Concrete Durability Research Activities in Nuclear Facilities

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OBJECTIVE OF PRESENTATION

- To describe and summarize research sponsored by the U. S. Nuclear Regulatory Commission (USNRC), Office of Nuclear Regulatory Research and conducted by the Oak Ridge National Laboratory, *Dr. Dan J. Naus*

Outline

- Why Long-Term Operation
- NRC Structural Aging/Concrete Durability Research Activities
- Conclusions

Why Long-Term Operation

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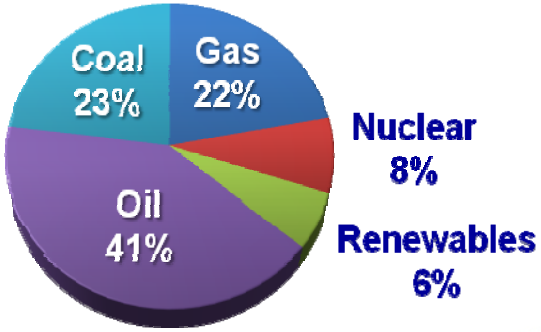
- EIA 2008 Annual Energy Outlook
  - Projects **30 - 50%** increase (1,150 TW-hr) in U.S. electricity consumption by 2030.
  - New load addition equivalent to 2006 consumption of California, Florida, Ohio, Pennsylvania, and Texas
  - Equivalent to 46 new 1,000-MW power plants

