Long Term Operations (QA)

Program Overview

Program Description

High capacity factors and low operating costs make nuclear power plants some of the most economical power generators available. Even when major plant components must be upgraded to extend operating life, these plants often represent a cost-effective, low-carbon asset. The decision to extend nuclear plant life involves a host of inter-related technical, economic, regulatory, and public policy issues. Unknown or uncertain technical inputs impact the decision-making process both directly and indirectly: directly, through design and operational contingencies; and indirectly, through impacts on regulatory actions and public policy.

Recognizing the many technical challenges confronting extended nuclear plant operations, the Long-Term Operations Program is conducting an array of research and development (R&D) activities to ensure the public, the nuclear plant owners, regulatory agencies, and all interested stakeholders have the information needed to make sound decisions regarding the ability of a nuclear plant to sustain safe, reliability, economic operations.

Research Value

The Long-Term Operations Program will develop that technical information base on which to base decisions regarding extended nuclear plant life. Research results will not only inform those plant owners considering life extension past 40, 50, or 60 years, but also those with relatively younger plants considering the long-term impacts of aging. Participants gain access to technical solutions and information in the following ways:

- Identifying and overcoming key technical barriers
- Investigating cost-effective modernization opportunities
- Informing potential regulatory issues
- Capitalizing on substantial government, participant, and global research and development investments

Approach

The factors driving interest in long-term nuclear plant operations correspond to specific challenges where technical insight can effectively inform decision-making. Although these challenges touch different aspects related to long-term operations—from the physical condition of the plant to the allocation of capital budgets for plant refurbishment—they all require focused research and development to ensure technical constraints and opportunities are fully understood. The Long-Term Operations Program is designed to address these constraints and opportunities, encompassing activities facing extended operation through 30 or 40 years, all the way up through 60 or more years. The program accomplishes its objectives through an integrated strategy that involves research defined by the Electric Power Research Institute (EPRI) and its participants, collaboration on complementary research activities through the Department of Energy's Light Water Reactor Sustainability Program, and engagement with other key stakeholders such as the Materials Aging Institute. This strategic integration and coordination ensures a technical basis will be in place to inform life extension decisions in the 2014-2019 timeframe.

The activities conducted through the Long-Term Operations Project are identified and prioritized in association with nuclear plant owners, regulators, and other key stakeholders. The project also builds on the technical experience and expertise accumulated through EPRI leadership in the U.S. license renewal effort in the 1990s and early 2000s.

Research products satisfy one or more of the following criteria: 1) modernization and enhancement opportunities for existing plants that offer significant cost and/or performance benefits; 2) technical bases for evaluating continued operation of systems or components likely to be subject to aging and considerable public and/or regulatory scrutiny; and 3) enhanced analytical capabilities that enable defensible technical assessments without long-term testing.

Research activities for 2012 are focused in seven technical areas:

- Primary system materials aging
- Concrete and containment aging
- Advanced nuclear fuel technology
- Safety analysis methods
- Instrumentation and control and information technology
- Life-cycle management
- Cable aging

Pilot demonstrations will play an important role in characterizing issues impacting long-term operations and, subsequently, in demonstrating mitigating actions and new technology capabilities. For example, EPRI, the Department of Energy (DOE), and Constellation Energy have established a multi-year collaborative effort to investigate aging concerns at the Ginna and Nine Mile Point nuclear plants, which are both more than 40 years old. Initial assessments will include a comprehensive concrete containment examination and an incremental reactor internals inspection for aging issues.

Accomplishments

EPRI's Long-Term Operations Project has grown into a large research effort with broad collaboration across multiple countries and entities. Significant research results will be emerging over the next few years. Key results from initial research activities include the following:

- Identified and prioritized long-term operations issues in a Long-Term Operation (LTO) Issue Tracking Table. This table is the basis for collaborative R&D programs at the Department of Energy (DOE) and EPRI.
- Compiled a report documenting concrete structures at U.S. nuclear power plants that can be used to identify and coordinate research targeting concrete aging.
- Issued a report documenting good practices, barriers, and gaps related to the use of information technology for driving improvements in equipment reliability.
- Initiated research to develop and validate an integrated framework and advanced tools that will enable accurate characterization and visualization of nuclear power plant safety margins. Such tools are needed to account for plant operational changes that can affect original design margins over time, such as power uprates.
- Developed a project plan defining flexible functional requirements for control room and underlying instrumentation and information technology infrastructure, architecture, and associated capabilities that will support plants throughout their extended operating life.
- Developed functional requirements for the Phoenix software, an advanced risk code that would enable analysis of all modes and hazards, and an integrated risk profile of the entire plant.

