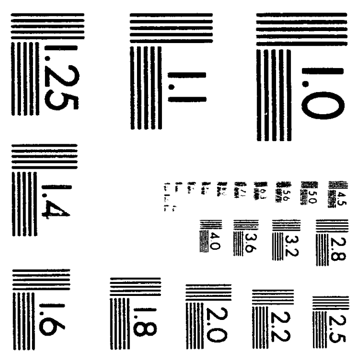

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OVERVIEW OF UNITED STATES DEPARTMENT OF ENERGY ACTIVITIES TO SUPPORT LIFE EXTENSION OF NUCLEAR POWER PLANTS

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ABSTRACT

Today, 109 nuclear power plants provide over 20 percent of the electrical energy generated in the U.S. The operating license of the first of these plants will expire in the year 2000; one-third of the operating licenses will expire by 2010 and the remaining plant licenses are scheduled to expire by 2033. The National Energy Strategy assumes that 70 percent of these plants will continue to operate beyond their current license expiration to assist in ensuring an adequate, diverse, and environmentally acceptable energy supply for economic growth. In order to preserve this energy resource in the U.S. three major tasks must be successfully completed: (1) establishment of regulations, technical standards, and procedures for the preparation and review of a license renewal application; (2) development, verification, and validation of technical criteria and bases for monitoring, refurbishing, and/or replacing plant equipment; and (3) demonstration of the regulatory process.

Since 1985, the U.S. Department of Energy (DOE) has been working with the nuclear industry and the U.S. Nuclear Regulatory Commission (NRC) to establish and demonstrate the option to extend the life of nuclear power plants through the renewal of operating licenses. This paper focuses primarily on DOE's Plant Lifetime Improvement (PLIM) Program efforts to develop the technical criteria and bases for effective aging management and lifetime improvement for continued operation of nuclear power plants.

This paper describes current projects to resolve generic technical issues in the principal areas of reactor pressure vessel (RPV) integrity, fatigue, and environmental qualification (EQ).

DOE PLANT LIFETIME IMPROVEMENT PROGRAM

Commercial U.S. nuclear generating units are licensed by the NRC for 40 years. The origin of this fixed license period was based on the capital amortization schedule for nuclear power plants and was not necessarily related to the useful life of the facility *[1]*. Plant refurbishment and extended life have already been demonstrated in non-nuclear generating facilities and have been shown to be economically desirable and technically feasible for nuclear generating plants *[2]*.

To facilitate continued operation of U.S. nuclear plants beyond the current license term, the following three major tasks must be successfully completed:

- Establishment of regulations, technical standards, and procedures for the preparation and review of License Renewal Applications (LRAs);
- Development of technical criteria and bases for monitoring, refurbishing or replacing plant equipment; and
- Demonstration of the regulatory process by a plant obtaining a renewed license.

Since 1985, the DOE Plant Lifetime Improvement (PLIM) Program has been cooperating in cost-shared efforts with the nuclear industry to address these three major tasks. A memorandum of understanding is in effect between DOE and the Electric Power Research Institute (EPRI) for cooperation in light water reactor (LWR) plant lifetime improvement and life cycle management research. This national effort also includes the Nuclear Management and Resources Council (NUMARC), lead plant utilities, codes and standards-making organizations and reactor manufacturers.

An aggressive program to develop the technical bases for license renewal has also been underway. As an important first step in the DOE cooperative research program, pilot plant feasibility evaluations on Surry Unit 1, a pressurized water reactor (PWR) of Westinghouse design, and Monticello, a boiling water reactor (BWR) of General Electric design were completed in 1987 *[1,3]*. These pilot studies involved identification of the major degradation mechanisms and estimation of the remaining useful life for the plant system, structure, or component. The major repair, replacement, or maintenance activities that would be required for life extension were identified and cost estimates were developed. Additional tests, inspections, and research and development efforts needed to enhance the feasibility of achieving life extension in a cost-effective manner were identified.

