Purpose and maintenance of control room logs and status boards. (Some data in decimals.)
- How to tour engineering spaces, observe engineering equipment, and interpret operating trends.
- Knowledge of nuclear power plant systems.

SPECIFIC: -Knowledge of supervisory techniques.

- Knowledge of ship's nuclear power plant logs and status boards.
- Knowledge of duties and responsibilities of all engineering watchstanders.
- Knowledge of ship's nuclear reactor systems.
- Knowledge of ship's steam propulsion systems.
- Knowledge of ship's reactor auxiliary systems.

TASK CODE: 1.4.2

WORKER FUNCTION LEVEL AND ORIENTATION						WORKER INSTRUCTIONS	GENERAL EDUCATIONAL DEVELOPMENT		
DATA	%	PEOPLE	%	THINGS	%		REASONING	MATH	LANGUAGE
5B	35	5	50	1C	15	5	5	3	4

TASK CODE: 1.4.2

GOAL: Operate the Nuclear Power Plant	**OBJECTIVE:** Supervise and coordinate nuclear power plant operations

TASK: Coordinates the engineering watchstanders in the performance of nuclear power plant evolutions ensuring the use of the appropriate procedures in the correct sequence based on standing ship's engineering orders, his own knowledge and experience, and changing nuclear power plant status in order to produce the power required by the bridge while operating nuclear power plant systems within established limits.

PERFORMANCE STANDARDS	TRAINING CONTENT
DESCRIPTIVE: - Monitors nuclear power plant system operation alert to system detail. -Evolutions are accurately and expeditiously executed. **NUMERICAL:** -100% accurate in implementing procedures. -Is apprised of nuclear power plant operating conditions at all times. -Zero failures in detection of inappropriate procedures and unsafe engineering practices (of watchstanders and repair/ maintenance personnel).	**FUNCTIONAL:** - Knowledge of nuclear power plant systems and functional inter-relationships. -How to use engineering procedures. -How to use communication equipment. -How to interrogate a computer. -Knowledge of secondary sources of information. **SPECIFIC:** -Knowledge of duties of all engineering watchstanders. -Knowledge of nuclear power plant operating characteristics. -Knowledge of nuclear power plant components and limits. -Use of nuclear power plant IC and control equipment. -Be familiar with nuclear power plant operating procedures.

TASK CODE: 1.4.3

WORKER FUNCTION LEVEL AND ORIENTATION						WORKER INSTRUCTIONS	GENERAL EDUCATIONAL DEVELOPMENT		
DATA	%	PEOPLE	%	THINGS	%		REASONING	MATH	LANGUAGE
5A	50	5	45	1C	5	5	5	3	4

TASK CODE: 1.4.3

GOAL: Operate the Nuclear Power Plant

OBJECTIVE: Supervise, and coordinate nuclear power plant operations

TASK: Evaluates the reports and recommendations of watchstanders, determines the appropriate action required and when necessary, implements the required action either by using approved nuclear power plant procedures whenever possible or by drawing from knowledge and experience when no procedure will suffice, in order to maintain the nuclear power plant in a safe condition.

PERFORMANCE STANDARDS

DESCRIPTIVE:

- -Recognizes the symptoms of casualties and carries out emergency procedure in an expeditious manner.
- -Coordinates the activities of watchstanders during casualty.

NUMERICAL:

- -Zero defect in recognition of symptoms of casualties and malfunctions.
- -100% accurate in implementing emergency procedures.

TRAINING CONTENT

FUNCTIONAL: -Knowledge of common nuclear power plant casualties and nuclear power plant system malfunctions.

- -Knowledge of nuclear power plant systems and functions.
- -How to scan and integrate panel indications.
- -How to manipulate controls.
- -Knowledge of watchstanders duties and responsibilities during casualties.

SPECIFIC: -Knowledge of ship's instrument panel layout.

- -Knowledge of nuclear plant limits and components.
- -How to use ship's communications equipment.
- -Knowledge of casualty symptoms and immediate countermeasures.
- -How to implement subsequent operator actions using appropriate checklist.

TASK CODE: 1.4.4

WORKER FUNCTION LEVEL AND ORIENTATION						WORKER INSTRUCTIONS	GENERAL EDUCATIONAL DEVELOPMENT		
DATA	%	PEOPLE	%	THINGS	%		REASONING	MATH	LANGUAGE
5A	50	5	45	16	5	5	5	3	4

TASK CODE: 1.4.4

GOAL: Operate the Nuclear Power Plant

OBJECTIVE: Supervise and coordinate nuclear power plant operations

TASK: Directs the engineering watchstanders in the performance of Emergency Operating Procedures during the threat or actual occurance of a casualty outside the engineering spaces, such as collision, grounding, ramming, on-board fire, etc., by using approved procedures or by drawing from knowledge and experience when no procedure will suffice, in order to maintain the power plant in a safe condition.

PERFORMANCE STANDARDS	TRAINING CONTENT
DESCRIPTIVE: - Recognizes probable threat and carries out emergency procedures in expeditious manner.	FUNCTIONAL: - Knowledge of possible consequences of major casualties.
NUMERICAL: - 100% accurate in implementing emergency procedures.	SPECIFIC: - Knowledge of result of emergency action - Knowledge of ship construction and location of outside compartments. - Knowledge of the nuclear power plant systems.

TASK CODE: 1.4.5

WORKER FUNCTION LEVEL AND ORIENTATION						WORKER INSTRUCTIONS	GENERAL EDUCATIONAL DEVELOPMENT		
DATA	%	PEOPLE	%	THINGS	%		REASONING	MATH	LANGUAGE
2	15	2	80	1A	5	2	3	1	4

TASK CODE: 1.4.5

GOAL: Operate the Nuclear Power Plant

OBJECTIVE: Supervise and coordinate nuclear power plant operations

TASK: Notifies higher authority (bridge, Chief Engineer, Master) by telephone in accordance with ship's watchstanding procedures to ensure that all concerned are informed when the capabilities of the nuclear power plant are limited by equipment or system malfunctions.

PERFORMANCE STANDARDS	TRAINING CONTENT
DESCRIPTIVE: -Accurate and concise reports are made to appropriate personnel in a timely manner. **NUMERICAL:** -All significant changes in plant capabilities are reported to appropriate personnel without exception.	**FUNCTIONAL:** -How to use communication equipment. -Knowledge of watchstanding procedures. -Knowledge of nuclear power plant systems and the effect of these systems on ship's propulsion capabilities. **SPECIFIC:** -How to use plant communications equipment. -Knowledge of ship's watchstanding procedures. -Knowledge of ship's nuclear power plant systems. -Knowledge of ship's nuclear power plant equipment or system malfunctions effect on overall propulsion capabilities of the ship.

TASK CODE: 2.1.1

WORKER FUNCTION LEVEL AND ORIENTATION						WORKER INSTRUCTIONS	GENERAL EDUCATIONAL DEVELOPMENT		
DATA	%	PEOPLE	%	THINGS	%		REASONING	MATH	LANGUAGE
5A	45	2	5	3A	50	4	5	3	4

TASK CODE: 2.1.1

GOAL: Maintain the nuclear power plant

OBJECTIVE: Perform maintenance and/or corrective repairs

TASK: When directed, performs maintenance and corrective repairs on the instrumentation and controls of the nuclear power plant systems, following required precautionary procedures in contaminated or radiation areas; using hand tools and precision measuring instruments (oscilloscopes, RMS voltmeters, etc); referring to check lists and technical manuals, interpreting drawings and specifications; and drawing from experience in order to maintain these components in good working condition.

PERFORMANCE STANDARDS

DESCRIPTIVE:

- Performs task expeditiously and follows precautionary procedures in hazardous areas to the letter.

NUMERICAL:

- 100% accurate in completing maintenance and repairs and recording the results.

TRAINING CONTENT

FUNCTIONAL:

- Knowledge of Fault-Finding Techniques
- Knowledge of radiation hazard
- Knowledge of instrumentation and controls
- Knowledge of precision measuring instruments
- Knowledge of technical manuals, drawings & specifications

SPECIFIC:

- Knowledge of controlled areas
- How to use oscilloscopes, RMS voltmeters and other measuring equipment
- Knowledge of the ship's instrumentation and controls and their maintenance manuals

TASK CODE: 2.1.2

WORKER FUNCTION LEVEL AND ORIENTATION						WORKER INSTRUCTIONS	GENERAL EDUCATIONAL DEVELOPMENT		
DATA	%	PEOPLE	%	THINGS	%		REASONING	MATH	LANGUAGE
5A	45	2	5	3A	50	3	4	3	3

TASK CODE: 2.1.2

GOAL: Maintain the nuclear power plant

OBJECTIVE: Perform maintenance and/or corrective repairs

TASK: When directed, performs maintenance and corrective repairs on mechanical components (Turbine-Generators, Turbine Auxiliaries, Valves and Piping, Pumps): following required precautionary procedures in contaminated or radiation areas; using hand tools (wrenches, pipe-cutters), welding and brazing equipment; refering to check lists and technical manuals; interpreting drawings and specifications; and drawing from experience in order to maintain these components in good working condition.

PERFORMANCE STANDARDS

DESCRIPTIVE:

- Performs tasks expeditiously and follows precautionary procedures in hazard areas to the letter.

NUMERICAL:

- 100% accurate in completing maintenance and repairs and recording the results.

TRAINING CONTENT

FUNCTIONAL:

- Knowledge of Fault-Finding Techniques
- Knowledge of tools, welding, and brazing
- Knowledge of radiation hazard
- Knowledge of technical manuals, drawings & specifications

SPECIFIC:

- Knowledge of control areas
- Knowledge of ship's mechnical components
- Knowledge of maintenance manuals
- Knowledge of welding & brazing techniques

TASK CODE: 2.1.3

WORKER FUNCTION LEVEL AND ORIENTATION						WORKER INSTRUCTIONS	GENERAL EDUCATIONAL DEVELOPMENT		
DATA	%	PEOPLE	%	THINGS	%		REASONING	MATH	LANGUAGE
5A	45	2	5	3A	50	3	4	3	3

TASK CODE: 2.1.3

GOAL: Maintain the nuclear power plant

OBJECTIVE: Perform maintenance and/or corrective repairs

TASK: When directed, performs maintenance and corrective repairs on electrical components (Conductors and Buses, Generators, Motors and Controllers, Switch boards, Circuits); following required precautionary procedures in contaminated or radiation areas; using hand tools and precision measuring instruments (RMS meters, power supplies, etc.) referring to checklists and technical manuals, interpreting drawings and specifications; and drawing from experience in order to maintain these components in good working condition.

PERFORMANCE STANDARDS

DESCRIPTIVE:

- Performs task expeditiously and follows precautionary procedures in hazardous areas to the letter.

NUMERICAL:

- 100% accurate in completing maintenance and repairs and recording the results.

TRAINING CONTENT

FUNCTIONAL:

- Knowledge of Fault-Finding Techniques
- Knowledge of radiation hazard
- Knowledge of electrical systems
- Knowledge of precision measuring instruments
- Knowledge of technical manuals, drawings & specifications

SPECIFIC:

- Knowledge of controlled areas
- How to use oscilloscopes, RMS voltmeters and other measuring equipment
- Knowledge of ship's electrical components

TASK CODE: 2.2.1

WORKER FUNCTION LEVEL AND ORIENTATION						WORKER INSTRUCTIONS	GENERAL EDUCATIONAL DEVELOPMENT		
DATA	%	PEOPLE	%	THINGS	%		REASONING	MATH	LANGUAGE
5B	35	5	50	1C	15	5	5	3	4

TASK CODE: 2.2.1

GOAL: Maintain the nuclear power plant

OBJECTIVE: Supervise and coordinate maintenance and repairs

TASK: Directs the workers to perform routine maintenance on equipment as scheduled (daily, weekly, monthly) as required by technical manuals or ship's operating procedures; insuring compliance with precautionary procedures (use of self-monitoring devices and protective clothing); observing when work is completed satisfactorily and properly recorded.

PERFORMANCE STANDARDS

DESCRIPTIVE:

- Effectively coordinates the activities of repair personnel in performance of maintenance tasks.

NUMERICAL:

- 100% accurate in having maintenance completed on schedule and examining the records for completeness.

TRAINING CONTENT

FUNCTIONAL:

- Knowledge of Preventive Maintenance System
- Knowledge of technical manuals operating procedures, drawings and specifications
- Knowledge of radiation hazards

SPECIFIC:

- Knowledge of the ship's Preventive Maintenance Plans
- Knowledge of the ship's Hazard Control Areas
- Knowledge of ship's plans, drawings, specifications, all equipment technical manuals and operating instructions

TASK CODE: 2.2.2

WORKER FUNCTION LEVEL AND ORIENTATION						WORKER INSTRUCTIONS	GENERAL EDUCATIONAL DEVELOPMENT		
DATA	%	PEOPLE	%	THINGS	%		REASONING	MATH	LANGUAGE
5B	35	5	50	1C	15	5	5	3	4

TASK CODE: 2.2.2

GOAL: Maintain the nuclear power plant

OBJECTIVE: Supervise and coordinate maintenance and repairs

TASK: Evaluates the impact of equipment failure on the safe operation of the nuclear power plant and directs corrective repair or reports to higher authority (Chief Engineer) that repair is beyond capacity of ship's force.

PERFORMANCE STANDARDS	TRAINING CONTENT
DESCRIPTIVE: - Recognizes the effect of equipment failure and accurately determines whether repairs are within the capabilities of ship's personnel. **NUMERICAL:** - 100% accuracy in decisions to repair equipment by ship's personnel.	**FUNCTIONAL:** - Knowledge of nuclear power plant systems and functional inter-relationships - Knowledge of Fault-Finding Techniques - Knowledge of tools and measuring instruments **SPECIFIC:** - Knowledge of ship's nuclear power plant operating characteristics and limitations - Knowledge of ship's plans, drawings, specifications, all equipment technical and operating manuals

TASK CODE: 2.2.3

WORKER FUNCTION LEVEL AND ORIENTATION						WORKER INSTRUCTIONS	GENERAL EDUCATIONAL DEVELOPMENT		
DATA	%	PEOPLE	%	THINGS	%		REASONING	MATH	LANGUAGE
5B	35	5	50	1C	15	5	5	3	4

TASK CODE: 2.2.3

GOAL: Maintain the nuclear power plant

OBJECTIVE: Supervise and coordinate maintenance and repairs

TASK: Directs the workers to perform the corrective repair insuring compliance with precautionary procedures (use of self-monitoring devices and protective clothing) observing when work is completed and that the equipment is satisfactorily tested; and reports status to higher authority.

PERFORMANCE STANDARDS	TRAINING CONTENT
DESCRIPTIVE: - Effectively coordinates the activities of the repair personnel in order to restore the power plant to working condition with minimum delay. **NUMERICAL:** - Zero failur- in having the equipment repaired, tested and working.	**FUNCTIONAL:** - Knowledge of nuclear power plant systems - Knowledge of radiation hazard - Knowledge of tool and measuring equipment - Knowledge of Fault-Finding techniques **SPECIFIC:** - Knowledge of the ship's power plant equipment including manuals, specifications and drawings - Knowledge of controlled areas - Knowledge of available tools and measuring instruments

TASK CODE: 3.1.1

WORKER FUNCTION LEVEL AND ORIENTATION						WORKER INSTRUCTIONS	GENERAL EDUCATIONAL DEVELOPMENT		
DATA	%	PEOPLE	%	THINGS	%		REASONING	MATH	LANGUAGE
3B	45	2	5	2A	50	4	5	3	4

TASK CODE: 3.1.1

GOAL: Provide protection from nuclear hazards

OBJECTIVE: Monitor level of shipboard radiation

TASK: Performs airborne particulate and smear surveys in all ship's spaces as required by ship's radiological controls procedures and schedules using high volume air samplers and surface contamination swipes in order to obtain samples for analysis on a regular basis to determine the level of airborne and surface radiation throughout the ship.

