3M Resolution Of Intersystem Loss Of Coolant Accident For ABWR

3M.1 Introduction

An intersystem loss of coolant accident (ISLOCA) is postulated to occur when a series of failures or inadvertent actions occur that allow the high pressure from one system to be applied to the low design pressure of another system, which could potentially rupture the pipe and release coolant from the reactor system pressure boundary. This may also occur within the high and low pressure portions of a single system. Future ALWR designs like the ABWR are expected to reduce the possibility of a LOCA outside the containment by designing to the extent practicable all piping systems, major system components (pumps and valves), and subsystems connected to the reactor coolant pressure boundary (RCPB) to an ultimate rupture strength (URS) at least equal to the full RCPB pressure. The general URS criteria was recommended by the Reference 1 and the NRC Staff recommended specific URS design characteristics by Reference 2.

3M.2 ABWR Regulatory Requirements

In SECY-90-016 and SECY-93-087 (References 3 and 4), the NRC staff resolved the ISLOCA issue for advanced light water reactor plants by requiring that low-pressure piping systems that interface with the reactor coolant pressure boundary be designed to withstand reactor pressure to the extent practicable. However, the staff believes that for those systems that have not been designed to withstand full reactor pressure, evolutionary ALWRs should provide (1) the capability for leak testing the pressure isolation valves, (2) valve position indication that is available in the control room when isolation valve operators are de-energized and (3) high-pressure alarms to warn main control room operators when rising reactor pressure approaches the design pressure of attached low-pressure systems or when both isolation valves are not closed. The staff noted that for some low-pressure systems attached to the RCPB, it may not be practical or necessary to provide a higher system ultimate pressure capability for the entire low-pressure connected system. The staff will evaluate such exceptions on a case-by-case basis during specific design certification reviews.

GE provided a proposed implementation of the issue resolution for the ABWR in Reference 5 and again in Reference 6. The staff in the Civil Engineering and Geosciences Branch of the Division of Engineering completed its evaluation of the Reference 5 proposal. Specifically, as reported by Reference 2 and summarized below, the staff has evaluated the minimum pressure for which low-pressure systems should be designed to ensure reasonable protection against burst failure should the low-pressure system be subjected to full RCPB pressure.

Reference 2 found that for the ABWR the design pressure for the low-pressure piping systems that interface with the RCPB should be equal to 0.4 times the normal operating RCPB pressure of 7.07 MPaG, the minimum wall thickness of low-pressure piping should be no less than that of a standard weight pipe, and that Class 300 valves are adequate . The design is to be in accordance with the ASME Boiler and Pressure Vessel Code, Section III, Subarticle NC/ND-

3600. Furthermore, the staff will continue to require periodic surveillance and leak rate testing of the pressure isolation valves per Technical Specification requirements as a part of the ISI program.

3M.3 Boundary Limits of URS

Guidance given by Reference 3 provides provision for applying practical considerations for the extent to which systems are upgraded to the URS design pressure. The following items form the basis of what constitutes practicality and set forth the test of practicality used to establish the boundary limits of URS for the ABWR:

(1) It is impractical to consider a disruptive open flow path from reactor pressure to a low pressure sink. A key assumption to understanding the establishment of the boundary limits from this practicality basis is that only static pressure conditions are considered. Static conditions are assumed when the valve adjacent to a low pressure sink remains closed. Thus, the dynamic pressurization effects accompanied by violent high flow transients and temperature escalations are precluded that would occur if the full RCPB pressure was connected directly to the low pressure sink. As a consequence, the furthest downstream valve in such a path is assumed closed so that essentially all of the static reactor pressure is contained by the URS upgraded region.

(2) It is impractical to design or construct large tank structures to the URS design pressure that are vented to atmosphere and have a low design pressure. Tanks included in this category are:

(a) Condensate storage tank,

(b) SLC main tank,

(c) LCW collector tank,

(d) HCW collector tank,

(e) FPC skimmer surge tank, and

(f) FPC spent fuel storage pool and cask pit.

(g) Condensate hotwell

These are termed low pressure sinks for the purposes of this report. See Table 3M-1 for approximate sizes of these tanks as an indication of the impracticality of increasing the design pressure. The size of these tanks would result in an unnecessary dollar cost burden to increase their design pressure to the URS value. The small tanks in Table 3M-1 are greater than 3 meters in height and diameter. (For perspective, remember the “3 meter board” at the swimming pool is the high dive.) The large condensate storage tank, if constructed with its height equal to the diameter, is approximately as tall as a four story building. The FPC System's tank, pool, and pit (Table 3M-1) have no top cover and are open to the large refueling floor (bay), so that their pressure can not be increased above the static head for which they are designed.