Several technical projects are currently under way in the DOE PLIM Program to achieve life extension through license renewal. These projects, based on and consistent with the three major tasks previously stated, are organized into the following program elements:

- Materials, Inspection and Monitoring Research & Development
- Equipment Aging Evaluations
    - Industry Reports
    - Aging Management Guidelines

- Lead Plant Demonstration Activities
- Codes & Standards and Regulatory Process Development
    - Codes & Standards for aging concerns
    - Safety regulatory processes compliance
- General Management and Technology Transfer

This paper will focus on those DOE PLIM Program activities associated with the Materials, Inspection and Monitoring Research & Development program element. Activities associated with the remaining program elements have been discussed elsewhere *[4]*.

MATERIALS, INSPECTION AND MONITORING RESEARCH & DEVELOPMENT

The materials research and development projects consist of a series of interrelated tasks which generally emphasize phenomena related to steel and organic materials degradation of long-lived components. The project objectives include:

- Assess and document the understanding of degradation mechanisms in LWRs,
- Determine the impact of degradation on component function,
- Assess component life expectancy and develop life assessment strategies, and
- Develop technology to extend/optimize service life.

The inspection and monitoring projects support the establishment of technical standards and criteria, or the use of the technical basis developed in an Industry Report, or lead plant process. This may require, for example, diagnostic systems which provide real-time status of critical equipment or sensors which measure critical parameters required to monitor a system state or a degradation mechanism mitigation parameter.

The activities under way through this program element can be grouped into the following three principal categories or issues that may impact the continued operation of commercial nuclear power plants:

- RPV Integrity
- Fatigue
- Environmental Qualification

These principal issue areas are described below along with specific projects under way to help resolve each issue:

RPV Integrity

1. RPV Flaw Distribution Development Methodology - Improving the life prediction methods and strategies for RPVs is an important aspect in providing realistic characterizations of RPV integrity after long-term exposure to neutron irradiation. To facilitate the improved characterization of RPV integrity, a methodology has been developed to obtain estimates of the RPV flaw size distribution and flaw

density using RPV inservice inspection (ISI) results *[5,6]*. The new methodology permits, for the first time, the analysis of vessel-specific ISI data for development of a vessel-specific flaw distribution. Unlike conventional histogram approaches, the new methodology can be used to develop an acceptable flaw distribution from an inspection results database containing very few flaws. The methodology uses a shape-flexible statistical distribution (Weibull) model of flaw size and incorporates the flaw detection reliability, flaw sizing accuracy and flaw detection threshold into the analysis. A procedure has also been developed to provide a preliminary quantitative assessment of the accuracy of the flaw distribution method in the analysis of ISI data *[7]*. In addition, the developed methodology can be used as justification for defining a vessel-specific "reference" flaw for calculating pressure-temperature limit curves in a deterministic evaluation of PWR reactor vessels *[7]*.

Efforts are presently under way through the DOE PLIM Program to assist the American Society of Mechanical Engineers (ASME) Boiler & Pressure Vessel Code Section XI in the development of guidance on the use of ISI results in RPV integrity analyses. Appropriate analysis tools are being developed for ASME Section XI to evaluate the available flaw distribution development methodologies to facilitate incorporation into the ASME Code.

2. Thermal Annealing Technology Development - LWR RPV material properties reduced by long-term exposure to neutron irradiation can be recovered through a thermal annealing treatment. This technique to extend RPV life provides a complementary approach to analytical methodologies to evaluate RPV integrity. RPV annealing has been successfully demonstrated in the former Soviet Union and on a limited basis by the U.S. (military applications only). Demonstrating the technical and institutional feasibility of annealing commercial U.S. RPVs is being pursued through a cooperative effort between the nuclear industry and the DOE PLIM Program. Presently, two separate activities are under way.

    a. Annealing Thermal/Stress Model Benchmarking Experiments - Accurate prediction of material behavior for the RPV, including the nozzle and flange regions, via thermal/stress computer models is an important element of successful demonstration of thermal annealing technology on U.S. commercial RPVs. Validation and verification of annealing computer model(s) is an important step in that accurate prediction.

    An activity is under way involving a series of 1-dimensional (1-D) experiments designed to provide heat transfer boundary condition and RPV material temperature response data to help benchmark thermal/stress finite-element annealing computer model(s). Heat transfer data generated can be used to verify the thermal boundary conditions used as model inputs.

