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0000-0100-5014-R0-NP
DRF No. 0000-0086-7813
Class I
April 2009

NON-PROPRIETARY INFORMATION

BWR Owners' Group Technical Report

Potential Effects of Gas Accumulation on ECCS Analysis as Part of GL 2008-01 Resolution

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1. Objective

On January 11, 2008, the U.S. NRC issued a generic letter (GL 2008-01) to address the issue of gas accumulation in the emergency core cooling, decay heat removal, and containment spray systems (Reference 1). One of the purposes of the generic letter is to request the operating plant license holders to submit information to demonstrate that the subject systems are in compliance with the current licensing and design bases and applicable regulatory requirements, and that suitable design, operational, and testing control measures are in place for maintaining this compliance.

This document provides an evaluation of the impact of gas accumulation in the ECCS lines. It is the objective of this report to provide a conservative PCT estimate for the U.S. BWR fleet for LOCA events and to provide an evaluation on other events where ECCS is relied on. This evaluation is not intended to supersede any plant-specific safety analysis.

2. Scope

There are two main tasks:

1. Impact of gas intrusion resulting in delay in ECCS: The scope includes an engineering evaluation of the gas intrusion impact on ECCS performance. The LOCA evaluation is based on a survey of representative plant analyses and generation of a table summarizing the PCT impact versus various delay times. This table will be constructed in a conservative manner to provide a "worst case" scenario for evaluating potential effect of gas accumulation in the ECCS lines. The other events where an ECCS component is credited will also be evaluated. The impact of a delay for these events will be discussed in a qualitative manner providing the justification for conclusions. The evaluations in Task 1 will be based on first principles and known sensitivities, and in some cases, computer runs if necessary.
2. Evaluation of gas voids passing through the core: This task includes a qualitative evaluation that investigates the path and mechanism for air to be injected into the core region. This evaluation will present the set of assumptions and qualitatively discuss the extent of potential impact of air passing through the core. This evaluation will support and complement the disposition of GL 2008-01 issues.

3. Impact of gas intrusion due to delay in ECCS

3.1. Loss of Coolant Accident

The air intrusion in the ECCS lines can temporarily reduce and delay the coolant injection. In this evaluation, the initial reduction in coolant injection flow is treated as part of the delay. In other words, [[

]]

A survey of Analysis of Record (AOR) for all BWR units in the entire U.S. fleet has been conducted. The survey collected information on the Peak Cladding Temperatures (PCTs) and [[

]] The heatup rate values versus PCT are shown approximately in Figure 1.

[[

]]

Figure 1. U.S. BWR fleet LOCA PCT Heatup Rates (units w. common analysis not shown).

[[

]] From these observations, it is concluded that some plants would further benefit from plant-specific analysis and such analysis could increase their tolerance to ECCS delays.

From the survey, it is determined that [[

]] the anticipated PCT impact on plant LOCA analyses is given in Table 1.

Table 1. LOCA PCT Impact for Hypothetical ECCS Delay Amounts.

Additional Delay in ECCS	PCT Impact
[[	
	]]

The delays indicated in Table 1 are assumed to be the additional delay in actuation of the ECCS component most effective in mitigating LOCA. For example, for a large-break LOCA, this would be LPCI or CS, for a small-break LOCA, either HPCI or HPCS. ADS is not considered to be impacted by the gas accumulation because these steam-venting lines do not contain liquid. [[

]] This example is provided for illustration purposes and should not be considered as 'allowable limits on ingested/accumulated gas volume'.

This evaluation is valid for [[

]] is not supported by this evaluation.

3.2. **Loss of Feedwater**

High-pressure systems (HPCI, HPCS, or RCIC, as applicable) are used to provide the vessel inventory makeup during a postulated Loss of Feedwater Flow (LOFW) transient event. For this event, the additional delay in the ECCS startup caused by the gas intrusion can reduce the margin for the minimum upper plenum water level to Top of Active Fuel (TAF). It is estimated that a delay of [[

]] Therefore, for the LOFW transient event, [[
]] would not have a significant effect on the water level margin and the level remaining above the TAF is ensured.

3.3. **Anticipated Transients Without SCRAM**

During a postulated Anticipated Transient Without Scram (ATWS) event, [[

]] Thus, the gas intrusion to ECCS resulting in [[ ]] has no impact on meeting the ATWS acceptance criteria.

