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Office of Nuclear Reactor Regulation
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555-0001

Transmittal of a brief historical summary of Emergency Response Guidelines with respect to Pressurized Thermal Shock

Mr. Mitchell,

The purpose of this letter is to respond to your request for information concerning a brief historical summary of the treatment of Pressurized Thermal Shock in the Generic Emergency Operating Guidelines for Babcock and Wilcox plants.

The information provided in the attachments to this letter demonstrates that many/most Pressurized Thermal Shock risk significant sequences have been identified by the work in the 1980s and that the Generic Emergency Operating Guidelines improvements have already been made to address those scenarios.

For any specific technical questions regarding this historical information, please contact Virgilio M. Esquillo at (434) 832-4267 for information on Babcock and Wilcox plants.

Sincerely,

Ronnie L. Gardner

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Treatment of Pressurized Thermal Shock in the B&W Generic Emergency Operating Guidelines

Introduction

The purpose of this document is to provide a brief summary on the state of Pressurized Thermal Shock (PTS) in the context of the emergency operating procedures (EOPs) and abnormal operating procedures (AOPs) for the Babcock and Wilcox (B&W) plants. This summary is divided into three parts:

1. Brief History

2. Incorporation of Lessons Learned

3. PTS in the Generic Emergency Operating Guidance (GEOG)

Brief History

B&W addressed thermal shock as early as 1969 with an evaluation for the Loss of Coolant Accident (LOCA) response on reactor vessel integrity, as documented in BAW-10018, "Analysis of the Structural Integrity of a Reactor Vessel Subject to Thermal Shock." Over the years, B&W continued to assess the properties of materials used in the B&W-constructed reactor vessels, publishing BAW-10046, "Methods of Compliance with Fracture Toughness and Operational Requirements of 10 CFR 50 Appendix G," in 1976, and BAW-1511, "Irradiation-Induced Reduction in Charpy Upper-Shelf Energy of Reactor Vessel Welds," in 1980.

Between 1979 and 1981, additional studies into Small Break LOCAs resulting from a loss of all feedwater with high pressure injection (HPI) continuing for extended periods. These efforts culminated in the topical report BAW-1648, "Thermal Mechanical Report - Effect of HPI on Vessel Integrity for Small Break LOCA Event with Extended Loss of Feedwater" in 1981. This topical discussed the potential for and possible conditions leading to, RV thermal stress. Additionally, it provided the bases and nature of operator actions needed to prevent RV brittle fracture. Accordingly, it provided discussions and guidance on HPI flow control, reactor coolant pump operation, and cooldown limits, particularly during LOFW conditions.

One of the key results of these investigations into SBLOCA was the importance of the internal reactor vessel vent valves. These valves provide a direct path from the core exit to the upper region of the downcomer and on to the break location for steam venting. These valves assure a supply of warm water to the upper region of the downcomer, ensuring that mixing is a sustained process, and thus mitigates PTS effects.

Other events that consider plant-specific features such as weld material properties, fluence, and actual weld locations was initiated in September 1981. Overcooling events in particular were evaluated, since they could pose more severe PTS conditions than an SBLOCA. They also began to utilize probabilistic or risk-informed methods, in addition to the strict deterministic worst-case methods.

Three historic transients were identified in SECY 82-465 as particularly significant for the B&W fleet: Rancho Seco in 1978, Three Mile Island Unit 2 in March 1979, and Crystal River 3 in 1980. The Rancho Seco and CR-3 events involved loss of non-nuclear instrumentation power supplies that rendered control room indicators inoperable. The more well-known TMI-2 event was a transient-induced SBLOCA caused by a loss of feedwater. Lessons learned from these events were incorporated into the development of the PTS guidance that exists today.

Incorporation of Lessons Learned

Since the above events, numerous actions have been taken by the B&W plant owners to minimize the possibility of PTS events. For example, operators received, and continue to receive, PTS-specific training. The information from which the operator must act has been improved both in quantity and quality. As examples, additional qualified flow and temperature indications ensure accurate data are received by operators to avoid or mitigate PTS. New control systems, such as the Emergency Feedwater Initiation and Control (EFIC) system and its analogs, ensure overcooling conditions are avoided when Emergency Feedwater is in operation. Power supply reliability has also been improved to reduce the possibility of a loss of power that could propagate into a PTS scenario. Further, procedures have been developed to provide optional responses when an event does not respond to the initial procedural actions.