    The experiments subjected an RPV test specimen to a linear temperature rise from ambient to 454°C (850°F) at three heat-up rates, namely 7°C/hr (13°F/hr), 14°C/hr (25°F) and 28°C/hr (50°F/hr). After thermal equilibrium was reached, the test specimen was cooled-down to ambient at approximately the same rate as the heat-up. The complete test setup is described elsewhere *[8]*. The experiments at the Sandia National Laboratories Radiant Heat Facility have been completed. Data reduction and analysis are still under way.

b. Annealing Re-embrittlement Data Base Development - The proper characterization of RPV material properties before and after an anneal is also critical to a successful annealing program. A limited amount of metallurgical research has been performed regarding the amount of material property recovery (Charpy impact and tensile properties) anticipated following an annealing treatment *[9]*. These studies focused on determining the optimum annealing time and temperature, and the amount of anticipated property recovery. Little effort has been put forth to investigate the rate at which RPV materials may re-embrittle following an anneal, i.e., the embrittlement rate of RPV materials following annealing compared to the rate of embrittlement prior to anneal. The determination of RPV material re-embrittlement rates is critical if the economic viability of annealing is to be evaluated for U.S. commercial pressure vessels.

An effort is under way to pursue initial development of a re-embrittlement data base through an irradiation-anneal-reirradiation (IAR) project involving typical U.S. RPV materials (base plate and weld). The plate materials under study include two types, American Society for Testing and Materials (ASTM) type A 533 Grade B and type A 302 Grade B. These materials are representative of those used in the fabrication of commercial U.S. RPVs. The weld being studied is a low Charpy upper-shelf impact energy material fabricated with Linde 80 flux. Due to its sensitivity to neutron irradiation, the Linde 80 weld material is expected to provide bounding information for typical RPV weld materials.

Standard Charpy V-notch and tensile specimens will be used to determine changes in impact and strength properties, respectively. Initial irradiations are under way to a target fluence of 3×10^{19} n/cm^2, E > 1 MeV. Thermal annealing of the irradiated materials will be performed at 454°C (850°F) for 168 hours. Annealed samples will be re-irradiated to a target fluence of 1×10^{19} n/cm^2, E > 1 MeV. Results of the IAR project will be compared with material property data on identical, unirradiated materials to determine recovery due to annealing and re-embrittlement rates after reirradiation.

3. Subsize Specimen Methodology Development - The continued operation of nuclear power plants will depend, in part, on a thorough characterization of RPV material properties during the original license period and through extended operation. This can be accomplished through materials surveillance programs. An effective

surveillance program, however, will require large amounts of archive vessel materials which will be in short supply for certain older vessels. The impact of a material shortage can be lessened through the use of miniature specimens. In addition, if a licensee chooses to anneal its RPV as an embrittlement management strategy, verification of material property recovery may be required. This can be accomplished through testing of miniature specimens removed from the RPV.

A proper correlation between miniature and full-size specimens must be demonstrated in order to realize these benefits. This project involves the development of an appropriate correlation methodology to estimate full-size Charpy V-notch impact results (upper shelf energy and ductile-to-brittle-transition temperature) from the testing of one-half and one-third size Charpy specimens. The developed methodology will be applicable in the ductile and brittle regime, typical of originally ductile RPV materials that embrittle after long-term exposure to neutron radiation. Preliminary results appear promising *[10]*.

4. On-Line Stress Corrosion Cracking (SCC) Monitor - On-line SCC monitors are used to assess the potential for stress corrosion crack propagation in RPV internals. Present on-line SCC monitor probes have historically demonstrated poor performance for the following reasons:

   - Size limitations of monitors have required difficult design considerations,
   - Harsh environment, and
   - Inaccurate modeling of intergranular SCC (IGSCC) phenomenon and crack growth to allow for simulation through monitor development.

   The DOE PLIM Program is providing assistance to a General Electric Company (GE) effort to improve the reliability of their in-core SCC monitors. DOE PLIM Program activities include:

   - development of an analytical model that probabilistically examines the influence of microstructural heterogeneity on IGSCC to assist development of a revised GE monitor design,
   - development of experimental methods to characterize grain boundary sensitization levels and to benchmark the analytical model, and
   - finite element modeling of revised SCC monitor designs.

