JACKET PERFORMANCE IS A CRITICAL FACTOR IN DBE SURVIVAL

Over the past decade, the performance of cables during and after a design basis event. For safety related cables, the electrical performance is of course of critical concern. Can the cable survive the very harsh environment during an event and keep providing important power and control until the event is finished. While the high temperature, pressure and radiation last only for a limited time, it is just as important that the cables perform for up to a year post-event.

It is well known that nuclear power plant cable insulations, like EPR and XLPE, can tolerate these harsh environments, even after significant accelerated thermal and radiation aging. However, earlier generations used jackets like CSPE that were less heat resistant than the insulation system. Under normal operation, this is likely not a problem.

These designs, are exposed to high temperatures necessary to accelerate aging of the insulation to the conditions at the end of 40 and 60 years. Therefore, it was necessary to either overage the jacket to meet the preaging conditions of the insulation, or to provide analysis to project the jacket condition at the 40- or 60-year endpoint. Current work is concentrating on 80-year life – 2x the original qualified life. This presents a challenge to the cable design!

If the jacket is marginal at the projected design life, it is very possible that jacket cracks may occur and that the cracking – particularly during a DBE – could cause the jacket to fall off the cable and end up in the critical sump system necessary to cool the reactor. Figure 1, below, shows the results of a CSPE jacked cable after aging, a LOCA and a 1-year post LOCA submersion.

You can see that the cable jacket is cracked and pieces are missing. Not a pretty picture!

General Cable, in updating its nuclear power plant cable design to meet the requirements of Gen III, developed an improved Ultrol 60+ jacket, a cross linked polyolefin (XLPO), that performs much better. The jacket stays intact and continues to the cable innards.

Figure 1. Conventional CSPE after LOCA and submersion

Figure 2. Ultrol 60+ after LOCA and submersion

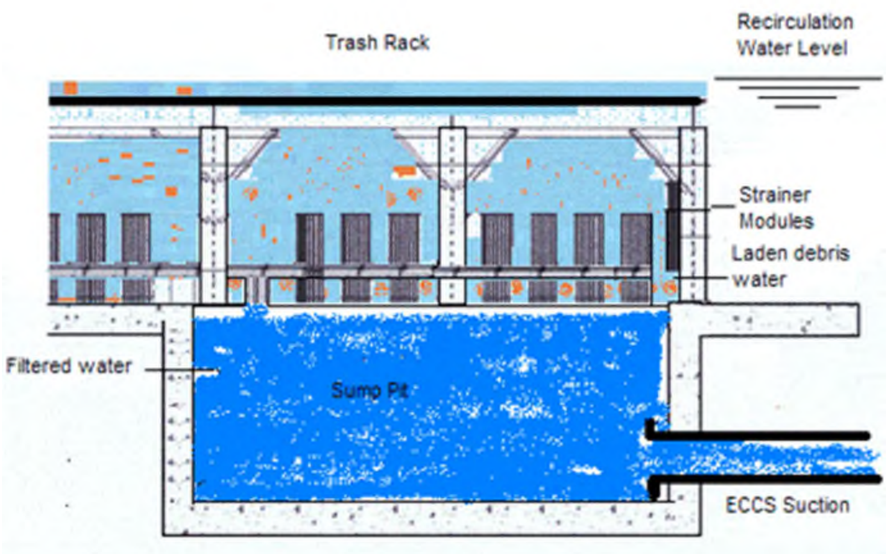
A Little History

Every U.S. nuclear power plant is required by regulations (10 CFR 50.46) to have an emergency core cooling system (ECCS) to mitigate a design basis accident. The emergency core cooling system is one of several safety systems required by the NRC. PWR sump or BWR RHR suction intake function must not be reduced by clogging.

There has been a longstanding concern that, following a LOCA, there is sufficient recirculation of cooling water when long-term recirculation of cooling water be maintained to prevent core-melt. The water must be sufficiently free of LOCA-generated debris and potential air ingestion so that pump performance is not impaired thereby seriously degrading long-term recirculation flow capability.

Actual sump designs vary from the pictures and figure on this page, but all share similar geometric features.

Illustration of Containment Sump



Reference: https://www.nrc.gov/reactors/operating/ops-experience/pwr-sump-performance/function-containment-sump.html

The NRC first addressed ECCS clogging issues in a review of Unresolved Safety Issue (USI A-43, "Containment Emergency Sump Performance."   The technical concerns evaluated under USI A-43 were identified as:

> "(1) PWR sump (or BWR RHR suction intake) hydraulic performance under post-LOCA adverse conditions resulting from potential vortex formation and air ingestion and subsequent pump failure.
>
> (2) The possible transport of large quantities of LOCA-generated insulation debris resulting from a pipe break to the sump debris screen(s), and the potential for sump screen (or suction strainer) blockage to reduce net positive suction head (NPSH) margin below that required for the recirculation pumps to maintain long-term cooling.
>
> (3) The capability of RHR and containment spray system (CSS) pumps to continue pumping when subjected to possible air, debris, or other effects such as particulate ingestion on pump seal and bearing systems."

The materials that have been the concern are fibrous insulations, qualified coatings and sludge. Fibrous insulations include fiberglass insulation, filter media, fire barrier materials and fibrous cable insulation.

