3.13 Secondary Containment and Divisional Separation Zones – Barrier Considerations

3.13.1 Introduction

The ABWR design extends the defense-in-depth concept to its plant buildings and structures. The ABWR design utilizes five fission product barriers—fuel pellets and cladding; reactor pressure vessel and primary coolant system pressure boundary; the primary containment; the secondary containment including the divisional separation zones; the reactor building; and the below ground and elevated release plant features. In addition, the ABWR design also provides multiple division, spacial, physical, electrical and environmental arrangements. These assure total independence between redundant and diverse engineered safeguard systems and their equipment. Even the I&C elements including sensors, data transmission, logic analysis and actuators are divisionally, electrically, and physically separated. In essence, the ABWR design is a three dimensional, multiple barrier, extensively separated, protection network. All of the above features are designed to prevent, mitigate or accommodate a wide spectrum of design basis events. The same features are also capable of successfully addressing a wider spectrum of beyond design basis and/or severe accident events such that the safety risk to the plant and general public is always maintained at an extremely low level.

The design basis of each of the plant containment-type structures, systems and barriers, and their interrelationships varies with the wide spectrum of plant events encountered. The events themselves vary with their anticipated frequency of occurrences and the severity of their consequences. Several key examples are given below:

- Primary and Secondary Containments are required for all DBA pipe breaks Occurring within primary containment and reactor fuel failure or damage events since the radiological consequences associated with core uncovery and for full cladding integrity loss considerations are usually severe and unacceptable without containment. Again, all of these events (e.g., LOCAs) occur inside primary containment.

- Potential breaks outside primary containment must isolate prior to fuel damage or core uncovery. Therefore, breaks outside primary containment do not result in fuel damage.

- Neither Primary or Secondary containment are required for DBA main steam line breaks outside primary containment.

- Secondary Containment is required for DBA refueling accident events since it serves as a primary containment function.

- Secondary Containment-Divisional Separation Zone integrities are required for DBA internal fires.

- ECCS Compartment/Divisional Separation is required for DBA flood events.

- Reactor Building-Divisional Separation Zone integrities are required for DB site related external events.

Each of the cited containment structures and systems has a variety of barrier features. In the case of the Divisional Separation Zones inside the Secondary Containment, the following barriers exist:

- Structural Walls
  - Between Reactor Building and Secondary Containment
  - Between Secondary Containment and Divisional Zones
  - Between Divisional Zones
  - Between Divisional Zones and Primary Containment
  - Between Divisional Zone Individual Compartments
  - Between Divisional Zones and Non-Divisional Areas
  - Ceilings and Floors between all of the above
- Access Openings
  - Access/Egress Doors (Fire, Water-Tight, Water-Resistant, Entry)
  - Hatches (Personnel, Equipment, Inspection)
  - Removable Walls (Block, Shield, Partition)
  - Stairwells
  - Elevators
  - Major Equipment Entries
  - Relief Panels (Blowout, Vents, Vacuum)
  - Piping Electrical and HVAC Tunnel Chases
- Penetrations
  - Piping (Water, Air, Gaseous, Oil)
  - Electrical (I&C, Power)
  - HVAC (Hardened, Soft Ductwork)

- Drains (Equipment, Floor)
- Sumps (HCW, LCW)
- Tunnel Connections (Internal, External)
- Entry Tunnels

Each of structures, systems and barriers are ultimately evaluated by a spectrum of different methodologies: DBA-deterministic and PRA-probabilistic radiologically and environmentally; structural and functional; system interaction-wise; event and effects duration-wise; man-machine wise, etc. The Secondary Containment (SC) and its Divisional Separation Zones (DSZs) serves a multitude of safety and non-safety related functions. This section addresses the general critical design basis considerations of these structures and systems with emphasis on the barrier aspects.

Each of structures, systems and barriers provide hardened separation protection for a vast majority of plant events. For a minor number of low probability events, the integrity of barriers are designed or permitted to be compromised or softened. The resultant integrity loss consequences from these softening or compromising allowances are shown to be acceptable. The accommodation of the resultant effects are an integral part of the design basis considerations (e.g., outside containment break environmental effects in any affected DSZs are tolerable since the equipment in those zones are qualified and specified for those adverse conditions).