U.S. Energy Demand 2006

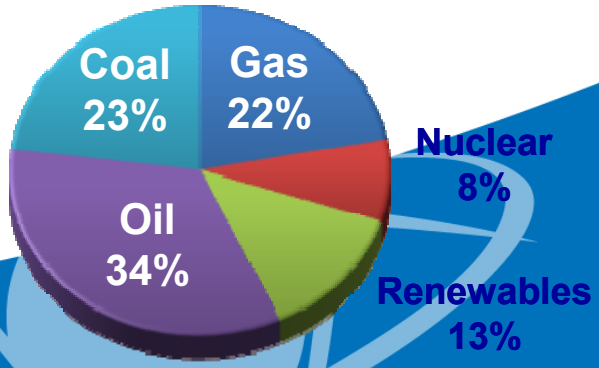
100 QBtu / Year
85% Fossil Energy



+ 11%

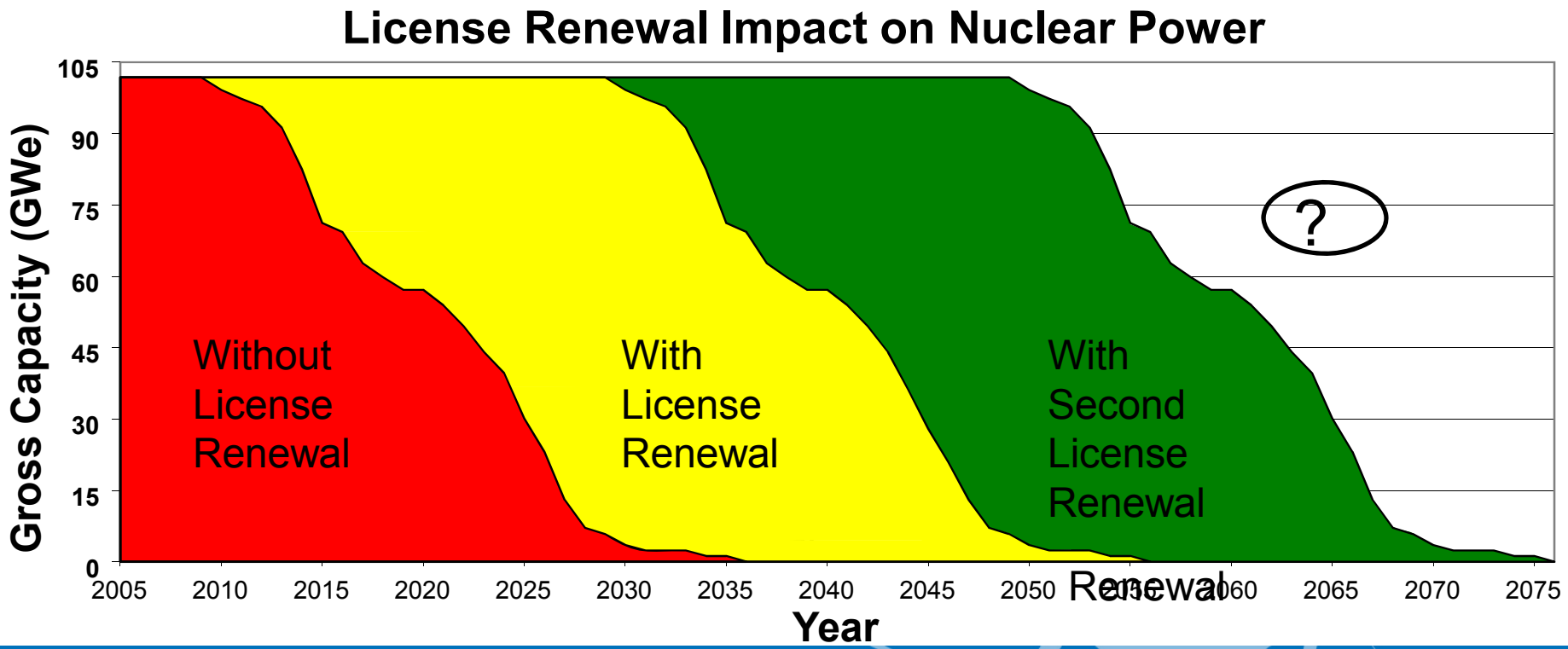
U.S. Energy Demand 2030

111 QBtu / Year
78% Fossil Energy



Why Long-Term Operation

- Steep fall-off in generating capacity if current nuclear operations not sustained
  - 5% total U.S. generating capacity lost by 2035; 15% by 2045
  - These shutdowns would not be for technical or economic issues, but from a failure to prepare for extended operations of safe, clean and secure energy supply



Age of US NPPs

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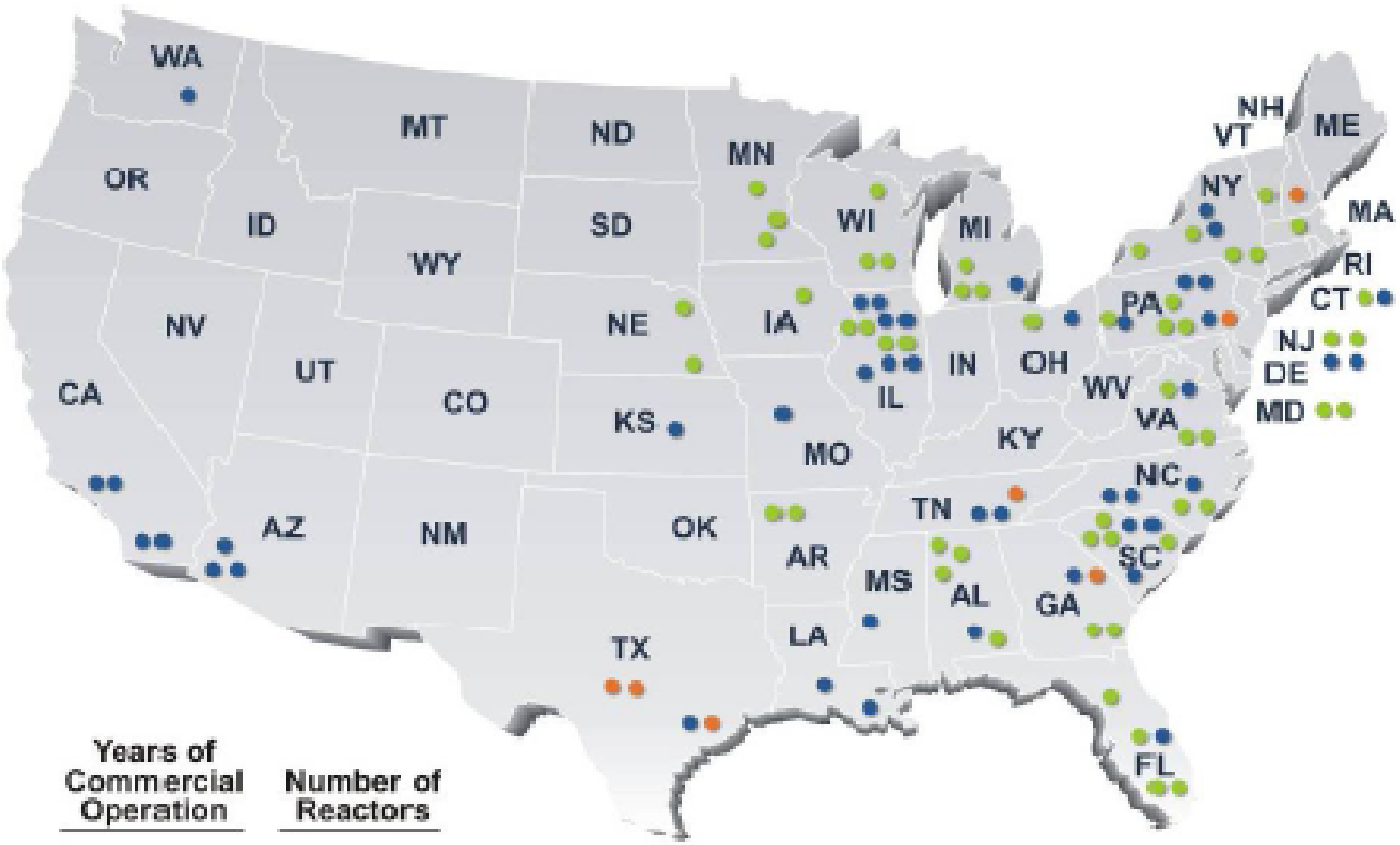