   GE is pursuing parallel activities to improve the reliability of their in-core SCC monitor design. Results of the DOE PLIM Program activities will being shared with GE in order to facilitate an improved SCC monitor design.

Fatigue

ASME Section III Fatigue Design Methodology Conservatism Study - The evaluation of potential fatigue damage is an important technical issue that may limit the feasibility of nuclear plant license renewal because of the impact on nearly all major plant systems, structures and components. Concern has been raised by the U.S. Nuclear Regulatory Commission that operating plants constructed in accordance with the provisions of American National Standards Institute (ANSI) B31.1 or ASME Section III do not necessarily demonstrate sufficient margin for continued operation.

An effort is under way to study the existing ASME Section III fatigue design analysis to determine if sufficient conservatism is present in the overall fatigue design process, and to document the nature and extent of those conservatisms. This information will assist in the preparation of technical positions regarding the adequacy of existing fatigue design methodologies.

Three different aspects of a typical fatigue design process are being quantified to identify the level of conservatism:

1. Differences between assumed (easy to analyze enveloping conditions) and actual plant transients
2. Differences between partial and total cycles, and
3. Simplified ASME Section III design analysis methods that provide more general fatigue usage characterizations compared to more detailed methods (e.g., finite element analyses of pipe stresses).

In addition, the magnitude of design conservatisms, associated with the three design practices listed above and/or other sources, will be compared with potential non-conservatisms that may exist in the overall fatigue design process. This information will be combined to estimate the level of overall conservatism that exists in the ASME Section III fatigue design methodology.

Environmental Qualification (EQ)

License renewal component evaluations have identified cables as critical components requiring detailed technical evaluation. The NRC's Equipment Qualification (EQ) Task Action Plan *[11]* focuses on cable EQ, especially differences in EQ requirements between older and newer plants.

The goals of the DOE and industry EQ efforts are to:

- Demonstrate that multiple EQ failures will not occur due to the presence of a harsh environment,
- Demonstrate that the existing EQ standards and regulations are adequate for all operating reactors,
- Reduce the level of uncertainty in current probabilistic risk assessment models, and
- Provide "adequate" reliability data.

With respect to cables, NRC comments on the Low-Voltage, Environmentally-Qualified Cable Industry Report focussed on the uncertainties and sufficiency of data regarding (1) synergistic and dose-rate effects and (2) the Arrhenius thermal aging methodology. Sandia's aging research project has developed unique experimental techniques and aging models which could help resolve both of these issues. In particular, the "combined environments" aging method developed for this project has successfully predicted the life of some cable materials used in operating plants. An important first consideration in "combined environments" simulations under accelerated environmental conditions is the elimination/understanding of anomalous diffusion-limited oxidation effects. Modulus and density profiling techniques developed by DOE/Sandia allowed this goal to be accomplished.

Cable Aging Project - Improvements in the life prediction of electrical cable materials is being supported through development of a "combined-environments" life prediction methodology that describes cable aging behavior in combined radiation and thermal environments *[12]*. This methodology has been successfully applied to predict cable degradation for several types of polymeric cable materials *[12,13,14]*. Further validation of this methodology is being pursued through comparison with natural aging experience. Through this activity the sufficiency and conservatism of the Arrhenius method for predicting cable lifetimes in thermal-dominated environments will be checked.

CONCLUSIONS

The DOE PLIM Program, through the various program elements described above, is pursuing its objective to establish U.S. technical requirements and procedures for license renewal and demonstrate the license renewal process. By working cooperatively with industry, DOE is contributing to the technology and information needed to establish the technical basis for safe operation during the license renewal term. In addition, the DOE PLIM Program is pursuing efforts to stimulate license renewal activities at a large number of utilities, preserve the license renewal option, and support demonstration efforts to verify and validate the regulatory process.