PERFORMANCE STANDARDS	TRAINING CONTENT
DESCRIPTIVE: -Properly uses air samplers and swipes to collect samples.	**FUNCTIONAL:** -Knowledge of radiological controls fundamentals and survey equipment
NUMERICAL: -Surveys and samples all required points at the required times.	**SPECIFIC:** -Knowledge of ship's radiological controls procedures and schedules

TASK CODE: 3.1.2

WORKER FUNCTION LEVEL AND ORIENTATION						WORKER INSTRUCTIONS	GENERAL EDUCATIONAL DEVELOPMENT		
DATA	%	PEOPLE	%	THINGS	%		REASONING	MATH	LANGUAGE
1	50	2	5	2B	45	4	5	3	4

TASK CODE: 3.1.2

GOAL: Provide protection from nuclear hazards

OBJECTIVE: Monitor level of shipboard radiation

TASK: Analyzes (in ship's radiological laboratory) air samples and swipes for subsequent alpha, beta or gamma activity using standard instruments and procedures, specified in ship's radiological control procedures and logs results in order to determine and document the level of airborne and surface radiation throughout the ship's living spaces on a regular basis.

PERFORMANCE STANDARDS

DESCRIPTIVE:

- Accurately determines airborne and surface radiation level in ship's living spaces.

NUMERICAL:

- 100% accurate in determination of alpha, beta or gamma activity in samples.
- Maintains accurate records of all analyses results.

TRAINING CONTENT

FUNCTIONAL:

- Knowledge of radiological controls fundamentals
- Knowledge of alpha, beta and gamma activity analysis equipment
- Knowledge of laboratory procedures and records.
- Knowledge of 10CFR20 Regulations

SPECIFIC:

- Knowledge of ship's radiological controls procedures and required records
- Familiar with ship's laboratory and analysis equipment

TASK CODE: 3.1.3

WORKER FUNCTION LEVEL AND ORIENTATION						WORKER INSTRUCTIONS	GENERAL EDUCATIONAL DEVELOPMENT		
DATA	%	PEOPLE	%	THINGS	%		REASONING	MATH	LANGUAGE
3B	45	2	5	2A	50	4	5	3	4

TASK CODE: 3.1.3

GOAL: Provide protection from nuclear hazards

OBJECTIVE: Monitor level of shipboard radiation

TASK: Draws samples of radioactive liquid effluent from sample points in tanks, process lines and equipment of the liquid waste disposal system using standard sampling equipment as specified in ship's radiological controls procedures in order to obtain samples for the analysis and determination of the effluent's radioactivity concentration.

PERFORMANCE STANDARDS	TRAINING CONTENT
DESCRIPTIVE: -Properly uses effluent sampling equipment to draw samples.	**FUNCTIONAL:** -Knowledge of radiological controls fundamentals -Knowledge of standard radioactive liquid effluent sampling procedures and equipment
NUMERICAL: -Properly draws water samples from all sample points at the required times with zero defect.	**SPECIFIC:** -Knowledge of ship's radiological controls procedures and schedules -Knowledge of location of ship's liquid waste disposal system sample points

TASK CODE: 3.1.4

WORKER FUNCTION LEVEL AND ORIENTATION						WORKER INSTRUCTIONS	GENERAL EDUCATIONAL DEVELOPMENT		
DATA	%	PEOPLE	%	THINGS	%		REASONING	MATH	LANGUAGE
4	50	2	5	2B	45	4	5	3	4

TASK CODE: 3.1.4

GOAL: Provide protection from nuclear hazards

OBJECTIVE: Monitor level of shipboard radiation

TASK: Analyzes (in ship's radiological laboratory) liquid effluent samples drawn from the liquid waste disposal system using standard instruments and procedures specified in ship's radiological controls procedures, with reference to 10CFR20 Regulations, and records results, in order to determine and document the concentration of radioactivity present in the effluent and the dilution required for compliance with 10CFR20 before the effluent can be released to the environment.

PERFORMANCE STANDARDS

DESCRIPTIVE:

- Accurately determines concentration of radioactivity in effluent samples and dilution required before effluent release.

NUMERICAL:

- 100% accurate in determination of radioactivity concentration of samples.
- Liquid effluents released in strict compliance with 10CFR20 Regulations with zero defect.
- Maintains accurate records of all analysis results.

TRAINING CONTENT

FUNCTIONAL:

- Knowledge of radiological controls fundamentals
- Knowledge of standard radioactive liquid effluent analysis procedures and equipment
- Knowledge of laboratory procedures and records
- Knowledge of 10CFR20 Regulations

SPECIFIC:

- Knowledge of ship's radiological controls procedures and required records
- Familiar with ship's laboratory and analysis equipment

TASK CODE: 3.2.1

WORKER FUNCTION LEVEL AND ORIENTATION						WORKER INSTRUCTIONS	GENERAL EDUCATIONAL DEVELOPMENT		
DATA	%	PEOPLE	%	THINGS	%		REASONING	MATH	LANGUAGE
4	60	2	5	1C	35	4	4	3	4

TASK CODE: 3.2.1

GOAL: Provide protection from nuclear hazards

OBJECTIVE: Monitor level of personnel exposure

TASK: Examines and records personnel dosimetry readings monthly with reference to ship's Radiological Controls Program in order to determine that ship's personnel exposure to radiation is within the prescribed limits of 10CFR20 and to take corrective action (e.g. additional training, limit access to restricted areas) if required.

PERFORMANCE STANDARDS

DESCRIPTIVE:

- Accurately examines and records personnel dosimetry readings.

NUMERICAL:

- Maintains accurate exposure records of all assigned personnel.
- 100% accurate in taking dosimetry readings.

TRAINING CONTENT

FUNCTIONAL:

- Knowledge of Radiological Controls fundamentals
- Knowledge of personnel dosimetry equipment
- Knowledge of health physics records

SPECIFIC:

- Knowledge of ship's personnel dosimetry equipment
- Knowledge of ship's personnel exposure records

TASK CODE: 3.2.2

WORKER FUNCTION LEVEL AND ORIENTATION						WORKER INSTRUCTIONS	GENERAL EDUCATIONAL DEVELOPMENT		
DATA	%	PEOPLE	%	THINGS	%		REASONING	MATH	LANGUAGE
4	55	2	15	1C	3	4	4	3	4

TASK CODE: 3.2.2

GOAL: Provide protection from nuclear hazards

OBJECTIVE: Monitor level of personnel exposure

TASK: Issues self-reading pocket dosimeters, personal exposure records and other dosimetry equipment (monitors with audio alarms, T.L.D., film badges) to members of the crew designated as radiation workers and shipyard maintenance personnel and verifies (reads and signs) daily and cumulative doses recorded by the worker on the personal exposure record card in order to ensure that workers in high radiation areas are not exposed beyond the limits in 10CFR20.

PERFORMANCE STANDARDS

DESCRIPTIVE:

- Makes special dosimetry equipment available to workers in high radiation areas.
- Closely monitors exposure records of these workers.

NUMERICAL:

- Issues special dosimetry equipment to all workers in high radiation areas.
- 100% accurate in detection of approach to out-of-limits exposure of any worker.

TRAINING CONTENT

FUNCTIONAL:

- Knowledge of dosimetry equipment and exposure records.
- Knowledge of 10CFR20 Regulations

SPECIFIC:

- Knowledge of workers who are assigned to work in areas of high radiation.
- Knowledge of ship's dosimetry equipment and exposure records

TASK CODE: 3.2.3

WORKER FUNCTION LEVEL AND ORIENTATION						WORKER INSTRUCTIONS	GENERAL EDUCATIONAL DEVELOPMENT		
DATA	%	PEOPLE	%	THINGS	%		REASONING	MATH	LANGUAGE
5B	20	4B	60	2B	20	5	5	3	4

TASK CODE: 3.2.3

GOAL: Provide protection from nuclear hazards

OBJECTIVE: Monitor level of personnel exposure

TASK: Conducts ongoing Radiation Protection Training Program consisting of periodical lectures to ship's personnel and indoctrination lectures to newly assigned personnel and visitors using films and other audio-visual equipment in order to increase personnel's awareness of the radiation hazard and the protective measures available (warning signs, zoning, audio alarms, dosimetry, special clothing and equipment).

PERFORMANCE STANDARDS

DESCRIPTIVE:

- Presents material interestingly and cogently with emphasis on personnel and ship's safety.

NUMERICAL:

- Lectures all personnel on the effects of radiation and protective measures.

TRAINING CONTENT

FUNCTIONAL:

- Knowledge of radiation protection and health physics
- Knowledge of training aids and lecturing and demonstration techniques

SPECIFIC:

- Knowledge of ship's Radiological Controls Program and protective equipment
- Knowledge of ship's training aids available

APPENDIX B

SOURCES OF INFORMATION AND REVIEW IN THE ANALYSIS

SOURCES OF INFORMATION

Information on the operation of nuclear power plants, including shipborne, was obtained from a number of sources. Captain Maurice A. Gross, with the U.S. Merchant Marine Academy, Kings Point, New York, provided information on the qualifications and training of the engineering personnel of the NS SAVANNAH and arranged for the use of the Final Safeguards Report and Reactor Plant Operating Manual of the NS SAVANNAH.[1] Mr. Jerry Holman, who had been a Second Assistant Engineer onboard NS SAVANNAH, also provided information concerning the operations of this ship.

The data concerning the proposed new nuclear ships was obtained from Dr. Zelvin Levine of the Office of Advanced Development, Maritime Administration. He provided access to the Preliminary Safety Analysis Report (PSAR) on the Competitive Nuclear Merchant Ship Program.[2]

Information concerning the qualifications of personnel operating stationary nuclear power plants was selected from a number of sources. The principal documents used were an NRC (AEC) publication, Utility Staffing and Training for Nuclear Power,[3] and an American National Standards Institute standard,

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[1] Babcock and Wilcox, Final Safeguards Report, Nuclear Merchant Ship Reactor, States Marine Lines, Inc. Lynchburg, Virginia: Babcock and Wilcox, January 1960, 5 vols.

[2] Babcock and Wilcox, Competitive Nuclear Merchant Ship Program Preliminary Safety Analysis Report. U.S. Maritime Administration, Lynchburg, Virginia: Babcock and Wilcox, April 1974, 5 vols.

[3] Atomic Energy Commission, Utility Staffing and Training for Nuclear Power, Washington, D.C., June 1973.

Selection and Training of Nuclear Power Plant Personnel.[4] Experienced General Physics personnel provided information on the operation of utility plants presently generating electrical power.

The data on Navy nuclear power operations was gained exclusively from the experience of General Physics' personnel since the Navy documents could not be made available. The persons contacted are listed below and brief resumes of their qualifications are provided.

John H. Beakes, Senior Engineer. Mr. Beakes was the Engineering Officer of a fleet ballistic submarine during the period 1972-1974. He supervised the operation, testing, and maintenance of the nuclear power plant and was responsible for the training of the engineering personnel.

Raymond C. Francis, Training Specialist. Mr. Francis is responsible for the development of training materials and implementation of training programs for both licensed operators and unlicensed personnel at commercial nuclear power plants. He has eight years of Navy experience, including duty on a nuclear-powered surface ship as a qualified electrical operator, and was responsible for the training and certification of nuclear power plant operators.

Albert M. Mangin, Senior Engineer. Mr. Mangin is responsible for developing and coordinating training programs for NRC operator license applicants. He has four years experience in the U.S. Navy in the nuclear power program, including duty on a nuclear-powered surface ship as Reactor Controls Division Officer, Engineering Officer of the Watch, and Engineering Duty Officer. He was also responsible for the requalification training program for all the ship's nuclear power plant operators.

David R. Roth, Senior Engineer. Mr. Roth is in charge of programs to determine the qualifications of prospective applicants for NRC operator licenses and is responsible for developing operator and technician training programs. He has five years experience in the U.S. Navy, including duty on a fleet ballistic submarine in the Reactor Control, Electrical, Mechanical, and Auxiliary Divisions. He also worked as a reactor operator examiner in the Division of Operator Licensing of the Atomic Energy Commission and was responsible for the preparation, administration and evaluation of examinations administered to personnel at civilian nuclear power generating stations.

Robert J. Howarth, Training Specialist. Mr. Howarth is a training specialist conducting classroom instruction in electrical and electronic instrumentation. His eight years of experience in the U.S. Navy includes successful completion of nuclear power school and two and one-half years fleet experience as a qualified reactor operator on a fleet ballistic missile nuclear submarine. During this period, he served as leading reactor operator, assistant training coordinator, and reactor operator instructor. He also was employed by Virginia Electric and Power Company as a senior nuclear controls technician at the North Anna Power Station.

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[4] American National Standards Institute, Inc., Selection and Training of Nuclear Power Plant Personnel, New York, New York, March 1971.

Albert R. Shawver, Training Specialist. Mr. Shawver is a training specialist conducting operational training on pressurized water reactor utility power plants. His eight years of experience in the U.S. Navy includes successful completion of nuclear power school and fleet experience as an engineroom supervisor on a fleet ballistic missile nuclear submarine. He operated and maintained all reactor plant and steam plant mechanical systems and was responsible for performing welding repairs. He also was a senior instructor at the Knolls Atomic Power Laboratory conducting training sessions in both mechanical and reactor operations.

Frederick B. Lobbin, Senior Engineer. Mr. Lobbin is manager of a group that provides consulting services to the nuclear utility industry in the areas of plant operation, quality assurance, licensing, startup test programs, records management, scheduling, and in other areas related to the operation phase of nuclear power plants. In addition to his knowledge of stationary nuclear power plant systems, he is familiar with nuclear merchant ship operation. He was a major contributor to the revisions of the NS SAVANNAH technical specifications. Mr. Lobbin is a graduate of the New York Station Maritime College and holds a U.S. Coast Guard license as a Third Assistant Engineer (steam or diesel, horsepower unlimited) in the Merchant Marine, and has had engineroom responsibility aboard a 20,000 shp turbo-electric ship.

REVIEWERS

The following representatives of the Merchant Marine were asked to review:

1. Captain M.J. Gross, USMS
   United States Merchant Marine Academy
   Kings Point, New York
   (Nuclear Merchant Ship Officer Training Programs)

2. Mr. Frank Boland
   Director of National Maritime Union
   Upgrading and Retraining School
   (Maritime Union)

3. Mr. Fred Schamann
   Director of Research
   Marine Engineers Benevolent Association
   (Maritime Union)

4. Mr. Eugene P. Spector
   Research Director
   National Maritime Union
   (Maritime Union)

5. Mr. Gilbert La Dona
   Calhoun-MEBA Engineering School
   (Maritime Union)

General Physics personnel not involved in the performance of the analysis also reviewed the task data for accuracy of content. They include Messrs. Roth, Howarth, Beakes, and Shawver, whose qualifications were previously summarized.

ORI study team members and Dr. Sidney A. Fine, developer of FJA, reviewed the task analysis data from the standpoint of methodology.

APPENDIX C

THE HAZARDS ASSOCIATED WITH NUCLEAR-POWERED MERCHANT SHIPS

INTRODUCTION

The purpose of this appendix is to identify the hazards associated with the use of pressurized water reactors onboard merchant ships as a result of normal operations and reactor accidents. Radioactive materials onboard merchant ships do not pose a threat to man unless they are released to the biosphere and granted access to a critical pathway to man in significant concentrations. Considerable research has been conducted in determination of what these concentrations are for each radionuclide. Title 10 of the Code of Federal Regulations Part 20 (10CFR20) Appendix B provides standards for isotope concentrations in air and water above the natural background for restricted and unrestricted areas. These standards are applicable to those activities under licenses issued by the Nuclear Regulatory Commission. In order to operate well within these limits, the Nuclear Power Directorate of the Naval Ship Systems Command has promulgated standards for all U.S. Naval nuclear-powered ships which are more stringent than those established in 10CFR20.

Detailed discussions of the following topics will be presented in this appendix:

- Sources of radiation in a nuclear power plant
- Safety measures used to protect personnel and the environment from radiation hazards
- The collection, processing, and disposal of radioactive wastes which are produced during the normal operation of a nuclear power plant
- Reactor accidents.

