ELECTRIC POWER RESEARCH INSTITUTE

EPRI Long Term Operations Work on Concrete

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Contents

- **Structures of Interest – LTO of Concrete**
- Individual projects
  - Irradiation damage in concrete (reactor cavities and biological shielding)
  - Boric acid attack of concrete (spent fuel pools)
- Conclusions / general
- 2014 New Projects
  - Concrete Creep
  - Alkali Silica Reaction

LTO of Concrete

- It is the goal of EPRI LTO to determine at what rate degradation is occurring and how it affects structures to determine if there is a basis to operate from 60 – 80 years.

Structures of Interest for Concrete LTO

2 Unit Nuclear Plant (Pressurized Water Reactor [PWR])

1 – Cooling Towers

2 – Containments

3 – Spent Fuel Pools

4 - Buried Pretensioned Concrete Pipe

5 – Intake Structure

EPRI Concrete Aging Structures Reference Manual

- In 2011 EPRI published a Nuclear Concrete Structures Aging Reference Manual (TR 1023035)
  - The goals of the Manual are:
    - Define possible degradation mechanisms
    - Discuss operational experience
    - Degradation Structures Index – a chart to cross-reference incidences of degradation with SSCs
    - A prioritization of research needs and gaps

Research Prioritization

- **Compiling the Index values and ranking them was done to create a ranked list of concrete research priorities for LTO. The ranking was based on 3 factors.**
  - Susceptibility of structures to exhibit a given type of degradation
  - Available knowledge of the degradation and its manifestation on structures of interest
  - The structural significance of the degradation occurring on a structure or component

Research Prioritization – Selected High Priority Issues

- Chloride Attack
- Irradiation Damage
- Corrosion of Rebar
- Boric Acid Effects (PWR Spent Fuel Pools)
- Posttensioning Tendon Relaxation
- Spent Fuel Pool Liner Inspection
- Containment Liner Corrosion

