McGuire Nuclear Station
LER Safety Analysis on UHI Isolation Failure
Supplement to Licensee Event Report 50-369/84-30

Safety evaluations of the two failure modes of concern, which would have resulted in either (i) premature isolation of the UHI accumulator due to the setpoint error, or (ii) failure of the isolation function due to the installation error, have been performed to assess any adverse impact on the FSAR Chapter 15 accident analyses. The design function of the UHI system is described first in order to establish the basis for the evaluation of each failure mode.

UHI Design Function

The UHI system delivers borated water at a high flowrate and high pressure for the purpose of reducing the peak clad temperature (PCT) during the blowdown phase of a LOCA. Approximately 900 ft^3 of water is delivered as the UHI accumulator depressurizes from ~1235 psig to ~669 psig in response to Reactor Coolant System (RCS) depressurization. Injection is terminated upon accumulator discharge valve isolation at a low water level indication in the accumulator. The duration of the injection period depends on the rate of RCS depressurization, and for example occurs between approximately 3 and 23 seconds for the design basis LOCA.

The main benefit of the UHI system is that it enhances the integrated performance of the total ECCS and thereby allows a higher licensed power level and/or higher power peaks in the core. Analyses using Appendix K assumptions have demonstrated that ECCS performance without UHI is acceptable for both LBLOCAs and SBLOCAs at power levels up to 46% for conservative power peaks. This result is applicable to the standard Westinghouse fuel currently in Unit 2, and, when analyzed, a similar result is expected for the optimized fuel design in use in Unit 1 and in future reloads.

Evaluation of Setpoint Error

The previously described setpoint error would have resulted in premature isolation of the UHI accumulator discharge and a reduction in the total volume of UHI water delivered to the reactor vessel. The erroneous actuation signal would have occurred after delivery of approximately 244 ft^3 rather than 672 ft^3 (excluding the liquid volume of the UHI surge tank ~30 ft^3). Including the isolation valve stroke time and the dynamic system response to the worst case LOCA, a net reduction in the total volume delivered of approximately 56-61.5% would have occurred. The effectiveness of UHI would therefore have been degraded.

The LBLOCA response with reduced UHI injection and including Appendix K assumptions would result in exceeding the 10 CFR 50.46 PCT limit of 2200°F since the current analysis result is 2175°F with full UHI injection. Appendix K is recognized by both NRC and the industry to include a significant amount of conservatism. For example, even including the conservative Appendix K assumptions, a new Westinghouse methodology which is expected to be approved by the NRC will allow an increase in F_Q from 2.15 to 2.26. The previously mentioned non-UHI analysis demonstrated that UHI is not even required below 46% power. These analysis results suggest that with more realistic assumptions to LOCA response including degraded UHI performance would prove to be acceptable.

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A best estimate UHI LBLOCA analysis has been performed by Battelle Pacific Northwest Laboratory under contract to NRC (NUREG/CR-3642, March 1984). Although this analysis assumed nominal rather than degraded UHI performance, the significant margin to the regulatory PCT limit that resulted could offset the negative impact of degraded UHI. The LOCA response was limited to a PCT of 1155°F occurring at 8 seconds followed by a rapid decrease to below 600°F that was maintained for the duration of the event.

For the spectrum of SBLOCAs it is expected that with realistic assumptions UHI injection is not required to remain below a PCT of 2200°F. The current Appendix K PCT is 1499°F, so that margin also exists including Appendix K assumptions to offset to some extent the negative impact of degraded UHI.

UHI injection would also occur for non-LOCA events, such as steam line breaks, that result in depressurizing the RCS to below the UHI nitrogen overpressure. A reduction in UHI injection for these transients would result in a greater depressurization of the RCS and a delay in refilling the RCS to makeup for the shrinkage caused by overcooling. A delay in boration of the RCS would also result. Although these consequences are undesirable, degraded UHI is of much greater significance for LOCA events.

