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Lessons Learned from Construction of Nuclear Facilities

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New Plant Quality Assurance Industry Task Force

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Lessons Learned from Past and Present Construction of Nuclear Facilities

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NOTICE

EXECUTIVE SUMMARY

NEI 09-02, *Lessons Learned from Past and Present Construction of Nuclear Facilities*, summarizes the results of the industry review of past and present experience/problems associated with new nuclear plant construction. The document also identifies current industry programs, processes and practices that have developed based in large part on past and present construction experience.

Several documents describing past and present construction activities were reviewed. The review of the documents identified about 300 issues that were categorized by the most relevant criterion of 10 CFR Part 50, Appendix B, *Quality Assurance Criteria for Nuclear Power Plants*. Once categorization was completed, the issues were reviewed to identify the most common problems and the degree of impact on the affected projects. The review concluded that issues were concentrated in five major focus areas: Quality Assurance; Corrective Action; Construction Project; Design; and Training, Knowledge, and Experience. Of these, Quality Assurance, Corrective Action, and Construction Project problems occurred more frequently and seemed to be more significant.

The U.S. nuclear industry has made major changes to improve performance is all aspects of nuclear facility design, construction and operation. Many of these improvements reflect changes in the licensing process for new plants and lessons learned from design, construction and operation of existing plants. Improved industry programs, processes and practices are expected to provide protection against recurrence of issues experienced during past and present construction projects. Effective problem identification and resolution is expected to protect against quality issues that do arise.

LESSONS LEARNED FROM PAST AND PRESENT CONSTRUCTION OF NUCLEAR FACILITIES

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LESSONS LEARNED FROM PAST AND PRESENT CONSTRUCTION OF NUCLEAR FACILITIES

1 INTRODUCTION AND BACKGROUND

Operators of the current fleet of nuclear power plants have become adept at sharing experiences so they can learn from issues and problems. With that in mind, learning from past and present construction experience is an important part of the nuclear industry's effort to improve the design and construction of new nuclear facilities and provide a solid foundation for safe, efficient facility operations. This document summarizes the results of a review of past and present construction experiences to identify lessons that can be applied to new plant construction projects.

A number of NRC and industry documents have examined past and present construction problems. The key documents representing industry construction experience, both past and present, were selected for review as listed in Section 3.1.1. Lessons from past and present construction efforts were also evaluated against current industry programs to determine if those programs would be effective in protecting against recurrence of the identified issues.

The review of industry construction experience identified about 300 individual issues that were categorized accordance to the most relevant criterion in 10 CFR Part 50, Appendix B, *Quality Assurance Criteria for Nuclear Power Plants*. Once categorization was completed, the issues were reviewed to identify the most common problems and the degree of impact on the affected projects. The review concluded that there were five major focus areas: Quality Assurance; Corrective Action; Construction Project; Design; and Training, Knowledge and Experience. Of these, Quality Assurance, Corrective Action, and Construction Project problems occurred more frequently and seemed to be more consequential.

2 PURPOSE AND SCOPE

2.1 PURPOSE

The purpose of NEI 09-02 is to document the industry's review and evaluation of 1) the lessons learned from past and present construction of nuclear facilities, and 2) the U.S. nuclear energy industry programs, processes and practices that exist today that are expected to assure high quality in the industry's new build efforts.

2.2 SCOPE

The scope of this review included evaluating past and present construction problems by discrete areas and comparing the lessons to current industry programs, processes and practices.

Section 3 identifies the main common causes of the issues identified in the reports reviewed.

Section 4 describes current industry programs, processes and practices that are expected to protect against the construction problems described in Section 3.

3 DOCUMENT REVIEW

3.1 REVIEW PROCESS

3.1.1 Reports Reviewed

There are numerous documents that discuss issues related to construction of nuclear facilities. Several NRC and industry reports were selected that describe issues and problems encountered in building the current fleet of nuclear power facilities. The documents selected and reviewed include:

1. NUREG-1055, Improving Quality and the Assurance of Quality in the Design and Construction of Nuclear Power Plants.

2. NRC Information Notice – 2007-04, Construction Experience Related to the Assurance of Quality in the Construction of Nuclear Facilities.

