EPRI's Long Term Operation Research on the Effects of Radiation on Concrete Biological Shields

Emma Wong
Senior Technical Leader
Electric Power Research Institute

NRC Regulatory Information Conference
March 15, 2018

Background

- Biological shield concrete is subjected to neutron fluence, gamma radiation, and sustained elevated temperature
- Effect of irradiation on concrete was performed in the 60's and 70's
- No issues with the concrete biological shield have been reported to date
- NRC EMDA (NUREG/CR-7153 Vol 4) identified irradiation as a research gap
- Since ~2010 more research is being performed

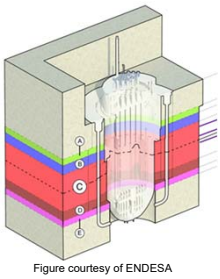
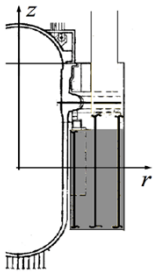


Figure courtesy of ENDESA

Sufficient technical basis that biological shields affected by irradiation will be able to perform their function during long term operations?

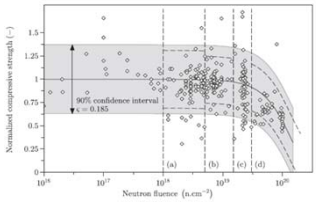
EPRI Research on Irradiation Damage in Concrete

- Effects of Radiation on Concrete – a Literature Survey and Path Forward (2012)
- Expected Condition of Reactor Cavity Concrete after 80 Years of Radiation Exposure (2014)
- Structural Disposition of Neutron Radiation Exposure in BWR Vessel Support Pedestals (2016)
- Long Term Operations – Impact of Radiation Heating on PWR Biological Shield Concrete (2016)
- Structural Model of PWR Concrete Reactor Pressure Vessel Supports – Effects of Chronic Radiation Exposure on Margin (2016)



Effects of Radiation on Concrete – A Literature Survey and Path Forward (2012)

- Total neutron fluence depends on:
  - reactor type
  - biological shield design
  - operation
- Physical property change will depend on aggregate type



Field et al., Nuclear Engineering and Design, 282, 126 (2015)

Neutron irradiation >1 x 10^{19} n/cm^2 can possibly impact the properties of concrete biological shielding

Expected Condition of Reactor Cavity Concrete After 80 Years of Radiation Exposure (2014)

- Maximum neutron fluence after 80 years of operation will be approximately 6.1 x 10^{19} n/cm^2 (E > 0.1MeV)
- BWR fluence is about an order of magnitude lower than PWR fluence

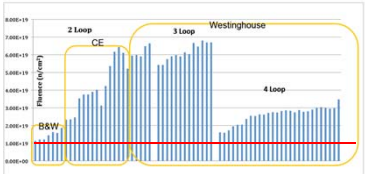
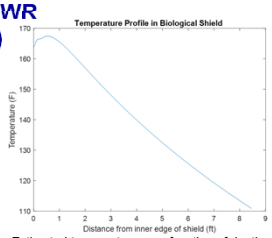


Figure: 1T location (RPV OD in beltline region) PWR 80 year neutron fluence estimates for US operating units extrapolated from surveillance data. Red line represents the threshold in the NRC SRP-SLR (NUREG-2192).

80 year neutron fluence estimated for the US fleet

Impact of Radiation Heating on PWR Biological Shield Concrete (2016)

- Simplified Monte Carlo n-Particle simulation of a generic 2-loop PWR
- Estimated heat loads in concrete biological shielding due to radiation
- Heat loads were used to estimate temperature profiles using finite element modeling

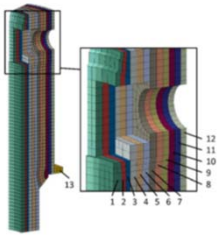


Estimated temperature as a function of depth from Monte Carlo simulation of irradiation heating

Temperature profiles within the ACI 349-13 App. E recommended temperature limits (200F local areas and 150F structures)

Structural Model of PWR Concrete Reactor Pressure Vessel Supports (2016)

- Simplified finite element model based on a decommissioned PWR
- Estimated the effects of radiation on the structural capacity
- Slight reduction of structural margin of the biological shield due to neutron irradiation
- Not expected to affect the structural function in the modeled case

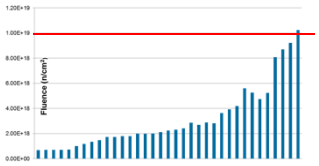


Preliminary model indicates structural margin may be maintained in the modeled PWR's concrete biological shields for operation to 80 years

Structural Disposition of Neutron Radiation Exposure in BWR Vessel Support Pedestals (2016)

- Bounding neutron fluence at the RPV support pedestals were estimated by applying a distance correction to the 1T data
- Bounding neutron fluences are below the threshold for damage in the NRC standard review plan for subsequent license renewal applications (NUREG-2192)

Figure – 1T location (RPV OD in beltline region) BWR 80 year neutron fluence data for US operating units extrapolated from surveillance data. Note: the threshold stated in the *NRC SRP SLR (NUREC 2192)* is 1 x 10^{19} n/cm² (red line).



Irradiation damage to the RPV support pedestals for BWRs are below 1 x 10^{19} n/cm^2

Compilation Report and Guidance (2018)

- Include summaries of previous EPRI reports
- Targeted Key Additions
  - Methods to determine fluence
  - Methods to determine expected degradation depth
  - Methods to estimate loads
  - Methods to estimate capacity

Intended to assist utilities in establishing a technical basis for long term operation of concrete biological shields

Summary

- Neutron irradiation can impact the properties of concrete biological shielding.
- 80 year neutron fluence was estimated for the US fleet of PWRs and BWRs.
- Biological shield design types were reviewed for Westinghouse units.
- It was demonstrated that irradiation damage to the RPV support pedestals may not be above the threshold of 1 x 10^{19} n/cm^2 for BWRs.
- Radiation heating is not likely exceeding ACI recommended temperature limits in PWR biological shields.
- A preliminary finite element model indicates that adequate structural margin will likely be maintained for the modeled PWR's concrete biological shields for operation to 80 years.
- A compilation report combining EPRI and the DOE LWRS work, including an analysis of accident scenarios, is planned for publication in 2018.
- Working with international parties on harvesting for confirmatory research

Together…Shaping the Future of Electricity