CONF-910603--10

SAND--91-0745C

SAND91-0745C

DE91 010477

APR 17 1991

Department of Energy Interest and Involvement In Nuclear Plant License Renewal Activities*

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ABSTRACT

Recognizing the importance of nuclear license renewal to the nation's energy strategy, the Department of Energy (DOE) initiated a plant lifetime improvement program during 1985 to determine the feasibility of the license renewal option for U.S. nuclear plants. Initial activities of the DOE program focused on determining whether there were technical and economic obstacles that might preclude or limit the successful implementation of the license renewal option. To make this determination, DOE co-sponsored with the Electric Power Research Institute (EPRI) "pilot-plant" efforts by Virginia Electric Power and Northern States Power. Both pilot-plant efforts concluded that life extension is technically and economically feasible. In parallel with the pilot-plant activities, DOE performed national economic studies that demonstrated the economic desirability of life extension. Having demonstrated the feasibility of life extension, DOE, in conjunction with EPRI, selected two lead plants to demonstrate the license renewal process. These lead plants are Yankee Atomic's Yankee Rowe facility and Northern States Power's Monticello facility. DOE also initiated activities to develop the technical and regulatory bases to support the license renewal process in the United States. These include (1) development of a methodology for identifying systems, structures, and components important to license renewal, (2) development of industry reports that describe industry-accepted approaches for license renewal of ten important classes of equipment, (3) development of technical basis to support license renewal, and (4) interaction/negotiation with the NRC through the Nuclear Management Resources Council (NUMARC) regarding appropriate regulatory requirements for license renewal. DOE has recently identified nuclear plant license renewal to be an important element of its National Energy Strategy. This paper summarizes the significant results, conclusions, and ongoing activities of the DOE effort.

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*This work was supported by the United States Department of Energy under contract DE-AC04-76DP00789

INTRODUCTION

Nuclear power is the second source of electricity within the United States, and it has been pivotal in reducing the use of oil and gas for electrical generation. Since 1970, over one-third of the total generating capacity added to meet the growing demand for electricity has been nuclear. Nuclear power in the United States supplies approximately 20 percent of our electrical generation, displaces about 2.5 million barrels per day of oil usage, and represents over $200 billion of investments. However, as things now stand, this important resource has an operating life that is limited not by technology or economics, but by the arbitrary term of the operating license.

Nuclear license renewal will (1) maintain the diversity of U.S. energy sources, (2) reduce the U.S. dependency on foreign energy supplies, (3) reduce foreign debt accumulation as a result of lower oil imports, (4) support clean air initiatives and provide a hedge against restrictions placed on the use of fossil fuels, and (5) reduce capital funding required for new construction resulting in a lower national cost of money.

For utilities, nuclear license renewal (1) avoids the premature loss of important baseload electrical generation capacity, (2) avoids capital costs associated with building replacement power units for the license renewal period, (3) avoids siting/environmental issues associated with new capacity construction, (4) maintains work force/worker morale as the initial license expiration date approaches, (5) justifies maintenance activities that enhance current operations, and (6) continues operation of a known facility that is accepted by the community, is currently staffed by trained personnel and whose structures and components are known commodities.

Based on these significant potential benefits from license renewal, DOE in 1985 initiated a cooperative pilot-plant program with the Electric Power Research Institute (EPRI) and two utilities to determine whether there were technical and/or economic issues that might preclude or limit the successful implementation of the license renewal option. The participating utilities were Virginia Electric Power which investigated one of its Surry units and Northern States Power which investigated its Monticello unit. Both pilot-plant efforts concluded that license renewal was technically and economically feasible. These results have been well documented [1-5].

In addition, DOE sponsored studies to assess, from a national perspective, the benefits and costs of nuclear license renewal compared with those of competing electrical generation options in the early 21st century. These studies concluded that nuclear license renewal yields large net benefits under a wide range of plausible economic and institutional conditions [6,7]. Under baseline (e.g., most likely) conditions, the net benefits of nuclear license renewal were predicted to total about 350 billion 1986 dollars (or almost $180 annually for 20 years for each U.S. family [7]).