RADIATION SOURCES

There are four general sources of radiation encountered in a nuclear power plant: (1) the reactor core, (2) the reactor shield and structural materials, (3) the reactor coolant, and (4) miscellaneous liquid, gaseous, and solid wastes.

During reactor operation, large quantities of both neutrons and gamma rays are produced in the reactor core by the fission process. The neutrons produced interact with the reactor coolant and the structural materials within the core to produce gamma rays. In addition to those produced directly by the fission process, large quantities of gamma rays are produced in the reactor core as a result of fission product decay, activation product decay, neutron inelastic scattering and neutron absorption reactions. Some of the neutrons escape from the core and interact with materials in the surrounding regions, creating additional sources of gamma rays. The radioactive nuclei in the reactor coolant are also carried outside the core, providing more sources of gamma rays. Table C.1 summarizes the sources of radiation during reactor operation.

TABLE C.1

PRINCIPAL RADIATION SOURCES DURING REACTOR OPERATION

Location	Neutron Sources	Gamma Ray Sources
Reactor Core	Fission Process	Fission Process Fission Product Decay Activation Product Decay Neutron Inelastic Scattering (n,γ) Reactions
Reactor Coolant	None	Fission Product Decay Activation Product Decay
Shield and Structural Materials	None	Activation Product Decay Neutron Inelastic Scattering (n,γ) Reactions

When the reactor is shut down, the source of neutrons and gamma rays due to the fission process is eliminated, but some of the gamma ray sources produced prior to shutdown are still present. Table C.2 summarizes the sources of radiation after reactor shutdown.

TABLE C.2

PRINCIPAL RADIATION SOURCES AFTER REACTOR SHUTDOWN

Location	Neutron Sources	Gamma Ray Sources
Reactor Core	None	Fission Product Decay Activation Product Decay
Reactor Coolant	None	Fission Product Decay Activation Product Decay
Shield and Structural Materials	None	Activation Product Decay

The reactor coolant is a particularly important source of radiation in a nuclear power plant. The buildup of radioactivity in the reactor coolant governs, to a large degree, the radiation levels in which nuclear power plant operators must perform their jobs. The radiation level also dictates the amount of treatment for liquid wastes before they can be discharged to the environment. As shown in Tables C.1 and C.2, the reactor coolant contains a gamma ray source resulting from fission product decay and activation product decay.

Fission products reach the reactor coolant in two general ways. The first is by direct recoil, where fission product nuclei, born inside or on the surface of the cladding, rebound directly into the coolant. Although the average path length of fission product nuclei is very short, there is a small but finite probability that they will penetrate the cladding. The second way in which fission products reach the reactor coolant is through defects which can occur in the cladding. The amount of fission products which reach the reactor coolant in this way can vary widely, depending on the reactor power level and the number and size of the defects.

There are two general classes of fission products, volatile fission products called fission product gases, which tend to separate from the reactor coolant, and non-volatile fission products which tend to go into solution or suspension in the reactor coolant. The principal volatile fission products are isotopes of the noble gases xenon and krypton, and small quantities of iodine. Xenon and krypton decay to the non-volatile elements cesium and rubidium, respectively. Rubidium decays to strontium and is the source of the biologically important isotope ^{90}Sr. Though classified as volatile, a significant portion of the iodine remains in solution.

In a pressurized water reactor, the fission product gases remain in the reactor coolant system and tend to collect in the gas space of the volume control tank. Most of the noble gases are relatively short-lived. Those which are not removed decay to their non-volatile daughter products which reenter the coolant.

The principal volatile fission products in the coolant are the longer-lived isotopes of iodine which remain in solution. The non-volatile daughter products of fission product gases, such as cesium, rubidium, and strontium, together with lesser amounts of non-volatile isotopes, such as ^{95}Zr, ^{95}Nb, ^{99}Mo, ^{99}Tc, ^{140}Ba, ^{132}La, ^{132}Te and ^{144}Ce, are also commonly found in the reactor coolant. Non-volatile fission products are removed in the reactor coolant purification system by the demineralizer. However, a large percentage adhere to surfaces in the reactor coolant system and are difficult to eliminate. Decay is the principal removal mechanism for short-lived isotopes. During reactor operation, the contribution of fission product decay to the radiation levels around the reactor coolant system is small compared to that of activation product decay. However, many of the fission products are relatively long-lived and remain a source of radiation after reactor shutdown. This radiation source complicates refueling and maintenance.

Activation products arise in the reactor coolant as a result of the activation of corrosion products suspended or dissolved in the reactor coolant and activation of the reactor coolant itself. The materials in the construction of the reactor coolant system and components include stainless steel (consisting primarily of iron, chromium, nickel and manganese); inconel (consisting primarily of chromium and nickel, with lesser amounts of iron, manganese and copper); zircaloy (consisting primarily of zirconium) and carbon steel (consisting primarily of iron, with small amounts of manganese). In addition, nickel is invariably found with cobalt. Table C.3 lists the wide variety of activation products which can be formed from these constituents of the reactor coolant system and components. These activation products are commonly referred to as activated corrosion products because they are released to the reactor coolant as the structural materials corrode or erode. Some of these activated corrosion products remain in solution and are continuously circulated throughout the reactor system. Large amounts of these products, however, are converted to various insoluble oxide forms which are commonly called crud. Some of the crud is filtered out in the reactor coolant purification system, and some if it remains suspended in the reactor coolant to be continuously circulated. Much of the crud is deposited on the surfaces of the reactor coolant system. The high temperature heat transfer surfaces of the reactor fuel rods and any relevant stagnant areas such as crevices are particularly susceptible to crud deposition.

The largest source of activation products in the reactor coolant during high power operation results from activation of the reactor coolant. Fortunately, most of these activation products are very short-lived so that this source of radiation disappears rapidly after shutdown. Table C.4 lists some of the activation products which can be formed in the reactor coolant. From a radiological standpoint during normal full power operation, ^{16}N is by far the most important of the activation products formed in the reactor coolant because of its relatively large formation rate and the high energy gamma rays which are emitted when it decays.

TABLE C.3

ACTIVATED CORROSION PRODUCTS OBSERVED IN REACTOR COOLANT

Activated Corrosion Product	Gamma Energy (Mev)	Gammas Per Disintegration	Half-Life	Production Reaction	Cross Section (barns)	Source
^{54}Mn	0.83	1.00	312 days	$^{54}Fe(n,p)^{54}Mn$	0.057	Iron in steel
^{56}Mn	0.84	0.50	2.58 hr	$^{55}Mn(n,\gamma)^{56}Mn$	13.3	Manganese in steel
	1.81	0.30				
	2.11	0.20				
^{64}Cu	1.34	0.005	12.7 hr	$^{63}Cu(n,\gamma)^{64}Cu$	4.5	Copper in structural materials
^{51}Cr	0.32	0.098	27.7 days	$^{50}Cr(n,\gamma)^{51}Cr$	17	Chromium in steel or Inconel
^{59}Fe	1.10	0.57	44.6 days	$^{58}Fe(n,\gamma)^{59}Fe$	1.2	Iron in steel
	1.29	0.43				
^{58}Co	0.81	1.00	7.13 days	$^{58}Ni(n,p)^{58}Co$	1.23	Nickel in steel or Inconel
^{60}Co	1.17	1.00	5.27 yrs.	$^{59}Co(n,\gamma)^{60}Co$	19	Cobalt in high cobalt alloys or in nickel
	1.33	1.00				
^{95}Zr	0.723	0.49	65.5 days	$^{94}Zr(n,\gamma)^{95}Zr$	0.08	Zircaloy in fuel rod cladding
	0.756	0.49				
^{95}Nb	0.765	1.00	35.1 days	$^{95}Zr \rightarrow {}^{95}Nb$		Zircaloy in fuel rod cladding
^{97}Zr	0.743	0.92	16.8 hr	$^{96}Zr(n,\gamma)^{97}Zr$	0.05	Zircaloy in fuel rod cladding
^{97}Nb	0.658	0.98	73.6 min	$^{97}Zr \rightarrow {}^{97}Nb$		Zircaloy in fuel rod cladding

TABLE C.4

ACTIVATION PRODUCTS PRODUCED IN REACTOR COOLANT

Activation Product	Gamma Energy (Mev)	Gammas Per Disintegration	Half-Life	Production Reaction	Cross Section (barns)	Source
^{13}N		None	9.97 min	$^{16}O(p,\alpha)^{13}N$		Oxygen in water
^{17}N	2.19	0.005	4.16 sec	$^{17}O(n,p)^{17}N$		Oxygen in water
	0.87	0.03				
^{16}N	7.12	0.20	7.11 sec	$^{16}O(n,p)^{16}N$	$2x10^{-5}$	Oxygen in water
	6.13	0.55				
^{3}H		None	12.33 yr	Fission		Ternary fission
				$^{2}H(n,\gamma)^{3}H$		Deuterium in water
				$^{10}B(n,\alpha)^{7}Li$		Boron in chemical shim
				$^{6}Li(n,\alpha)^{3}H$		Lithium for pH control
				$^{7}Li(n,n\alpha)^{3}H$		Lithium for pH control

Tritium, ^{3}H, is an isotope of hydrogen which is produced in reactors in significant amounts. It decays by beta emission to ^{3}He. No gamma radiation accompanies this decay. For this reason, tritium is not a significant contributor to radiation levels during power operations or shutdown. Because of its relatively long half-life and chemical characteristics, however, it is of great concern with respect to waste disposal. Other liquid, gaseous, and solid wastes generated during the operation of nuclear power plants are important sources of radiation while they are being processed by the waste treatment facilities or being stored. In this respect they constitute a radiation protection problem as well as a waste treatment problem.[1]

RADIATION PROTECTION

Reactor shielding is designed to reduce the exposure of individuals and equipment to ionizing radiation. The Preliminary Safety Analysis Report (PSAR) for the Competitive Nuclear Merchant Ship Program sets the following major shielding design objectives:

[1] R.W. Deutsch, F.B. Lobbin, and W.R. Scott, Jr., Practical Nuclear Power Plant Technology, 3rd ed., Columbia Maryland: General Physics Corporation, 1974.

1. Normal Operation and Anticipated Operation Occurrences - to ensure that radiation dosages to crew members and to the general public are within the exposure limits set forth in 10CRF20 and 10CFR50, and that they are as low as practicable.

2. Emergency Conditions - to ensure that crew members are adequately protected and to preclude undue hazards to the general public.

3. Shield Optimization - to provide an efficient design that will afford maximum protection with minimum shield weight.

Radiation zones are assigned to all regions throughout the plant and ship indicating the radiation environment. In order for an area to have unlimited access for unlimited periods, the radiation levels must be low enough so that an individual cannot receive a dose of 2.5 mrem in any hour or 100 mrem in five consecutive days. Any area in which the radiation levels are in excess of those prescribed for an uncontrolled area, must be designated as a controlled area. If the radiation level in a controlled area is greater than 5 mrem per hour but less than 100 mrem per hour, the area is designated as a "Radiation Area." Any area within a controlled area in which the radiation level is greater than 100 mrem per hour is designated as a "High Radiation Area."[2]

Controlled and limited access areas are identified by warning signs. Access to all controlled areas must be through controlled check points. Limited access areas can be entered only after the radiation levels are determined and working time limits established. If the radiation is too high, the radiation level may be reduced by shutting down the reactor or using temporary shielding.

Adequate shielding must be provided so that access is permitted to the reactor controls, gauges, meters and manually-operated valves as well as access to equipment in need of inspection, preventive maintenance or repair. Also, it is necessary to have access for the processing and disposal of radioactive waste. In addition to biological protection, the shield design involves limiting radiation damage to equipment and materials and reducing neutron activation of equipment and piping. Other shield design considerations involve penetration location, determination of supplementary shielding requirements, residual radiation and abnormal conditions.

Radiation zone designations are based on permissible doses, levels, and concentrations contained in 10 CFR20. Recommended maximum allowable whole body doses are: 5 rem in any year, 1-1/4 rem in any quarter of a year (this can be raised to 3 rem under certain circumstances), and accumulated lifetime dose of 5 (N-18) rem where N is the age of the individual. A weekly guideline of 100 mrem per week during normal operations is sometimes observed. If an

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[2] Competitive Nuclear Merchant Ship Program Preliminary Safety Analysis Report, U.S. Maritime Administration. Lynchburg, Virginia: Babcock and Wilcox, April 1974, 5 volumes.

individual's exposure reaches the 10CFR20 limit, the person must not be exposed further. In addition to these limits, Regulatory Guides 8.8 and 8.10 require that exposures be kept "as low as practicable" under all conditions. What is "practicable" is determined by the state of technology and by the economic costs and benefits of reducing exposure.[3]

In conjunction with shielding, zoning, signs, signals, and controls, a comprehensive program of crew health physics lectures, visitors' briefings, area surveillance and contamination control surveys will contribute to the effort of keeping shipboard exposures as low as practicable during all evolutions. In addition to receiving health physics lectures, those persons using protective clothing should be instructed in their proper use. Dosimeters will be used by all personnel with appropriate daily exposure readings taken and records maintained. Protective clothing and respiratory equipment will be readily available for use in areas of significant contamination or airborne radioactivity. Airborne monitors will operate continuously to detect alpha, beta, or gamma activity in the work atmosphere and Smear surveys will be conducted to detect surface contamination. Those areas not normally monitored will be routinely surveyed by health physics personnel for possible contamination. An active program combining all of these safeguards will result in the early detection and containment of contamination.[4]

RADIOACTIVE EFFLUENTS

During its normal operation, a nuclear power plant produces gaseous, liquid, and solid radioactive by-products which are of no use in the plant, much like the ash or slag which forms in a coal- or oil-fired power plant. Due to the radioactive nature of these wastes, special radioactive waste treatment systems are required to collect and process these wastes.

Three basic techniques are broadly applied in radioactive waste management systems: (1) delay and decay, (2) dilute and disperse, and (3) concentrate and contain. The disposal technique used is a function of the waste's degree of radioactivity, half-life and form. The delay and decay technique applies to radioactive materials with reasonably short half-lives, which are retained at the site where they are generated until their natural decay rate has caused the radioactivity to dissipate (generally a period equal to about ten half-lives of the particular radioisotope). The dilute and disperse technique is appropriate for wastes of low radioactivity which can be reduced to permissible levels for release into the environment by dilution. Concentrate and contain applies to solid waste materials which have been separated, compressed and packaged for transfer ashore.[5]

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[3] Deutsch, op. cit.

[4] Babcock and Wilcox, op. cit.

[5] The Environmental Impact of Electrical Power Generation: Nuclear and Fossil, WASH 1261. Washington, D.C.: Government Printing Office, 1973

The radioactive fission products gases of prime interest and concern are the noble gases xenon and krypton. Other gases are produced, but they are of less concern due to their small quantities and short lives. Iodine may be released in small amounts as gas, depending upon the release path and the solubility of the iodine containing medium. Table C.1 lists the major fission gases which are processed by the gaseous radioactive waste system of a typical pressurized water reactor with the estimated specific activity of each isotope.[6]

TABLE C.1

RADIOACTIVE FISSION GAS WASTES

Isotope	Half-Life	Max. Activity (μCi/ml)
^{83}Kr m	1.86 hr	0.288
^{85}Kr m	4.4 hr	1.53
^{85}Kr	10.74 yr	3.15
^{87}Kr	76 min.	0.837
^{88}Kr	2.79 hr	2.68
^{131}Xe m	11.96 day	2.25
^{133}Xe m	2.26 day	2.84
^{133}Xe	5.27 day	249.00
^{135}Xe m	15.7 min	0.926
^{135}Xe	9.16 hr	5.08
^{138}Xe	14.2 min	0.511

NOTE: m indicates metastable state.

