November 29, 2000

MEMORANDUM TO: Thomas L. King, Director, DRAA/RES

FROM: Mark A. Cunningham, Chief, PRAB/DRAA/RES **/RA by M. Drouin/**

SUBJECT: SUMMARY OF NOVEMBER 14, 2000, PUBLIC MEETING REGARDING USE OF WARM PRE-STRESS (WPS) AND LARGE EARLY RELEASE FREQUENCY (LERF) IN PRESSURIZED THERMAL SHOCK (PTS) ANALYSES

The meeting was requested by the Materials Reliability Project (MRB, an Electric Power Research Institute-organized group), to discuss acceptability of using WPS in PTS analyses, and to discuss NRC's plans for using LERF as part of the acceptance criteria for PTS risk at nuclear power plants.

The attached minutes of the subject meeting will be distributed to attendees and other staff and industry persons known to be interested, and will be made available to the general public following the usual procedures for public meetings (e.g., availability on ADAMS).

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Attachments: Minutes of subject meeting

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Summary of Public Meeting Regarding Use of Warm Pre-Stress (WPS) and Large Early Release Frequency (LERF) in Pressurized Thermal Shock (PTS) Analyses

NRC Headquarters, TWFN Room 10A1

NOVEMBER 14, 2000

The meeting was requested by the Materials Reliability Project (MRB, an Electric Power Research Institute-organized group), to discuss acceptability of using WPS in PTS analyses, and to discuss NRC's plans for using LERF as part of the acceptance criteria for PTS risk at nuclear power plants.

The meeting started with an industry statement by Ted Meyer (Westinghouse) that WPS is a phenomenon that can be demonstrated to be effective in preventing reactor pressure vessel (RPV) failure during certain types of potential PTS transients, and that WPS should therefore be taken into account in PTS risk analyses, contrary to the currently used version of the probabilistic fracture mechanics (PFM) code developed by the Oak Ridge National Laboratory ("FAVOR") which doesn't do so.

A detailed explanation of the WPS mechanism is beyond the scope of these minutes (and their author), but is related to "blunting of the crack's edge." That is, WPS results in a crack whose leading edge is broader than it would be without WPS, e.g., imagine a cut in the edge of a piece of paper shaped like the following: (. Then, imagine a cut in the edge of a piece of paper shaped like < . It would be harder to rip the paper starting from the former shaped cut (associated with WPS) than from the latter shaped cut (associated with no WPS); the difference is analogous to the WPS effect in RPVs.

WPS is effective during transients that cause a steadily decreasing (or at worst not increasing) total stress (i.e., pressure stress plus thermal stress) in the RPV at the crack location. In such transients, it has been experimentally observed that if the RPV does not fail at the time of maximum stress (usually early in the transient, when pressure in the RPV and resulting pressure-related stresses are high), then the RPV will not fail later in the transient, even though fracture mechanics calculations that do not include WPS may predict such failure.

Such failure predictions occur because, even though the pressure-related stress in the RPV is decreasing as the pressure decreases, the thermal stress (caused by non-uniform cooling thru the RPV wall thickness) may be increasing sufficiently to cause the total stress to be decreasing only slightly, and meanwhile the RPV may have cooled to temperatures where its resistance to failure may be low enough to result in a condition where the total stress is greater than the vessel's theoretical resistance to failure from that stress. However, under those conditions, using fracture mechanics models modified to include WPS, RPV failure is not predicted, and extensive experimental evidence has shown that the codes with WPS are correct.

It was agreed that the NRC will explore the need to take account of WPS in its PTS calculations. The first quantitative results of those calculations, the "scoping study" results for Oconee, will include appropriate groups of transients of the type where WPS should be effective. The initial set of thermal hydraulic (TH) and PFM calculations for those groups may not include WPS (i.e., the TH calculations may not include actions that would contribute to the effectiveness of WPS, such as termination of SI, and WPS may not yet have been built into the PFM code). However, the total RPV failure frequency resulting from all events in those groups will be noted, and if it agreed that it is a significant fraction of the total PTS RPV failure frequency, then the TH calculations for those groups will be modified to include actions that would contribute to the effectiveness of WPS, and WPS will be modeled in the PFM code for subsequent use.

As an example of how this could be done, TH and PFM calculations for RPV overcooling events would be made for cases where Safety Injection (SI) is terminated by the operators according to procedure (which prevents repressurization and makes WPS effective), in addition to TH and PFM calculations that would have already been made for cases where SI was not terminated due to operator error (which results in RPV repressurization and negates the effects of WPS).