(3) It is impractical to design piping systems that are connected to low pressure sink features to the URS design pressure when the piping is always locked open to a low pressure sink by locked open valves. These piping sections are extensions of the low pressure sink and need no greater design pressure than the low pressure sink to which they are connected.

In summary, the following low pressure sinks are protected by an adjacent closed valve and are impractical to design to the URS design pressure.

(1) **Suppression Pool —** Provides a normal low pressure sink, approximately 4.9 kPaG above atmospheric for its interfacing systems and the first closed valve is at least 2.83 MPaG rated. The suppression pool is designed to Seismic Category I.

(2) **Condensate Storage Tank—** Vented to atmosphere and its locked open valves insure it is a low pressure sink for its interfacing systems. The first closed valve of each interfacing system with URS upgrade is at least 2.82 MPaG rating.

(3) **SLC main tank**—Vented to atmosphere with the first closed valve at least 2.82 MPaG rating. The SLC main tank is designed to Seismic Category I.

(4) **LCW Collector Tank** - Vented to atmosphere, and the first closed valve is at least 2.82 MPaG and one of the four tank's inlet valves is locked open.

(5) **HCW Collector Tank—** Vented to atmosphere, and the first closed valve is at least 2.82 MPaG and one of the three tank's inlet valves is locked open.

(6) **FPC Skimmer Surge Tank**— The Fuel Pool Cooling Cleanup System's skimmer surge tank is open to the near atmospheric pressure of the refueling floor. The first closed valve is at least 2.82 MPaG rated. The FPC skimmer surge tank is designed to Seismic Category I.

(7) **FPC Spent Fuel Storage Pool and Cask Pit—** The Fuel Pool Cooling Cleanup System's spent fuel storage pool and cask pit is open to the near atmospheric pressure of the refueling floor. The first closed valve is at least 2.82 MPaG rated. The FPC spent fuel storage pool and cask pit is designed to Seismic Category I.

(8) **Condensate Hotwell**— During reactor high pressure operation, the hotwell operates at a vacuum pressure.

3M.4 Evaluation Procedure

The pressure of each system piping boundary on all of the ABWR P&ID's was reviewed to identify where changes were needed to provide URS protection. Where low pressure piping interfaces with higher pressure piping connected to piping with reactor coolant at reactor pressure, design pressure values were increased to2.82 MPaG. The low pressure piping boundaries were upgraded to URS pressures and extend to the last closed valve connected to piping interfacing a low pressure sink, such as the suppression pool, condensate storage tank or other open configuration (identified pool or tank). Some upgraded boundaries were located at normally open valves, but the upgrading would be needed if the non-normal closed condition occurred. Each interfacing system's piping was reviewed for upgrading. For some systems, with low pressure piping and normally open valves, the valves were changed to lock open valves to insure an open piping pathway from the last URS boundary to the tank or low pressure sink.

Typical systems for this upgrade include the:

(1) Radwaste LCW and HCW collector tank piping,

(2) Fuel Pool Cooling System's RHR interface piping connected to the skimmer surge tanks,

(3) Condensate Storage System's tank locked open supply valves,

(4) Makeup Water Condensate and Makeup Water Purified Systems with locked open valves and pump bypass piping to the Condensate Storage Tank.

All test, vent and drain piping was upgraded where it interfaces with the piping upgraded to URS pressure. Similarly, all instrument and relief valve connecting piping was upgraded.

3M.5 Systems Evaluated

The following fourteen systems, interfacing directly or indirectly with the RCPB, were evaluated.

	Tier 2 Figure No.
1. Residual Heat Removal (RHR) System	5.4-10
2. High Pressure Core Flooder (HPCF) System	6.3-7
3. Reactor Core Isolation Cooling (RCIC) System	5.4-8
4. Control Rod Drive (CRD) System	4.6-8
5. Standby Liquid Control (SLC) System	9.3-1
6. Reactor Water Cleanup (CUW) System	5.4-12
7. Fuel Pool Cooling Cleanup (FPC) System	9.1-1
8. Nuclear Boiler (NB) System	5.1-3
9. Reactor Recirculation (RRS) System	5.4-4
10. Makeup Water (Condensate) (MUWC) System,	9.2-4
11. Makeup Water (Purified) (MUWP) System.	9.2-5
12. Radwaste System (LCW Collector Tank, HCW Collector Tank).	11.2-2
13. Condensate and Feedwater (CFS) System	10.4-6
14. Sampling (SAM) System	—

Attachment 3MA contains a system-by-system evaluation of potential reactor pressure application to piping and components, discussing the URS boundary and listing the upgraded components. For some systems, certain regions of piping and components not upgraded are also listed.