The relatively small amounts of fission gases produced in a pressurized water reactor are periodically stripped from the reactor coolant and stored in tanks to permit the shorter-lived isotopes to decay. The bulk of the radioactivity ultimately released to the atmosphere consists of the relatively long-lived isotopes of krypton and xenon, such as ^{85}Kr and ^{133}Xe.

The Competitive Nuclear Merchant Ship PSAR states that the release from the gaseous radioactive waste system will be to the main stack, having

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[6] Duetsch, op. cit.

a minimum elevation of approximately 41 meters above sea level. Controlled releases will normally be made in the open sea at least 20 miles from the nearest shoreline with the ship at a speed of at least 4 knots. The PSAR stipulates that the consequences of predicted gaseous releases are in conformance with the guidelines of 10CFR50, Appendix I.

The major sources of solid wastes in a pressurized water reactor are demineralized resins and miscellaneous contaminated and activated solids such as filter elements, tools, containers, rags and maintenance parts. Demineralized resins are generally dehydrated, dumped into 55 gallon drums, and mixed with concrete. Shielded casks are required to store and transport the worn-out filter elements from filter-demineralizers. The paper, rags and other compressible materials are compacted and baled for handling and storage. The PSAR stipulates that the system that fills, seals and stores tanks or drums containing solid waste is designed to protect operating personnel and contain all radioactive materials for offsite disposal. The transfer and disposal of solid radioactive waste is governed by 10CFR20, 71, and 73, and Department of Transportation regulations 49CFR173 and 178. The nuclear merchant ship solid radioactive waste will not present a radiation hazard to the marine environment during normal operations.

The major sources of liquid wastes are reactor coolant blowdown, equipment drains, leaky valves and fittings, and solutions used to regenerate demineralizers. The sources of radiation in these liquids are non-volatile fission products, activated corrosion products and activated products formed in the reactor coolant. Several treatment methods are commonly used for liquid wastes, including holdup, filtration, demineralization and evaporation. The type of treatment used depends on the condition of the waste. If the water is reasonably pure, it may be economical to demineralize it and return it to the reactor coolant system. If the water has a high content of solids, concentration may be the best method.[7]

The principal fission products which are produced by liquid radioactive waste systems are iodine, cesium, rubidium, and strontium. Table C.2 presents a list of fission product isotopes normally processed by a pressurized water reactor liquid radioactive waste system along with typical activities of each.[8]

The bulk of liquid releases from shipboard reactors occurs when reactor coolant water expands as a result of being heated to operating temperature. Before release the coolant is passed through a purification system ion exchange resin bed. The radionuclides present in the coolant which represent the principle source of radioactivity are reactor plant corrosion and wear products including tungsten 187, chronium 51, hafnium 181, iron 59, zirconium 95

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[7] Ibid.

[8] Ibid.

TABLE C.2

FISSION PRODUCT ISOTOPES
IN PRESSURIZED WATER REACTOR LIQUID WASTES

Isotope	Typical Activity (μCi/ml)
Rb-88	2.70×10^{-2}
Sr-89	4.51×10^{-5}
Sr-90	1.46×10^{-6}
Sr-91	2.85×10^{-4}
Sr-92	8.72×10^{-5}
Y-90	1.01×10^{-2}
Y-91	5.66×10^{-2}
Mo-99	4.12
I-131	3.23×10^{-2}
I-132	2.25×10^{-2}
I-133	3.78×10^{-2}
I-134	4.58×10^{-3}
I-135	1.90×10^{-2}
Cs-134	4.09
Cs-136	0.740
Cs-137	12.7
Cs-139	0.734
Ba-137m	11.7
Ba-139	7.60×10^{-4}
Ba-140	5.63×10^{-5}
La-140	2.25×10^{-5}
Ce-144	5.18×10^{-6}

tantalum 182, manganese 54, cobalt 58, and cobalt 60. Cobalt 60 with a 5.3 year half-life is the predominant radionuclide present and also has the most restrictive concentration limit in water.[9]

[9] M.E. Miles, G.L. Sjoblom and R.D. Burke, "Environmental Monitoring and Disposal of Radioactive Wastes from U.S. Naval Nuclear-Powered Ships and Their Support Facilities, 1973," Radiological Health Data and Reports, Vol. 15, No. 9 (Oct. 1974), pp. 625-646.

A major problem in liquid waste disposal is tritium, ^3H, an isotope of hydrogen which is produced in reactors in significant amounts. Being an isotope of hydrogen, tritium will form tritiated water and cannot be removed from liquid waste by normal filtration and distillation processes. It decays by beta emission to ^3He. There are no gamma rays which accompany this decay. Tritium is formed in a variety of ways in a nuclear reactor, the two most important being ternary fissions and boron activation. About one of every 12,500 fissions is a ternary fission, in which a tritium atom and two other fission products are formed. In a typical nuclear power plant, this reaction leads to the production of about 10,000 curies of tritium per year of full power operation. Most of this tritium is contained within the fuel rods; however, about 1% diffuses through the cladding to the reactor coolant. Therefore, approximately 100 curies of tritium per year of full power operation are released to the reactor coolant from ternary fission.[10]

Tritium is also formed when fast neutrons interact with the boron isotope ^{10}B, found in control rods, burnable poison and the chemical shim. The chemical shim is an important contributor to tritium activity in a pressurized water reactor. In a large pressurized water reactor about 1,000 curies of tritium per year of full power operation are formed from the chemical shim. The boron in control rods and burnable poison is generally encased in stainless steel. Thus, the fraction of the total tritium produced which is released to the reactor coolant is comparable to that released from stainless steel clad fuel rods due to fission. In a typical nuclear power plant, about 2,000 curies of tritium per year of full power operation are formed from control rods and burnable poison. Some reduction in tritium production can be obtained by replacing the boron carbide control rods with more expensive silver-cadmium-indium control rods. Table C.3 presents tritium release data for several operating reactors.[11]

Table C.4 is a comparison of radioactive effluent releases from pressurized water reactors used in the commercial utility industry, onboard U.S. Navy ships, the N.S. SAVANNAH and Competitive Nuclear Merchant Ships. The difference in amounts of tritium released between first and second generation commercial plants is due to the use of zircaloy as the fuel cladding material. The zircaloy cladding retains tritium in the fuel more effectively than stainless steel. For a 1,000 MWe pressurized water reactor, 30 percent of the tritium produced by fission will diffuse through a stainless steel clad as opposed to one percent for zircaloy clad. In addition, smaller quantities of corrosion and wear products are released to the reactor coolant from zircaloy than from stainless steel cladding.[12]

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[10] Deutsch, op. cit.

[11] Ibid.

[12] T.J. Kirk, ed., Radiation Protection and Management, Columbia, Maryland: General Physics Corporation, 1975.

TABLE C.3

LIQUID EFFLUENT COMPARISON BY YEAR
TRITIUM (CURIES)

Pressurized Water Reactors	Power MWe	Clad	1970	1970	1972	1972 DATA: Average Concentration (mCi/ml)	1972 DATA: Percent of Limit
Maine Yankee	790	Zircaloy	----	----	9.22	9.57×10^{-8}	1.91
Palisades	700	Zircaloy	----	----	208.0	2.60×10^{-7}	0.430
Yankee	175	Stainless Steel	1500	1680	803.0	4.92×10^{-6}	0.166
Indian Point 1	265	Stainless Steel	410	725	574.0	1.16×10^{-6}	0.040
R. E. Ginna	490	Zircaloy	110	154	119.0	1.64×10^{-7}	0.00547
Connecticut Yankee	575	Stainless Steel	7400	5830	5890.0	7.64×10^{-6}	0.255
H. B. Robinson	700	Zircaloy	----	118	405.0	1.88×10^{-7}	0.000625
San Onofre	430	Stainless Steel	4800	4570	3480.0	5.99×10^{-6}	0.2
Point Beach 1,2	497	Zircaloy	----	266	563.0	1.13×10^{-6}	0.037
Surry 1	788	Zircaloy	----	----	5.03	3.64×10^{-8}	0.091

TABLE C.4

COMPARISON OF RADIOACTIVE EFFLUENT RELEASES FROM PRESSURIZED WATER REACTORS

	First Generation Commercial Plants		Second Generation Commercial Plants		Nuclear Merchant Ships		Total, All U.S. Navy Ships, 1973
Plant	Indian Point 1	San Onofre	H.B. Robinson	Crystal River 3	N.S. Savannah	CNMS	107 Ships
Began Commercial Operation (year)	1962	1963	1971		1965		Various
Power (Megawatts)	615 mwt	1347 mwt	2094 mwt	2452 mwt	80 mwt	312.9 mwt	Various
Fuel Cladding Material	Stainless Steel	Stainless Steel	Zircaloy	Zircaloy	Stainless Steel	Stainless Steel	Various
Annual Tritium Release in Liquid Effluent (curies)	574 (.93 curies/mwt)	3,480 (2.58 curies/mwt)	405 (.19 curies/mwt)	356 (est.) (.15 curies/mwt)		407 (est.) (1.30 curies/mwt)	< 200
Annual Liquid Effluent Release excluding Tritium (curies).	25.4	30.3	0.862	0.39 (est.)		4.93 (est.)	0.4
Airborne Effluent Release, Noble Cases (curies).	0.543	19.1	0.257	230 (est.)		10,780 (est.)	< 0.001

The estimated values of effluents for the CNMS are relatively higher because of (1) the anticipated use of stainless steel cladding, and (2) safety analysis reports use very conservative assumptions in deriving these estimates. Operating experience has shown that actual releases are on the order of one percent of those estimated in the Safety Analysis Report.

It is the policy of the U.S. Navy to reduce to the minimum practicable the amounts of radioactivity released to the environment, but particularly within 12 miles from shore including into harbors. In support of this policy, the U.S. Navy analyzes harbor water and sediment samples for radioactivity associated with naval reactors in all harbors frequented by its nuclear ships. In 1973, the cumulative discharge from all U.S. Naval nuclear-powered ships within 12 miles of shore was less than .002 curies. Although of less significance than the amount of radioactivity, the volume of waste has also been reduced. The average volume released into all harbors in the middle 1960s was 5 million gallons per year. In 1973, the volume released was less than 25,000 gallons. The Nuclear Power Directorate of the Naval Sea Systems Command reports that this was achieved by the reduction of waste generation and by processing and reusing waste water. As indicated in Table C.4, the total quantity of radioactivity released by the U.S. Navy to the open ocean in 1973 was 0.4 curies.[13]

The comprehensive Navy environmental monitoring program consists of analyzing samples of harbor water and sediment, supplemented by shoreline surveys, posted dosimeters and effluent monitoring. Effluent monitoring logs maintained by individual ships are audited annually by the Nuclear Power Directorate. Harbor water samples taken quarterly are analyzed for gross gamma radioactivity and for cobalt-60 content. These analyses consider direct exposure, such as to sediment along shorelines and by drinking harbor water, and indirect pathways such as consumption of bottom feeding fish or shellfish. Analyses to date have indicated that personal exposure from this radioactivity is far too low to measure and that based on the radioactivity released, the maximum radiation exposure in a year to any member of the general public would be less than 0.01 mrem. This figure is less than one ten-thousandth of the average annual exposure of 125 mrem to members of the general public from natural radioactivity or from exposure to medical diagnostic X-rays.[14]

Navy procedures have prohibited the sea disposal of solid radioactive materials since 1969. These materials are packaged in strong, tight containers, shielded as necessary and shipped to burial sites licensed by the NRC or a state under agreement with the NRC. The effort to minimize the generation of radioactive waste has been applied to solid wastes as well as liquid wastes. It is reported that the average annual volume of solid waste for the entire Naval nuclear propulsion program could be contained in a cube measuring 15 yards on a side.[15]

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[13] Miles, op. cit.

[14] Ibid.

[15] Ibid.

Comparative data for the NS SAVANNAH is not readily available. The National Academy of Sciences study, "Nuclear Merchant Ships," states:

> Although the savannah was designed to contain all liquid radioactive wastes, more wastes were generated than could be held in her 38 m^3 storage tank. The liquid wastes are primarily from leakage at the buffer-seal charge pumps, pressurized relief valve, and sampling relief valve. During the first six months of experimental commercial operation by the Savannah in 1965-66, 0.006 Ci or radioactivity, mostly ^{54}Mn and ^{60}Co., were discharged into the sea in accordance with the recommendations outlined in NAS-NRC Publication 658. Solid wastes and demineralizer resins were disposed of on land. Off-gases from the containment vessel were passed through a series of filters prior to release to the atmosphere.

As a final note on the subject of radioactive effluents, the "Nuclear Merchant Ships" report comments that:

> If national or international law prohibits the disposal of wastes at sea from nuclear-powered ships, the environmental problem of radioactivity from the normal operation of nuclear-powered ships disappears and becomes a shipbuilding problem of constructing ships that can contain all the radioactive wastes that they produce.

REACTOR ACCIDENTS

With the advent of nuclear plants in merchant ships, the greatest potential hazard is a reactor accident occurring while the ship is in port or in the process of entry or departure. This accident could be the result of an internal engineering malfunction or an external source such as a collision or grounding.

The impact of a nuclear-powered ship accident is difficult to predict because of the many variables involved. Of greatest concern are those that could result in the release of large fractions of the more volatile fission products into densely populated port areas. The public health risk from nuclear accidents at stationary nuclear power plants has been estimated to be very small. This is the basic conclusion reached by a two-year study of nuclear power plant safety, known as the Rasmussen Report. The risks had to be estimated rather than measured because, although there are more than 50 such plants now operating, there have been no nuclear accidents to date.[16]

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[16] N.C. Rasmussen, et. al., "Reactor Safety Study - An Assessment of Accidental Risks in U.S. Commercial Nuclear Power Plants, Summary Report, Draft," Washington, D.C.: U.S. Atomic Energy Commission, August 1974.

Future nuclear merchant ships will be constructed to the same strict criteria imposed upon stationary nuclear power plants. Based on the experience of date of operating these plants, Navy ship nuclear plants, and the NS SAVANNAH plant, it can be stated that the risk from accidents resulting from abnormal situations or failures other than ship-related accidents is relatively small. Potential hazards can be terminated automatically by the operation of the reactor protection systems which maintain the integrity of the fuel and the reactor coolant system, or terminated by the operation of engineering safety features if one or more of the protective barriers are not effective. This automatic operation, complemented with manual overrides, maintains the integrity of the core and reactor containment and contains the radiation hazard.

Obviously, the mobility of a nuclear merchant ship increases the risk of ship-related normally accepted credible marine accidents such as collisions, rammings, groundings, effects of heavy weather, fires, explosions, flooding and sinking. Collisions are the most frequent type of accident, and with the increasingly higher speeds and displacements of planned ships, it appears that in the future collisions will be, on the average, more serious than in the past. A serious collision to an unprotected nuclear power plant could cause the release of radioactive material to the outside environment. Again, determining the environmental impact of such a collision is difficult to predict because of the many variables involved.

The probability density of a proposed nuclear merchant ship colliding with other ships of various types, sizes, and speeds could be defined. Such a definition was carried out for the NS SAVANNAH using a statistical approach applied to the various trade routes considered for the ship, listing the ships of sufficient size and speed to constitute a hazard. In estimating the probability of collisions involving damage to the reactor compartment, the "Minorsky method" was fo-lowed. This method predicts the condition under which the reactor space of a nuclear ship will remain intact and, consequently, what structural strength should be built into the hull of a nuclear ship outboard of the reactor plant to safely absorb a given amount of kinetic energy in a collision.

Since high percentages of collisions occur in harbor channels and territorial waters, it would be expected that any future nuclear ship would be designed to prevent damage to the reactor when a collision occurs in the expected speed ranges for navigating these waters. Since most collisions are attributable to human error and poor visibility, it would be expected that suitable detection and warning system would be installed in order to reduce the risk. Another factor that should be considered in reducing the potential radioactive hazard due to accidents in harbors is related to the predicted size of future ships. The draft of these vessels will require offshore loading and discharge facilities and therefore eliminate the necessity for operating these vessels in densely populated port areas.