Years of Commercial Operation	Number of Reactors
10-19	7
20-29	44
30-39	53

Note: There are no commercial reactors in Alaska or Hawaii.

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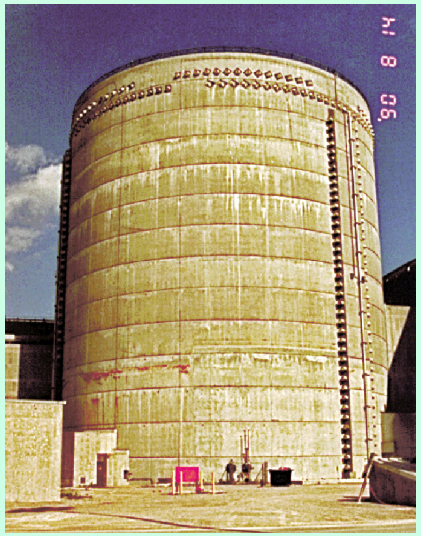
Each BWR and PWR is Located Within a Much Larger Metal or Concrete Containment



As NPPs Age, Assurances should be Provided that the Capacity of Safety-Related Systems to Mitigate Extreme Events has not Deteriorated Unacceptably due to Aging or Environmental Effects

Structural Aging Research Plan

- **-Development of a staff review guidance and acceptance criteria for safety assessment of degraded containments**

- DEGRADATION AND OPERATING EXPERIENCE
- Degradation Factors
- Operating Experience

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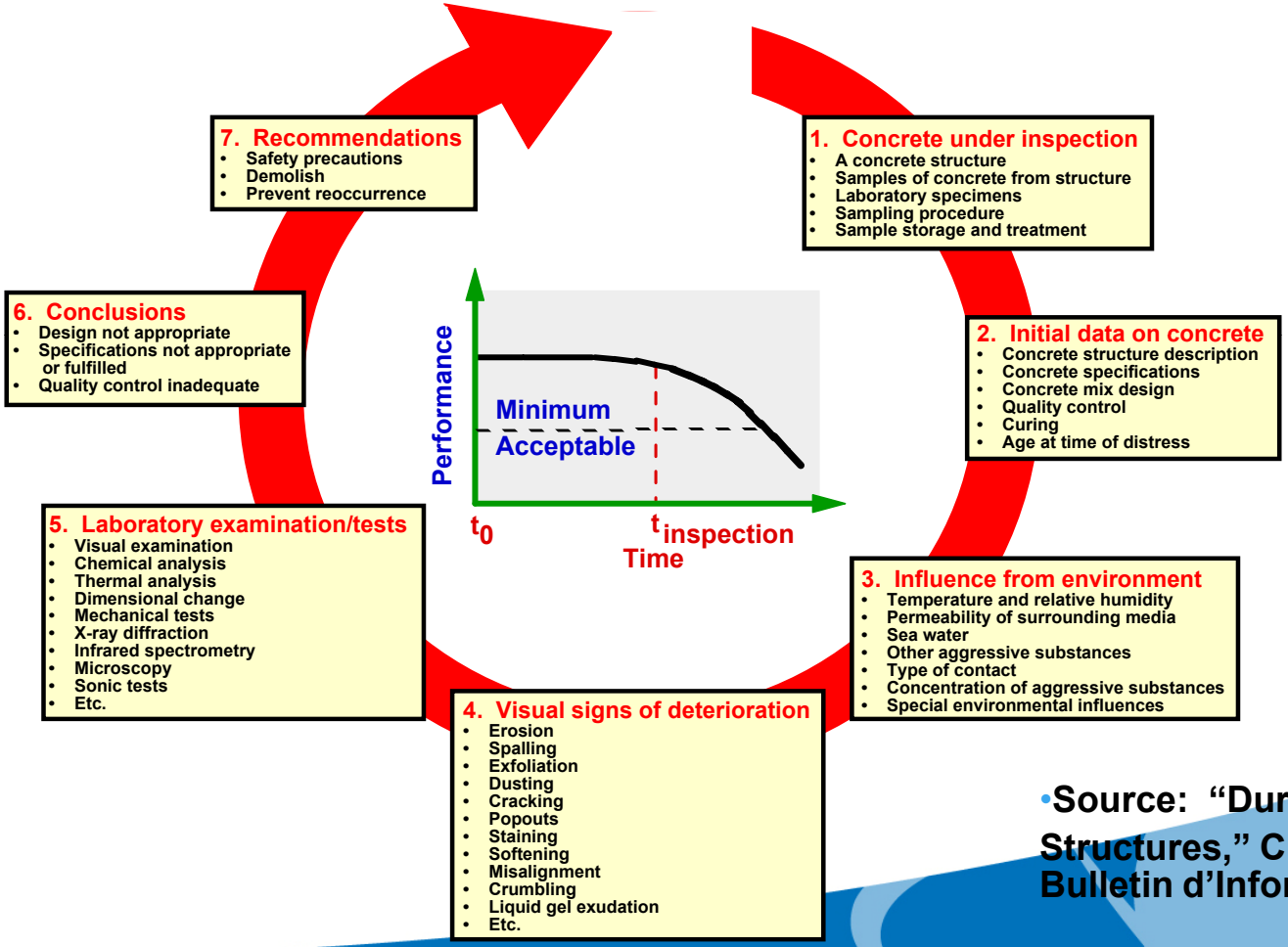
- ASSESSMENT & REMEDIATION OF AGED/DEGRADED SAFETY RELATED STRUCTURES
- Guidance
- Assessment Methods