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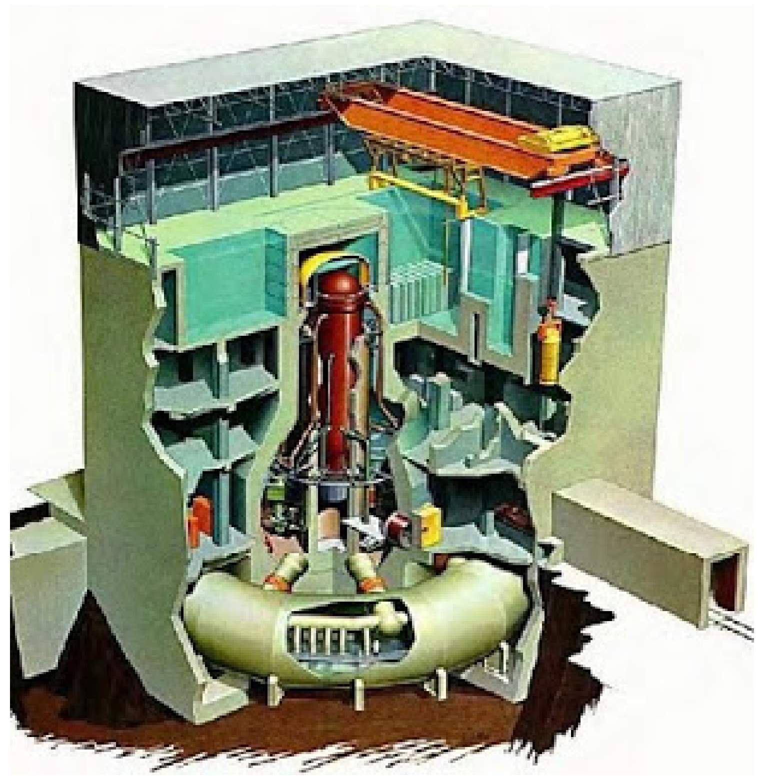
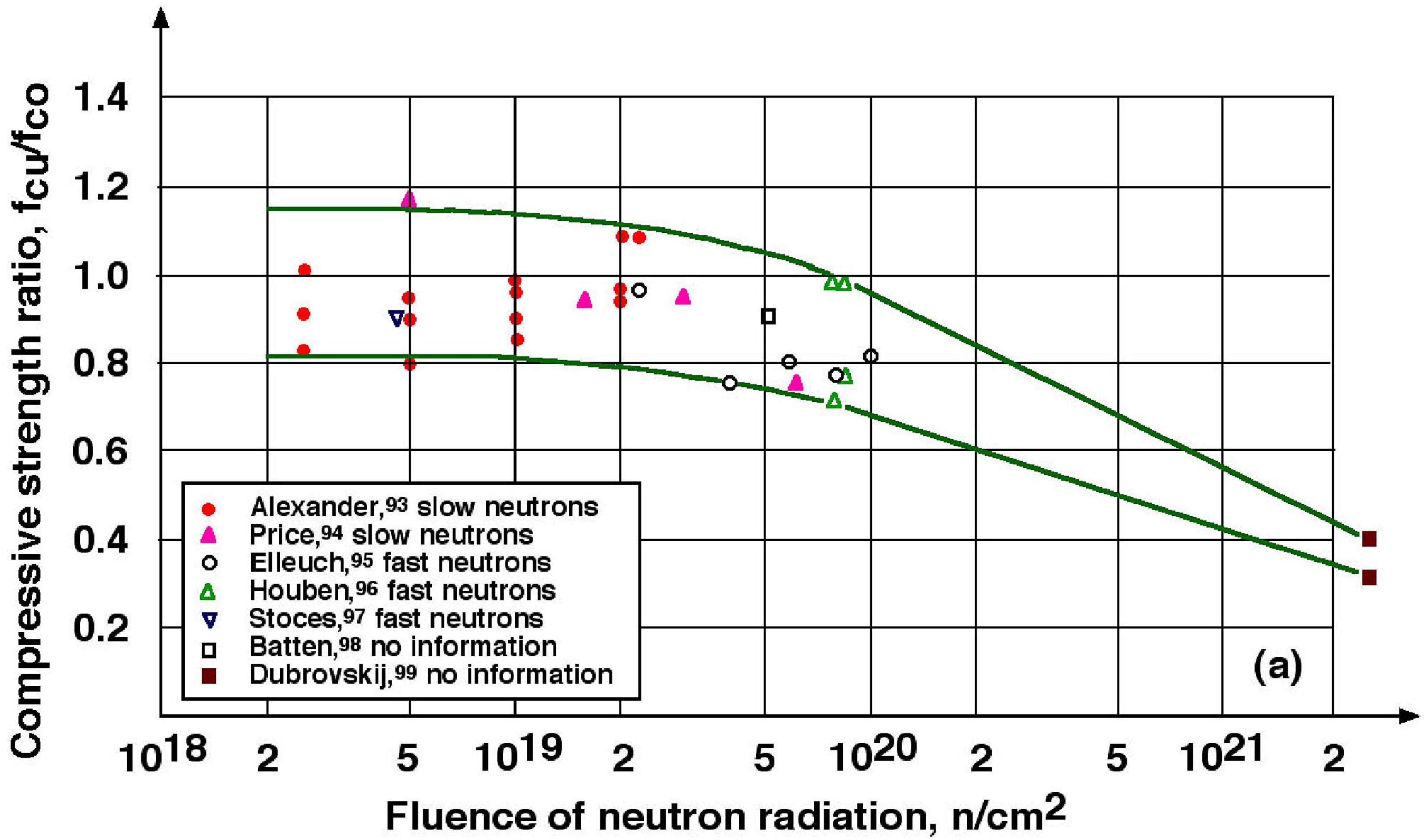
Irradiation Damage in Concrete

- Scope of the project – structures exposed to chronic irradiation due to reactor operation:
  - RPV cavity
  - RPV support pedestal
  - Biological shielding