APPENDIX D

FUTURE NUCLEAR MERCHANT SHIPS[1]

GENERAL DESCRIPTION

The Maritime Administration (MarAd) has proposed the construction of at least three similar nuclear power plants to supply propulsion power for three merchant ships. The nuclear ships will be operated from the United States of America to ports of call identified by the owner/operator. Each ship has a pressurized water reactor nuclear steam system utilizing the steel-shell, pressure-suppression containment concept (hereafter referred to as Consolidated Nuclear Steam Generator or CNSG). The reactor unit operates at a rated core power level of 312.9 MWt resulting in a net power output of 120,000 shp and an average ship speed of 18.8 knots. The first ship is expected to be delivered by mid-1980; the remaining ships are to follow at approximately one-year intervals.

The consolidated nuclear steam generator (CNSG) is an integral pressurized water reactor with the core and steam generator inside the reactor vessel and an electrically heated pressurizer connected to the vessel externally. Four horizontally mounted reactor coolant pumps are located alternately with the steam nozzles at the reactor vessel nozzle belt. Feedwater nozzles are located in a nozzle belt below the steam generator. The reactor core consists of stainless steel tubes containing enriched uranium dioxide pellets enclosed by welded end plugs. The tubes are supported in assemblies by a spring-clip grid structure. The mechanical control rods are clusters of absorber rods that move in guide tubes within the fuel assembly. The steam

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[1]This appendix has been excerpted from Babcock and Wilcox, Competitive Nuclear Merchant Ship Program Preliminary Safety Analysis Report, prepared for the U.S. Maritime Administration. Lynchburg, Virginia: Babcock and Wilcox, April 1974, 5 vols.

generator is a helically coiled, once-through unit located in the annulus above the top level of the core. The operation of the steam generator utilizes four sets of feedwater inlet and steam outlet nozzles. The steam generator counterflows heat transfer with tubeside boiling to produce steam at a constant pressure. The reactor coolant system (RCS) operates at a constant average temperature over the normal load range.

The reference nuclear ship is a 600,000 dead-weight-ton (DWT) tanker denoted as a VLCC, designed for long-distance oil transport. It is designed and arranged to carry approximately 4,701,000 barrels of cargo oil. As required by the U.S. Coast Guard and the American Bureau of Shipping, the two-compartment standard of subdivision has been incorporated in the ship design. The reactor compartment is aft of amidship and above and aft of the machinery space. The auxiliary propulsion boilers are located forward of the reactor compartment. The reactor compartment houses the reactor vessel, the containment, and the reactor-associated auxiliaries. The compartment is bounded on either side by longitudinal structural bulkheads; the spaces outboard of the bulkheads are designated as collision resistance areas. Propulsion is provided by twin screws, each having a rating of 60,000 shp. The screws are driven by cross-compound steam turbines through locked-train, double helical reduction gearing. The propulsion machinery is located below the reactor compartment. The ship is fitted with navigation and collision/grounding avoidance systems to direct the movement of the ship in response to manual bridge commands and to data accumulated automatically from the various electronic systems. The systems provide data on ship position, heading, speed, sea depth, heel and trim. In addition, the systems provide the position and track of other vessels in the area and warn of necessary course changes.

The automatic control system for the reactor/propulsion plant comprises two redundant channels. Each channel contains a digital "minicomputer" which calculates coordinated control signals for the plant using modern control techniques. Although both channels receive information from the plant and calculate control signals, only one is closed with the plant at any given time. The controllers are self-checking and control is transferred automatically to the alternate channel when a fault is detected. In addition, the control channels are monitored by a digital-based operator information system. Semiautomatic control is also provided; it consists of reactor-following (turbine control on manual) and turbine-following (reactor control on manual) modes. Finally, manual controls are provided for all control devices.

The CNSG reactor core consists of 57 fuel assemblies having an active fuel length of 65 inches. Each fuel assembly is a 15 by 15 array of 184 type 304 SS clad, helium prepressurized fuel rods, 20 control rod guide tubes, 20 lumped burnable poison (LBP) rods, and one spacer-grid-positioning tube at the dioxide pellets. Rated core thermal power output is 312.9 MW with an average linear heat rate of 5.36 kW/foot. Excess reactivity is controlled by a combination of fixed LBP rods and 37 movable control rod clusters. A four-year, one-batch fuel cycle is utilized for fuel management.

A compact pressure-suppression containment system, similar to those used for land-based power plants, provides the secondary containment for the CNSG. The system comprises two compartments - the dry well and the wet well or suppression pool. All penetrations into the primary coolant system are made through the dry well; thus, the dry well accepts the discharge from any loss-of-coolant accident (LOCA) and as it pressurizes, the mixture is forced into the wet well. These pipes are submerged in the wet well water which condenses the effluent. The water in the pool also serves as a radiation shield. The containment shell is a free-standing steel cylinder supported at the bottom withthe main operating floor approximately half-way up the containment. The upper head of the containment is elliptical. The center section of the upper head is removable for servicing and installation of major components and for refueling; it is fitted with a double seal. The personnel hatch, which is also a double-barrier design, is located near the main operating floor, providing access for routine maintenance and inspection. Inflooding valves prevent collapse of the containment vessel in the event that the ship sinks. The vapor suppression pool is formed by a second cylindrical shell below the operating floor; the pool is located as close to the reactor vessel as feasible. The annular wet well is divided into separate compartments with one vent discharging into each compartment. Low-pressure rupture discs in the vent pipes normally separate the dry and wet well, preventing water from entering the dry well at extreme ship attitudes. The atmosphere within the containment is maintained at subatmospheric pressure to improve the performance of the pressure suppression system. The containment dry well cooling system aids in controlling containment pressure during a LOCA.

The auxiliary service requirements and engineered safety features of the CNSG plant have been evaluated and combined for maximum system reduction and simplification consistent with reliability, operability, safety, and function. All auxiliary systems are based on current pressurized water reactor technology coupled with consideration of shipboard duty and environment. All systems and components are designed and fabricated in accordance with nuclear service codes and standards, or their equivalent, in combination with appropriate consideration of the functional importance of said system and/or component. Components are selected and systems are arranged so as to afford high operational safety requirements and the degree of functional combination.

The makeup and purification system is a closed loop that includes letdown paths, coolers, a makeup tank, chemical dosing facilities, filters, demineralizers, and makeup pumps. The system controls reactor coolant inventory purifies the coolant, and provides the means to maintain water chemistry during normal plant operation. The makeup capability of the system is sufficient under normal operating conditions to maintain the primary coolant inventory and pressure during planned normal power changes from 100 to 0% power level (hot).

SHIP'S MANNING - ENGINE DEPARTMENT

The following indicates the typical duties of engineering personnel of the nuclear merchant ship. The crew comprises the minimum number of personnel required for safe and efficient operation of the vessel.

The engine department is responsible for all of the machinery on the ship. It is headed by the chief engineer who is assisted by eight assistant engineers and seven unlicensed ratings. The chief, the first-assistant engineer, and the four second-assistant engineers shall be certfied as senior reactor operators (SROs). The three watchstanding third engineers shall be certified as reactor operators (ROs). The water chemistry and health physics functions will be performed by one of the second-assistant engineers, who will normally be assigned to day work. The first-assistant engineer will be trained and assigned collateral duty as instrumentation and electronics officer, and the electronics technician reports to him. Figure D.1. details the organizational arrangement of the engine department which will be manned as follows:

Rate	Number
Chief engineers, SRO (nonwatchstander)	1
First-asst engineer, SRO (nonwatchstander)	1
Second-asst engineer, SRO (watchstander)	3
Second-asst engineer, SRO (nonwatchstander, staff health physicist/chemist)	1
Third-asst engineer, RO (watchstander)	3
Electronics technician (nonwatchstander)	1
Electrician (nonwatchstander)	1
Qualified member engine department	3
Pumpman (nonwatchstander)	1
Wiper (nonwatchstander)	1
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The chart below shows the proposed shift assignments for day workers and watchstanders.

AM			Noon	PM	
12 - 4	4 - 8	8 - 12	12 - 4	4 - 8	8 - 12
2nd (SRO)	2nd (SRO)	2nd (SRO)	2nd (SRO)	2nd (SRO)	2nd (SRO)
3rd (RO)	3rd (RO)	3rd (RO)	3rd (RO)	3rd (RO)	3rd (RO)
QMED	QMED	QMED	QMED	QMED	QMED

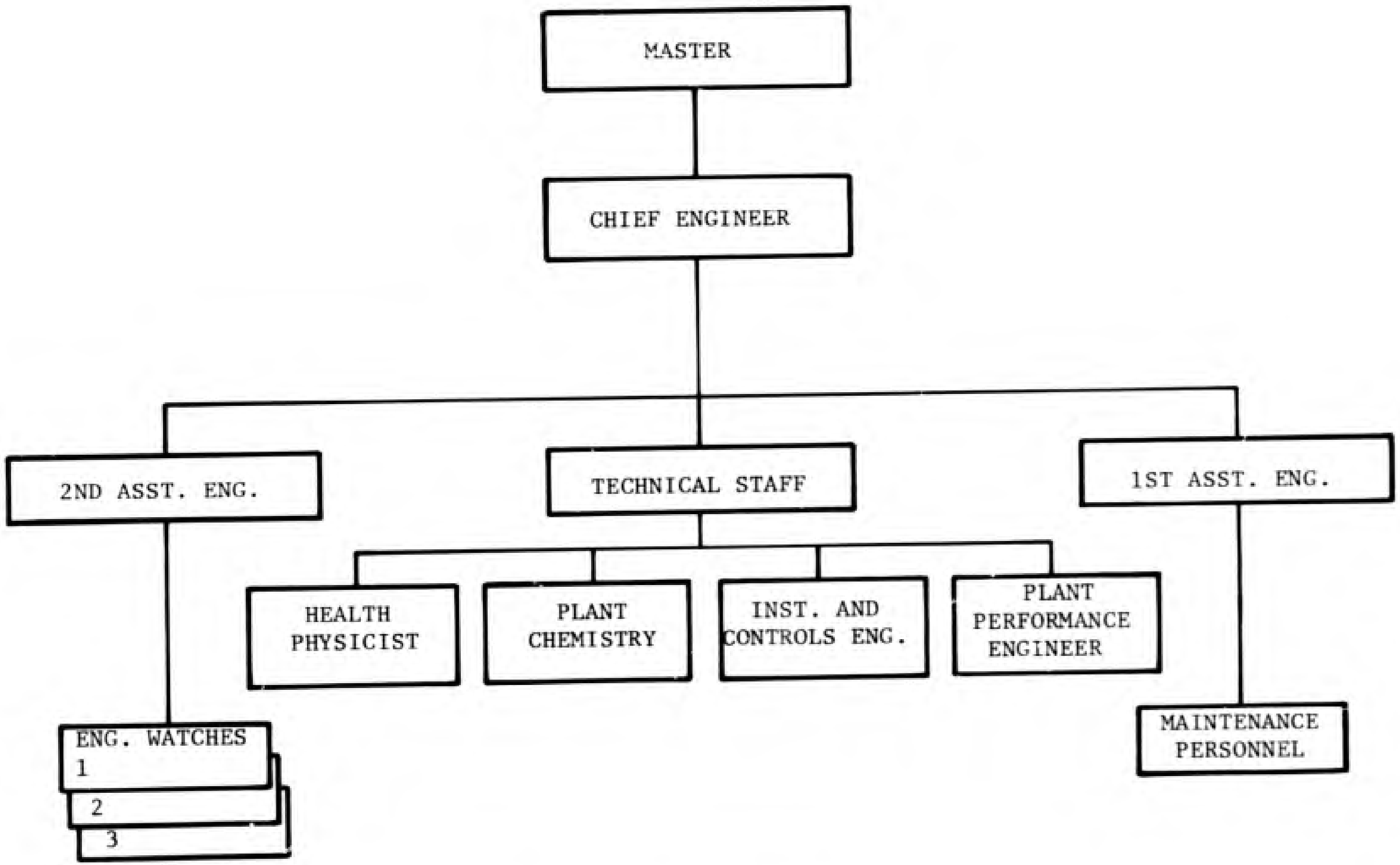

FIGURE D.1. COMPETITIVE NUCLEAR MERCHANT SHIP (120,000 shp)

Day Workers

Chief (SRO)

1st (SRO)

2nd (Staff HP/chem)

Electronics tech

Electrician

Wiper

Pumpman

Notes: 1. All day workers are available for off hour work as required.

2. This schedule is for at-sea watches with 4 hours on and 8 hours off, except day workers. When the ship is in port for extended time, the watches revert back to 8 hours on and 16 hours off.

Engine Department Duties

- Chief Engineer. The chief engineer is in charge of, supervises, and has the command function over the engine department. He is responsible for the operation, maintenance and repair of all machinery onboard the ship. He is responsible to the master and the ship owner for the performance of his duties. He must possess an unlimited Chief Engineer's license issued by the USCG and must be licensed by the NRC as a senior reactor operator.

- First-Assistant Engineer. The first-assistant engineer assists the chief engineer in the performance of his duties. Normally, he does not stand a watch and is in charge of the dayworking personnel, including engineers, QMEDs, the electronics technician, and the electrician. One of his collateral duties, in port and at sea, is the close supervision of all maintenance and repair on the NSS. He is available for relieving the engineer in charge of the watch when required. He must hold an unlimited First-Assistant Engineer's Steam license for any horsepower and is licensed by the NRC as a senior reactor operator.

- Second-Assistant Engineers. The second-assistant engineers are in charge of the engine room during their respective watches. Their collateral duties, in port and at sea, include the close monitoring of operation, maintenance, and repairs of the main propulsion system. They must hold USCG unlimited

Second-Assistant Engineer's Steam licenses (any horsepower) and must be licensed by the NRC as SROs. The fourth second-assistant engineer is the staff health physicist/chemist. His qualifications are the same as those for the other second-assistant engineers, with the exception of specialized training in health physics and chemistry. For the health physics function, he reports administratively to the chief engineer and functionally to the master.

- Third-Assistant Engineers. Three watchstanding third-assistant engineers assist the second-assistant engineers on their respective watches. Their collateral duties, in port and at sea, consist of close monitoring of maintenance operations and repairs. They must hold unlimited Third-Assistant Engineer's Steam licenses for any horsepower and be licensed by the NRC as reactor operators.

- Electronic Technician. The electronic technician is a day worker whose duties consist of maintenance and repairs of all instrumentation associated with the nuclear steam generating plant, the electrical distribution system, all motors and controls, and all propulsion plant instruments that are not hydraulic or mechanical which are associated with the nuclear steam generating plant. He reports directly to the first-assistant engineer and must hold a qualification certificate issued by the USCG.

- Electrician. The electrician, a nonwatchstander, is responsible for electrical maintenance and repairs on ship's service electrical equipment. He is responsible to the chief engineer but reports directly to the first-assistant engineer. The electrician must hold a qualification certificate issued by the USCG.

- Qualified Member Engine Department. Three qualified members of the engine department (QMEDs) perform the mechanical maintenance and repair of the entire machinery plant during their watches. They may also assist the electrician/electronic technician. The QMEDs shall hold USCG certificates for their rating.

- Pumpman. The pumpman is a nonwatchstander whose duties consist of operation of the cargo oil and ballast systems during loading and discharge of the vessel. The pumpman is also responsible for maintenance and repair of the cargo oil and ballast systems, as well as cargo tank hatches, fittings, etc. In cargo and ballast operations he works for the deck department under the direction of the chief officer. In performing maintenance and repairs, he is responsible to the engine department, reporting to the chief engineer or the first-assistant engineer. The pumpman must hold a qualification certificate issued by the USCG.

- Wiper. The wiper is assigned to day work; he performs janitorial services or may be assigned to help the other day workers or watchstanders during the workday. He holds a USCG certificate for his rate.