3. INPO document 08-005, Historical Construction Experience to apply to New Plant Deployment.

4. NRC Inspection Report No. 70-3013/2006-001 Louisiana Energy Services.

5. STUK Investigation Report 1/06, Translation 1.9.2006, dated 10/07/06 – Management of the Safety Requirements in Subcontracting During the Okiluoto 3 Nuclear Power Plant Construction Phase.

6. Huadian Datong Pipe Rupture Event 10/31/2006.

7. Selected NRC documents describing Counterfeit/Fraudulent Material Experiences, including:
    - IE Bulletin 83-06 (Tube-Line)
    - IE Bulletin 83-07 (Ray Miller)
    - IE Bulletin 88-05 (West Jersey Manufacturing)
    - Information Notice 2008-04: Counterfeit Parts Supplied to Nuclear Power Plants

8. NRC Information Notices
    - IN 2007-21: Pipe Wear Due to Interaction of Flow-induced Vibration and Reflective Metal Insulation

- IN 2008-07: Cracking Indications in Thermally Treated Alloy 600 Steam Generator Tubes
- IN 2009-04: Age-related Constant Support Degradation
- IN 2009-06: Construction-Related Experience with Flood Protection Features

3.1.2 Review Process

Issues discussed in the above documents were evaluated. The issues were categorized according to the applicable criteria of 10 CFR Part 50, Appendix B. The issues were broken down to the key common causes that would assist licensees in evaluating whether their design and construction programs provide adequate protection against recurrence of the problems.

3.2 RESULTS OF REVIEW

The issues identified in the review were organized in accordance with the most relevant 10 CFR Part 50, Appendix B, QA criterion. The identified issues were concentrated in five major focus areas: Quality Assurance; Corrective Action; Construction Project; Design; and, Training, Knowledge, and Experience. While important issues were identified in all these areas, most issues fell into three of the five areas: Quality Assurance, Corrective Action, and Construction Project.

For each of the five major focus areas, Sections 3.2.1 through 3.2.5 identify the key common causes of the problems identified during past and present construction.

3.2.1 Quality Assurance

Inadequate quality assurance (QA) was identified as a significant issue during the past and present construction of nuclear facilities. The most notable issues were related to establishing an organization for the development and execution of QA measures, implementing the QA Program, and problems with implementing the independent audit and inspection functions.

3.2.1.1 Establishment of the Organization to Implement the QA Program

Review of the referenced reports clearly indicated that the establishment of the overall organization for implementing the QA Program was problematic for many utilities and contractors building nuclear facilities. The quality assurance organization includes personnel from the highest levels of management to the workers implementing the construction procedures and is not limited to the group(s) performing the independent oversight. The following factors were identified as key causes of the problems experienced in establishing an effective QA organization:

- Management lacked understanding of the requirements for effective QA as evidenced by a lack of commitment to quality, treating QA as an overhead expense rather than a tool to assure quality, and not providing sufficient resources with nuclear experience to oversee design and construction.
- Management lacked a clear understanding of the importance of nuclear-related quality standards, as evidenced by not establishing an independent QA/Quality Control (QA/QC) role, failing to implement adequate quality assurance controls over design, and limiting the QA/QC role to only safety-related activities/materials.

3.2.1.2 Implementation of a Quality Assurance Program

Implementing an effective QA Program was problematic for many utilities and contractors building nuclear facilities. The following key causes were identified:

- Management did not effectively implement a QA Program as evidenced by roles and responsibilities for contractors and utility oversight not being clearly defined, and inadequate communication to contractors of the importance of an effective QA Program.
- The scope and clarity of the QA Program was deficient as evidenced by a lack of adequate procedures and guidance to implement an effective QA program, including inconsistent implementation of a QA records program.
- Utility oversight of contractors was not effective as evidenced by a lack of planned oversight activities; some organizations did not implement the QA Program as defined in the QA Program Description.

3.2.1.3 Quality Assurance/Quality Control Department

The QA/QC department involved with building nuclear facilities was not always effective in implementing their roles and responsibilities. The following key causes were identified:

- The QA/QC department was not effectively established within the overall organization in accordance with quality standards and requirements, as evidenced by QC not being independent of construction/production, poor communication of important information to management (e.g., too many organizational layers filtered the importance or nature of the information), and undue impact of cost and schedule pressures on QA/QC personnel.
- The QA/QC department failed to establish and implement QA Program requirements for their functions, as evidenced by a lack of procedures/processes, inconsistent or improper handling of nonconformances, performing informal inspections rather than using appropriate procedures and reports, not reporting inspection results at the time of inspection, not having QC inspections integrated into the construction schedule so as to have inspections performed when needed, not defining QA/QC requirements for non-safety-related work, ineffective

QA audits that did not always ensure effective corrective action, and lack of QC personnel independence from construction workers.