Irradiation Damage In Concrete – Previous Work

- Hilsdorf Curve – Effect of neutron irradiation on compressive strength

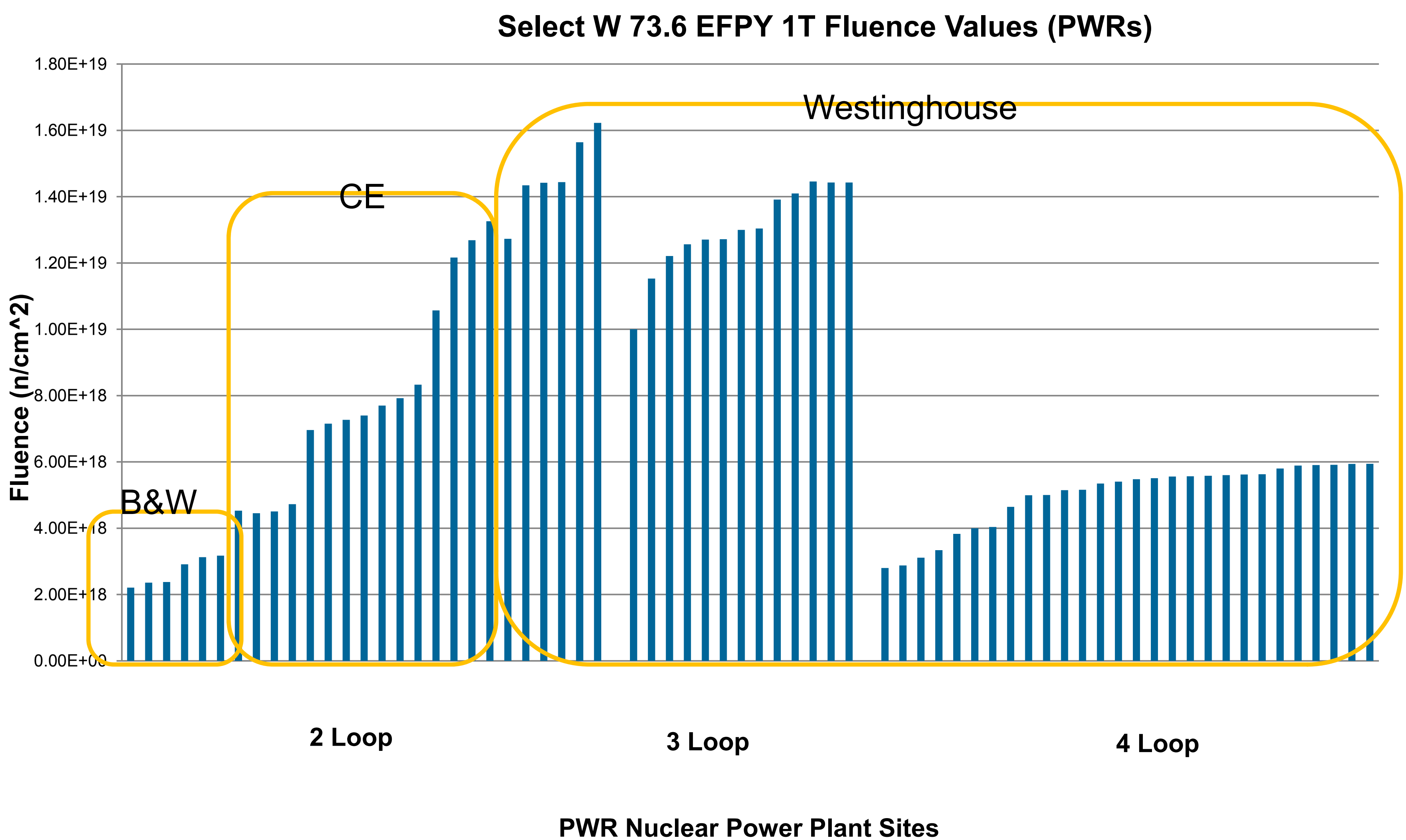


Irradiation Damage in Concrete - Research Plan

EPRI and ORNL-LWR Sustainability have partnered to study the effects of radiation on concrete.