3.13.2 Secondary Containment and Divisional Separation Barriers – General Design Basis

The Secondary Containment (SC) and the Division Separation Quadrants or Zones and their individual and collective compartments serve a number of safety and non safety-related functions. This section addresses the general design basis considerations of the Reactor Building, Secondary Containment and Divisional Separation Zones, their structures, systems and barriers. The barriers include – walls, floors, ceilings, doors, hatches, penetrations, HVAC duct work.

3.13.2.1 Reactor Building (RB)

The general design basis considerations for the Reactor Building include:

- The Reactor Building is classified as a safety-related structure.
- The Reactor Building protects the equipment required for safe and orderly shutdown equipment from adverse site-related environmental events (e.g., seismic, flood, storm, wind, snow, etc.).

- The Reactor Building encompasses the Secondary Containment and its ECCS Divisional Separation Zones.
- The Reactor Building also houses and provides spacial, physical and electrical separation to other Divisional Separation Equipment Zones or Compartments (e.g., Emergency DG Rooms, Emergency Electrical Equipment Rooms)
- The Reactor Building provides environmental controls to safety related equipment during normal operation and plant transients.
- The Reactor Building is devoid of HELB sources. It also contains only a limited number of fire, flood or radiological sources.
- The Reactor Building and the Secondary Containment share structural and barrier walls, and penetrations.
- Reactor Building is a relatively friendly environs although it provides controlled access to important safety equipment.
- Reactor Building’s radiological barrier capabilities are not required for DBA events.
- Reactor Building’s structural integrity is assured for DBA events.

3.13.2.2 Secondary Containment (SC)

The general design basis considerations for the Secondary Containment include:

- The Secondary Containment provides an additional (secondary) radiological barrier to the Primary Containment. It provides a controlled collection, treatment and elevated release pathway for design basis LOCAs caused leakage from the primary containment. It also provides an environmentally controllable atmosphere for vital equipment required to safely shut the plant down under these conditions.
- The secondary containment provides primary containment during refueling or shutdown operations when postulated refueling pool or open primary coolant system accidents are assumed to occur.
- The Secondary Containment also provides a primary containment function for steam or liquid leaks from reactor coolant pathways outside the primary containment during normal or transient operations.
- The Reactor Building encloses the Secondary Containment and the lower portions of the secondary containment are situated below site ground level.
- Under design basis LOCA inside primary containment conditions, the Secondary Containment is subjected to isolation and standby gas treatment operation. Normal HVAC

is terminated. Breaks inside primary containment are assumed to result in core uncoveries and fission product release although the ABWR design does not show this result. Divisional Separation Zone compartments will be relatively unaffected by the break effects.

- Under design bases LOCA outside containment breaks in the MS tunnel, the Secondary Containment may be subjected to isolation. The post event use of the Standby Gas Treatment System and need for secondary containment integrity is not required although they may be available. These breaks do not result in core uncovery or significant fission product releases. Therefore, Secondary Containment is radiological, controls are not needed. Primary containment is also not needed.

3.13.2.3 Divisional Separation Zones (DSZs)

The general design basis considerations for the Divisional Separation Zones include:

- The three (3) special divisional separation zones or compartments are provided to independently house one of the three (3) ECCS/ESF divisions. A fourth but unique zone is set aside for non-safety-related equipment. The reactor, suppression pool and spent fuel cleanup systems are housed in this fourth quadrant or zone.

- The Divisional Separation Zone compartments also protect each division's equipment from any potential adverse effects of design basis breaks inside primary containment. Special individual DSZ HVAC systems provide heat removal service to the operating ECCS equipment and the surrounding rooms.

- The Divisional Separation Zone compartments provide limited protection from breaks outside the primary containments but, inside secondary containment (e.g., CUW System breaks and RCIC System breaks). The DSZ provide complete protection for breaks in the MS tunnel. The effects of this event do not adversely affect the Divisional Separation Zone rooms or equipment.