3M.6 Piping Design Pressure for URS Compliance

Guidelines for URS compliance were established by Reference 2, which concluded that for the ABWR:

(1) The design pressure for the low-pressure piping systems that interface with the RCPB pressure boundary should be equal to 0.4 times the normal operating RCPB pressure of 7.07 MPaG, and

(2) The minimum wall thickness of the low-pressure piping should be no less than that of a standard weight pipe.

3M.7 Applicability of URS Non-piping Components

Reference 2 also provided the NRC Staff's position that:

(1) The remaining components in the low-pressure systems should also be designed to a design pressure of 0.4 times the normal operating reactor pressure. This is accomplished in Tier 2 by the revised boundary symbols of the P&IDs to the 2.82 MPaG design pressure, which includes all the piping and components associated with the boundary symbols. A stated parameter (e.g., design pressure) of a boundary symbol on the P&ID applies to all the piping and components on the P&ID that extend away from the boundary symbol, including along any branch line, until another boundary symbol occurs on the P&ID. The components include flanges, and pump seals, etc. as shown on the P&ID.

ABWR heat exchangers are not affected by ISLOCA upgrades to the URS design pressure. The following heat exchangers are in systems evaluated for ISLOCA, but the heat exchangers were not upgraded.

(a) The Reactor Water Cleanup System (CUW) heat exchangers are designed for the high reactor pressure already above the URS.

(b) The Residual Heat Removal (RHR) heat exchanger are designed for 3.43 MPaG on the tube side which exceeds the 2.82 MPaG URS design pressure. The heat exchanger’s tube side carries the reactor water. The shell side which carries the Reactor Building Cooling Water (RCW) system’s cooling water which has a design pressure of 1.37 MPaG, which is the same as the RCW design pressure. Since the heat exchanger’s tube side is designed well above the URS design pressure, an over pressurization failure was not assumed that would apply reactor pressure to the shell side.

(c) The Fuel Pool Cooling and Cleanup (FPC) System heat exchangers are isolated from a potential exposure to reactor pressure so that no upgrade was applicable.

(2) A Class 300 valve is adequate for ensuring the pressure of the low-pressure piping system under full reactor pressure. The rated working pressure for Class 300 valves varies widely depending on material and temperature (ASME/ANSI B16.34). However, as a lower limit bounding condition, within the material group that includes the stainless steels, the lowest working pressure is 2.86 MPaG at 204 °C , which exceeds the URS of 2.82 MPaG. For lower temperatures the working pressure increases. The material group that includes the carbon steels has working pressures above this value. More typical working pressure values at 93°C range between 4.12 MPaG to 4.81 MPaG.

3M.8 Results

The results of this work are shown by the markups of the enclosed P&IDs, which are Tier 2 figures. The affected sheets are listed below

System	Tier 2 Figure No.	Affected Sheet Nos.
1. Residual Heat Removal (RHR) System	5.4-10	1, 2, 3, 4, 6, 7
2. High Pressure Core Flooder (HPCF) System	6.3-7	1, 2
3. Reactor Core Isolation Cooling (RCIC) System	5.4-8	1, 3
4. Control Rod Drive (CRD) System	4.6-8	1, 3
5. Standby Liquid Control (SLC) System	9.3-1	1
6. Reactor Water Cleanup (CUW) System	5.4-12	1, 3
7. Fuel Pool Cooling and Cleanup (FPC) System	9.1-1	1, 2
8. Nuclear Boiler (NB) System	5.1-3	1, 5
9. Reactor Recirculation (RRS) System	5.4-4	1
10. Makeup Water (Condensate) (MUWC) System	9.2-4	1
11. Makeup Water (Purified) (MUWP) System	9.2-5	1, 2, 3
12. Radwaste System (LCW Collector Tank, HCW Collector Tank)	11.2-2	1, 3, 7
13. Condensate and Feedwater (CSF) System	10.4-6	
14. Sampling (SAM) System		

Also, see Attachment A for more detail.

The design pressure of the following tank was upgraded as a result of the evaluations performed in Attachment 3MA.