- Perform irradiation experiments at a test reactor (TBD)
  - Identify samples of interest (diff. aggregate types)
    - Cylinder samples of e.g., 2” D x 4 “ L
  - Irradiate samples up to 1.5×10^{20} n/cm^2 E > 0.1 MeV
    - Control core temperature to < 100 degC
    - Monitor temperature and output gas during irradiation.
  - Post irradiation examination
    - Petrography
    - Mechanical Testing

PWR 1T Fluence for 80 y Operation (E > 1 MeV)



Bounding Fluence

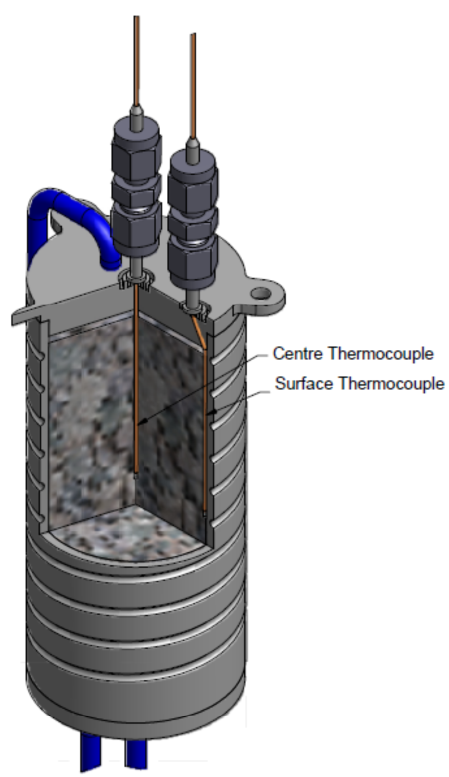
- 6.1 E19 n/cm2 seems to bound the US fleet for neutron damage in concrete to 80 years operation for energy > 0.1 MeV

- Next step is to perform an experimental investigation of neutron fluence above the bounding fluence to disposition radiation damage as a stressor for long term operation.

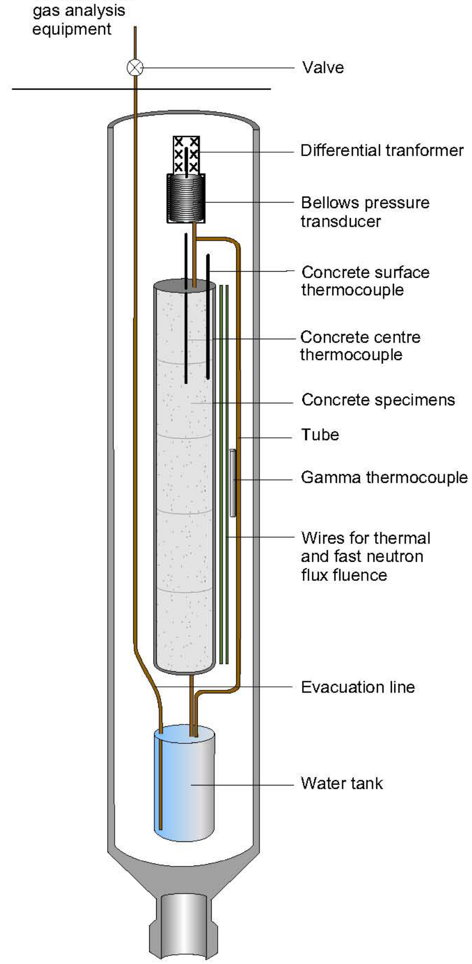
  Target Fluence: 1.5 E20 n/m2 (2 times bounding fluence)

Irradiation Damage in Concrete – Research Plan

- Example experimental Setup



Concrete Sample Holder



Irradiation Damage in Concrete - Conclusions

- Neutron irradiation damage in concrete is possible due to the effects of lattice distortion.

- Previous work on the effects of irradiation on concrete properties is inadequate for use as a technical basis for long term operation (80 y)

- EPRI and ORNL- LWR Sustainability have partnered to conduct a study on the effects of irradiation on concrete under more realistic conditions than were previously studied.

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Boric Acid Attack – Introduction

- PWR spent fuel pools contain boric acid in the water to absorb neutrons emitted from the fuel.