- The QA/QC department was not an effective conscience for the construction organization, as evidenced by a lack of an effective QA/QC approach to problem identification, failing to audit` some areas as required by the QA Program, and having deficient QC oversight of prime and subcontractors.

3.2.2 Corrective Action

Utilities and contractors constructing nuclear facilities had difficulty in developing and implementing effective corrective action processes. The following key causes were identified:

- Clear processes and expectations were not established to ensure effective identification and reporting of problems as evidenced by a lack of management focus on identifying problems, failure to establish an atmosphere (safety culture) that encouraged problem reporting and resolution at all levels, and failure to identify recurring problems.
- Clear processes and expectations were not established to ensure effective and timely corrective actions were taken as evidenced by root cause evaluations that focused on symptoms and not the underlying cause, corrective actions for problems were not identified, and untimely responses to identified problems.

3.2.3 Construction Project

Review of the reports clearly indicated that utilities and contractors constructing nuclear facilities had difficulty in effectively controlling construction activities. As identified in the following sections, the problems were most notable in project management, project control, scheduling, contracts, and constructor implementation problems.

3.2.3.1 Project Management Problems

Processes and procedures for managing the project were not clearly established by contractor and utility management to provide effective oversight of key functions of project management to assure appropriate quality. This was evidenced by a lack of management experience and knowledge in nuclear facility construction, not establishing clear contracts and subcontracts, and ineffective procurement control processes.

3.2.3.2 Project Control Problems

Processes and procedures for controlling the project were not clearly established or effectively implemented by the contractor and/or utility. This was evidenced by the lack of, or poor, quality project manuals/procedures and construction procedures; inadequate establishment and communication of roles and

responsibilities; and not assuring adequate staffing and facilities for the construction effort.

3.2.3.3 Project Scheduling Problems

Plans and schedules for controlling the project were not clearly established or effectively implemented by the contractor and/or utility. This was evidenced by failure to consider details of test activities and the interrelationship of systems in the scheduling of major activities; failure to include key activities in project schedules, such as as-built configurations and QC inspections; and generally unrealistic and aggressive schedules to complete design and construction.

3.2.3.4 Project Contract Problems

Contracts for projects were not clear, as evidenced by contracting practices that did not facilitate productivity, control, and adequate inspection of the work; contracts that did not consistently represent the best interests of the owner; and contracts that emphasized cost and schedule to the detriment of quality.

3.2.3.5 Constructor Implementation Problems

Constructor implementation of project activities was not clearly established or effectively implemented, as evidenced by inadequate protection of equipment after removal from controlled storage and/or after installation; inadequate measuring and test equipment calibration programs; and warehouse and storage areas not being controlled to ensure proper storage of materials and equipment.

3.2.4 Design

Design activities for the project were not clearly established or effectively implemented. This was evidenced by the design schedule not being integrated into the project schedule to support construction; the detailed design not being completed to a level to support the start of construction; inadequate detail in design criteria, specifications and drawings; lack of rigorous design control procedures and procedure adherence; insufficient design reviews; and improperly prepared calculations.

3.2.5 Training, Knowledge and Experience

Utilities and contractors constructing nuclear facilities had difficulty providing training to personnel appropriate to their level of knowledge and experience. Training requirements for projects were not clearly established or effectively implemented. This was evidenced by workers' lack of experience with nuclear-related standards; insufficient knowledge and experience in ASME codes and nuclear standards; inadequate training for subcontractors and manufacturers on the special construction requirements for nuclear facilities; and management not being involved in establishing training for non-craft and supervisory personnel.

4 REVIEW OF CURRENT INDUSTRY PRACTICES

This section describes current industry programs, processes and practices that are expected to protect against the construction problems described in Section 3.

4.1 GENERAL IMPROVEMENTS

Over the last 40-plus years, the industry has made numerous improvements in processes, programs, procedures, and standards used to design, build and operate nuclear plants. These improvements were made for a number of reasons. Some of the changes were made to improve efficiency, resolve past problems or lessons learned, streamline efforts, and standardize practices. The following summarizes a number of the more significant improvements that are expected to help protect against the problems experienced during past and present construction.