Condition Assessments Used to Determine Performance Characteristics and Cause and Extent of Observed Distress



- Source: "Durability of Concrete Structures," CEB, Lausanne, Bulletin d'Information 152, 1984.

Evaluation Methods for NPP Structures Generally Fall Into Three Categories

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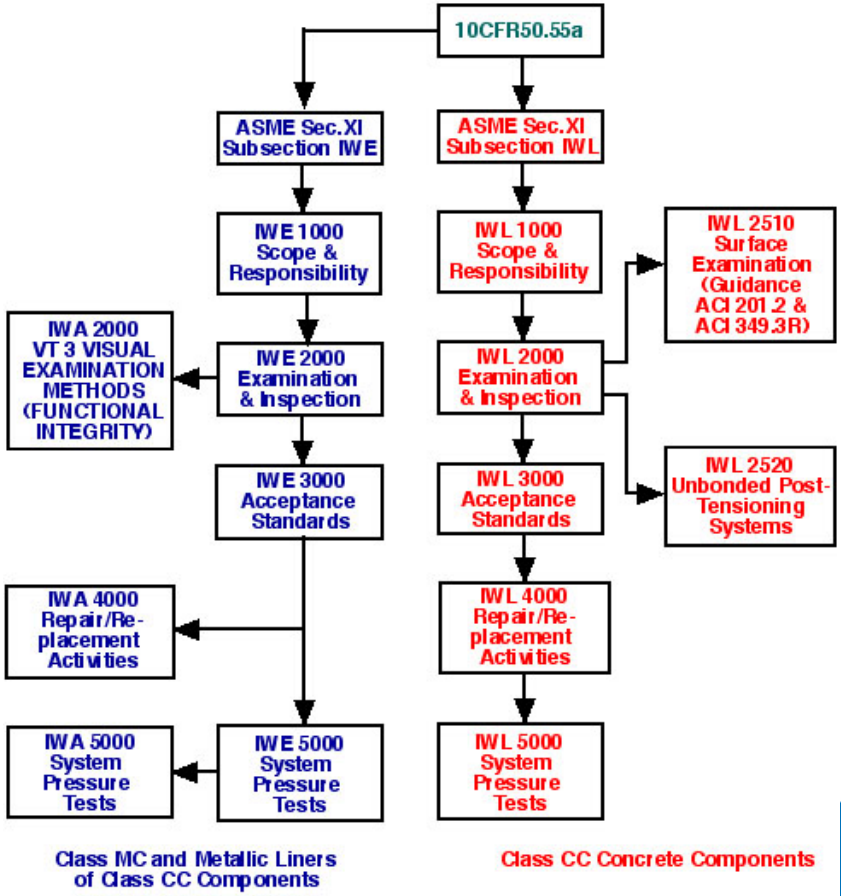
- *Visual Examinations*
  - Many of manifestations of concrete degradation appear at the surfaces as visible indications or discontinuities
  - Scope of investigations should include all exposed concrete surfaces, joint and joint material, interfacing structures and materials, and attached components
  - Aggressiveness of local operating environment and condition of surrounding structures (e.g., settlement)
- *Destructive and nondestructive testing*
  - Structure-specific
  - Environment-specific
- *Analytical reassessment*
  - Reevaluate behavior/resistance of structures (e.g., structural margins)
  - Finite-element and ultimate strength design