QUALIFICATION REQUIREMENTS FOR NUCLEAR FACILITY PERSONNEL

Figure D.2. summarizes the qualifications of the members of the engine department of the proposed nuclear merchant ship. All members of the nuclear merchant crew will hold USCG ratings commensurate with their position. Engine department personnel will hold NRC reactor operator (RO) or senior reactor operator (SRO) licenses as indicated in their duties and responsibilities. The ship's master will not be required to hold an SRO license but will have the background required to sit for examination for such license. The educational and experience qualifications for reactor plant personnel will meet or exceed those specified in ANSI N18.1.

TRAINING PROGRAM FOR A LICENSED PERSONNEL

The personnel to whom propulsion plant operation will be entrusted are engineers duly licensed as marine engineers by the USCG and licensed as necessary by the NRC. Qualification for a USCG operating license is gained either by successfully completing the scholastic requirements of an accredited maritime academy, such as one of the state academies or the U.S. Maritime Academy at King's Point, or by advancing through the unlicensed grades of engine and fireroom personnel. Upon attaining the prescribed proficiency, the applicants in either case are given a comprehensive written examination by the USCG; the examination lasts for several days and covers such subjects as safety rules and regulations, mathematics, steam generation equipment, propulsion engines, auxiliary equipment (pumps, heat exchangers, etc.), electrical power generation equipment, etc.

For the personnel who have received their training via the practical route as unlicensed members of a ship's engine department, the usual practice is their taking instruction to aid in successfully completing the USCG examination. This instruction is usually taken at privately operated schools

		LICENSE		TRAINING
		USCG	NRC	
1	Chief Engineer	Unlimited Chief Engineer	SRO	Nuclear Power Plant Operation
1	First Assistant Engineer	Unlimited First Engineer	SRO	Nuclear Power Plant Operation
3	Second Assistant Engineer	Unlimited Second Engineer	SRO	Nuclear Power Plant Operation
1	Second Assistant Engineer (Staff Health Physicist)	Unlimited Second Engineer	SRO	Nuclear Power Plant Operation and Health Physics/Chemistry
3	Third Assistant Engineer	Unlimited Third Engineer	RO	Nuclear Power Plant Operation
1	Electronics Technician	Qualification Certificate	None	Speciality and Radiation Safety
1	Electrician	Qualification Certificate	None	Speciality and Radiation Safety
3	Qualified Member Engine Dept	Qualification Certificate	None	Speciality and Radiation Safety
	Pumpsman	Qualification Certificate	None	Speciality and Radiation Safety
	Wiper	Qualification Certificate	None	Speciality and Radiation Safety

FIGURE D.2. QUALIFICATIONS OF PERSONNEL OF PROPOSED NUCLEAR MERCHANT SHIP whose teaching staffs hold marine licenses. The licensed personnel may also attend these schools preparatory to upgrading.

Personnel, qualifying through formal education, must graduate from a college or academy which specializes in the marine field and has as its basic purpose the furnishing of qualified engineering personnel to the U.S. Navy and the U.S. Merchant Marine. The college courses last a period of four or five years and include a period of practical shipboard operation as a cadet, either aboard a training ship or a merchant ship, during which time first-hand knowledge of practical applications is gained. The training ship duty gives the trainee a chance to actually perform the duties of a watchstanding and repair engineer. His practical experience will include assisting the ship's crew in repairs and overhauls but will not normally include handling of the throttle, which is a licensed engineer's responsibility.

TRAINING PROGRAMS FOR NON-LICENSED PERSONNEL/SPECIALIST TRAINING

As a minimum, there will be training for individuals to carry out particular functions for which specific instruction and capabilities are necessary. Instruction will be provided in the areas described below. (A single individual may be qualified in more than one specialty.)

Instrument and Control Electronics Technician (Electronics Technician)

The instrument and control technician will receive a program that provides him with a detailed understanding of electronic components, installation, and maintenance procedures. This program includes training by the equipment supplier and covers both background material and specific details of the installed equipment.

Chemistry

Each crew will have a staff health physicist/chemist (licensed second-assistant engineer) who has completed a water chemistry course so that he can operate a water chemistry laboratory to process routine samples and to interpret accurately the significance of unusual results. This course will cover nuclear power water requirements, radiochemistry, and cold water chemistry and will include sufficient laboratory time so that the individual will develop the proficiency to perform these tasks at sea without assistance.

Health Physics

Each crew will have a qualified staff health physicist/chemist who has completed a prescribed course of study and has demonstrated his proficiency.

Other Training Programs

All operating and maintenance personnel assigned to the engine department will be trained in radiation safety and procedures. Electrical, mechanical, and instrument and control maintenance personnel will receive specialized training relative to their job requirements and, where applicable, will be certified by the USCG.

TRAINING FOR GENERAL SHIPBOARD PERSONNEL

The crew of the nuclear-powered merchant ship requires some additional training to support their work and personnel safety aboard ship. Instruction will be conducted in modules, and each crew member not in the engine department will attend the appropriate module.

Module 1 - General Orientation for Nuclear Power Service

This course will present the basic concept of the nuclear propulsion plant, hazards associated with nuclear power, and the protection systems provided. It provides practical training in the conduct of radiation monitoring, utilization of protective clothing, and dosimetric monitoring.

Module 2 - Nuclear Propulsion Plant Orientation

This course provides deck officers with sufficient knowledge of the nuclear propulsion plant to exercise their responsibilities in ship control. A more detailed presentation of the plant construction and operation is included, over and above that provided in Module 1. In addition, the course covers the overall limiting conditions, power transient responses, and particular limitations that can result from plant startup, trip, degraded modes of operation, and major casualty conditiors.

APPENDIX E

STANDARDS AND LEGAL REQUIREMENTS RELATED TO QUALIFICATIONS

ANSI N18.1-1971

In 1971, Standards Committee N18 of the American National Standards Institute approved the standard known as ANSI N18.1-1971, on the "Selection and Training of Nuclear Power Plant Personnel." This standard was prepared by the Reactor Operations Subcommittee of the American Nuclear Society Standards Committee. In developing this standard, substantial assistance and participation was obtained from utilities with much experience in both nuclear and fossil-fueled power plants.

The standard recognizes that individual utilities have their own job titles and job descriptions, but defines positions in terms of "Functional Levels and Assignment of Responsibility." These include:

1. Managers--those persons with overall responsibility of the nuclear power plant, its technical aspects, its operations and its maintenance.

2. Supervisors--those persons principally responsible for directing the actions of operators, technicians, and repairmen.

3. Professional/Technical--those persons responsible for supervising and in certain cases pefrorming technical services in support of overall plant operations.

4. Operators, Technicians, Repairmen--those persons principally involved in the manipulation of plant controls, monitoring or instrumentation, or the operation of equipment, and persons who principally calibrate, repair, maintain or perform other craft and technical activities in the plant.

5. Support personnel--those persons, including members of the organization (e.g., the headquarters engineer-in-charge or consultants) whose technical expertise is available to the operating staff.

Furthermore, the standard specifies minimum general qualifications and specific educational, training, and experience qualifications for all functional levels within an operating organization that have a direct relationship to technical, operations, and maintenance aspects of a nuclear power plant. It also specifies minimum general and specific characteristics of training programs for personnel requiring NRC licenses (and for those who do not) at both supervisory and non-supervisory levels. Provisions for retraining and replacement training are included to assure that qualification levels are maintained. Figure E.1 summarizes the minimum requirements. The Nuclear Regulatory Commission generally endorses the requirements of ANSI N18.1-1971. Accordingly, reactor operators typically have a high school education, possess an aptitude for physics and electricity, and undergo specialized reactor operator training and education on pertinent subjects. Senior reactor operators typically have a year or two of college, considerable conventional power plant experience, and undergo specialized senior operator training and education on pertinent subjects.

NRC REQUIREMENTS FOR LICENSING UNDER 10CFR55

The Code of Federal Regulations (CFR), Title 10, refers to codes dealing with atomic energy. Part 55 of Title 10, preferably written as 10CFR55, deals with operators' licenses. Specifically, it sets forth the provisions under which operators (those who manipulate reactor controls) and senior operators (those who direct the licensed activities of licensed operators) are individually licensed to operate a particular reactor. Unlike most other licenses, reactor operator and senior operator licenses are issued for a specific facility rather than for a class of facilities. One license can cover more than one unit in a multi-unit facility, but only when the applicant has need for a license on each unit and has been examined accordingly. Requirements for personnel to qualify as licensed operators and licensed senior operators are set forth through the NRC's Operator Licensing Program.

Regulatory requirements under 10CFR55 have resulted in the conduct of "hot" and "cold" operator examinations. At new reactor facilities, licensed operators are needed to begin fuel loading and startup. Obviously, an actual startup demonstration as part of an operator or senior operator licensing examination cannot be given at a facility which has not yet loaded fuel, thus, these activities must be simulated by discussion between the applicant and the examiner. These operating tests are known as "cold" examinations, as opposed to the term "hot" examinations which refers to the tests that require actual startup demonstrations.

Operator and senior operator examinations are divided into three major parts: (1) a written test, usually lasting one day, (2) an oral test usually lasting half a day, in which the operator demonstrates his understanding of the

This chart is not part of the standard but for information only.

	REQUIRED						SUGGESTED				REMARKS
	Experience (years)						Education (years)				
	Total Power Plant	Nuclear Power Plant	Other Applicable	Academic Training	License RO	License SRO	Academic		Related Technical Training	Amount of Education (2) Creditable for Experience	
Managers											
Plant Manager (or Assistant)	10	3				(1) X	4			4	
Operations Manager	8	3				X	2	or	2	2	
Maintenance Manager	7	1					2	or	2	2	
Technical Manager		1	7				4			4	
Supervisors											
Supr. Requiring AEC Licenses	4	1			X or X		2	or	2	2	High school diploma or equiv. req'd.
Supr. not Requiring AEC Licenses			4								High school diploma or equiv. req'd.
Professional - Technical											
Reactor Engineering and Physics			2	4							
Instrumentation and Control			5				2	or	2	4	6 mo. experience in nuclear B & C
Radiochemistry			5				2	or	2	4	1 yr. experience in Radio-chemistry
Radiation Protection			5				2	or	2	4	
Operator - Technician - Repairman											
Operators to be AEC Licensed	2	1			X						High school diploma or equiv. req'd.
Technicians			2						1		
Repairman			3								
Technical Support Personnel											
Engineer-in-charge			5	4							Shall be competent in their field
Other personnel											

These values are minimum and it is recommended that the above be exceeded.

(1) SRO license are not required for plant manager but he or the assistant shall have the background required to sit for examination.

(2) Academic or related technical training in this column may *not* be credited toward nuclear power plant experience. See section 4.0 paragraphs 2 and 3 for nuclear power plant experience equivalence.

FIGURE E.1. MINIMUM EDUCATION & EXPERIENCE FOR SELECTION AND TRAINING OF NUCLEAR POWER PLANT PERSONNEL

of the specific reactor hardware, procedures, and operational behavior, and (3) an actual demonstration that the applicant can bring the reactor critical and adjust power level. The senior operator written test (see Table E.1) includes the operator written test plus a senior test of about equal duration. The senior oral and operating tests cover much the same ground as the operator test, except that the applicant must demonstrate a higher degree of competence and knowledge than that required for the operator; must display wider and more thorough knowledge of administrative controls and provisions of applicable regulations; and must demonstrate more breadth of knowledge of the facility.

The applicant must also show that he has been properly trained by the facility management, (usually by certification that lists subjects taught, number of subject hours, extent of experience) and states that he has demonstrated, to the satisfaction of the facility licensee, the ability to operate the controls in a competent and safe manner, and that there is a need for his services.

Licenses are issued for a period of two years and may be renewed, subject to confirmation of continued competence, need, and medical qualifications. Recently, the NRC issued a rule change to 10CFR55 which will require that licensed individuals participate in requalification programs in order to establish continued competence for license renewal without reexamination. In essence, the program consists of lectures, required control manipulation, and study of normal and emergency procedures. Facility management is required to maintain appropriate records including examination results to indicate an individual's competence.

TABLE E.1

SECTION HEADINGS OF THE WRITTEN TEST FOR LICENSED OPERATOR AND SENIOR OPERATORS

Operator	Senior Operator (Taken in Addition to Operator Test)
A. Principles of Reactor Operation	H. Reactor Theory
B. Features of Facility Design	I. Radioactive Material Handling, Disposal, and Hazards
C. General Operating Characteristics	J. Specific Operating Characteristics
D. Instruments and Controls	K. Fuel Handling and Core Parameters
E. Safety and Emergency Systems	L. Administrative Procedures, Conditions, and Limitations
F. Standard and Emergency Operating Procedures	
G. Radiation Control and Safety	

Scope of Operator and Senior Operator Examinations

The operating tests administered to applicants for operator and senior operator licenses are generally similar in scope. The operating test, to tne extent applicable to the facility, requires the applicant to demonstrate an understanding of:

1. Pre-startup procedures for the facility, including associated plant equipment which could affect reactivity.
2. Required manipulation of console controls to bring the facility from shutdown to designated power levels.
3. The source and significance of annunciator signals and condition-indicating signals and remedial action responsive thereto.
4. The instrumentation system and the source and significance of reactor instrument readings.
5. The behavior characteristics of the facility.
6. The control manipulation required to obtain desired operating results during normal, abnormal and emergency situations.
7. The operation of the facility's heat removal systems, including primary coolant, emergency coolant, and decay heat removal systems, and the relation of the proper operation of these systems to the operation of the facility.
8. The operation of the facility's auxiliary systems which could affect reactivity.
9. The use and function of the facility's radiation monitoring systems, including fixed radiation monitors and alarms, portable survey instruments, and personnel monitoring equipment.
10. The significance of radiation hazards, including permissible levels of radiation, levels in excess of those authorized and procedures to reduce excessive levels of radiation and to guard against personnel exposure.
11. The emergency plan for the facility, including the operator's or senior operator's responsibility to decide whether the plan should be executed and the duties assigned under the plan.
12. The necessity for a careful approach to the responsibility associated with the safe operation of the facility.

Requalification Program Requirements

1. Schedule. The requalification program shall be conducted for a continuous period not to exceed 2 years, and upon conclusion shall be promptly followed, pursuant to a continuous schedule, by successive requalification programs.

2. Lectures. The requalification program shall include preplanned lectures on a regular and continuing basis throughout the license period in those areas where annual operator and senior operator written examinations indicate that emphasis in scope and depth of coverage is needed in the following subjects:

a. Theory and principles of operation

b. General and specific plant operating characteristics

c. Plant instrumentation and control systems.

d. Plant protection systems.

e. Engineered safety systems.

f. Normal, abnormal, and emergency operating procedures.

g. Radiation control and safety.

h. Technical specifications.

i. Applicable portions of Title 10, Code of Federal Regulations.

Other training techniques including films, videotapes and other effective training aids may also be used. Individual study on the part of each operator shall be encouraged. However, a requalification program based solely upon the use of films, videotapes and/or individual study is not an acceptable substitute for a lecture series.

3. On-the-job training. The requalification program shall include on-the-job training so that:

a. Each licensed operator of a production or utilization facility manipulates the plant controls and each licensed senior operator either manipulates the controls or directs the activities of individuals during plant control manipulations during the term of their licenses. For reactor operators and senior operators, these manipulations shall consist of at least 10 reactivity control manipulations in any combination of reactor startups, reactor shutdowns or other control manipulations which demonstrate skill and/or familiarity with reactivity control systems.

b. Each licensed operator and senior operator has demonstrated satisfactory understanding of the operation of all apparatus and mechanisms and knows the operating procedures in each area for which he is licensed.

c. Each licensed operator and senior operator is cognizant of the facility design changes, procedure changes, and facility license changes.

d. Each licensed operator and senior operator reviews the contents of all abnormal and emergency procedures on a regularly scheduled basis.

e. A simulator may be used in meeting the requirements of paragraphs 3a and 3b if the simulator reproduces the general operating characteristics of the facility involved, and the arrangement of the instrumentation and controls of the simulator is similar to that of the facility involved.

