From: William Huffman, NRR
To: George Hubbard
Date: Thu, Jul 13, 2000 2:08 PM
Subject: Zirc Fire T-H SECY

George,

attached is the draft SECY that I threw together awhile back. This is for your information only. I am not trying to influence in any way the DSSA conclusions or process used to solve this internal DSSA issue.

------------------Bill

4205

Possible Draft Commission Paper

Decommissioning Regulatory Options Based on SFP Risk Study

PURPOSE

To request Commission approval of using standardized assumptions when performing a thermal-hydraulic analysis of a spent fuel pool's vulnerability to a zirconium fire.

BACKGROUND

Plants undergoing decommissioning are required to maintain emergency planning (EP) programs and insurance coverage at the same level as required for full-power operating plants. The commission has, for the most part, required decommissioning plants to maintain full EP and insurance coverage until it can be demonstrated that a zirconium fire accident (described below) is no longer possible, after which, licensees will typically be granted exemptions that provide significant reductions in EP and insurance. Since there is no regulatory guidance for reducing EP or insurance at decommissioning plants, licensees have questioned if the requirements could be reduced based on the low risk of the zirconium fire accident. Consequently, the staff conducted a study to quantify the risk of SPF accidents at decommissioning plants and determine if a technical basis for any future rulemaking or exemptions requests in the areas of EP or insurance for decommissioning reactors.

In the recently issued study, the staff assessed the risk associated with storage of spent fuel in a spent fuel pool at decommissioning nuclear power reactors. The study primarily examined loss of water accident scenarios resulting in uncovery of the spent fuel. Following uncovery of the spent fuel in the pool, the fuel heats up to a temperature where the zirconium cladding undergoes rapid oxidation releasing significant energy which intensifies the oxidation resulting in a fire type condition. This fire has been postulated to potentially involve more that one core's worth of fuel. Therefore, offsite consequences of such an accident can be very large. The study concluded that the risk was not significantly different from that found at an operating reactor spent fuel pool provided the licensee maintained certain standards for the spent fuel pool support system configurations, procedures, and activities during the first five years of spent fuel decay time. After five years, the potential for a zirconium fire is considered to be essentially non-existent due to the low decay heat level of the spent fuel.

The potential for zirconium fires in spent fuel pools is not confined to decommissioning nuclear power plants. The staff has previously assessed the risk of a zirconium fire for operating plants in its resolution of GSI-82 and concluded that the risk is sufficiently low to preclude the need for any additional requirements from a regulatory perspective. Specifically, the risk is low (frequency on the order of a large early release from an operating reactor) and is dominated by a severe beyond-design-basis earthquake initiator. Regulations require only limited design related measures for severe accidents (e.g., ATWS rule and SBO rule), and rely primarily on plant siting and EP as defense-in-depth measures to help mitigate the consequences from severe beyond-design-basis events that lead to offsite releases.

Although the technical report on SFP risk at decommissioning plants found the overall risk posed by a zirconium fire accident (based on event frequency) to be very low, the report did not conclude that the zirconium fire was sufficiently remote or hypothetical such that consideration of this accident is unnecessary from a regulatory perspective. The staff is now in the process of developing recommendations on how to proceed with decommissioning rulemaking in the areas of EP and insurance. Since the risk study did not conclusively rule out the need to address a zirconium fire accident, the time at which a zirconium fire is no longer possible must still be established to permit substantial reductions in EP and insurance coverage. The technical report provided an estimate of 5 years after shutdown as a conservative decay time after which the zirconium fire can be dismissed for all spent fuel configurations based on current spent fuel maximum allowable burnups and SFP rack designs and densities. However, the staff believes that most licensees will not find it economically advantageous to wait 5 years before obtaining substantial reductions in the EP and insurance programs and will continue to submit early EP and insurance exemption requests based on plant specific SFP zirconium fire vulnerability analyses. By standardizing assumptions used in the zirconium fire vulnerability calculations, a potential improvement in the efficiency and effectiveness of the analyses performed by the licensee and the review performed by the NRC can be realized. The staff considers the assumptions justifiable when considered in light of the low risk posed by the posed by the zirconium fire event at decommissioning spent fuel pools.