ACKNOWLEDGEMENT

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Overview of United States Department of Energy Activities To Support Life Extension of Nuclear Power Plants

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Overview of United States Department of Energy Activities To Support Life Extension of Nuclear Power Plants

Presentation

- Introduction
- DOE Plant Lifetime Improvement Program
- Materials, Inspection and Monitoring Research and Development
  - » Reactor Pressure Vessel (RPV) Integrity
  - » Fatigue
  - » Environmental Qualification (EQ)
- Summary
- Future Anticipated Activities

Overview of United States Department of Energy Activities To Support Life Extension of Nuclear Power Plants

Introduction

- Approximately 22% of U.S. electrical energy is provided by 109 nuclear power plants.
- U.S. nuclear generating units licensed for 40 years of operation.
  - » One-third of operating licenses will expire by 2010
  - » All plant licenses will expire by 2033
- National Energy Strategy assumes 70% license renewal to assist in ensuring an adequate energy supply for economic growth.

Overview of United States Department of Energy Activities To Support Life Extension of Nuclear Power Plants

DOE Plant Lifetime Improvement Program

- To ensure the continued viability of nuclear power in the U.S. three major tasks must be successfully completed:
  - » Establish regulations, technical standards, and procedures for preparation and review of a license renewal application
  - » **Develop, verify, and validate technical criteria and bases for monitoring, refurbishing, or replacing plant equipment**
  - » Demonstrate the regulatory process by a plant obtaining a renewed license
- DOE Plant Lifetime Improvement (PLIM) Program is cooperating in cost-shared efforts with the nuclear industry to address these major tasks
  - » Program under way since 1985
  - » Coordination with NUMARC, EPRI, lead plant utilities, codes and standards -making organizations and reactor manufacturers.

Overview of United States Department of Energy Activities To Support Life Extension of Nuclear Power Plants

DOE Plant Lifetime Improvement Program (continued)

DOE PLIM Program elements:

- » **Materials, Inspection and Monitoring Research and Development**
- » Equipment Aging Evaluations
  - Industry Reports
  - Aging Management Guidelines
- » Lead Plant Demonstration Activities
- » Codes & Standards and Regulatory Process Development
  - Codes & Standards for aging concerns

Overview of United States Department of Energy Activities To Support Life Extension of Nuclear Power Plants

Materials, Inspection and Monitoring Research and Development

- Objectives:
  - » Assess and document the understanding of degradation mechanisms in light water reactors
  - » Determine the impact of degradation on component function
  - » Assess component life expectancy and develop life assessment strategies
  - » Develop technology to extend/optimize service life
- Principal issues being addressed

  I. RPV integrity

  II. Fatigue

  III. Environmental Qualification (EQ)

Overview of United States Department of Energy Activities To Support Life Extension of Nuclear Power Plants

I. RPV Integrity

RPV Integrity Projects

1. Thermal Annealing Technology Development
2. RPV Flaw Distribution Development Methodology
3. Subsize Specimen Development
4. On-line Stress Corrosion Cracking Monitor Development

Overview of United States Department of Energy Activities To Support Life Extension of Nuclear Power Plants

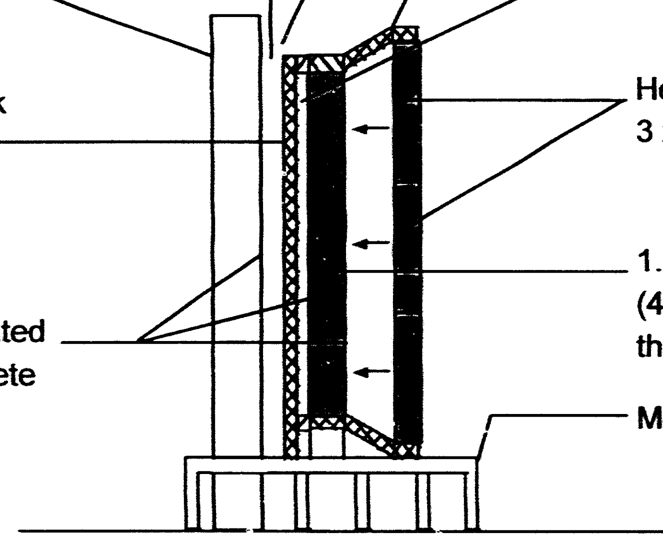
1. Thermal Annealing Technology Development