- **ASME Section XI In-Service Inspection and Repair Guidelines Flow Diagram**

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RESEARCH RESULTS

- NUREG 1800, "Improved License Renewal Guidance Document"
- NUREG 1801, Generic Aging Lessons Learned
- American Concrete Institute (ACI), 349.3R, "Evaluation of Existing Nuclear Safety-Related Concrete Structures"
- Title 10, Code of Federal Regulations, Part 54, "The License Renewal Rule"

License Renewal Status

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- Initial Renewed Licenses (i.e., 40 – 60 Years of Operation) Issued for 59 Units at 31 Sites
  - Reviewing applications for 18 units at 13 sites
  - Expects submittal of 11 applications for 14 units through fiscal year 2010
- Industry Expected to Submit Subsequent Renewal Applications (i.e., 60 – 80 Years of Operation) Starting in 2013-2015
  - In order to support regulatory decisions, research is needed to determine what impacts aging will have on NPPs in the second, and subsequent, renewal period.

NRC's Aging Management Research

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- NRC research into potential technical issues that may challenge long-term safe operation
- Challenges include:
  - Reactor vessel and internals
  - Electric cable insulation
  - Buried/submerged structures
  - **Concrete exposed to high temperature and radiation**

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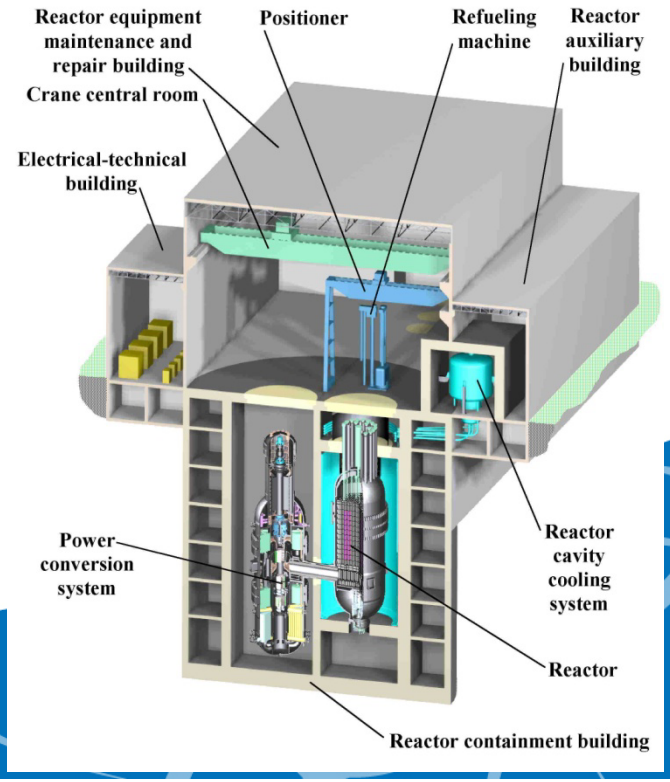
PRESENT RESEARCH EFFORTS

- Effect of High Temperature on Concrete

In the new High Temperature Gas Cooled Reactors (HTGRs), concrete structures may be subjected to sustained high temperature.