Coordinated Industry Audits

The nuclear industry has implemented numerous programs to perform audits, surveillance, and assessments of activities to ensure that Quality Assurance Programs are properly implemented. Some of the relevant programs include:

- NUPIC (Nuclear Utilities Procurement Issues Committee) - NUPIC was established to perform multi-utility audits of nuclear industry suppliers. The audit results are shared with utility NUPIC members.

- NIAC (Nuclear Industry Assessment Committee) – NIAC was established to perform audits of subtier suppliers used by primary vendors in the nuclear industry. The audit results are shared with the primary vendors.

- NIEP (Nuclear Industry Evaluation Program) – Most nuclear operating plants are required to perform independent audits/assessments on the implementation of their Quality Assurance Programs. NIEP was created to perform the independent QA Program audits/assessments. These audits/assessments are supported by members of the QA organizations from the operating plant utilities.

These programs are implemented industry-wide and help promote a consistent high level of performance.

Improvements in Overall Operations and Information Sharing

The Institute of Nuclear Power Operations (INPO) was formed in the early 1980s and has assisted utilities and vendors to improve their operations and maintain performance at the very highest levels. As part of these efforts, INPO has implemented programs to help the nuclear industry share information relative to problems identified, lessons learned, and other types of operation experience to help the industry learn from experience. Sharing of operating experience, combined with numerous INPO evaluations and assistance efforts has contributed

to significantly improved overall industry performance as evidenced by both INPO and NRC performance indicators.

Analogous to its program for sharing of operating experience, INPO has recently launched a program for the sharing of new plant construction experiences.

Development and Implementation of a Strong Safety Culture

Since the late 1970s, the industry has addressed the need to establish a strong safety culture at nuclear facilities to encourage the raising of safety issues so that they can be resolved with the appropriate attention based on their significance.

The NRC adopted additional regulations and policies, and the nuclear industry developed additional standards focused on establishing a Safety-Conscious Work Environment (SCWE). These regulations and standards have evolved over the last 30 years providing benefits that were not fully developed or available during previous periods of construction. These benefits apply to utility and contractor personnel alike and include:

- Work environments in which employees feel free to raise concerns both to their own management and the NRC without fear of retaliation.
- Active management engagement in identifying and resolving problems.
- Expectation established by Senior Management that harassment, intimidation, retaliation or discrimination (HIRD) of any employee will not be tolerated.
- Employee Concerns Programs (ECP) that provide an alternative way for employees to raise various types of concerns. There is no regulatory requirement that organizations implement neither an ECP nor any scope or limit to its areas of responsibility. However, as a good practice, many organizations have developed various programs, practices, and policies that identify alternate means to raise safety issues and, if desired, maintain anonymity.

It is incumbent upon management to ensure an ongoing SCWE wherein problems are identified and corrective actions are promptly implemented, while assuring concerned individuals are protected from HIRD. Success is achieved when there is an atmosphere of mutual respect in which concerns are received, identified evaluated, and resolved.

Improved Standards

Industry standards and guidance were in their infancy during past construction of nuclear facilities. Consequently, during the original construction of nuclear facilities, industry standards and requirements were not clearly understood or consistently applied. Today, there is a broader understanding and knowledge of the industry standards and requirements, and a larger pool of experienced

personnel. This understanding and knowledge will help assure that new facilities are constructed with consistently high quality to well-understood standards.

Standardization

The nuclear industry has long recognized the benefits of standardization and is committed to standardization as a core principle underlying new build efforts. Among the benefits expected from standardization are improved information sharing regarding resolution of operational and safety issues; focus on a small number of advanced, NRC-certified designs; and reduced life-cycle costs for plant design, licensing, construction, operations, and maintenance. A substantial amount of design standardization is achieved via the NRC's 10 CFR Part 52 design certification process. Additional standardized design information is being developed through individual Design Centered Working Groups (DCWGs).

In addition to standardizing designs, the industry is committed to standardizing its operational programs to the extent practical. Through NEI, the industry has developed a number of generic, NRC-approved templates for operational programs that have been submitted in new plant combined license applications. This has provided for more efficient licensing reviews, as well as the framework for standardized program implementation. Standardization of design and operational information will help assure consistent, successful new plant deployment and more effective information sharing about construction, operational and safety issues.