PTS in the GEOG

All of the B&WOG plants' reactor vessels satisfy the screening criteria for RTNDT per 10CFR50.61 such that the risk from PTS events is acceptable within the framework of SECY 82-465 (using B&W-specific probabilistic evaluations). However, should a rapid vessel cooling occur, it is prudent to limit the pressure stresses. The PTS operational guidance in the GEOG is based on evaluations of two basic types of vessel cooling events: injection of cold BWST water (events such as LOCA, HPI cooling, etc.) and rapid RCS cooldown (events such as steam line breaks, SG overfeed, etc.).

The GEOG include actions to terminate overcooling events as soon as possible, but the pressure stresses should be limited both during and following such events. Some events, such as a LOCA, will not be terminated until long-term cooling is established; however, it is still important to limit the pressure stresses for the duration of the event.

The GEOG utilizes the concepts of Rules. Rules are used for specific guidance that always applies when the stated conditions exist. This also reduces the need for repeated steps, but more importantly, fosters the better response and consistency that is achievable using rule-based behavior. Accordingly, the PTS Rule must be invoked whenever the following criteria are met, and once invoked the PTS Rule must remain invoked until an evaluation determines otherwise.

PTS Rule Entry Criteria

- RCP-On or Natural Circulation with HPI-Off

  Excessive cooldown rates do not require invoking the PTS guidelines while the RV downcomer fluid temperature is above 338°F. However, the operator is still required to try to maintain the cooldown rate within the Technical Specification RCS normal allowable rates. With an RCP On or with natural circulation with HPI-Off, the cold leg temperature sensors (Tcold) in the loop with the operating RCP or natural circulation flow can be used to provide an indication of the RV downcomer fluid temperature. Instrument errors must be accounted for. The 338°F value represents actual downcomer fluid temperature.

- RC Pumps Off With HPI On

  Whenever all the RCPs are off and HPI is on, then PTS guidelines must be invoked. "HPI-on" means one or more HPI pumps are on while taking suction from the BWST and injecting through one or more of the HPI valves. In addition, at DB-1, "HPI-On" can also mean the normal and alternate injection lines are in use with MU pump suction from the BWST.

PTS Rule Action

Whenever a PTS criterion is met, core outlet temperature and pressure must be maintained as close to the subcooling margin (SCM) limit as possible without violating required RCP NPSH, if an RCP is on. By reducing core outlet temperature and pressure close to the SCM limit, reactor vessel stresses are reduced. Generally, the further SCM can be reduced the better. However, if an RCP is operating, RCS pressure must not be reduced below required RCP NPSH values. The thermal mixing benefits (reduced RV thermal gradients) provided by the RCP outweigh any additional benefit of further reducing pressure, which could threaten RCP operations. If an RCP is not running, then further SCM reductions, i.e., to as close to the SCM limit as possible, are warranted. Should an RCP subsequently be started, SCM should be increased only as necessary to satisfy RCP NPSH requirements.

If RCPs are off and HPI is on, then a restart of an RCP as soon as possible is desirable if the RCP restart criteria in Chapter IV.A are met. The operator instruction to increase the core outlet subcooling to 20°F before starting a RCP does not apply when HPI is on without SG heat transfer. Increasing subcooling would aggravate the PTS condition and does not serve the purpose for which the instruction is intended. The intent is to prevent a loss of SCM when starting an RCP when primary to secondary natural circulation cooling exists, which could lead to tripping the RCPs and a loss of the previously existing primary to secondary heat transfer. RCS pressure should be increased only as necessary to meet RCP NPSH requirements.

When depressurizing the RCS to reduce SCM, pressurizer cooldown rates that exceed prescribed limits are permitted for specific scenarios: Steam Generator Tube Rupture (SGTR) and a direct PTS event (e.g., severe overcooling). This is because of the benefits provided by expeditious and continued RCS depressurization, it is important that RCS depressurization and cooldown not be delayed by the need to monitor and maintain pressurizer cooldown rates for those scenarios. For all other scenarios, the pressurizer cooldown rate limit applies.

Once invoked, the PTS guidelines must be followed for the remainder of the RCS cooldown unless an evaluation is performed to determine otherwise. This is true even if conditions change such as by reducing the cooldown rate to within the Technical Specification values or starting an RCP. Other than to satisfy RCP NPSH requirements, RCS pressure must not be increased while PTS is invoked.

The guidelines assume the Technical Specification RCS normal P-T limit is adjusted for plant-specific instrument error and for pressure sensor location. With an RCP on or with natural circulation without HPI on, the cold leg temperature sensors (Tcold) in the loop with the operating RCP or natural circulation flow can be used to provide an indication of the RV downcomer fluid temperature. Instrument errors must be accounted for.

Although holding ("soaking") the plant in an isothermal condition during cooldown helps relieve some of the significant thermal gradients due to the overcooling, soaking has not been analyzed as part of these guidelines and therefore, soaking cannot be used to undo the PTS guidance invocation.