Based on the demonstration of economic desirability and technical feasibility, in 1988 DOE initiated activities to resolve the license renewal regulatory issues associated with allowing prolonged operation of existing nuclear units. Moreover, since both national and utility interests are served by nuclear plant license renewal, DOE has indicated that achievement of license renewal is an important element of the National Energy Strategy.

CURRENT ACTIVITIES

DOE's current program has two primary goals, namely (1) to establish the license renewal process and (2) to demonstrate the viability of the license renewal process. Establishing the license renewal process is being achieved through:

1. Development of a methodology for identifying systems, structures, and components (SCCs) that are important to license renewal.

2. Development of industry reports for ten important classes of equipment that describe industry-accepted approaches for license renewal.

3. Interaction/negotiation with the NRC to get the industry positions formally endorsed by the NRC.

4. Support of codes and standards revisions to facilitate license renewal.

5. Development of lead plant license renewal applications (one pressurized water reactor, PWR, and one boiling water reactor, BWR) based on the screening method, the industry reports, and plant specific analysis.

6. Critique of NRC draft license renewal rulemaking documents based on industry pilot- and lead-plant experiences.

Demonstrating license renewal is being achieved through:

1. Development of lead plant license renewal applications for submittal to the NRC.

2. Development of technical bases to support license renewal, including the areas of materials evaluations, information systems, and diagnostics.

3. Achievement of NRC approval of license renewal applications.

In achieving its goals, DOE is working closely with the Nuclear Management Resources Council (NUMARC), with EPRI, and with nuclear utilities through the NUMARC Nuclear Plant Life Extension Working Group (NNWG).

DOE sponsored the development of a "Methodology to Evaluate Plant Systems, Structures and Components for License Renewal" which was endorsed by the NNWG and submitted to the NRC as a basis for license renewal decisionmaking [8]. This methodology provides a basis for identifying the scope of plant systems, structures, and components that are important for license renewal and describes the breadth and depth of initial evaluations that should be performed as past of the renewal application. Under NUMARC auspices, discussions regarding the methodology are being held with the NRC. The industry goal is to have the methodology endorsed by an NRC Safety Evaluation Report.

In cooperation with EPRI and NUMARC, DOE has sponsored the development of ten industry reports that describe industry-accepted approaches for license renewal for ten important classes of equipment. The ten industry reports are:

1. BWR Reactor Pressure Vessel
2. BWR Reactor Pressure Vessel Internals
3. BWR Primary Coolant Pressure Boundary
4. BWR Containment
5. Class 1 Structures
6. Low-Voltage, Harsh-Environment Cables
7. PWR Reactor Pressure Vessel
8. PWR Reactor Pressure Vessel Internals
9. PWR Reactor Coolant System
10. PWR Containment

Each industry report has been submitted to the NRC for its review. The NRC has developed a set of comments on each industry report and provided them to the industry through NUMARC. NUMARC, DOE, EPRI, and the nuclear utilities are currently discussing the comments with the NRC with the goal of obtaining NRC endorsement of each industry report through issuance of Safety Evaluation Reports by the end of 1992.

DOE in conjunction with EPRI have also chosen two lead plants which will develop license renewal applications based on the industry's methodology to evaluate plant equipment, the industry reports, and plant-specific analysis. The two lead plants are (1) Yankee Rowe, a PWR and (2) Monticello, a BWR. Both plants expect to submit their license renewal applications to the NRC during 1991.

Several of these elements of the DOE-sponsored program are described by related papers at this conference. In particular, papers are being presented regarding the Yankee lead plant project, the Monticello lead plant project, the industry report effort, and NUMARC coordinated activities to review/critique NRC draft license renewal documents. Hence, the remainder of this paper focuses on DOE supplemental activities to develop technical basis to support license renewal.