3.4. **Station Blackout**

For station blackout (SBO), high-pressure systems (HPCI, HPCS, or RCIC, as applicable) are used to provide the vessel inventory makeup during a postulated SBO event. The coolant injection begins with the automatic initiation based on the water level signal. [[

]] A hypothetical [[ ]] for injection due to gas intrusion in ECCS systems has an insignificant impact on the ability of the water makeup system to maintain the vessel water level above the top of active fuel (TAF) [[

]]

3.5. **Appendix R Fire Safe Shutdown**

For Appendix R fire protection, the worst fire scenario [[

]] for injection due to gas intrusion in ECCS systems would have an insignificant impact either on the ability of the high-pressure system to maintain the vessel water level above TAF or on the ability of the low-pressure systems along with ADS/SRV to maintain the peak cladding temperature below the Appendix R limit of 1500°F.

4. **Evaluation of gas voids passing through the core**

The BWR Design Basis Accident (DBA) LOCA event begins with a rupture or a break in the recirculation line. The system pressure drops as the coolant inventory is discharged through the break. After the accident begins, the fuel rods undergo boiling transition that initiates at a time and last a time that depends on the break size. During boiling transition, the heat removal from the rods is significantly degraded, resulting in cladding temperature rise.

The Emergency Core Cooling System (ECCS) is designed to mitigate the adverse effects of a LOCA event by reducing the time that the fuel rods are in boiling transition. BWR ECCS contains high-pressure and low-pressure components. In many BWR/3 and /4 plants, High Pressure Coolant Injection (HPCI) is connected to the feedwater (FW) line, whereas the Low Pressure Coolant Injection (LPCI) is connected to recirculation line. BWR/5 and /6 designs employ a High-Pressure Core Spray (HPCS) which is delivered to the upper plenum region. All BWR plants operating in the U.S. have a low-pressure Core Spray (CS/LPCS).

Air injected into the system via the high-pressure or low-pressure spray (i.e., by HPCS or CS/LPCS) would not find its way into the core, since the air-coolant mixture would be delivered into the upper plenum and only the water would flow down into the channels and the bypass region. Air would separate from the air-coolant mixture and would be swept upward together with the steam.

Any small amount of air carried into the system by the coolant injection (i.e., by LPCI or HPCI) would not cause an adverse effect either. In the case of HPCI, the vessel would contain a large amount of coolant during the injection into the FW line. The air would most likely partition in the downcomer and mix with the steam in the dome and upper parts of the voided vessel. If any amount of air can get into the core region, it would be extremely small, and its effects would be insignificant because the BWR geometry allows air and steam to pass through the core. In the case of LPCI delivered to the recirculation line, some air can be carried downward through the jet pumps into the lower plenum. Some of this air will be passing through the core: some in bypass region and some in the fuel channels. At the time of LPCI initiation, the reactor would be at relatively low pressure, because most of the liquid in the lower plenum region had already flashed. The cladding would be exposed to significant voiding as high quality two-phase flow condition is present in the core. During this time, convective heat transfer is dominated by steam cooling and radiation heat transfer for the higher PCTs becomes a significant part of the overall heat removal. In these conditions, addition of a small amount of air passing through the core would have insignificant impact on the progression of the accident, since it would not alter the heat transfer by any significant amount.

In summary, three main factors would determine why air bubbles (i.e., gas voids) passing through a BWR core do not pose an additional safety concern: (1) unlikely path for air to get into the core, (2) high void conditions already present in the core during a LOCA, and (3) air that does enter the core does not accumulate there, but passes through into the upper plenum and upper parts of the vessel.

5. Conclusions

The survey of BWR LOCA analyses were conducted and a limiting [[
]]is determined for the entire U.S. BWR fleet. Using this heatup rate, [[

]] This evaluation is provided as a conservative "worst case" scenario; the majority of the units would benefit from plant-specific evaluations or analyses.

An assessment on the potential impact of gas voids passing through the core is provided. This assessment justified that gas voids passing through the core do not pose an additional safety concern mainly because of the unlikely path for air to get into the core and high void conditions in the core present during LOCA.

Assessments on the LOFW and ATWS events concluded that a delay of [[

]] The evaluation of station blackout events indicate that a delay of [[

]] Similarly, it is concluded that a delay of [[
]] on meeting the acceptance criteria in Appendix R fire safe shutdown analysis.

The results of the evaluation provided in this report are not intended to supersede the plant specific design basis safety analyses.

6. References

1. "NRC Generic Letter 2008-01: Managing Gas Accumulation in Emergency Core Cooling, Decay Heat Removal, and Containment Spray Systems," January 11, 2008.