DISCUSSION

The point at which a spent fuel stored in a SFP is no longer susceptible to a zirconium fire accident is difficult to establish using a case specific thermal-hydraulic (T-H) approach. The results are highly dependent on the assumptions made in the analysis. ***Most of these assumptions are not mechanistically defensible and can be reasonably disputed even taking a bounding approach.***

For example, the technical report stated that the building ventilation flow is an important factor in the zirconium fire analysis. Many previous exemption related analyses assumed an unlimited amount of ambient-temperature fresh air available to continuously remove decay heat. This results in an overall forced ventilation requirements on the order of 10,000 to 15,000 (????) standard cubic feet per minute of fresh air through the spent fuel pool building. Given a severe earthquake initiator of a SFP drain down sequence, it would virtually impossible to predict the failure mode of the SFP building and the resulting ventilation through the building (either forced circulation if ventilation fans and electricity are still functional or nature circulation). It is also likely that any scenario resulting in temperatures approaching 600°C or greater in the spent fuel pool building area would easily exceed the environmental qualification of the building's HVAC system and more than likely render it inoperable. Consequently, any ventilation assumption could be challenged.

Other parameters that important to the analysis include rack geometric parameters such as pitch, baseplate hole size, downcomer width, and availability of open spaces near the assembly for air flow. In addition, the fuel bundle flow resistance, intermediate flow mixers, grid spacers and tie plates also contribute to air cooling flow calculations. While these parameters can be modeled on a case-by-case basis, the sophistication of the analytical code to accurately account for the flow resistance of these components has not been explicitly validated. Furthermore, any debris in the air flow channels or rearrangement of the assumed geometry (such as might be associated with a seismic event or a cask drop accident) would invalidate the analysis. Also, the cooling phenomenology of a partial drain down event where the bottom of the racks remains covered with water blocking air flow through the assemblies may be more limiting than complete drainage of the pool - however, this has not been determined.

In addition, previous spent fuel heat up analyses have assumed that the cool air flowing down into the spent fuel pool is at the building ambient temperature. This assumption neglects the mixing that occurs between the hot air rising from the bundles and the cooler air descending into the SFP. Limited assessment by the staff finds that the calculated peak cladding temperatures can be very sensitive to mixing. The staff's report states that a complex three-dimensional computational fluid dynamics calculation may be necessary to accurately analyze the heat up.

Finally, the staff has not determined an acceptable computer code capable of performing the analysis. There are several computer codes (e.g.,SFUEL, SFUEL1, SHARP, and COBRA-SFP) which have been used to analyze the spent fuel heat up following a drain down of the pool water. None of these codes has been rigorously verified, validated, or benchmarked for this application to the standards normally associated with deterministic nuclear-related T-H analyses. Development and staff approval of such a code could require years of research and large resource expenditures.

In conclusion, there does not appear to be a justifiable way to model the SFP following a severe seismic event or cask drop. There are also significant uncertainties in even the most sophisticated T-H methodologies used to analyze a SFP heat up which could invalidate a reasonable conclusion that a zirconium fire is no longer possible. An accurate and realistic T-H calculation of zirconium fire vulnerability would probably require further code development as well experimental research.

Considering that the frequency of event scenarios that could result in a zirconium fire are extremely low, the staff would support a risk-informed policy decision by the Commission to simplify the T-H model and analysis needed to establish an acceptable decay time for which EP and insurance coverage could be reduced on a plant specific basis. The approach would recognize that the resultant T-H calculation is not deterministically accurate. However, the calculation, in conjunction with the low probability of events leading to a zirconium fire condition, should be sufficient grounds for significantly reducing EP and insurance requirements. The simplified T-H analysis would define standardized assumptions for such things as building ventilation flows, flow mixing, and assembly down flow resistance. In addition, the staff could endorse the use of several readily available computer codes for performing the simplified analysis despite inadequacies in the staff's technical report. The calculation would become a reasonableness test that sufficient decay time had elapsed to eliminate EP and insurance programs, rather than proof that a zirconium fire is no longer possible.

RECOMMENDATION

Based on the low probability of event scenarios leading to a SFP drain down, the staff would support a policy decision by the Commission that a simplified approach be developed for performing zirconium fire T-H vulnerability calculations including the use of standardized parameters. Details of the simplified T-H calculational approach would be specified in a regulatory guide. In making its decision, the Commission should clearly recognize that such a simplified T-H calculation would not definitively establish when a zirconium fire is no longer possible but would represent reasonable assurance that the zirconium fire need no longer be considered a basis for maintaining offsite EP and insurance programs.

The staff requests Commission approval of this approach as a policy decision since it does not conflict with any existing regulations and involves a judgement as to what extent low probability, beyond design basis events must be considered when relaxing regulatory requirements for EP and insurance.