DOE is currently supporting several specific activities aimed at enhancing the technical basis for license renewal. Activities include:

1. Determination of the extent of low-temperature, low-flux embrittlement during the license renewal period for reactor vessel support structures such as neutron shield tanks.

2. Investigation of whether improved, less conservative reactor flaw distributions can be developed and used for license renewal purposes.

3. Evaluation of the correlation between full size and subsize irradiated Charpy specimens so that limited supplies of reactor vessel Charpy surveillance material can be effectively employed during the license renewal period.

4. Assessment of the engineering feasibility of reactor vessel annealing as a potential supporting technology for the license renewal period.

5. Development of improved cable life prediction methods to support aging management programs required for license renewal.

6. Development of improved methods for assessing and controlling stress-corrosion cracking within a BWR reactor vessel.

7. Development of improved condition-monitoring techniques for enhancing the reliability of the starting system of emergency diesel generators, and

8. Assessment of the availability/usefulness of modern digital electronics to support nuclear plant life extension activities.

To demonstrate the extent of these activities, two are highlighted for further discussion in this paper, namely (1) investigations to assess whether improved, less conservative reactor vessel flaw distributions can be developed and used for license renewal purposes, and (2) investigations into cable aging behavior.

REACTOR VESSEL FLAW DISTRIBUTION

Neutron irradiation embrittlement of the vessel beltline region is the most significant degradation mechanism for the reactor pressure vessel of pressurized water reactors (PWRs). Embrittlement levels must be adequately controlled to insure safety with respect to the issues of pressurized thermal shock (PTS), low upper shelf Charpy energy, and pressure-temperature operating limits. For the PTS and low upper shelf issues, the NRC maintains adequate safety levels by specifying screening criteria for Charpy transition temperatures and upper shelf energies. If these screening criteria are exceeded, deterministic or probabilistic fracture mechanics analysis is required to demonstrate maintenance of adequate levels of safety. Currently, such fracture mechanics evaluations are based either on a conservatively assumed flaw size or a distribution of conservative flaw sizes. To determine pressure-temperature operating limits, utilities currently must perform conservative calculations based on an assumed quarter thickness vessel flaw. Operational benefits could potentially be gained if the fracture mechanics safety evaluations were based on more realistic flaw distributions.

To assess whether the development of a more realistic flaw distribution was worthwhile, the Department of Energy first performed a sensitivity study to quantify the effects that an assumed flaw distribution would have on the results of a fracture mechanics PTS evaluation [9]. Six flaw distributions of varying conservatism were evaluated using probabilistic fracture mechanics techniques. Results of the evaluation indicated that the conditional probability of vessel failure varied by over three orders of magnitude depending on the assumed flaw distribution. The evaluation also identified that the critical size flaw that would cause failure under the assumed transient was approximately 0.25 inches for all the distributions considered. This suggested the importance of being able to detect and size flaws of this magnitude.

The Department of Energy then reviewed the current status of state-of-the-art inspection equipment to detect and size flaws of this magnitude [9]. The review was based on data generated by

EPRI, the Pressure Vessel Research Council (PVRC) and the European Plate Inspection Steering Committee (PISC) studies. The review concluded that the detection reliability and sizing accuracy of present ultrasonic inspection systems would allow for a more representative flaw distribution.

Currently the DOE-sponsored program is acquiring in-service inspection data for several PWR vessels. This data is being evaluated to develop an initial estimate of a realistic flaw distribution for U.S. vessels. Additional PTS probabilistic fracture mechanics evaluations are being performed to assess the life extension benefits that could be realized from use of this "real" flaw distribution in preference to the NRC-recommended conservative distribution. One finding from this effort is that inspection sizing errors presently allowed by Appendix VIII of ASME Section XI [10] may be too large to allow for development of a useful vessel-specific flaw distribution. Hence utilities that wish to achieve the life extension benefits associated with vessel-specific flaw distributions will need to satisfy more stringent sizing errors during their reactor vessel inspections than those currently specified by Appendix VIII of ASME Section XI.