A. Thermal/Stress Model Benchmarking Experiments

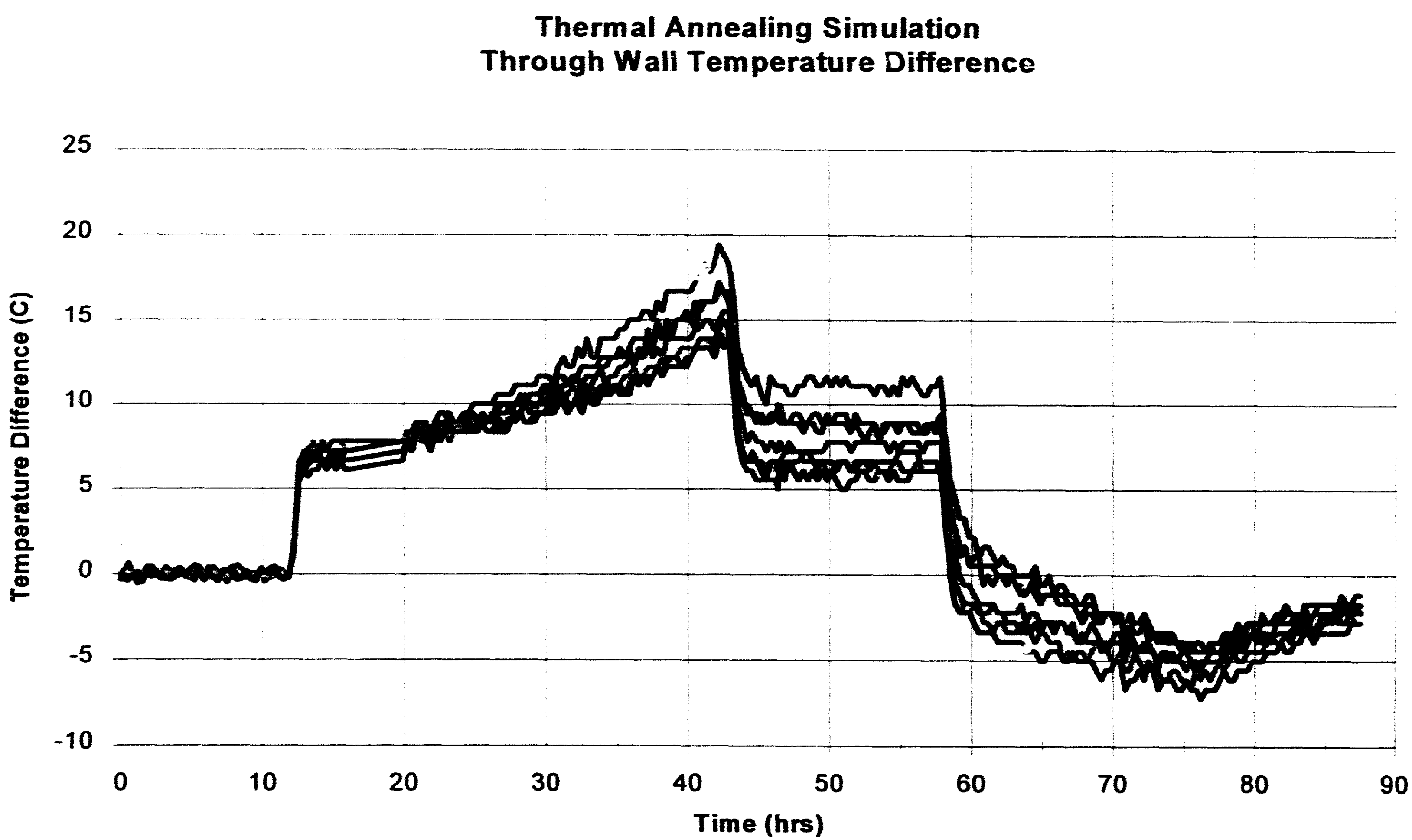
- 1-dimensional heat transfer experiments designed to help validate thermal/stress finite-element annealing computer models
  - » Provide heat transfer boundary conditions
  - » Provide RPV material temperature response.
- Unirradiated RPV section - 1.2m x 1.2m x 17.1cm
  - » ASTM A 533 Grade B plate material including circumferential weld
  - » Stainless steel cladding: 3.2 - 4.8 mm.
- Linear temperature rise from ambient to 454 °C at three heat-up rates, 7°C/hr, 14°C/hr and 28°C/hr. Cool-down rate approximately equal to heat-up rate.
- Extensive instrumentation to fully characterize RPV material temperature response.