- The Divisional Separation Zone compartments can maintain their integrity for minor leaks within the compartment's barrier. They can accommodate larger leaks without compromising other DSZ compartments or equipments.

- Breaks outside primary containment do not require secondary containment or divisional separation compartment integrity. These breaks do, however, require successful operation of at least the equivalent of some parts of the one or more divisions of ECCS. Equipment in divisional compartments are designed for intra and inter DSZ compartment breaks.

- Not all of the break, fire, flood and harsh environs protection features in the Divisional Separation Zone compartments are required to be maintained at all times and under all conditions. Fire barriers do not preclude break effect impositions. Flood door barriers integrities are not expected nor required during outside break conditions.

- Divisional compartments are entered from common corridors to enhance inspection and maintenance capabilities. These corridors are defined as divisional or non-divisional zones depending of fire, flood or break aspects.
- Divisional separation throughout the secondary containment is not necessarily required for all events (fire, flood, breaks or adverse environs).
- Under both design basis fire conditions, the Divisional Separation Zone barriers maintain their design integrity. It's only under outside break conditions that the barriers are challenged and allowed to be breached. Under flooding in one DSZ compartment, excess water is permitted into the non-divisional corridor. Entry into other DSZ compartments is precluded.
- Breaks inside the Divisional Separation compartments are vented outside the compartment and within the secondary containment then out of the secondary containment to the site environs in a relatively controlled manner.
- For breaks in the Secondary Containment or in Divisional Separation Zone compartments, the break effects are by design quickly terminated (valve closures), vented to the MS tunnel (through blowout panels) or to other secondary containment volumes. These immediate break effects are limited to the affected area. Ultimately, residual or possible carryover effects to other compartments or zones is expected and designed into the shutdown equipment qualification specifications.
- Only two areas have high energy lines (CUW and RCIC).
- Based on evaluation of the outside containment break risk (frequency of occurrence X severity of consequences), these events represent less than 1% of the total plant risk.
- During normal operation or during transients, the Secondary Containment and Divisional Separation Zone barriers are not subject to abnormal operating conditions, their integrity is maintained, and their status is monitored.

3.13.3 General ABWR Containment Structures, Systems and Barrier Descriptions

General structure, system and barrier descriptions are located throughout this document. References are given to specific locations below:

- Overall Plant Design and Equipment Layout
  - Refer to Figures 1.2-2 thru 1.2-31
- Reactor Building
  - Refer to Section 3.8, Figures 1.2-4 thru 1.2-12

- Secondary Containment
  - Refer to Section 6.2, Figures 1.2-4 thru 1.2-12
- Divisional Separation Zones
  - Refer to Figures 1.2-2 thru 1.2-12
- Design Basis Accident Inside Containment
  - Refer to Section 6.3 and Chapter 15
- Design Basis Breaks Outside Containment Inside Secondary Containment
  - Refer to Section 6.3 and Chapter 15
- Reactor Building/Secondary Containment/Divisional Separation Zone – HVAC Systems
  - Refer to Section 9.4, Figures 9.4-3 thru 9.4-5
- Secondary Containment Penetrations
  - Refer to Section 6.2, Table 6.2-9
- RB/SC Fire Hazard Analysis
  - Refer to Appendix 9A, Table 9A.6-2
- RB/SC Flooding Analysis (Internal and External)
  - Refer to Section 3.4, Table 3.4-1, Section 2.0, Table 2.0-1
- RB/SC/DSZ Safe Shutdown Equipment – Qualifications
  - Refer to Appendix 3I, Tables 3.6-1 and 3.6-2
- Engineered Safety Features
  - Refer to Sections 6.2, 6.3 and 6.4
- Postulated Pipe Break Aspects
  - Refer to Section 3.6
- PRA - Plant and Public Risk Analysis
  - Refer to Sections 15.5.6, 19.8 and 19.9, and Appendix 19E

- Technical Specifications- Containment Structures and Systems
  - Refer to Chapter 16

3.13.4 General Safety Evaluation

3.13.4.1 Overall Perspective

The Reactor Building, the Secondary Containment and the Divisional Separation Zones have been evaluated for the four major (faulted conditions) design basis accident events—a) the reactor core/recirculation internal pump trip-thermohydraulic/ thermodynamic anomaly, b) the refueling bundle drop accident, c) large coolant piping breaks inside primary containment, and d) large coolant piping breaks outside of primary containment. All four events are examined in Chapter 15. All of the events treated with deterministic safety requirements (e.g., single failure criteria, expected isolation valve closures, etc.)

