Ex-vessel Neutron Dosimetry Program

Background

In many PWRs, the neutron exposure rate at the surveillance capsule locations in the reactor vessel is much greater than that at the peak location. The ratio of these exposure rates is referred to as the “surveillance capsule lead factor.” Lead factors of three to five are not uncommon. With a high lead factor, the reactor vessel material samples in a surveillance capsule can, if left in the reactor, receive neutron exposure well beyond any projected end-oflife (EOL) condition, thus rendering them useless. For example, a capsule with a lead factor of five would receive a 60-year exposure in as little as 12 years. To address this issue, Westinghouse offers the ex-vessel dosimetry program.

Description

NRC 10 CFR 50, Appendix H requires that neutron dosimetry be present to monitor the reactor vessel throughout plant life and that material specimens be used to measure damage associated with the EOL fast neutron fluence exposure of the reactor vessel. Each operating reactor currently has a reactor vessel surveillance program, usually consisting of six to eight surveillance capsules located between the core and the reactor vessel in the downcomer region near the reactor vessel wall. The neutron sensors contained in these capsules provide the monitoring requirements established by 10 CFR 50, Appendix H.

This issue is particularly important for those plants planning for a license renewal. If the current surveillance capsules are left in place, the material specimens will be irradiated well beyond the predicted EOL fast neutron exposure. At a projected EOL of 40 years, a surveillance capsule with a lead factor of four will experience an equivalent reactor vessel fluence of 160 years.

In the ex-vessel neutron dosimetry program, passive neutron sensors are located in the reactor cavity so the neutron exposure of the reactor vessel can be continuously monitored throughout plant life, as required by Appendix H. The surveillance capsules can be removed and stored onsite, thereby preserving this critical, irreplaceable material for future use.

The ex-vessel neutron dosimetry program can also provide additional data to support a license renewal application. As a comprehensive system to characterize the neutron exposure of the reactor vessel, it has the flexibility to:

- Monitor important azimuthal and axial exposure gradients over the entire beltline region of the reactor vessel (unavailable with surveillance capsules) and provide measurements in proximity to critical areas on the reactor vessel
- Provide long-term monitoring that permits continuous evaluation of the effect of changing fuel management schemes on the reactor vessel exposure
- Minimize the uncertainty in reactor vessel exposure projections using a combination of measurements and analytical predictions

The ex-vessel neutron dosimetry program verifies fast neutron exposure distributions within the reactor vessel wall and establishes a mechanism to enable longterm monitoring of those portions of the reactor vessel and vessel support structure that could be susceptible to significant radiation-induced increases in reference nil-ductility transition temperature (RTNDT) over the service lifetime of the plant.When used in conjunction with dosimetry from internal surveillance capsules and with the results of neutron transport calculations, the ex-vessel neutron measurements allow the projection of embrittlement gradients through the reactor vessel wall with a minimum uncertainty.

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Minimizing the uncertainty in the neutron exposure projections will, in turn, help ensure reactor operation in the least restrictive mode possible.

Comprehensive sensor sets, including radiometric monitors (RMs), are installed at discrete locations within the reactor cavity to characterize the neutron energy spectrum variations axially and azimuthally over the beltline region of the reactor vessel. In addition, stainless steel gradient chains are used in conjunction with the encapsulated dosimeters to complete the mapping of the neutron environment between the discrete locations chosen for spectrum determinations.

Benefits

- Surveillance capsules can be pulled out and saved for future use.
- Additional data gained can be used to verify vessel fluence.
- Dosimetry can be removed and replaced in approximately 20 minutes.
- Low-induced activity in the irradiated sensors facilitates shipping and handling.
- The patented Westinghouse ex-vessel neutron dosimetry program hardware permits measurements to be made over multiple fuel cycles without interfering with other operating plant equipment or refueling operations.

Deliverables

- Dosimetry and support hardware to permanently attach the dosimetry system in the reactor cavity with change-out capability from the area below the reactor vessel
- A licensing evaluation, a description of the design and an installation procedure as required by the customer
- Installation of the primary dosimetry and support hardware in the reactor cavity
- A pre-irradiation report (WCAP format) describing the as-built sensor sets and the as-installed measurement locations in the reactor cavity
- E-size Westinghouse drawings showing the as-installed hardware configuration
- The use of a Westinghouse-owned DOT Specification 7A Type A shipping container suitable for the safe transport of the irradiated materials to Pittsburgh, and an activation analysis of the dosimetry to prepare shipping papers (shipping costs included)
- A post-irradiation analysis and evaluation of the multiple foil sensor sets and gradient chains

The disposal of the radioactive material following evaluation is also included.

Experience

- Westinghouse uses state-of-the-art fast neutron radiation transport methods that have been reviewed and accepted by the NRC.
- Westinghouse has successfully provided ex-vessel neutron dosimetry programs to nuclear plants since 1974, including:

- Almaraz
- Asco
- Braidwood
- Brunswick
- Byron
- Callaway
- Catawba
- Comanche Peak
- Vandellos
- Connecticut Yankee
- Diablo Canyon
- Farley
- H. B. Robinson
- Kori
- McGuire
- Mihama
- Palisades
- Point Beach
- Ringhals
- South Texas
- St. Lucie
- Turkey Point
- Ulchin
- Vogtle
- V. C. Summer
- Wolf Creek
- Yonggwang
- Zion

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