4. Evaluation. The requalification program shall include:

a. Annual written examinations which determine areas in which retraining is needed to upgrade licensed operator and senior operator knowledge.

b. Written examinations which determine licensed operator's and senior operator's knowledge of subjects covered in the requalification program and provide a basis for evaluating their knowledge of abnormal and emergency procedures.

c. Systematic observation and evaluation of the performance and competency of licensed operators and senior operators by supervisors and/or training staff members including evaluation of actions taken or to be taken during actual or simulated abnormal and emergency conditions.

d. Simulation of emergency or abnormal conditions that may be accomplished by using the control panel of the facility involved or by using a simulator. If the control panel of the facility is used for simulation, the actions taken or to be taken for the emergency or abnormal condition shall be discussed; actual manipulation of the plant controls is not required. If a simulator is used in meeting the requirements of paragraph 4c, the simulator shall accurately reproduce the operating characteristics of the facility involved and the arrangements of the instrumentation and controls of the simulator shall closely parallel that of the facility involved.

e. Provisions for each licensed operator and senior operator to participate in an accelerated requalification program where performance evaluations conducted pursuant to paragraphs 4a through 4 d clearly indicate the need.

5. Records. Records of the requalification program shall be maintained to document each licensed operator's and senior operator's participation in the requalification program. The records shall contain copies of written examinations administered, the answers given by the licensee, results of evaluations and documentation of any additional training administered in areas in which an operator or senior operator has exhibited deficiencies.

6. Alternative training programs. The requirements of this appendix may be met by requalification programs conducted by persons other than the facility licensee if such requalification programs are similar to the program described in paragraphs 1 through 5, and the alternative program has been approved by the Commission.

APPENDIX F

SURVEY OF NUCLEAR POWER PLANT OPERATION

NS SAVANNAH

Like a conventional ship, the crew of the NS SAVANNAH was built around members of the deck department, responsible for navigation and overall operation of the vessel, and of the engine department, responsible for the operation of the ship's propulsion and other machinery. In each department there were officers, licensed by the U.S. Coast Guard as possessing the technical competence required for their jobs, and certified or unlicensed personnel, skilled in the performance of shipboard duties but at a lesser technical level. Each person who served as an officer or crew member of the NS SAVANNAH was licensed or certified in accordance with "Rules and Regulations for Licensing and Certification of Merchant Marine Personnel," Publication C.G. 191, of the U.S. Coast Guard.

Officers Qualifications

All engine officers had to meet the following C.G. 191 requirements before obtaining an original license:

1. Must be at least 21 years of age. (Third assistant engineer can be 19, but cannot raise grade prior to 21st birthday.)

2. Must be a citizen of the United States (native born or naturalized).

3. Must present satisfactory documentary evidence of eligibility in respect to educational and service requirements.

4. Must pass a physical examination given by a medical officer of the U.S. Public Health Service.

5. Must hold a First Aid Certificate, obtained by successfully completing an examination based on the contents of "The Ship's Medicine Chest and First Aid at Sea," a standard text published by the U.S. Government Printing Office. This certificate is issued by the U.S. Public Health Service.

In addition to points 1 through 5, an applicant for an original unlimited third assistant engineer's license must have served three years in the engine department of steam vessels (or motor vessels in the case of diesel licenses) of over 4,000 horsepower. Two and one-half years of the three must have been as fireman, oiler, watertender or other qualified member of the engine department, or have served three years as an apprentice to the machinists trade together with one year of service in the engine department of steam vessels as oiler, watertender, or junior engineer. The applicant could also qualify if he were a graduate of the U.S. Merchant Marine Academy, or of a duly recognized college of marine engineering, together with three months service in the engine department of steam vessels. Graduates in electrical or mechanical engineering from duly recognized schools of technology with six months service in the engine department of steam vessels could also qualify.

Each applicant, after fulfilling the above requirements, must then successfully complete a written examination given by the U.S. Coast Guard. For engine officers, the examinations covers such subjects as electricity, basic thermodynamics, fluid flow, boiler water chemistry, combustion, lubrication, principles of operation of reciprocating, turbine and diesel engines, and associated subjects. These examinations are carefully prepared and regulated by the U.S. Coast Guard. The examinations usually require 3 to 5 days to complete.

Merchant marine officers must take additional examinations in order to raise their grade of license. The examinations are taken after the officer has sailed one year in charge of a watch in a position equal to the grade of license held, or for two years in a lower officer's position. The successive grades for engineers licenses are third assistant engineer, second assistant engineer, first assistant engineer and chief engineer. The examinations become more comprehensive and difficult at each grade and are designed to assure that the applicant is prepared to assume increased responsibilities.

Unlicensed Engine Force

All members of the unlicensed engine force, except the wipers, had to have certificates as "Qualified Member of the Engine Department." To qualify for such certificates, the men must meet requirements specified in C.G. 191, and then successfully complete a written or oral (at the discretion of the examiner) test to obtain the desired ratings of:

a. Oiler

b. Deck engineer

c. Refrigerating engineer

d. Junior engineer

e. Electrician

f. Machinist.

Engine Department Organization

The engine department was headed by a chief engineer, responsible to the captain of the ship. The chief engineer was in charge of all reactor operation, as well as of the propulsion and other machinery and equipment aboard ship. Reporting to him were the second assistant engineers and two third assistant engineers, each of whom was in charge of a watch, and the first engineer (to whom the day workers reported) who was responsible for specified maintenance and other activities.

By way of marine experience, the chief engineer was required to be an individual who had served at sea for at least 15 years on large vessels, and a total of 20 years in the shipping business. The first assistant engineer was required to be a person of at least 12 years experience at sea, 7 of these in the capacity of chief or first assistant engineer on large vessels. The experience of the other assistant engineers varied from one to 20 years with the majority having over 10 years at sea. All of those engineers with the lesser seagoing experience had degrees from engineering or nautical schools.

Duties and Responsibilities - Watches

The engine department was divided into three watches as shown in Figure F.1. Each watch group consisted of two licensed marine engineers who had been trained and qualified as reactor operators on the SAVANNAH reactor, and one oiler. Each group stood watches of four hours on duty and eight hours off while at sea. In port, the watches were eight hours on duty and sixteen off.

One engineer on each watch was designated as the senior watch officer. While on duty he was responsible for the operation of the reactor and all associated equipment, as well as all of the equipment in the engineroom. He was assisted by another assistant engineer who was a qualified reactor operator. The senior watch engineer or his assistant remained in the control room at all times while the other worked in both the control room and the engineroom. The engineer stationed in the control room monitors and logs the operation of all equipment, both nuclear and conventional. It was the responsibility of the senior watch engineer to notify immediately the chief engineer and the officer in charge on the bridge of any unusual happenings in the engine department. He took any remedial steps necessary to protect the vessel, passengers, crew and cargo. For reactor startup, maneuvering, or other non-routine work in the control room, the watch crew was augmented by members of the engine crew normally assigned to other watches and by the chief engineer and the first assistant engineer.

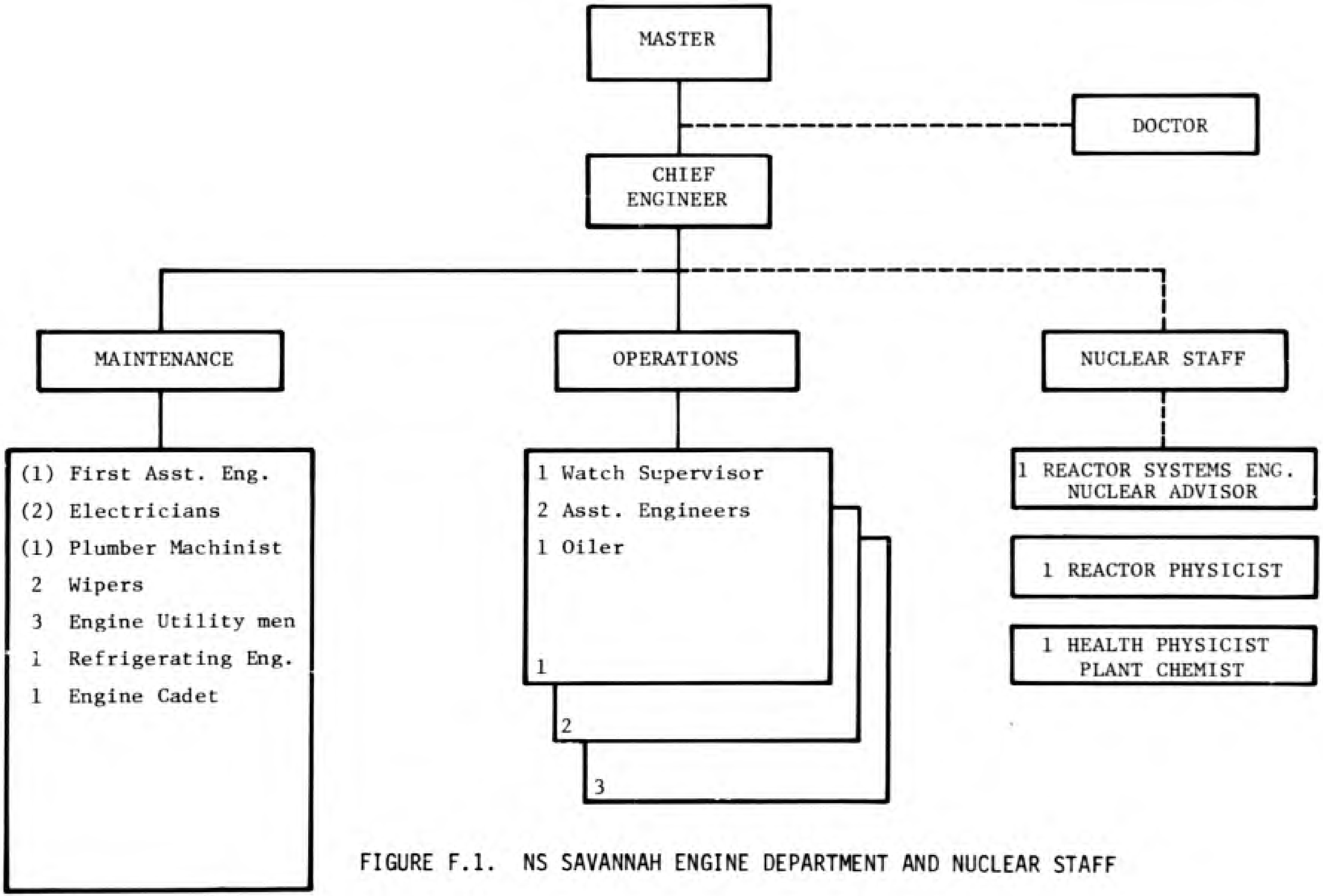

FIGURE F.1. NS SAVANNAH ENGINE DEPARTMENT AND NUCLEAR STAFF

The oiler was stationed in the engineroom where he observed the operations of all equipment and took and logged readings periodically. He examined line shaft bearings and stern tube packing and checked the operation of the steering engine and associated equipment.

The operation of the evaporators, the transferring of liquids in the ship and the pumping of cargo hold and engine space bilges was handled by the men on watch in the engineroom as directed by the chief engineers, the senior watch engineers, and/or the officer in charge of the watch on the bridge. Speed changes under normal conditions were made as directed by the master, either by use of the engine order telegraph or verbally through the chief engineer. In emergencies, such order came directly from the officer in charge of the bridge by use of the engine order telegraph.

Duties and Responsibilities - Day Workers

There were the following day workers aboard the SAVANNAH in the engine department:

1 First Assistant Engineer

2 Electricians

1 Plumber Machinist

2 Wipers

3 Engine Utilitymen

1 Refrigerating Engineer

1 Engine Cadet

The first assistant engineer was in charge of the day workers in the engine department and, subject to the chief engineer's instructions, laid out and directed the housekeeping and maintenance work which this group accomplished. The day workers were ordinarily on duty eight hours a day from 8:00 a.m. to 5:00 p.m., while the vessel was at sea or in port, but could be called on to work at any other time. Inventory control and the requisitioning of consumable and expendable stores were handled under the personal supervision of the first assistant engineer.

The electricians maintained operating records on all electrical equipment and carried out periodic routine maintenance as directed. They maintained stocks of electrical spare parts, wire, switch gear, lamps and associated equipment and prepared requisitions periodically in order to replenish these stocks. The plumber machinist operated the machine tools to assist with repairs and handled any plumbing jobs which occurred. The wipers were responsible for keeping the engineroom clean and shipshape, including painting and scaling when necessary. They handled stores and assisted with the handling of equipment and tools when repairs were made. The engine utilitymen assisted the first assistant engineer and others in the handling of routine maintenance and repair work. The refrigerating engineer was responsible for operation and maintenance of refrigeration and other cooling equipment. The engine cadet was a trainee and was called on to assist with various jobs while on day work and he occasionally was assigned to watches so that he could become familiar with the routine operation of the vessel.

ENGINEER OFFICERS TRAINING PROGRAM

Purpose and Scope of Program

The engineer officers training program was designed to provide well trained, competent and qualified reactor operators for the NS SAVANNAH nuclear propulsion plant. All personnel picked for this training were licensed marine engineers. Upon satisfactory completion of the program the trainee understood the design and operating characteristics of all the systems that make up the plant and the normal and emergency operating procedures covering these various systems.

Training Program Description

The engineer officers training program was divided into three phases:

Phase I: Lynchburg, Virginia

1. Academic Training
2. Practical Training

Phase II: Field Training

1. Hanford Facilities
2. Army Package Power Reactor - Fort Belvoir, Virginia
3. Vallecitos Boiling Water Reactor
4. NMSR Control Rod Drive Test Facility at San Jose, California
5. Naval Damage Control School, Philadelphia, Pennsylvania
6. Naval Reactors Branch at Idaho Falls, Idaho
7. Army Reactor Branch at Idaho Falls, Idaho

Phase III: On-The-Job Training

1. Shipyard Maintenance Training Program
2. SAVANNAH Nuclear Plant Qualification Program

3. Specialized Qualification Program

4. Simulator Training

ENGINEER OFFICERS QUALIFICATION PROGRAM

<u>Organization and Responsibility</u>

The Engineering Officer's Qualification Program conducted by the New York Shipbuilding Corporation, was designed to certify the competence of the licensed States Marine Lines operating engineers in the operation of the NS SAVANNAH reactor and steam plant systems.

Within the New York Shipbuilding Corporation, the qualification program was the responsibility of the Manager, SAVANNAH Nuclear Power. This responsibility was delegated to the Superintendent of SAVANNAH Nuclear Operations who directed the program with the assistance of the Qualification Program Director. Student proficiency was tested by the qualification examiners who were Babcock and Wilcox design and service engineers with extensive knowledge of the ship's systems and components.

The engineering officers supplemented the information received in the formal training program through lectures by design engineers and vendor representatives specializing in the power systems, by simulator training, and by observation of construction and testing of the ship and its power plant at Camden, New Jersey. Design field changes in the power plant were presented by the qualification examiners to keep officers appraised of the power plant design, as installed.

The qualification program was dividied into two major steps - preoperational or provisional qualification and final qualification. Provisional qualification was granted to officers who have demonstrated thorough knowledge of the SAVANNAH power plant, including the design, location and identification of components, and of operating procedures for the equipment, and had completed the SAVANNAH simulator training. Provisional qualification was completed prior to installation of fuel elements in the ship. Final qualification was granted to officers who had demonstrated proficiency during testing of the SAVANNAH in the operation of the overall ship's propulsion system.

Final qualification was certified by the New York Ship Corporation's Manager, SAVANNAH Nuclear Power.

<u>Provisional Qualification</u>

Provisional qualification was based on an oral examination of each officer by the qualification examiner. These examinations were conducted on each system, using Qualification Check Sheets as a guide. The check sheets were divided into the four parts described in the following paragraphs.

1. Central Control Room - The officer was required to locate and identify all instrumentation and controls for the system in the control room and to demonstrate his ability to operate the system under startup, shutdown, normal and casualty conditions. For provisional qualification, the operations were demonstrated by oral examination and operation of the SAVANNAH simulator.