Improved Project Management Tools

Since initial construction of nuclear facilities, there has been tremendous improvements in project management tools and technology, including computer hardware, computer software, and computer data management, advanced planning and scheduling, to name a few. These improvements will allow the sites to better track and monitor the construction activities, improve processes, and understand the status of items.

Industry Coordination

The nuclear industry has worked to improve supplier cooperation and coordination through groups including INPO, EPRI (Electric Power Research Institute), NUPIC, NIAC, and others. This cooperation has helped improve the suppliers' understanding and implementation of requirements, standards, and guidance related to construction of nuclear facilities. This cooperation and coordination is being strengthened for the construction of new nuclear facilities through vendor participation on NEI taskforces and the DCWGs.

Clarified NRC Requirements and Guidance

In an effort to address issues of the past NRC has established new regulatory requirements and guidance related to new nuclear facility licensing including:

10 CFR Part 52; the NUREG-0800 Standard Review Plan; and numerous regulatory guides.

One of the more significant changes to new reactor licensing process is the Part 52 requirement for licenses to identify the inspections, tests, analyses, and acceptance criteria (ITAAC) that a constructed facility must satisfy prior to operation. The ITAAC process is expected to make new plant licensing, construction, and start-up more predictable and efficient by establishing these construction acceptance criteria up front in the license.

4.2 QUALITY ASSURANCE PROGRAM

Over the last 40-plus years, the industry has developed mature QA Programs that provide oversight of important areas. Nuclear industry management has developed and implemented programs that facilitate the ability to provide proper implementation of the QA Program.

Mature and effective QA programs in use at current operating plants were used as a basis for developing a standardized Quality Assurance Program Description (QAPD) template for new plants. The QAPD template (NEI 06-14) is in the process of being approved by the NRC for use with the new plant build effort. This standardized QAPD template will help improve applicant, licensee, and contractor understanding and implementation of the QA Program requirements necessary for assuring quality construction and safe operation of new nuclear plants.

Through cooperative efforts (such as NUPIC and NIAC) and sharing of experiences, there has been an improvement in the training and knowledge of QA Program requirements and how to implement them. Within the NUPIC process, a New Plant Development Committee has been established with the objectives of assuring consistent implementation of QA Programs, consistent implementation of surveillances conducted at supplier shops, and completion of audits using the highest standards.

There have also been changes to the ASME NQA-1 quality assurance standard used by the industry. These changes provide clarifications related to previous NRC positions and changes in technology. The revised NQA-1 provides the basis for the NEI 06-14 template and new plant QAPDs.

Quality Assurance Programs and implementing procedures have improved significantly since earlier periods of construction. The industry's focus on quality and robust Quality Assurance Programs has been a major contributor to the sustained excellent performance of the existing fleet of U.S. nuclear plants and provides a solid basis for like performance by future plants.

4.3 CONSTRUCTION CORRECTIVE ACTION PROCESSES

Construction corrective action processes ensure issues are identified and actions are taken to correct and effectively prevent the problem in the future, and are central to an effective quality assurance program. Since the time that existing facilities were built, the companies operating nuclear power plants and major safety-related equipment suppliers to the nuclear industry have developed and improved the corrective action programs (CAP) that they employ.

Licensees now have extensive experience with the administration and implementation of effective corrective action programs at operating nuclear facilities and are applying this experience to assure effective construction corrective action process implementation for new nuclear construction. Programs provide training along with expectations and procedure guidance on the basic elements of CAP. The industry has made cultural improvements to promote self-identification of problems. Licensees have learned that the CAP needs strong management oversight, and CAPs now have several management review activities built into the process. Root causes exhibit clear ties between the evaluation, cause, and corrective actions. During construction, licensees are required to retain responsibility for any portion of the construction corrective action process that they delegate to vendors, and will thus be providing oversight of that program's implementation.

The industry has improved CAP by implementing a variety of computer-based programs and overall data management. Computers have made the issues and resolutions more visible to management and allow more effective use of trending and other approaches to identify and resolve issues.

Outside agencies (e.g., INPO & NRC) have increased their knowledge of effective corrective action programs. They have contributed to the industry improvement over the last forty years by identifying weaknesses and providing insight on areas that need improvement. The same can be said for licensees and their continuing oversight of suppliers.

The industry now has available multiple vendors offering many different types of effective causal analysis techniques and tools, along with associated training. Current cause analyses techniques look deeper into contributing organizational factors versus the old "broke-fix" approach that often did not address underlying causes.