SLC test tank

3M.9 Valve Misalignment Due To Operator Error

An important result to observe is that because of the widespread application of the URS boundary for the ABWR design as compared to previously constructed BWRs, misalignment of valves due to operator error is a contributor to ISLOCA that has no known consequence. The ABWR design with the ISLOCA URS applied for the boundary described by this appendix and its attachement, has extended the increased design pressure (URS) over the full extent of regions that could potentially experience reactor pressure, so that operator misaligned valves will not expose piping to reactor pressure not designed to the URS pressure.

The ISLOCA issue that has been dealt with for existing BWRs, where valve misalignment due to operator error was a significant contributor to ISLOCA considerations, had to use the design pressures used for plant construction that were accepted before ISLOCA issues were considered. As a result, operator error of valve misalignment could possibly result in situations where high pressure might occur in piping regions design pressures below the current accepted URS design pressure (2.82 MPaG).

3M.10 Additional Operational Considerations

The periodic surveillance testing of the ECCS injection valves that interface with the reactor coolant system might lead to ISLOCA conditions if their associated testable check valve was stuck open. To avoid this occurrence, the RHR, HPCF, and RCIC motor operated injection valves will only be tested during low pressure shutdown operation. This practice follows from the guidance given by Reference 3, page 8, paragraph 7.

Although the following is not a new design feature, the RHR shutdown cooling suction line containment isolation valves are also only tested during shutdown operation. These valves are interlocked against opening for reactor pressure greater than the shutdown cooling setpoint approximately 0.93 MPaG.

3M.11 Summary

Based on the NRC staff's new guidance cited in References 1 through 4, the ABWR is in full compliance. For ISLOCA considerations, a design pressure of 2.82 MPaG and pipe having a minimum wall thickness equal to standard grade has been provided as an adequate margin with respect to the full reactor operating pressure of 7.07 MPaG by applying the guidance recommended by Reference 2. This design pressure was applied to the low pressure piping at their boundary symbols on the P&IDs, and therefore, impose the requirement on the associated piping, valves, pumps, tanks, instrumentation and all other equipment shown between boundary symbols. Notes were added to each URS upgraded P&ID requiring pipe to have a minimum wall thickness equal to standard grade and requiring valves with a design pressure of 2.82 MPaG or greater to be a minimum of Class 300. Upgrading revisions were made to 13 systems.

3M.12 References

(1) Dino Scaletti, NRC, to Patrick Marriott, "GE, Identification of New Issues for the General Electric Company Advanced Boiling Water Reactor Review", September 6, 1991

(2) Chester Poslusny, NRC, to Patrick Marriott, "GE, Preliminary Evaluation of the Resolution of the Intersystem Loss-of-Coolant Accident (ISLOCA) Issue for the Advanced Boiling Water Reactor (ABWR) - Design Pressure for Low-Pressure Systems", December 2, 1992, Docket No. 52-001

(3) James M. Taylor, NRC, to The Commissioners, SECY-90-016, "Evolutionary Light Water Reactor (LWR) Certification Issues and Their Relationship to Current Regulatory Requirements", Jan. 12, 1990

(4) James M. Taylor, NRC, to The Commissioners, SECY-93-087, "Policy, Technical, and Licensing Issues Pertaining to Evolutionary and Advanced Light-Water Reactor (ALWR) Designs", April 2, l993

(5) Jack Fox, GE, to Chet Poslusny, NRC, "Proposed Resolution of ISLOCA Issue for ABWR", October 8, 1992

(6) Jack Fox, GE, to Chet Poslusny, NRC, "Resolution of Intersystem Loss of Coolant Accident for ABWR", April 30, 1993.

Table 3M-1 Low Pressure Sink Component Sizes

Tank Name	Volume m^3	Diameter m	Height m	Length m	Width m	Design Pressure MPaG	Note
Condensate storage tank	2110	13.9	13.9			1.37	(1)
SLC main tank	32	3.44	3.44			SWH	(1)
LCW collector tank	140	5.63	5.63			SWH	(1)
HCW collector tank	140	5.63	5.63			SWH	(1)
FPC skimmer surge tank	30	2.3	7.2			SWH	
FPC spent fuel storage pool	2960		11.8	17.9	14.0	SWH	
FPC cask pit	121		11.8	3.2	3.2	SWH	
Condensate hotwell	7800		20	30	13		

Notes:

(1) Diameter and height calculated from volume based on diameter = height.

SWH = Static water head