CABLE AGING STUDIES

Aging management requirements associated with license renewal require that plants make long-term predictions of aging degradation for cable materials exposed to low dose-rate and low temperature aging environments in nuclear plants. For safety-related cables that must function during design basis accident conditions, this has historically been accomplished through a qualification approach that includes cable aging assessment based on accelerated thermal and radiation conditions. Qualification aging data for cable materials was usually developed using a sequential application of elevated temperature exposure followed by an accelerated radiation exposure. The elevated thermal exposure conditions were typically chosen based on the Arrhenius method while the accelerated radiation exposure conditions were based on an "equal dose - equal damage" concept. Such aging simulation techniques were endorsed by an industry standard, IEEE Standard 383-1974, "IEEE Standard for Type Test of Class 1E Electric Cables, Field Splices, and Connections for Nuclear Power Generating Stations [11]."

Operating plant experience as well as research results have qualitatively demonstrated that some cable materials are susceptible to synergistic effects, which may lower the aging endurance of the impacted materials compared to aging endurance levels determined by the historical test methods [12]. NRC regulations, namely 10 CFR 50.49, require the consideration of synergistic effects during the qualification of safety cables that must function during harsh environments [13]. NRC Regulatory Guide 1.89, "Environmental Qualification of Certain Electric Equipment Important to Safety for Nuclear Power Plants [14]," indicates that "synergistic effects known at this time are dose rate effects and effects resulting from the different sequence of applying radiation and (elevated) temperature."

In 1984 a quantitative method for predicting the impact of dose rate effects for a polyvinyl chloride cable jacket material was developed [15]. The quantitative model was based on an understanding of the underlying mechanistic degradation mechanisms that lead to synergistic effects for PVC. As input to the modeling technique, "combined-environments" radiation and thermal aging data were used and extrapolated to the lower temperature and lower dose rate conditions typical of the long duration aging conditions typical of nuclear plant operation. Predictions based on the model exhibited excellent agreement with 12-year natural aging data obtained from the Department of Energy's Savannah River reactor facility.

As part of the DOE program, we have generalized the "combined-environments" extrapolation methodology and empirically assessed its usefulness for several other cable materials, namely selected products manufactured of low density poylethylene (LDPE), cross-linked polyethylene (CLPE), HYPALON, NEOPRENE, Silicone, ethylene propylene rubber (EPR), and cross-linked polyolefin (CLPO). For most of these products we noted that the "combined-environments" methodology provided aging predictions that were empirically self-consistent, were comparable to long-duration natural aging results obtained from the Department of Energy's N-Reactor and Savannah River reactor facilities, were comparable to German long-duration aging data, and were consistent with thermal-only aging exposure data and activation energies [16-18]. We concluded that the "combined-environments" method provided substantial insight regarding the aging behavior for many of the products we investigated. We have documented these insights in a set of graphs that illustrate those combinations of radiation and thermal aging conditions that would be necessary to achieve equivalent degradation of the cable materials [15-17].

For a few CLPO and EPR products we noted that raising the temperature to accelerate the irradiation aging rate actually reduced the degradation rate. For these products, low temperature irradiations produce the most aging degradation. Based on this insight we have also generated aging predictions for these materials [17].

The methods and data developed through this DOE activity provide a technical bases for addressing synergistic effect concerns. The methods and data also provide information to assess the life of cables important to license renewal that have not historically been included as part of a plant's equipment qualification program. Thus this DOE activity provides valuable information for evaluating cable life during the license renewal period.

CONCLUSION

The Department of Energy recognizes the importance of the nuclear power option to the nations future energy security and stability and has included license renewal as an important element of the National Energy Strategy for the United States. Moreover, DOE is actively engaged in cooperative activities to establish and demonstrate a viable license renewal regulatory process. This includes support for the two lead plant demonstrations, development of industry reports (IR) delineating standards and criteria for plant equipment, interaction/negotiation for NRC formal approval of the IR's, and development of the information and technical bases to facilitate future license renewals.

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