Overview of United States Department of Energy Activities To Support Life Extension of Nuclear Power Plants

Test Setup (Side view)



Overview of United States Department of Energy Activities To Support Life Extension of Nuclear Power Plants



Overview of United States Department of Energy Activities To Support Life Extension of Nuclear Power Plants

Thermal/Stress Model Benchmarking Experiments - Status

- Two tests completed at a heat-up rate of 14 °C/hr.
- One test completed at a heat-up rate of 28 °C/hr.
- One test completed at a heat-up rate of 7 °C/hr.
- Data reduction and analysis are in progress
  - » Temperature profiles for through wall, inner surface and outer surface
  - » Incident and absorbed heat flux on inner surface
  - » Direct measurement of concrete wall temperature
  - » Direct measurement of air flow between RPV insulation and concrete
  - » Other.
- Report to be published - Spring 1994.

Overview of United States Department of Energy Activities To Support Life Extension of Nuclear Power Plants

B. Annealing Re-Embrittlement Data Base Development

- Limited research performed regarding rate at which RPV materials re-embrittle following annealing treatment
  - » Faster re-embrittlement rate may diminish effectiveness of annealing treatment.
  - » Re-embrittlement rate may dictate annealing parameters (annealing temperature, time-at-temperature).
- Irradiation-anneal-reirradiation (IAR) study in progress to assess re-embrittlement behavior of RPV materials
  - » ASTM Types A 533 Grade B and A 302 Grade B.
  - » Low Charpy upper-shelf energy weld material fabricated with Linde 80 flux.

Overview of United States Department of Energy Activities To Support Life Extension of Nuclear Power Plants

IAR Test Matrix

Capsule A - Part I, Irradiation Only (As-irradiated condition)
Target Fluence - 3 x 10^{19} n/cm^2, E > 1 MeV
Irradiation Temperature - 288°C (550°F)

Material	Type	Samples
Weld (Linde 80)	Charpy	9
Plate (A 533B)	Charpy	8
Plate (A 302B)	Charpy	8
Plate (A 302B)	Tensile	2
Total - Capsule A, Part I		**27**

Capsule A - Part II, Irradiation-Anneal (As-annealed condition)
Annealing Temperature - 454°C (850°F), 168 hrs.

Weld (Linde 80)	Charpy	9
Plate (A 533B)	Charpy	8
Plate (A 302B)	Charpy	8
Plate (A 302B)	Tensile	2
Total - Capsule A, Part II		**27**

Capsule B - IAR (Re-embrittled condition)
Irradiated, annealed with Capsule A, Part II
Reirradiated target fluence - 1 x 10^{19} n/cm^2, E > 1 MeV

Weld (Linde 80)	Charpy	14
Plate (A 533B)	Charpy	12
Plate (A 533B)	Tensile	2
Plate (A 302B - Surface, fine grain size	Charpy	8
Plate (A 302B - Surface, fine grain size	Tensile	2
Plate (A 302B)	Charpy	8
Plate (A 302B)	Tensile	2
Total - Capsule B		**48**
Total Samples Tested		**102**

Overview of United States Department of Energy Activities To Support Life Extension of Nuclear Power Plants

Annealing Re-Embrittlement Data Base Development - Status

- Initial irradiation in progress, completion - November 1993
- Anneal Capsule B and select samples from Capsule A, test Capsule A samples - Beginning November 1993.
- Complete re-irradiation activities - January 1994.
- Complete postirradiation testing of Capsule B samples - April 1994.
- Final report - August 1994.