To promote consistent, effective corrective action process implementation during new plant construction, the nuclear industry developed NEI 08-02, *Corrective Action Processes for New Nuclear Power Plants During Construction.* Workshops and training have been given and more are planned to ensure vendors and licensees understand how to implement NEI 08-02, and the industry is working towards endorsement by the NRC in a regulatory guide.

4.4 NUCLEAR CONSTRUCTION PROJECT

Many current operating plants have recently completed significant modifications, including steam generator replacements, turbine generator repairs and replacements, and reactor vessel closure head replacements. Many sites have also constructed dry cask spent fuel storage facilities. The organizations involved have learned from these activities and continued to make improvements in their processes in order to perform modifications more effectively in the future. Where lessons are learned and good practices identified, they are shared within the industry through groups such as INPO, EPRI, and NRC. The recent successful restart of Brown's Ferry by TVA and the major refurbishment efforts of the Fort Calhoun Station by Omaha Public Power District are prime examples of how the industry has learned from past and present construction experience. TVA is also currently in the process of completing construction of Watts Bar Unit 2.

In addition, U.S. companies are benefitting from recent new build experience overseas. Each of the new build projects moving forward in the U.S. includes foreign partners that have recent experience building new nuclear facilities. The construcion of a number of standardized plants in South Korea and Japan in recent years provide examples of good construction experience. Many of the principles used in construction of nuclear facilities in foreign countries will be used to improve construction at sites within the United States.

The enhancements in construction industry processes and practices in the following areas are expected to result in improved quality of new facility construction:

- Extensive use of modular construction in a controlled shop environment.
- Use of new technology for:
    - Welding, including automated/robotic techniques.
    - Computerized control of postweld heat treament activities, including time/temperature measurements.
    - Enhanced radiography and ultrasonic examination practices.
    - Bar coding and radio frequency identification (RFID) practices to improve the identification and control of equipment and materials.
    - Photogametry and laser scanning for the measurement and recording of dimensions and configuration.
    - GPS/laser surveying.
- The evolution and better understanding of Section III of the ASME Code as a result of Code interpretations, Code Cases and experience gained through use of the Code.
- Application of human performance principles to the construction environment activities.

- Policies and practices that assure quality is built in, not inspected in.
- Standardized equipment and improved oversight of vendors.
- Extensive use of computer systems for:
    - Document control.
    - Configuration management.
    - Communication.
    - Control of quality records.
    - Sharing lessons learned.
- The inspection, test, analysis and acceptance criteria (ITAAC) approach will assure that critical steps in the construction process are scheduled, performed, reviewed and documented to assure appropriate requirements are met.

4.5 DESIGN

Standard Designs and Design Before You Build

The design effort for new nuclear facilities is being done much differently than previous nuclear facilities. The existing fleet of operating plants were of various designs incorporating various codes and standards. Plants were constructed as the designs were being finalized. Arguably the most significant difference in the design and construction of new facilities is that standardized plant designs will be essentially complete before construction begins. This reflects a major lesson learned from previous construction in the U.S. and is encouraged by the 10 CFR Part 52 licensing process for new reactors. These new rules are intended to promote standardization and reduce uncertainty in the licensing process by issuing a license for construction and operation of a certified reactor plant design. Among the benefits expected as a result of design certification and standardization are improved plant operations, information sharing and resolution of safety issues, as well as a reduced number of different designs in the future fleet of reactors. The NRC Standard Review Plan, NUGEG-0800, has been revised to emphasize the use of common codes, standards and operating programs, and incorporates requirements based on industry experience. Standardized designs will use standardized equipment and components to the maximum practical extent.

Incorporation of Lessons Learned

New designs will incorporate lessons learned from the TMI Accident documented in NUREG-0737 and included in 10 CFR 50.34. Design-related TMI requirements include facility specific probabilistic risk assessments, reliability evaluations of safety-related SSCs, consideration of human factors, and post-accident design features. Programmatic requirements include administrative procedures for evaluating operating, design, and construction experience, and for ensuring applicable industry experience will be provided in a timely manner for

those constructing the facility. Specific requirements of the Quality Assurance program and organization are included in 10 CFR 50.34. Requirements were added to improve the design process by ensuring independence of the organization performing the checking function from the organization originating the design; including Quality Assurance personnel in the documented review of and concurrence in quality-related procedures associated with design, construction and installation; addressing qualification requirements for Quality Assurance and Quality Control personnel; requiring personnel involved with design and analysis activities be indoctrinated in quality assurance, and procedures for maintenance of as-built documentation.