Current Year Activities

Long-Term Operations research for 2012 will focus on the following:

- Application of *Concrete Structures Reference Manual* and Degradation Database
- Characterization, modeling, and mitigation of intergranular stress corrosion cracking in nickel alloys and irradiation-assisted stress corrosion cracking in stainless steel
- Enhanced safety analysis and tools development for safety margin characterization
- Enhanced centralized online monitoring methods and pilot studies for critical systems, structures, and components
- Methods and database enhancements for life-cycle management of key components, refurbishments, and uprates

Selected reports and products may be prepared in whole or in part in accordance with the EPRI Quality Program Manual that fulfills the requirements of 10CFR50 Appendix B, 10CFR21 and ANSI N45.2-1977.

Estimated 2012 Program Funding

$6.0M

Program Manager

John Gaertner, 704-595-2666, jgaertner@epri.com

Summary of Projects

Project Number	Project Title	Description
P41.10.01.01	Primary System Materials Aging (base) (QA)	
P41.10.01.02	Concrete and Containment Aging (base) (QA)	
P41.10.01.03	Advances in Nuclear Fuel Technology (base) (QA)	
P41.10.01.04	Safety Analysis Methods (base)	
P41.10.01.05	I&C and Information Technology (IT) (base)	
P41.10.01.06	Life Cycle Management (base)	
P41.10.01.07	Cable Aging (base) (QA)	

Primary System Materials Aging (base) (QA)

Key Research Question

Degradation of metals in the primary systems of nuclear power plants is a focus of aging management activities at operating nuclear plants. Failures or unexpected degradations significantly affect safety, plant availability, and cost of operation; and their impact will only increase with long-term operation. Better understanding of crack initiation and propagation processes, improved predictive models, and effective countermeasures against embrittlement and stress corrosion cracking are imperative. The degradation models enable prediction of remaining-useful-life and the development and testing of mitigation methods.

Approach

This project plan is comprised of 5 projects that address the problems considered of highest priority for long-term operations:

- Extension of Materials Degradation Matrix (MDM) and Issues Management Tables (IMT) to Include Failure Mechanisms to 80 Years.
- Environmentally-Assisted Cracking (EAC): Evaluation of Crack Initiation and Propagation Mechanisms in Light Water Reactor (LWR) Components
- Irradiation-Assisted Stress Corrosion Cracking (IASCC): Identifying Mechanisms and Mitigation Strategies for IASCC of Austenitic Steels in LWR Core Components
- Reactor Pressure Vessel Embrittlement
- Advanced Welding Methods for Irradiated Materials

Impact

Results from these projects can serve numerous industry objectives ranging from identifying inspection needs and responding to emergent operating experience issues in the near term to identifying new alloys for future plant applications.

How to Apply Results

The specific products for LTO will be compilations of these research results into useful tools and methods such as automated knowledge bases, predictive algorithms or models, modeling and simulation tools, implementable inspection methods, and aging management guidelines, including repair and replacement guidance.

Selected reports and products may be prepared in whole or in part in accordance with the EPRI Quality Program Manual that fulfills the requirements of 10CFR50 Appendix B, 10CFR21 and ANSI N45.2-1977. Reports and products developed under the EPRI QA program will be marked and identified as such.

Concrete and Containment Aging (base) (QA)

Key Research Question

Aging of civil infrastructure in commercial nuclear power plants is a potential “show-stopper” in lieu of long term operation. There are a variety of kinetic processes that can lead to the degradation of civil structures—and these may be accelerated by operating environments specific to nuclear plants (for example, spent fuel pool leakage). It is important that the industry understand the impact of accelerated aging of civil infrastructure, particularly for LTO, as individual utilities will be required to provide both sound technical and economic justifications to continue operation to 80 or 100 years.

Approach

The goal of this project is to examine various degradation phenomena being experienced in operating plants. The project will initially compile an *Aging Reference Manual* that clearly defines the physics of kinetic degradation processes and discusses the corresponding operational issues. The manual will contain a framework for identifying at-risk structures and applicable degradation mechanisms. Individual research projects, aimed at further understanding of those degradation mechanisms and structures identified as “at-risk”, will be commenced. The results of the individual studies will be merged into an Aging Management Toolbox Platform as an open-ended tool for operators to assess severity of damage and explore repair or mitigation options.

Impact

It is anticipated that the project will developed a valuable tool for utilities to manage aging concrete structures. The value of the tool will increase as more degradation mechanisms and structure modules are added in out years. The product will be left open-ended to allow expansion as new issues emerge.

How to Apply Results

Pilot plant investigations for LTO issues are expected to yield one or more industry examination guidelines for concrete aging assessment.

