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UNITED STATES
NUCLEAR REGULATORY COMMISSION
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
WASHINGTON, D. C. 20555

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MEMORANDUM TO: ACRS Members and Staff

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FROM: A. W. Cronenberg

SUBJECT: Central Issues Related to Power Uprate Reviews

This memo outlines key issues that I believe should be addressed in anticipated ACRS meetings with the staff, related to the conduct/content of agency reviews of License Amendment Requests for power uprates. Recommendations stem from my prior review of operational events noted for uprated plants, and indications of potential synergistic safety implications for aged/uprated plants which involve an extended fuel cycle.

1) Adequacy Of Agency Uprate Review Procedures: The agency's Maine Yankee Lessons Learned effort (*Report of the Maine Yankee Lessons Learned Task Group,* internal NRC document, 1996) indicated the need for a more comprehensive/consistent review of power uprate applications, with a primary recommendation for development of a Uprate Standard Review Plan. A similar recommendation was made by an independent review of power uprates by Scientech Inc, (J. S. Miller, *Power Uprate* Review, Scientech. Inc, SCIE-NRC-249-96, Oct. 1996). My observations lead to a similar recommendation of the need for a more formalized approach to review of power uprate requests. My examination of agency uprate Safety Evaluation Reports (SERs) does not reveal consistency in the scope and level of detail of the subject matter reviewed. The SERs do not generally specify how the review was accomplished, the acceptance criteria for the conclusions reached, or include staff analysis to audit the accuracy of information provided by the licensee. This type of information would normally be expected under stipulations of a Standard Review Plan.

Agency in-action for a more comprehensive uprate review process is being justified by risk arguments of minor changes in CDF for power uprates. This indeed may be the case, nevertheless operational events have been noted for uprated plants, as well as violations of Tech. Specs. In light of these considerations, I recommend that ACRS encourage a more formalized approach to review of power uprates, specifically the development of a Uprate Standard Review Plan.

2) NRC Audit Analysis of Licensee Submittal Information: A large part of a licensee's submittal for a power uprate centers on a re-analysis of information similar to that found in the original FSAR but at the higher power level; examples being a re-evaluation of design basis accidents (DBA) and off-normal transients at the elevated power, operational core cooling and core thermal-hydraulic conditions, DNB (departure from nucleate boiling) margins, analysis of the thermal capacity of the residual heat removal and emergency core cooling systems. Balance-of-plant thermal-hydraulic analysis must also be provided by the licensee, such as predictions of secondary-side feedwater flow/temperature conditions at the increased thermal load. This information generally takes the form of code predictions which are reviewed by the NRC staff and findings reported in the uprate Safety Evaluation Report (SER).

A review of a number of uprate SERs (i.e. Brunswick, Limerick, Maine Yankee, North Anna, Surry, Callaway, and Wolf Creek plants) reveals little in the way of staff audit analysis of licensee submittal predictions. The question then is how can the staff validate the accuracy of submittal analysis without aid of it's own/independent audit calculations. If this had been done for Maine Yankee, the faulty LOCA analysis might have been reveled by the staff rather than from whistle-blower accusations. I strongly urge the ACRS to press the staff for some sort of audit analysis of Licensee submittal thermal-hydraulic predictions. I would also urge additional staff audit analysis of core neutronics predictions by the licensee, specifically when an uprate request involves use of extended fuel duty times and/or for cores involving new fuel configurations, e.g new fuel designs or reload configurations with a mixture of multi-vendor fuel types (see INPO report on problems noted for restart with multi-vendor fuel; *Design and Operating Considerations for Reactor Cores,* SEOR-96-2, 1996).

3) Potential Synergistic Safety Issues: Several recent operational events for uprated plants point to circumstantial evidence of compounding degradation due aging/uprate and high-burnup/high-power effects, which have not been addressed in prior uprate reviews.

Aging/Uprate Effects: A significant number of major pipe ruptures have been noted for uprated plants, where synergistic effects on pipe corrosion appear largely responsible for such ruptures. A recent example is the Aug. 11/99 event at Callaway-1(PWR), where a double-ended guillotine break occurred in an 8" diameter steam line leading to a feedwater heater. It is noted that power uprates often involve increased feedwater flow/temperature conditions to accommodate the thermal load; where pipe corrosion is exacerbated at increased flow/temperature conditions. Another example is the more recent Susquehanna-2 (BWR) event in 1999, where weld failure in the BWR re-circulation line has been attributed to weld fatigue related to increased vibrations at the higher speed of the re-circulation pumps needed to accommodate the uprated power begun in 1995 (see Nucleonics Week, Vol. 40/No. 51, Dec. 23, 1999). A compilation of reactor pipe ruptures has been recently documented in an EPRI report [EPRI, *Nuclear Reactor Piping Failures at US Commercial LWRs: 1961-1997,* TR-110102, Dec. 1998], indicating in excess of 170 dramatic pipe rupture events in LWRs, ranging from single-ended pipe breaks to full double-ended guillotine ruptures of the Callaway type. The cause of such ruptures is generally due to flow/erosion or flow-assisted corrosion effects. Flow-assisted ruptures would be expected to be exacerbated at the higher flow rates that generally accompany a power uprate (primary and secondary side for BWRs, secondary side for PWRs); thus potential synergistic concerns exist and deserve additional attention in uprate reviews by the staff.