Various design issues were identified in NRC Information Notices, Bulletins and Circulars in the 1970's and 1980's. Additional problems in the same timeframe were documented in various 10 CFR Part 21 reports and made available to the industry. Examples of such issues included the failure to properly consider pipe support design loads, block wall construction, amplified response spectra loads, and computer software errors. The lessons learned in these areas have been captured in industry guidance documents and applied to the new standard designs being certified by NRC. NRC generic communications on these and other topics have helped make industry design personnel more aware and sensitive to these issues.

4.6 TRAINING, KNOWLEDGE AND EXPERIENCE

Nuclear Training Academy

Considerable improvements have been made in the areas of training, knowledge, and experience of nuclear plant personnel. Improvements include development of the Nuclear Training Academy and enhancement of standards that require training and certification of nuclear workers. In the past, there was a reliance on self-study and reading outside the classroom. In the ensuing period, more rigor was brought to training when licensees and others adopted the INPO systematic approach to training (SAT) as defined in 10 CFR 55.4.

Development of Training Consortia

Many new companies were formed to serve the training needs of the industry. For example, licensees have come together to form training consortia such as the Mid Atlantic Nuclear Training Group, The American Society for Training and Development, the Energy Industry Computer Based Training Alliance, the International Society for Performance Improvement, and the Western States Training Group.

Special classes on rigging and lifting, new rules around rigging, and an increased safety focus by both licensees and contractors have focused on correcting the lifting errors of the past. For example, contractors and licensees alike now consider safety function, rather than strictly weight, when determining lift plans.

There is a general scarcity of skilled craftsmen to support major new construction projects. In the nuclear industry, in particular, the need is critical. In response to the need for skilled craftsmen, some contractors have created regional training facilities to support their contract operations. Additionally, some contractors and licensees have formed alliances with trade schools and technical colleges, providing instructors, instruction materials, and ultimately jobs for the trainees. The training continues on-the-job, in union halls, and in continuing education classrooms.

Contractors are improving their probability for success and flattening the learning curve by hiring personnel from nuclear operating companies and from authorized inspection agencies. These new hires include people that have extensive nuclear industry experience. These people are fully trained and can pass on their knowledge of nuclear regulations and industry codes and standards.

Training and Qualification of Quality Assurance and Quality Control Personnel

With NEI support, INPO is currently developing a guidance document establishing the necessary body of knowledge for nuclear QA/QC personnel. This guidance will assure a consistent industry approach to training and certification of QA/QC personnel.

5 CONCLUSIONS FROM REVIEW OF CURRENT INDUSTRY PRACTICES

The Nuclear industry has made major changes to improve performance is all aspects of nuclear facility design, construction and operation. Many of these improvements reflect changes in the licensing process for new plants and lessons learned from design, construction and operation of existing plants. Chief among these improvements are:

- Completing design information before construction begins
- Standardization of designs and operational programs to the extent practical
- Effective Quality Assurance and Quality Control Programs
- Effective Corrective Action Programs
- Industry coordination and information sharing related to quality issues
- Modern project management practices and tools
- Establishment of strong nuclear safety culture, including Safety Conscious Work Environment

In addition to improved programs and practices, it is clear that knowledgeable and experienced QA/QC personnel, adequate training of all personnel performing

quality related activities, and management oversight of issues affecting quality are critical ingredients for construction quality and overall project success. It will be important for new plant licensees to ensure that appropriate priority and resources are directed to these critical areas.

Improved programs and practices, implemented and overseen by trained and qualified personnel, are expected to provide substantial protection against quality breakdowns in future construction projects, including the common causes described in Section 3 of problems identified in the review of past and current construction projects.

Even so, given the size and complexity of these projects, human performance and other problems can be expected to arise and create quality issues during construction of new nuclear facilities. As such, a key lesson from past construction experience is that prompt, effective problem identification and resolution is central to assuring quality construction and a successful project. In this regard, it is significant that many of the industry's improvements indentified in this report are directed toward establishing the programs, practices, culture, and commitment necessary to ensure that quality problems are promptly identified and effectively resolved and communicated.