Overview of United States Department of Energy Activities To Support Life Extension of Nuclear Power Plants

2. Flaw Distribution Development Methodology

- Methodology developed to estimate RPV flaw size distribution and flaw density using RPV inservice inspection (ISI) results.
  - » Permits, for the first time, "credit" to be taken for an accurate vessel-specific ISI
  - » Model incorporates
    - Flaw detection reliability
    - Flaw sizing accuracy
    - Flaw detection threshold
  - » Procedure developed to estimate the accuracy of the flaw distribution developed from ISI data

- Efforts under way to assist the American Society of Mechanical Engineers (ASME) Boiler & Pressure Vessel Code in developing guidance on the use of ISI results in RPV integrity analyses.

Overview of United States Department of Energy Activities To Support Life Extension of Nuclear Power Plants

3. Subsize Specimen Development

- Continued characterization of RPV integrity through extended operation or after thermal annealing will require large amounts of archive material
  - » Adequate archive material may be in short supply
  - » Use of subsize specimens will greatly extend available materials
- Correlation under development to predict full-size Charpy V-notch transition temperature and upper-shelf energy from testing of subsize specimens.
  - » Correlation to apply in ductile and brittle regimes
  - » Includes use of notched-only and notched and pre-cracked samples
- Efforts to standardize subsize Charpy specimen configuration
- Development of American Society of Testing and Materials (ASTM) round-robin on subsize specimen testing using internationally characterized materials.

Overview of United States Department of Energy Activities To Support Life Extension of Nuclear Power Plants

4. On-Line Stress Corrosion Cracking (SCC) Monitor

- Present monitors used to assess potential for SCC in RPV internals have performed poorly
  - » Size limitations of monitors have required difficult design considerations
  - » Harsh environment
  - » Inaccurate modeling of intergranular SCC (IGSCC) and crack growth for simulation
- Assistance being provided to General Electric to improve reliability of in-core SCC monitors. DOE PLIM Program efforts include:
  - » Development of an analytical model to examine the influence of microstructure on IGSCC
  - » Development of experimental methods to characterize grain boundary sensitization levels and to benchmark the analytical model
  - » Finite element modeling of revised SCC monitor designs

Overview of United States Department of Energy Activities To Support Life Extension of Nuclear Power Plants

II. Fatigue

ASME Section III Design Methodology Conservatism Study

- Study existing ASME Section III fatigue design analysis
  - » Determine if sufficient conservatism is present in overall fatigue design process
  - » Document nature and extent of conservatisms, and non-conservatisms, if any
- Conservatism in overall fatigue design process being quantified through:
  - » Differences between assumed and actual plant transients
  - » Differences between partial and total cycles
  - » Simplified design analysis methods that provide more general fatigue usage characterizations compared to more detailed methods

Overview of United States Department of Energy Activities To Support Life Extension of Nuclear Power Plants

III. Environmental Qualification (EQ)

1. **Life Prediction Methods for Cable Aging -** Combined-environments life prediction methodology being developed to improve life prediction of electrical cable materials
   - » Describes cable aging in combined radiation and thermal environments
   - » Successfully applied to predict cable degradation for several types of polymeric cable materials
   - » Further validation being pursued through comparison with natural aging experience

Overview of United States Department of Energy Activities To Support Life Extension of Nuclear Power Plants

Summary

- Efforts under way through the U.S. Department of Energy Plant Lifetime Improvement Program to develop, verify, and validate technical criteria and bases for monitoring, refurbishing, or replacing plant equipment
  - » Help resolve outstanding technical issues
  - » Ensure continued viability of nuclear power in the U.S.
- Activities are coordinated with various elements of the nuclear industry and the U.S. Nuclear Regulatory Commission

Overview of United States Department of Energy Activities To Support Life Extension of Nuclear Power Plants

Future Anticipated Activities

Additional RPV integrity efforts:

- » Continuation of re-embrittlement data base development
- » Nondestructive evaluation methods to determine material property recovery
- » Development of ASME Code allowable stresses for annealing.
- » Continuation of heat transfer boundary condition experiments: 3-D heat transfer experiments involving RPV section that includes nozzle region.
- » Potential participation in full-scale annealing demonstration activity:
  - » Nearly completed but never operated facility
  - » Cooperative effort with U.S. nuclear industry elements
  - » Provide proof-of-concept engineering feasibility for U.S. commercial RPV annealing.

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