Proposed New NPPs

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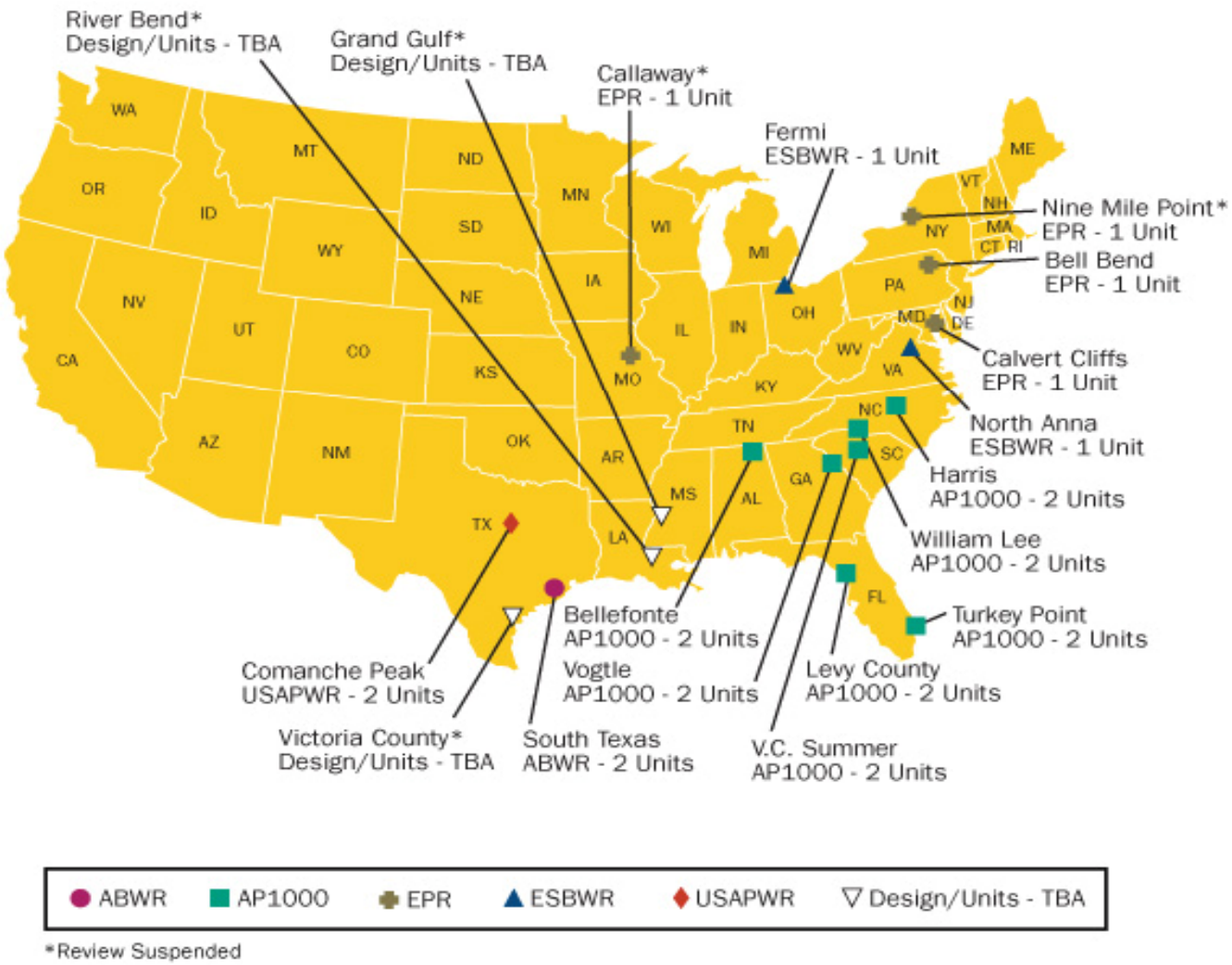

*Review Suspended

OBJECTIVE

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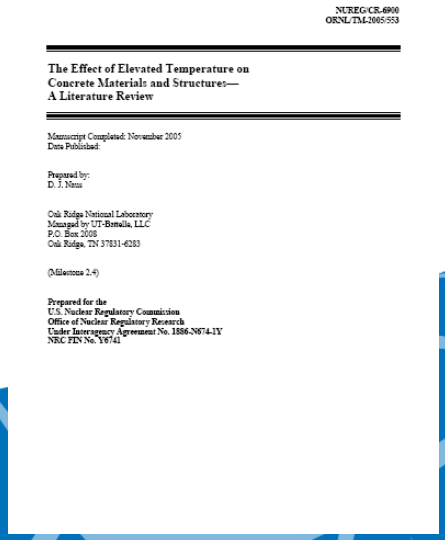
- **To investigate the change in concrete properties when it is subjected to sustained high temperatures. In the current American Concrete Institute (ACI) Code, the temperature limits specified for concrete are 150°F for long term, 200°F for normal use , and 300°F for abnormal conditions.**
- **Lessons learned from facilities where concrete was found to be subjected to high temperatures for long durations were investigated and utilized.**



NUREG/CR-6900
ORNL/TM-2005/553

The Effect of Elevated Temperature on Concrete Materials and Structures—A Literature Review

Manuscript Completed: November 2005
Date Published:

Prepared by:
D. J. Naus

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(Milestone 2.4)