Selected reports and products may be prepared in whole or in part in accordance with the EPRI Quality Program Manual that fulfills the requirements of 10CFR50 Appendix B, 10CFR21 and ANSI N45.2-1977. Reports and products developed under the EPRI QA program will be marked and identified as such.

Advances in Nuclear Fuel Technology (base) (QA)

Key Research Question

The overall objective of this work is to assess the performance of silicon carbide fuel cladding, a material that shows promise for substantial power uprate potential (perhaps 30-40% higher power) and may eliminate consequences of design basis accidents (the ability of the clad to withstand temperatures higher than the current 2200°F peak cladding temperature during a loss-of-coolant accident [LOCA], which could revolutionize the safety margins and emergency core cooling systems [ECCS] requirements).

Approach

The LTO project will address two specific concerns with SiC cladding:

- Establish a viable fuel rod thermal-mechanical design. All fuel rod designs require a fuel performance code to optimize the design (for example, fuel and clad dimensions, enrichment, and rod pressure), but advanced codes such as EPRI's FALCON did not previously have the necessary materials models to assess SiC cladding.
- Develop a reliable bond between the tube and the end cap. This is challenging because the common approaches (for example, brazing with a glassy material) will not hold up reliably under LWR conditions.

Impact

The key benefits are improved fuel performance, including power uprate capability, higher burnup levels, and greater thermal margins during transient or accident conditions. This advanced fuel concept also will likely become a significant focus of the DOE Light Water Reactor Sustainability (LWRS) Program, so a key aspect of this project in LTO is its ability to inform (and thereby focus and accelerate) the larger DOE effort.

How to Apply Results

The objective of this effort is to have fuel rod segments in a test reactor in 5years and full-length rods in a commercial LWR in 10 years. Successful completion of these efforts is expected to lead to commercial offerings from fuel suppliers.

Selected reports and products may be prepared in whole or in part in accordance with the EPRI Quality Program Manual that fulfills the requirements of 10CFR50 Appendix B, 10CFR21 and ANSI N45.2-1977. Reports and products developed under the EPRI QA program will be marked and identified as such.

Safety Analysis Methods (base)

Key Research Question

To achieve long-term operation (LTO), it will be imperative that nuclear plants maintain high levels of safety and economic performance. Thus, nuclear power plants (NPPs) will have a continuing need to undergo design and operational changes as well as manage aging degradation while simultaneously preventing the occurrence of safety significant events and analytically demonstrating continued compliance with license safety margins.

Approach

First, as plants age, it is anticipated that new challenges to nuclear plant safety will emerge. These challenges could be due to any number of causes, such as a change in regulatory policy or the occurrence of an event at one or more operational plants.
Second, as new technologies and capabilities become available, it will be desirable to take advantage of these opportunities to enhance plant technical and economic performance. Examples could include performing extended power uprates or implementation of new technologies or materials.

In each situation, a comprehensive and integrated assessment of the impact on nuclear safety will be required to support effective and efficient decision-making. This project will develop both the analysis framework—risk-informed safety margin characterization (RISMC)—and, as appropriate, calculation tools to support safety analyses. This effort is tightly coordinated with DOE efforts on advanced analysis tools.

Impact

The major objectives of the Risk-informed Safety Margin Characterization (RISMC) research activities are as follows.

- Achieve significant progress toward a consensus approach accepted by nuclear plant operators, regulatory authorities, and other stakeholders for risk-informed safety margin assessments
- Through collaboration with the DoE LWRS Program's R7 development effort, achieve significant progress on developing advanced / enhanced deterministic safety analysis (DSA) capabilities, computational engines, results visualization, and validation
- Support the development of the broad application of an integrated probabilistic risk assessment (PRA) tool (Phoenix) with advanced computational methods, full scope PRA aggregation capabilities, results visualization, and connectivity to plant information for configuration risk management
- Achieve significant progress towards implementation of an integrated RISMC capability including interface of PRA and DSA codes with provisions to achieve broad connectivity to plant information and simulation capability

Application of these technical results is expected to both improve accuracy and reduce efforts for plant safety analyses and to assist utilities in maintaining required safety margins for extended plant operations.

How to Apply Results

This research project will develop and validate an integrated framework and advanced tools for risk-informed assessments that enable accurate characterization and visualization of plant safety margins. One outcome of this research effort will be to integrate the results obtained from the Phoenix software, which is being developed to provide advanced probabilistic risk analysis (PRA) and configuration risk management (CRM) capabilities. Software tools, application guidance, and pilot demonstration efforts will be used to implement research results.