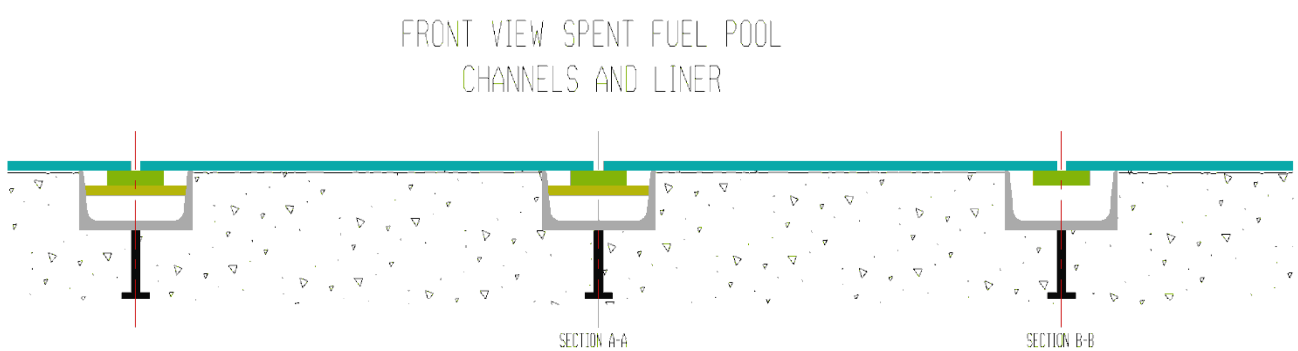
- Spent fuel pools are susceptible to leakage due to cracking in the seam and plug welds in the liner.

- Boric acid is known to react with cement paste and some aggregates, causing degradation of mechanical properties

1 in. = 25.4 mm

Boric Acid Attack – Introduction

- Leakage is collected by the leakage collection channels located beneath the seam welds.
- Collection channels can be obstructed by reprecipitated minerals leached from the cement paste in the concrete.
  - This can result in pooling of water beneath the liner.



Boric Acid Attack – New Project

- EPRI launched a new project in 2013 to study the effects of boric acid on concrete degradation in spent fuel pools

- This study will build upon previous work done to include
  - Reactivity of different types of aggregate
  - Computational modeling of the reaction process
  - Characterization of the reaction products
  - More accurate determination of the reaction front

This will be a 3 year LTO project after which we hope to have a disposition for the structural effects of SFP leakage (if any)

Boric Acid Attack - Conclusions

- PWR spent fuel pools contain boric acid in concentrations around 2,000 ppm.

- Spent fuel pools are leaking and the concrete is degrading
  - there is much interest in characterizing the rate of degradation to determine if it will at some point be a structural issue

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Conclusions - General

- EPRI is active in looking at concrete degradation and inspection for Long Term Operation in 2 areas
  - Radiation damage: Will radiation affect the integrity of the reactor cavity and biological shielding during operation to 80 y
  - SPF boric acid corrosion: Will SFP leakage become a structural issue during operation to 80 y

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Concrete Creep

- EPRI is beginning to look at creep deformation of concrete structures in NPPs
- Concrete deforms slowly and nonlinearly with time when subjected to loading (postensioning, static loading)
  - Dimension change
  - Loss of post stressing
  - Cracking
  - Liner deformation

Concrete Creep

- Nonlinear ultrasound will be benchmarked as a method to determine the amount of creep damage in concrete
  - Application is posttensioned containments
  - Goal is to correlate acoustic nonlinearity to the remaining useful life of the structure.
    - Relationship between acoustic nonlinearity and mechanical properties.
  - Quantification of creep damage / remaining useful life

Alkali Silica Reaction (ASR)

- Caused by a reaction between the alkali cement and amorphous silica in aggregates.
  - Causes formation of an expansive gel that causes the concrete to swell and crack
  - Causes mechanical properties to degrade
  - Reaction between the cement and aggregates requires water
  - Depends on aggregate mineralogy

Alkali Silica Reaction (ASR)

Timeline

- 2014 – Develop a map of types of aggregates used in nuclear plants.
- 2015 – Reactivity of aggregated used in the existing fleet based on current testing procedures.
- 2015 – Toolbox with inspection procedures for utilities for early detection of ASR.

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