The WPS question for the above example (i.e., how much does the WPS effect decrease PTS-related RPV failure frequency) could then be resolved by industry and NRC by determining the fraction of such events that would actually occur with SI termination (i.e., with WPS effective), and the fraction that would occur with overpressurization (i.e., where the operator errs and does not terminate SI so that WPS is not effective). Human reliability analyses (e.g., the timing of operator actions, causes of operator errors, the nature and effectiveness of operator training) would likely dominate such determinations.

The meeting continued with an NRC presentation by Mark Cunningham (RES/DRAA/PRAB) about NRC staff work on the PTS Acceptance Criterion, including a scoping study regarding the feasibility of including LERF as part of that criterion (slides summarizing that presentation are attached). Mark stated that the objectives of the LERF scoping study are to better determine the scope and nature of the containment performance issues and offsite consequences associated with a PTS-related RPV failure, and to better determine the feasibility of addressing those issues as part of the PTS effort.

This was followed by a presentation by INEEL, the contractor performing the LERF scoping study for NRC (Darrell Knudson made the presentation). He identified and briefly discussed the 14 “top level events” of an event tree that can be used to determine LERF due to PTS. They are:

1) RPV Break Induced Core Damage. Would direct effects of the break in the RPV result in immediate core damage (this involves determining the integrity of the core barrel, lower core support structures, and fuel rods following blowdown through the break).

2) RPV Break Size. How large, and where, would the break be?

3) Safety Injection. Would the SI system be capable of cooling the core if it remains inside the RPV?

4) Recirculation Core Cooling. Would the Recirculation Core Cooling system be capable of maintaining long term core cooling?

5) Core Water Level. Would the break location and cooling systems' performance result in ability to successfully cool the core?

6) Core Debris. Would the core debris be retained over the long term in the RPV (depends on heat transfer from the debris).

7) RPV Cavity Condition. Would it be dry? This affects potential for steam explosions and core/concrete interactions.

8) Containment Penetrations. Are they intact, or would they fail due to movement of the RPV and resulting movement of piping that passes through penetrations?

9) Containment Isolation. If containment is otherwise intact, would necessary valves align properly for containment isolation?

10) Short Term Containment Pressure Suppression. Would containment sprays operate (for dry containment designs), or would sufficient ice be present (for ice condenser containment designs)?

11) Long Term Containment Pressure Suppression. Would fans and containment sprays operate (for all containment designs), and would sufficient ice be present (for ice condenser containment designs)?

12) H_2 Detonation Containment Failure. Would it occur due to core oxidation and igniter failure?

13) Steam Explosion Containment Failure. Would it occur due to failure of in-RPV-debris-containment, and presence of a wet RPV cavity?

14) Core/Concrete Containment Failure. Would it occur due to failure of in-RPV-debris-containment, and presence of a dry RPV cavity? [It is currently believed most likely that the RPV cavity will not by dry when the vessel fails, so this item is unlikely to be relevant.]

The conclusion of the INEEL presentation is that a PTS-induced LERF estimate is feasible without new experiments or code development (i.e., that all relevant questions can be adequately addressed using presently available data and methods).

Following the INEEL presentation, industry and NRC staff representatives agreed that the relevant questions are being addressed by the scoping study (i.e., is a PTS LERF analysis feasible, and if so, will it result in an answer that does not contain so much uncertainty as to be useless), and thus is should continue. Whether or not it will ultimately prove useful depends upon the more detailed answers being sought for the 14 “top events,” and also answers to any other issues that may be identified as the study progresses (e.g., relevant source term if the core damage occurs in an air environment, and integrity of the exterior RPV support structure during vessel rupture were mentioned as possible additional issues that might need to be addressed).

Action Items identified during the meeting were:

The NRC staff should broaden the scope of the public meeting with the MRP planned for January, 2001 (currently scheduled to mostly address PFM-related issues) to include “acceptance criteria” and “LERF” issues, and also PRA and TH issues.

The NRC staff will explore the need to take account of WPS in its PTS calculations. The first quantitative results of those calculations, the “scoping study” results for Oconee, will include appropriate groups of transients of the type where WPS should be effective. These results will be used to determine the need to include WPS in subsequent PTS calculations.

The NRC staff should continue development of the simplified TH and PFM models currently under development at U. of Md., and should integrate the model into a unified package which will make it easier to identify events that might benefit from WPS.

The NRC staff should request the Oak Ridge National Laboratory to provide quantification of expected break size in RPVs that fail under various PTS conditions, based on their past vessel failure experiments with scaled RPVs.

The INEEL should identify what they can do in the immediate future to prepare to perform LERF analyses for the four “PTS” plants.

LIST OF ATTENDEES: LERF & WPS PTS PUBLIC MEETING
November 14, 2000

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