NUREG-0897, Revision 1, "Containment Emergency Sump Performance" (October 1985), contained technical findings related to USI A-43, and was the principal reference for developing revised regulatory guidance. An event at Barsebäck demonstrated that the it is possible for a pipe break to generate insulation debris and transport a enough debris to clog the ECCS strainers. Events at the Perry Nuclear Power Plant demonstrated that high strainer pressure drop could be caused by the filtering of suppression pool particulates (corrosion products or "sludge") by fibrous materials adhering to the ECCS strainer surfaces. The effect of particulate filtering on head loss had been previously unrecognized and its effect not considered. An event at Limerick Unit 1 demonstrated the importance of foreign material exclusion practices to ensure adequate suppression pool and containment cleanliness. In addition, the event re-emphasized that materials other than fibrous insulation could clog strainers.

BL 96-03, “Potential Plugging of Emergency Core Cooling Suction Strainers by Debris in Boiling-Water Reactors,” requested BWR licensees to implement appropriate procedural measures and plant modifications to minimize the potential for clogging of ECCS suction strainers by debris generated during a LOCA.

A subsequent assessment determined that larger quantities of debris and finer debris increase the potential for clogging of the ECCS sump screens and therefore, PWRs should evaluate the performance of ECCS strainers considering the effects of debris. Concern over qualified protective coating delamination over time prompted GL 98-04, “Potential for Degradation of the Emergency Core Cooling System and the Containment Spray System after a LOCA Because of Construction and Protective Coating Deficiencies and Foreign Material in Containment,” dated July 14, 1998, to obtain necessary information from licensees to evaluate how they implement and maintain their coating programs. RG 1.54, “Quality Assurance Requirements for Protective Coatings Applied to Water-Cooled Nuclear Power Plants” was revised to update guidance for the selection, qualification, application, and maintenance of protective coatings in nuclear power plants. NRC RES also conducted research and evaluated the failure modes of coatings, their likely causes, the characteristics (e.g., size, shape) of the debris, and the timing of when coatings would likely fail during an accident.

The PWR industry is implementing a two-step program to assess the current sump conditions and evaluate sump recirculation performance. The program consists of the performance of actions recommended in two NEI guidance documents to address an NRC BL and an NRC GL.

The first guidance document, NEI 02-01, “Condition Assessment Guidelines: Debris Sources inside Containment,” was published in September 2002. NEI issued the guideline so that plants may perform condition assessments and appropriate supporting walkdowns during scheduled outages. NEI 02-01 recommends that during a walkdown, identify the “location and characteristics of potential debris sources (i.e., fiberglass, calcium silicate, mineral wool, etc.) present within a region potentially affected by impinging jets from identified pipe break locations.”

The second NEI document, NEI 04-07, was input for an NRC Safety Evaluation for Generic Letter 2004-02, GSI-191 SER, to ensure a comprehensive evaluation of containment debris. It suggests “dielectric materials, such as plastics and exposed cable jackets, may be principle candidates for inspection.”

To address potential concern with pressurized water reactor (PWR) containment sump performance, the NRC issued Generic Safety Issue GSI- 191, “Assessment of Debris Accumulation on PWR Sumps Performance.” As part of GSI- 191 technical assessments, the NRC performed parametric evaluations of PWR sump performance.

Major modifications were made to plants to ensure satisfactory sump performance (responding to request in GL 2004-02). All licensees have significantly increased the size of their sump screens, and some have replaced fibrous insulation with reflective metal insulation whose debris is considered less likely to reach or impede flow through sump screens.

The remaining challenge involves adequately demonstrating that performance of the modified sumps would be adequate. The plant systems involved cannot be tested in a debris environment, so testing must be done at an offsite facility on a model of the sump. The plant would need to show that the test conducted on the model is adequately similar to what would occur in the plant in the unlikely event of a loss-of-coolant accident.

In March 2015, Westinghouse issued WCAP-1 7938-NP (APP-GW-GSR-012), titled “AP1000 In-Containment Cables and Non-Metallic Insulation Debris Integrated Assessment” to address concerns in Generic Safety Issue (GSI)-191, and Generic Letter (GL) 2004-02. The AP1000 evaluation states that no fibrous debris will be generated during a loss of coolant accident (LOCA). The AP1000 plant design includes cabling that may be directly impinged upon by a

LOCA jet. These cables may contain fibrous and other materials (jackets, wrappings, and filler materials) that were not considered in the initial GSI- 191 debris source term evaluation. Jet impingement testing and component characterization was performed on AP1000 cables that may be directly impinged upon by a LOCA jet.

Submergence testing of cables was not needed as submerged cables was a part of the AP1000 plant design from the design's inception. A new requirement for qualification included that the cables did not crack after LOCA and one year of being submerged, post event in hot boric acid, simulating the environment after a postulated accident. AP1000 reactors rely on passive convection of coolant so despite the removal of fibrous insulation, the cable required assurance as it would not contribute to a clogged sieve.

Five types of AP1000 plant cables were tested for the cable jet impingement test (LV) jacketed, insulated single conductor, LV jacketed multi-conductor, and medium voltage (MV) jacketed power cables. These cables were AP1000 qualified for LOCA and subsequent one-year submergence in hot boric acid coolant. After those events the jackets on the cables were observed to have no cracks.

NUREG- 1918, written in February 2009, concluded that the consequences of chemical effects based on cable debris are small when compared with other sources of chemical effects. The main concern with submerged cables had been the formation of chloride ions due to radiation induced breakdown of the cable insulation. Ultrol 60+ cable jacket and insulation used in the AP1000 plant is constructed of cross-linked polyolefin and cross linked polyethylene respectively and does not have a major chloride component.

Want more information, including the superior performance of General Cables Ultrol™ 60+ cables?

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