High-burnup/Elevated-power Effects: Control rod insertion problems have also been noted for extended-life fuel assemblies (burnup effect) exacerbated at high-power core locations (uprate effect). At Wolf Creek PWR plant 5 control rods failed to properly insert during a plant trip on January 30, 1996. All of the affected control rods involved Westinghouse VANTAGE-5H fuel assemblies with burnups greater than 47,6000 MWD/t-U. As indicated, the Wolf Creek plant received agency approval in 1993 for a 4.5-% power uprate from 3411MWt to 3565MWt. Root cause analysis revealed that the control rod insertion problems were caused by fuel assembly guide thimble tube distortion resulting from excessive compressive loading. The compressive loading was caused by excessive irradiation induced growth of the Zircaloy thimble tubes at high power/high-burnup core locations, indicative of potential synergistic elevated-power/extended fuel life effects.

At the recent ANS-San Diego meeting, utilities were talking of both power uprates and extended fuel duty times (higher burnup levels) in terms of nuclear plant economics in a deregulated environment. It is noted that Commonwealth Edison plans for both the Quad Cities and Dresden uprates involve not only power increase of 17-%, but in combination for with the use of the new GE-14 extended life fuel. The ACRS should question the staff on issues of potential synergistic high-burnup/high-power effects.

4) Content of Uprate Safety Evaluation Reports (SERs): The uprate SERs reviewed in my study were those for the Brunswick, Limerick, Maine Yankee, North Anna, Surry, Callaway and Wolf Creek plants. In general these SERs did not reveal any particular in-depth probe of potential issues or evidence of independent audit predictions by the staff. Indeed, a reading of these SERs gives one the distinct impression that information contained in the licensee submittal is simply paraphrased in the SERs. The following are excerpts of staff review findings found in a typical uprate-SERs, in this case the Wolf Creek Uprate SER:

Emergency Core Cooling System (ECCS): "From the licensee's study, no adverse impact to ECCS operability or vulnerability to single failure due to the re-rated conditions was identified. The licensee submitted revised ECCS performance analyses in support of Amendment 61, which justified various changes associated with Cycle 7 operation. The licensee performed large and small break analyses at the limiting re-rate conditions and determined that all acceptance criteria continued to be satisfied. The NRC staff has reviewed the licensee's analyses and concludes that the ECCS analyses referenced in support of the re-rate conditions continues to be in compliance with 10CFR50.46 and App. K. The Wolf Creek ECCS is, therefore, acceptable for operation at the re-rated conditions."

Main Steam System: "The main steam system dissipates energy generated by the reactor core to the turbine generator and auxiliary steam loads, the main condenser via the steam dump valves, or to the atmosphere via atmospheric relief valves or main steam safety valves. Isolation of the main steam system is achieved by the main steam isolation valves and main steam bypass isolation valves. The licensee evaluated the capability of the main steam system components to perform their design functions under the proposed re-rate conditions. The licensee determined that the existing set-points and capacity of the main steam safety valves are adequate to prevent exceeding 110-% of design pressure of the main steam system under the most limiting transient. The set-point and capacity of the atmospheric relief valves were found to remain adequate to control the design load shed of 10-% rated thermal power. In addition, the atmospheric relief valves were found to have adequate capacity to achieve a 50 F/hr cool-down if the main condenser was unavailable. The main steam isolation valves were evaluated to ensure the valves will continue to perform their isolation function under the maximum differential pressure conditions and within the time limits assumed in the safety analysis. The staff concludes that the existing main steam system components are adequate to perform their safety functions under the re-rated plant conditions."

Main Feedwater: "The main feedwater system delivers feedwater, at the required pressure and temperature, to the four steam generators. The safety-related portions of the system ensure isolation capability and provide a path to permit the addition of auxiliary feedwater for reactor cool-down following design basis transients. The licensee's evaluation shows that the existing design basis for the main feedwater isolation valves and main feedwater bypass isolation valves is not significantly affected by operation at the re-rate conditions. The piping configurations associated with the feedwater and auxiliary feedwater systems do not change as a result of the re-rate conditions. The ability of the auxiliary feedwater system to perform its heat removal function was addressed by the licensee. The staff finds that the safety functions of the feedwater system will continue to be satisfied during operation at the re-rate conditions."

In each of the above examples, no independent NRC analysis are cited to support the staff conclusions reached in the SER. The SERs did not specify the scope of the subject matter reviewed, how the review was accomplished, or acceptance criteria for the conclusions reached. Such information is required in the review of the original plant FSAR, as specified in the Standard Review Plan. Of particular note are standardization of acceptance criteria. In the FSAR-SRP the technical bases for the acceptance criteria are specified, including the solutions and approaches that are acceptable, which are codified in a form so that staff can rely on uniform and well-understood positions for its review. Standardization of requirements/acceptance criteria is desirable to assure consistency/adequacy of the uprate review process and documentation of staff findings and conclusions in the SER.

5) Safety Margins/Risk Measures: The uprate applications and associated SERs reviewed in my study did not reveal significant efforts related to an assessment of the risk, or change-in-risk, associated with the uprated power. This may be due to the fact that these submittals were reviewed prior to agency efforts at risk-informed regulation. However, future uprate approvals should require some sort of assessment of the change-in-risk or safety margins associated with the uprate. For example, one might estimate the change in failure probability and impact on risk for a piece of equipment, say for a feedwater pump or piping, operated at the higher flow rates/temperatures for uprated conditions, versus the failure probability of the same pump or pipe if it remained at the prior/lower power level. Another example relates to the Susquehanna-BWR experience, where one might estimate the failure probability of a recirculation pump due to increased vibrational fatigue at the higher flow rates of the uprated plant, versus the pump failure probability (and impact on overall risk) at the lower/slower pumping conditions at the prior power level; where delta-risk would be of interest. Some indication of the change-in-risk, or change-in-safety margin, should be required for power uprate applications.