Westinghouse BWR Fuel Reliability – Recent Experience and Analyses

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Fuel reliability and failure free fuel has always been one of the most important objectives in the development work at Westinghouse Electric Sweden. Significant efforts have been devoted to investigate the root cause of leakers. This additional knowledge is used as input for the development work. The objective of the development work is twofold; to decrease the number of primary failures and to reduce the consequences of a failure. A consistent idea throughout the years has been to use a multi-level approach. In order to successfully attack complex issues it is often necessary to use a variety of interacting measures that separately may not be enough, but together can eliminate the problem. An important step in tailoring remedies against both primary and secondary fuel failures is to understand the failure mechanisms.

Primary Failure Mechanism

The only failure mechanism that has caused leakers in modern Westinghouse BWR fuel in the last couple of years is fretting from foreign debris. This does not mean that other failure mechanisms are not relevant, since design improvements and resultant changes in operation can reduce the margin for other types of failures. One such failure mechanism is PCI (Pellet Cladding Interaction). A combination of increasing burnup and improved thermal margins makes it possible to operate modern fuel much more aggressively. It is therefore necessary to always ensure that the PCI margin is maintained. Another failure mechanism that requires constant attention and re-evaluation is cladding corrosion.

In order to increase the understanding of the current dominant cause of BWR fuel failures an investigation has been performed with the objective to map the steps leading to a debris fretting fuel failure and to understand the mechanisms behind each step. The investigation includes observations during fuel inspection, information from the power plants, statistical analysis of fuel failure experience, experimental work and calculations.

Mitigating actions against debris fretting fuel failures can and should be implemented at as many stages as possible in the process leading up to fuel failures, i.e. starting with the prevention of harmful debris entering the process. Remedies acting in series will be much more powerful than single efforts. Remedies that have been implemented within the current Westinghouse fuel design are the TripleWave debris filter, which is a standard SVEA-96 Optima2 feature and a refined spacer design that has been introduced with the SVEA-96 Optima3 design. The improvement in fuel failure frequency by the use TripleWave debris filter has now been demonstrated.

Secondary Degradation Mechanism

The radiological and economical consequences of a failed fuel rod depend on the degree of secondary degradation. It ranges from about 400,000 € for a non-degraded fuel failure to about 4,000,000 € for a fuel failure that forces a plant to perform an extra shut-down to remove the failed fuel. Since the current trend within the industry is lower limits for activity release from failed fuel, the margin for continued operation is becoming smaller. Therefore it is more important than ever to minimize the secondary degradation of failed fuel.

The first step towards mitigating secondary degradation is to understand the mechanisms involved and to understand the dependency upon the power plant operation. Secondary fuel degradation studies, including testing of several remedies, have been carried out in a test in a BWR loop in the Halden test reactor. In addition, the existing 10x10 BWR fuel failure database has been assessed to identify trends in the severity of secondary degradation.

Westinghouse is working on several measures for reducing the probability of a primary failure developing into a severe secondary failure and its associated uranium washout. Optimized iron content in liner and ADOPT pellets are both part of this programme.