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FUTURE RESEARCH

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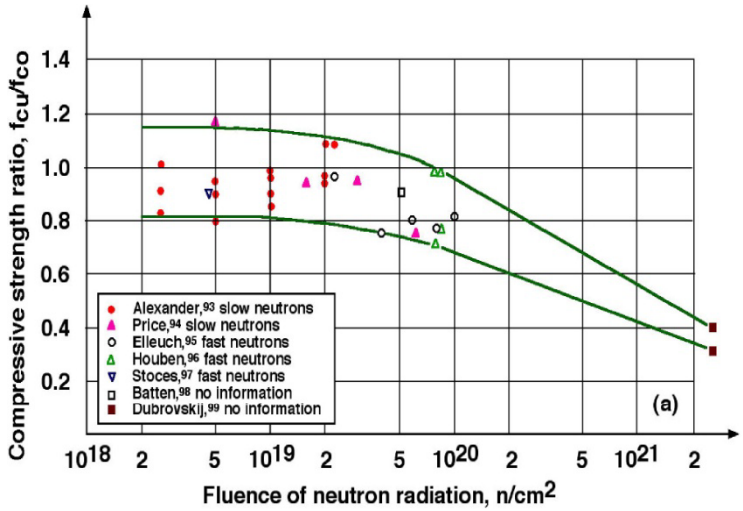
Prolonged Exposure of concrete to Radiation



Source: H.K. Hilsdorf, ACI SP-55, American Concrete Institute, 1978.

- Data on effects of radiation on concrete properties are somewhat limited due to difficulties in conducting experiments
- Difficult to separate radiation from thermal effects and to compare results from different researchers because of concrete composition and test method differences

For operation >40 years, are radiation levels sufficient to affect concrete shielding effectiveness and load-bearing capacity?

FUTURE RESEARCH

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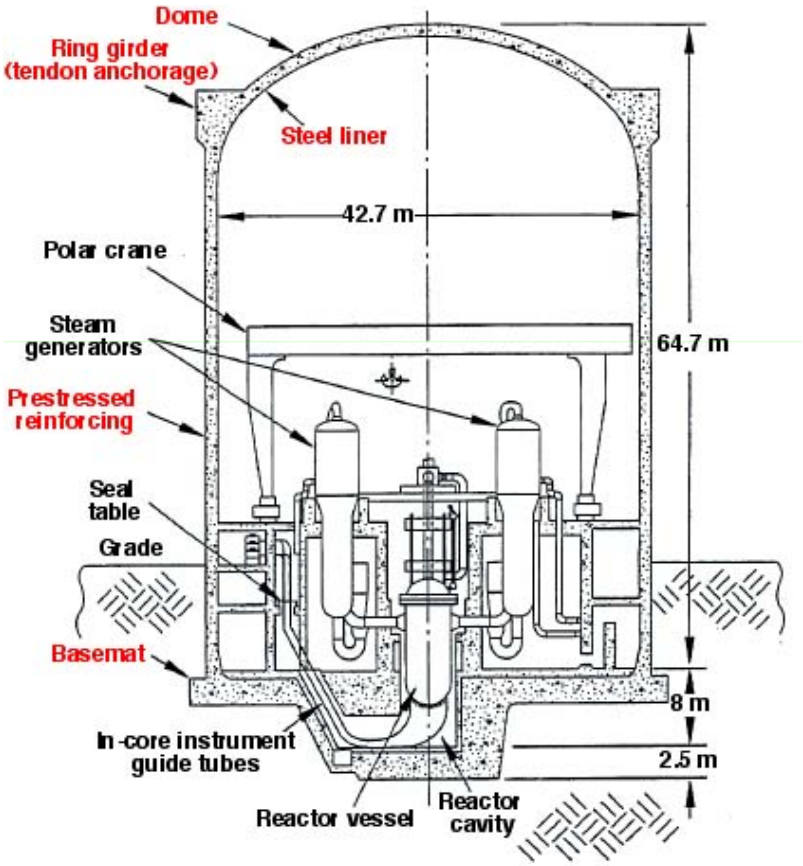
- Information Tool Knowledge Capture & Utilization
- Identify Degradation Scenarios Not Addressed in NUREG-1801, “Current Generic Aging Lessons Learned (GALL) Report”
- Identify Inspection and Monitoring Programs and Associated Requirements for Highly Likely Degradation Scenarios

Areas Identified Where Improvements in NDE Methods are Desired



PWR Large Dry Prestressed Concrete Containment

- Thick, heavily reinforced concrete sections
  - As-built or current structural features
  - Flaw detection and characterization
  - Honeycomb and embedded items
  - Voids adjacent to liner
- Basemats and other inaccessible areas
  - Based on indirect approach (i.e., environmental qualification)
- Liners –
  - Global inspection methods
  - Inaccessible areas
- Prestressing tendons
  - Force measurements
  - Estimation of time-dependent prestressing force losses