In summary, the setpoint error would result in a reduction in the volume of UHI inventory delivered. The consequences would include exceeding the 10 CFR 50.46 PCT limit of 2200°F for the worst case LOCA using Appendix K assumptions. The limiting SBLOCA might also exceed the PCT limit although some margin exists to offset the negative impact. With more realistic assumptions it is expected that the resulting PCTs for all LOCAs would remain less than 2200°F. No dose calculations were considered to be necessary since the methodology for calculating post-LOCA doses is prescribed by Regulatory Guides that are not dependent on the specific result of the LOCA analysis. The existing FSAR doses are considered to remain bounding and conservative.

Evaluation of Installation Error

The previously described installation error would have resulted in the failure of the UHI accumulator isolation valves to close, an automatic action that normally occurs upon reaching a low water level setpoint in the accumulator. Depending on the magnitude and duration of RCS depressurization associated with a given transient, this failure mode could result in the delivery of the total UHI water volume (~1800 ft^3) and injection of the nitrogen cover gas. An evaluation of this failure mode has identified four potential safety concerns:

(i) Increase In The Total Volume of UHI Water Injected
Although it would seem that UHI performance would improve as additional water is delivered to the reactor vessel, a negative impact (higher PCT) has been indicated by LBLOCA analysis under certain modeling assumptions related to fluid mixing in the vessel head. Utilizing other mixing assumptions an increase in water delivery indicates that an improvement in post-LOCA core cooling (lower PCT) would result, which is more consistent with expectations. Analyses based on both mixing assumptions are part of the FSAR licensing basis.

(ii) Effect of Nitrogen Injection on Post-LOCA Reflood
Calculations show that UHI water injection would end and nitrogen injection into the discharge piping would begin once the UHI accumulator depressurized to approximately 420 psig. Nitrogen injection would initially enhance core cooling by forcing water in the upper regions of the reactor vessel down into the core. Subsequently, the nitrogen would negatively impact core cooling during the reflood phase by resulting in slower RCS depressurization and therefore a reduction in the ECCS injection flowrate.

(iii) Effect of Nitrogen Injection on Peak Containment Pressure
The current worst case peak containment pressure is 14.8 psig which is 0.2 psi less than the design pressure of 15.0 psig. Injection of the UHI nitrogen mass and heat transfer to the gas would result in approximately a 2.2 psi increase in the peak pressure.

(iv) Effect of Nitrogen Injection on Steam Generator Heat Transfer
For events that would depressurize sufficiently to inject n rogen, the operator would respond by tripping the reactor olant pumps on loss of RCS subcooling. In the absence of forced circulation the nitrogen would accumulate in the system high points, in particular the vessel head and the steam generator tube U-bends. The presence of nitrogen in the steam generator tubes would result in a degradation of heat transfer and the potential for interruption of natural circulation.

The impact of these four potential safety concerns on the FSAR Chapter 15 accident analyses has been assessed for the following four accident categories:

A. LBLOCAs

B. Larger SBLOCa - Those SBLOCAs for which the RCS depressurizes to below steam generator pressure.

C. Smaller SBLOCAs - Those SBLOCAs for which RCS pressure stabilizes at or above steam generator pressure.

D. Non-LOCA transients that result in UHI actuation.

A. LBLOCAs

Potential safety concerns (i), (ii), and (iii) are associated with LBLOCAs. Items (i) and (ii) could result in an increase in PCT. Since the current limiting PCT is 2175°F, any negative impact would result in exceeding the 10 CFR 50.46 limit of 2200°F with Appendix K assumptions. The best estimate UHI LBLOCA analysis performed by Battelle demonstrated that a significant margin to the regulatory limit exists to offset the potentially negative impact of excessive UHI delivery and a slightly reduced core reflooding rate due to nitrogen injection. Item (iii) could result in the containment design pressure being exceeding by 2.0 psi. Supplement 7 to the McGuire SER states that the lower bound ultimate capacity of the containment is 48 psig. As such, the integrity of containment is not challenged by nitrogen injection in a realistic sense.