2. Outside Central Control Room - The officer was required to locate, identify and describe the function of each component in the system and to operate any equipment with local controls under startup, shutdown, normal and casualty conditions. The operating requirements for provisional qualification was accomplished through an oral examination at the equipment control center on the ship.

3. General Knowledge - The officer was required to describe both orally and graphically the basic system and component design and to demonstrate a knowledge of the operating parameters, emphasizing system limitations and operating precautions.

4. Functional Design Theory Knowledge - The officer was required to prove his knowledge of the basic design theory involved with system operation.

Upon satisfactory completion of all system examinations, the officers were granted Provisional Qualification, which certified their competence to participate as operators in the test program.

Final Qualification

As the power plant construction and testing progressed and the completed systems became operational, the officers performed the operational portions of the Qualification Check Sheets on the actual equipment. While provisional qualification was based on oral examinations and simulator operation, final qualification was based on demonstrated proficiency in the operation of the installed power plant. Upon completion of all the Qualification Check Sheets, each officer completed a written comprehensive examination on the over-all plant. The written examination was followed by a terminal interview with the Superintendent of SAVANNAH Nuclear Operations and other key personnel in the qualification program. Final certification of the officer's qualification to operate the SAVANNAH power plant was endorsed by the New York Shipbuilding Corporation's Manager, SAVANNAH Nuclear Power. Once certified to operate the power plant, the personnel were licensed by the AEC in accordance with the Code of Federal Regulations, 10CFR55.

Nuclear Staff. As previously indicated, the crew of the SAVANNAH, specifically those in the deck and engine departments, had extensive training and indoctrination in the fundamentals, theory and practical aspects of reactor design, operation and maintenance. It was difficult to determine the specific judgment and understanding of reactor performance and operation which results from long experience. Accordingly for an initial period of the ship's operation, certain personnel were assigned aboard the ship in a staff capacity. Included in their functions were conducting training and development programs for crew personnel. These programs were coordinated with systems and procedural development.

Reactor Physicist. He collects and analyzes reactor operating data. A schedule of routine physics tests was established to indicate trends in reactor physics characteristics. Data from the tests and from routine operations were used to evaluate the efficiency and safety of the plant and procedures. Procedures and procedural modifications were reviewed with and/or developed in cooperation with the crew to assure workability, completeness and a mutual appreciation of the safety considerations involved. In cooperation with other members of the nuclear staff, a comprehensive list of technical operating limits was prepared to provide mandatory guide-posts that define the conditions and actions required to minimize the hazards associated with nuclear plant operations.

Reactor Systems Engineer. During the routine operation of the ship following the startup program, he provides technical and engineering services to the crew and company management with regard to the reactor plant. Emphasis was on developing routine and special operating and maintenance procedures and on training the crew in their use. This phase of activities was directed toward the objective of raising the technical competence and operating capabilities of the ship's crew to a level which would not require continual engineering coverage during reactor operation.

Health Physicist. Serving in a staff capacity, he ensured that the radiological safety programs on the SAVANNAH were properly integrated in the Ship's Bill, and that they were carefully and definitely followed in all phases and procedures, and that an adequate onboard training program was carried out for replacement personnel. In addition, he ensured that all reports and records were promptly and properly submitted, and that all pertinent information and data were properly logged and recorded.

Maintenance Engineer. An engineer with experience in the problems associated with maintenance and equipment in nuclear plants was assigned in a staff capacity with responsibility for refueling and maintenance activities of the vessel. Specifically he originated and reviewed nuclear maintenance procedures for use both aboard ship and at dockside, ensured that the required material, tools and other equipment were available and, working with the Health Physicist, ensured that the work was performed safely and adequately from an engineering standpoint. He also planned from a maintenance standpoint the execution of equipment changes which were to be made from an improvement standpoint.

U.S. NUCLEAR NAVY

In 1972, the United States had in operation 104 nuclear-powered submarines, which had a combined operating experience of 900 ship-years and an estimated cumulative steaming distance (through 1970) of over 16 million miles. Comparable figures for the seven U.S. nuclear-powered surface combatants are 48 ship-years through 1972 and 1.5 million miles through 1970. One ship year is equivalent to the operation (including in-port and ship-yard time) of one ship for one year, calculated from the date of the launching.

Qualification for operating these nuclear powered vessels is controlled through the Nuclear Powered Directorate of the Naval Sea Systems Command. The Directorate is also a branch of the Energy Research and Development Administration.

Each ship or submarine is required to have a qualification program that is periodically reviewed by members of the Directorate as well as members of a Nuclear Power Engineering Board which inspects each vessel every year and conducts an Operational Reactor Safeguard Examination (ORSE).

Figure F.2 depicts a representative organization of a U.S. Navy nuclear vessel. The chief engineer is a graduate of the Officer Nuclear Power Training Program and is qualified to perform his duties by the Nuclear Power Directorate. He generally attends a 2½ month refresher course and there is examined by the staff of the Directorate. If he passes the written and oral examinations, he is designated qualified.

The Division Officers are also graduates of the Officer Nuclear Power Training Program. The Officer Nuclear Power Training Program consists of 6 months academic training and 6 months practical training on one of the Navy's prototype nuclear reactors.

The academic course covers the vital technical areas of reactor theory, radiation protection, plant chemistry, instrumentation and controls, and review of thermodynamics, electricity, mathematics and physics. The training on the nuclear reactor prototype consisted of 8 weeks classroom study on systems followed by actual watch standing on all watch stations.

The majority of the enlisted men assigned to the Engineering Department were trained in the Navy's nuclear power program. This training program consisted of 6 months of school and 6 months of watch standing on one of the Navy's prototype nuclear reactors.

Upon completion of training each officer and man is assigned to a nuclear powered ship. The officers are usually assigned as Division Officers and the men, depending on their designator, i.e.. Machinists Mate, Electrician, Electronic Technician, are assigned to one of the divisions. Each must qualify to stand watches both underway at sea and in-port and in addition perform maintenance tasks. The following is a typical watch while underway:

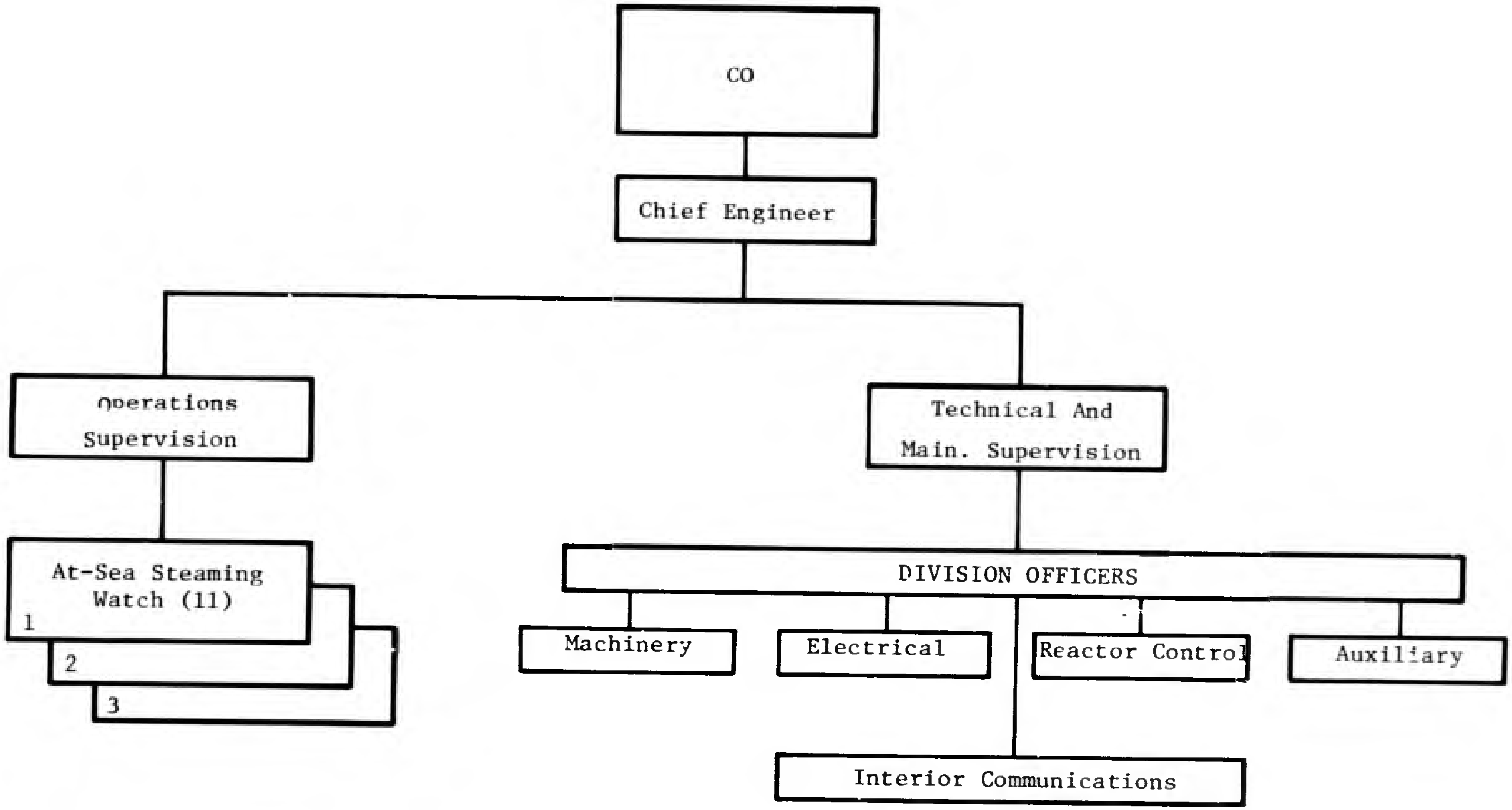

FIGURE F.2. REPRESENTATIVE ORGANIZATION FOR U.S. NUCLEAR NAVY

Watch	Manned by
Engineering Officer of the Watch	An Engineering Officer
Engineering Watch Supervisor	Chief Petty Officer, Engineering Type
Reactor Operator	Electronic Technician 1st or 2nd Class
Electrical Operator	Electrician's Mate 1st or 2nd Class
Throttleman	Electrician's Mate 3rd Class
Machinery Two Upper Level	Electronics Technician 3rd Class
Machinery Two Lower Level	Machinist's Mate 3rd Class
Engine Room Supervisor	Machinist's Mate 1st Class
Engine Room Upper Level	Machinist's Mate 2nd or 3rd Class
Engine Room Lower Level	Machinist's Mate 3rd Class
Auxiliary Electrician Aft	Electrician's Mate 3rd Class

All of the above watchstanders are qualified by the Commanding Officer after a period of training and certification by the Chief Engineer. These qualifications are similar to those of licensed Senior Reactor Operator and Reactor Operator in the utility nuclear power plants.

UTILITY STAFFING AND TRAINING FOR NUCLEAR POWER

The NRC report, "Utility Staffing and Training for Nuclear Power, June 1973," presents qualification standards and guidance for staffing the individual utility. Although plant staff organizations can reflect variations in company policies and practices, particularly in the mode of using first line supervisors, the representative organization shown in Figure F.3 is an arrangement which can be satisfactorily employed to operate a current generation single unit station.

Each operating shift crew consists of a senior licensed shift supervisor, two licensed control operators, and two auxiliary or equipment operators. Five such crews should be well trained to handle all normal and abnormal operating procedures.

Direct, day-to-day technical support for plant operations is a necessity. The vital technical areas are radiation protection, plant chemistry, instrumentation and control, reactor, turbine-generator, and balance of plant equipment. Functions include routine monitoring, surveys, sampling, analysis instrument checking and maintenance, performance analysis, test preparations and evaluation of results.

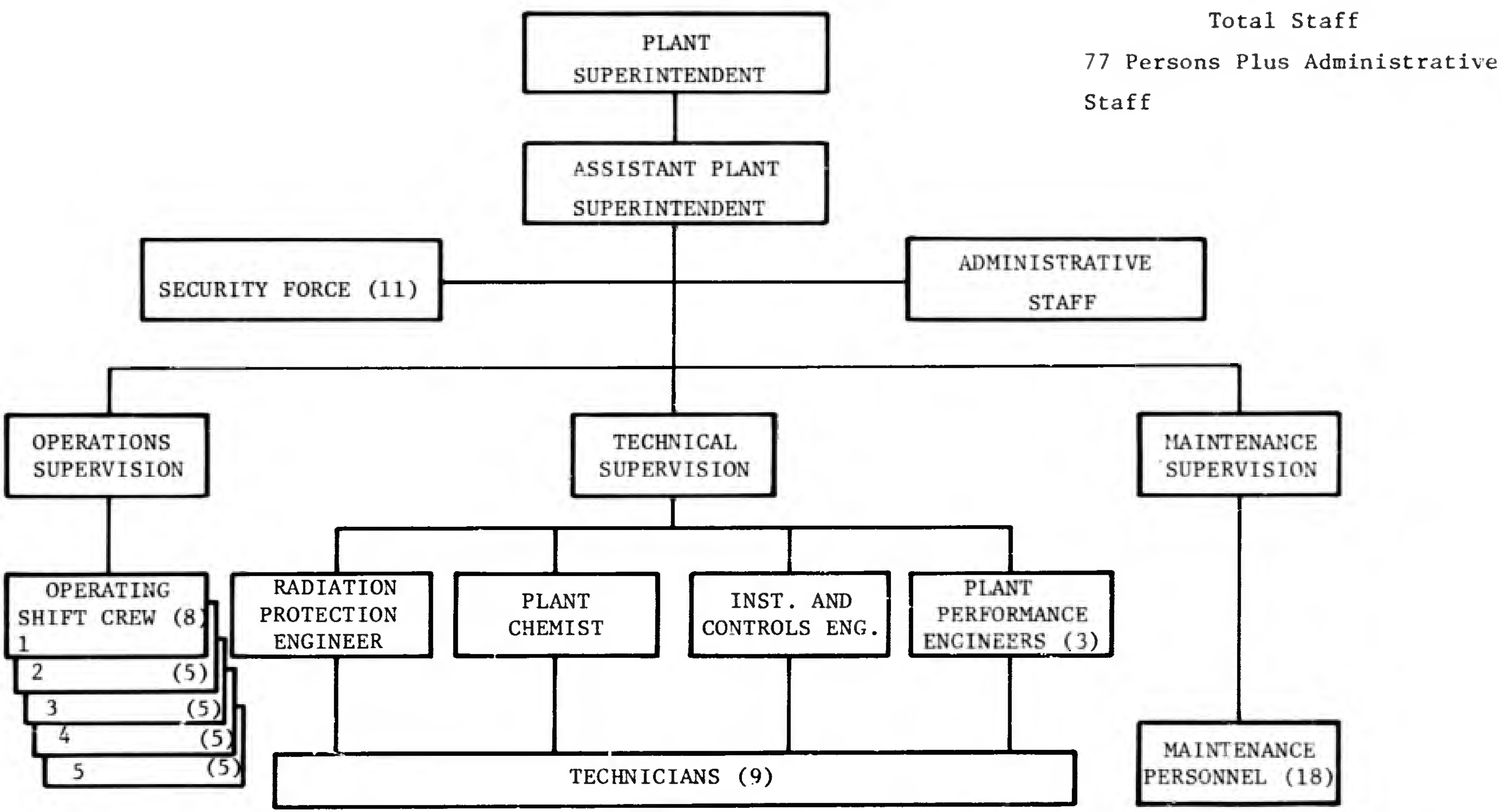

FIGURE F.3. REPRESENTATIVE ORGANIZATION FOR A SINGLE UNIT CENTRAL STATION NUCLEAR POWER PLANT

Electrical and mechanical maintenance requirements noted are largely aimed at the preventive maintenance program but will allow for some repair and corrective maintenance. Certain specialized craft skills not routinely needed at the plant site may come from a more centralized system-wide maintenance staff or from outside organizations.

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