NRC Aging Management Research

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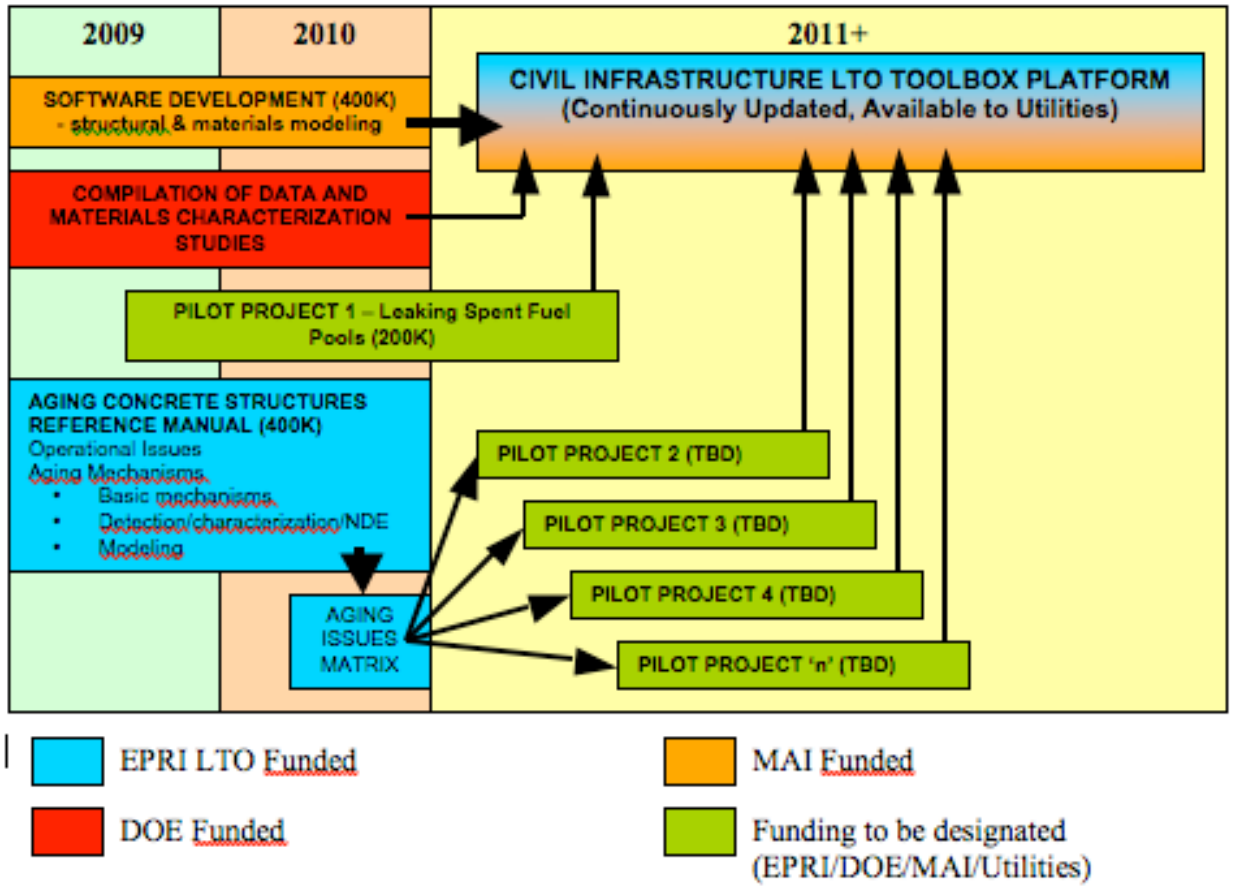
- Develop a Comprehensive Electronic Database of Inspection Results Recommended by NUREG-1801 and Plant-Specific Aging Management Programs (AMPs) Committed To By Licensees In Their Applications For License Renewal.

- Develop Domestic and International Partnerships to Share Expertise, Capabilities and Resources Related To Aging Management Research

Concrete evaluations expected to be a joint effort with EPRI and MAI



International Forum for Reactor Aging Management

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- IFRAM's purpose is to promote worldwide cooperation to address NPP aging management issues.
- Initial Workshop held in Seoul, S. Korea, October 2009
- Next Workshop to be held at Petten, Netherlands, May 25-28, 2010

Conclusions

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- Research is necessary to establish basis for long-term operation of existing nuclear plants beyond 60 years, and this research will:
  - Answer safety questions on aging, reliability, and long-term operability of systems, structures and components
- Industry has lead role to drive the process and identify issue resolutions
- NRC ensures that safety-significant issues are identified and resolved in a timely manner
  - NRC seeking to collaborate with DOE, industry and international partners in an integrated, holistic program to ensure long-term safety

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