B. Larger SBLOCAs

Potential safety concerns (i) and (ii) are associated with larger SBLOCAs. Item (i) would improve the ECCS performance for SBLOCAs since any additional water delivered to the vessel enhances core cooling. The potentially negative effect of excessive water delivery is not applicable to SBLOCAs. The potentially negative impace of item (ii) is offset by the benefit of item (i). For larger SBLOCAs core reflooding will be complete at approximately the same time that nitrogen injection begins. However, the additional water delivered due to isolation failure and prior to nitrogen injection will significantly reduce the depth and duration of core uncovery. The integrated ECCS performance will improve and a lower PCT will result. For larger SBLOCA the break flow removes RCS stored energy and decay heat, and the steam genertors are not required as a heat sink. Successful long term core cooling can be maintained by injection/recirculation cooling, and therefore item (iv) does not present a problem.

C. Smaller SBLOCAs

Only potential safety concern (iv) is associated with smaller SBLOCAs. Since by definition smaller SBLOCAs do not depressurize sufficiently to result in nitrogen injection, the concern is limited to the injection of nitrogen during the manual cooldown and depressurization of the RCS. An operator-controlled cooldown and depressurization will proceed similar to a normal cooldown. Although UHI will have partially injected prior to the cooldown, the opportunity exists for the operator to recognize that further injection from the UHI system is not necessary. The appropriate action would be to manually isolate UHI from the RCS. Should this action be taken, nitrogen injection would be prevented. If UHI remained unisolated, the opportunity exists during the subsequent depressurization for the operator to recognize that UHI failed to isolate. Control room indications confirming this automatic actuation are expected by the operator based on extensive classroom and simulator training on LOCAs. Should UHI remain unisolated nitrogen injection could occur. Although undesirable, this occurrence can at worst result in an interruption of natural circulation. Feed and bleed cooling is then available as a backup method of decay heat removal.

D. Non-LOCA Transients

The spectrum of non-LOCA FSAR transients have been reviewed to identify those that could result in UHI injection. Only severe overcooling events such as steam line breaks are characterized by sufficient RCS depressurization to result in significant UHI injection. Calculations have confirmed that nitrogen injection cannot result for any non-LOCA transients. Without a loss of RCS inventory, the shrinkage due to overcooling cannot cause a depressurization sufficient to result in nitrogen injection. The additional delivery of borated water due to isolation failure enhances refill of the RCS. No negative impact on non-LOCA transients has been identified.

In summary, the occurrence of the installation error that would have resulted in a failure of the UHI accumulator discharge valves to isolate on low level has been determined to result in four potential safety concerns. The current limiting PCT of 2175°F for the worst case LOCA including Appendix K assumptions leads to the conclusion that any net negative impact will result in exceeding the 2200°F limit. With more realistic assumptions and considering the results of the best estimate UHI LOCA analysis, it is concluded that a large margin exists in a realistic sense to offset any negative impact. The additional UHI injection water delivered will improve ECCS performance for larger SBLOCAs. For smaller SBLOCAs nitrogen injection will not occur unless the UHI accumulator remains unisolated during the manual cooldown and depressurization of the RCS. Ample opportunity and time exists for the operator to recognize that UHI is no longer required and can be isolated, or to identify the failure of automatic isolation. It is expected that nitrogen injection would thereby be prevented. Nitrogen injection would not occur for non-LOCA transients. The worst case increase in peak containment pressure does not present a challenge to containment integrity. No dose calculations were considered to be necessary since the methodology for calculating post-LOCA doses is prescribed by Regulatory Guides that are not dependent on the specific result of the LOCA analysis. The existing FSAR doses are considered to remain bounding and conservative.

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Subject: McGuire Nuclear Station Unit 1
Docket No. 50-369
Supplement to LER 369/84-30
UHI Isolation Failure Safety Analysis

Gentlemen:

Attached please find a supplement to the subject Licensee Event Report. This supplement contains an analysis of the safety significance of the postulated failure of the upper head injection accumulator isolation valves to close on low accumulator level.

Very truly yours,

Hal B. Tucker

Hal B. Tucker

SAG/mjf

Attachment

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