I&C and Information Technology (IT) (base)

Key Research Question

In the broad context of technology shift from analog to digital instrumentation and control (I&C), nuclear plants are facing increased maintenance costs and replacement supply issues with maintaining their original analog-based systems. This issue will continue to grow over time. This project will develop cost-effective strategies and implementation guidance to support the transition to digital technology.

Approach

This EPRI project will focus on two key areas:

- EPRI will participate on the LWRS Working Group on Advanced I&C and Human Systems Interaction (HSI). This working group includes utility representatives from Exelon, Entergy, Duke, Wolf Creek, and the STARS Alliance. Through the working group, the DOE LWRS program is sponsoring pilot studies of advanced applications of I&C and other information technology projects at individual utilities. LWRS also is developing an Advanced I&C User Facility to support these applications and to perform related R&D at INL. EPRI will participate in these activities on behalf of the LTO project membership.
- EPRI will develop a repository of advanced I&C, HSI, and other information technology requirements and good practices from the pilot studies and from other industry activities. The purpose of this repository is to have a living resource for utilities to review the state-of-the-art and good practices in the industry related to I&C enhancement projects.

Impact

Effective and licensable implementation of digital I&C technology can reduce current maintenance costs associated with analog systems, improve operator interfaces and resulting decision-making, and provide enhanced data sources for identifying potential operating issues.

How to Apply Results

The vision for this project is to develop and maintain a living repository of advanced I&C requirements and attributes for upgrades and replacements of I&C systems, human system interface with information systems, and other information technology in support of plant processes. These requirements and other attributes will be developed from utility applications done in collaboration with the DOE LWRS Program, other applications initiated by individual utilities, and demonstrations of technology at the DOE LWRS I&C test facility. It is expected that this repository will grow in size and sophistication throughout the next 8years of the project, and it will evolve as technology advances.

Life Cycle Management (base)

Key Research Question

To achieve long0-term operation (LTO), nuclear plant operators must maintain and/or enhance high levels of safety, reliability, and economic performance as are enjoyed today. Plant operators will need to be equipped with sound scientific and consistent technical knowledge bases to provide them the optimum information in support of their plant asset extended operation decisions of 60 years and beyond. Refurbishment and/or replacement of large capital assets not normally considered during the original licensed life may now come into play. This project will identify those large capital assets. This project will develop a standard knowledge base for selected large capital assets, supported by science, as well as operating experience and methods that provide consistency of information that plant operators can utilize in support of their long range plant and fleet strategic technical and business decision models.

Approach

Two principal deliverables will result form this project:

- An asset database that will define the large capital assets needed to support an integrated long-range plan, with required fields and guidance for the use of the database
- A guidance document that describes the integrated methodology and attendant bases for the timing, cost, and levelization of large capital assets for the remainder of plant operation

The guidance document and database will be developed concurrently to ensure that the data are appropriately structured to support the method. As appropriate, pilot applications of the database information per the guidance document process will be used to demonstrate and confirm the technical approach.

Impact

The guidance from this project will provide the capability for simulation and sensitivity analysis for the input variables with ability to forecast end-of-plant life, expected capital funding requirements, and optimization of input variables. The intent of this guidance is to provide plant operators with the best available information to support their decision for the extended operation of their facilities.

How to Apply Results

The database in conjunction with the guidance document is expected to allow a wide range of capital/maintenance investment assessments using utility-specific costing models and tools.

Cable Aging (base) (QA)

Key Research Question

Operating plant experience has identified the potential for cable failures as a result of aging and environmental factors. The data generated from operations are not sufficient to establish predictive capabilities or to define improved nondestructive evaluation (NDE) techniques for detecting aging effects that lead to failure. A reproducible, accelerated, cable aging process could be used to address these issues for cable life management.

Approach

This project seeks to develop a process for accelerated aging of pink ethylene propylene rubber cable insulation under wet, energized conditions. Based on success in development work, the project will perform accelerated aging of multiple samples of pink ethylene propylene rubber insulation to determine point of first detectible level of degradation; continue aging of additional specimens to establish aging model/curve of aging time versus test result; and continue testing through failure of a significant portion of the sample population

Impact

Successful development of a reliable process for cable aging will allow follow-on development of better NDE techniques for detection of cable degradation damage and development of better remaining life prediction approaches.

How to Apply Results

Development of a successful cable aging process is a necessary first step in a robust life management process that will allow utilities to avoid in-service failures and to better plan and execute cable replacement efforts as required.

Selected reports and products may be prepared in whole or in part in accordance with the EPRI Quality Program Manual that fulfills the requirements of 10CFR50 Appendix B, 10CFR21 and ANSI N45.2-1977. Reports and products developed under the EPRI QA program will be marked and identified as such.