The same subject structures, systems and barriers are evaluated for other postulated plant events (e.g., internal fires, internal floods, external floods). These evaluations are presented in detail in Sections 3.4, Appendix 9A and Chapter 19. In other words, all of the above events were treated with both deterministic and probabilistic evaluation methodologies.

The same subject structures, systems and barriers are also evaluated for less probable and more severe consequence events. These include unrecoverable breaks inside containment, breaks outside containment without immediate isolation, SBO events, loss of all data communication (ATWS, Loss of Immediate Core Cooling, etc). All of these events were treated with probabilistic analysis methodologies in Chapter 19.

In essence, the ABWR is designed and evaluated to the following critical key events or conditions:

(1) Reactor Building is designed and evaluated to withstand site related events (seismic, wind, snow, storm and flood conditions)

(2) Primary Containment is designed and evaluated to maintain its integrity for DBA-LOCA inside containment events.

(3) Secondary Containment is designed and evaluated to maintain its integrity for DBA-LOCA and core anomaly events inside primary containment.

Divisional Separation Zones are designed and evaluated to maintain their separation criteria and provide adequate safe shutdown capabilities for:

(i) DBA-LOCA breaks inside containment; DBA-core anomaly events and DBA refueling events. All potential core damage resultant events;

(ii) divisional and non-divisional fires, floods, and harsh environs effects. These are non-radiological effects events;

(iii) high energy line breaks outside containment with timely isolation valve closures. These are non-fuel damage events; and

(iv) minor or mild ECCS system leaks in DSZ components events. These are non-radiological concern events.

The barriers for the Divisional Separation Zones in general have a number of different and often conflicting safety and non-safety functions. They are therefore designed to a number of different criteria. The Divisional Separation Zone walls are designed and expected to maintain their structural integrity during all DBA events. The access doors are selectively designed for several uses. Most are expected under normal conditions to be closed. Some are designed to be water tight. Many are fire resistant. Most will remain in place but not necessarily closed under outside containment break conditions. Divisional Separation Zone internal penetrations are fire resistant and flood protected. Under outside break conditions their integrity is not assured nor assumed. The equipment in the DSZ compartments are qualified for environmental conditions that do not depend on most barrier functions.

3.13.4.2 Fire Events

Divisional Separation Zones separation criteria are maintained during design basis fire events. Internal fire in one affected zone will not propagate to other divisions. Smoke is removed from the affected zone. Other zones are pressurized and also vented. Fire suppression techniques are confined to the affected zone. Refer to Fire FIVE Analysis in Appendix 9A. Divisional barriers doors, penetrations, walls, etc. are designed to preclude any external fire effects. Divisional fire impact on other zones is negligible. Fire threat has been minimized by fire source reduction, fire retardant materials and timely fire detection and adequate fire suppression capabilities.

3.13.4.3 Flood Events

Divisional Separation Zones separation criteria are maintained during design basis internal or external flooding events. Internal flooding in one affected zone will not propagate to other divisions. Divisional flooding will be initially directed to basement levels (–8,200 mm). Divisional sumps will collect and remove residual waters. For a Special Event--Suppression Pool drain-out to a specific LPCS room (Divisional Separation Zone), the affected divisional zone will direct some controlled flooding to the non-divisional corridor at the –8,200 mm level to a level of 2.5 meters high. This subsequent flooding to the non-divisional corridor will be confined to the corridor only. The flooding of the other divisional compartments will be precluded by the water tight doors of the other divisions at that level. This is a unique event due

to the volume of the Suppression Pool. Most other potential flood sources are small and well controlled within the affected compartment.

3.13.4.4 Pipe Break Events

- Breaks inside Primary Containment will not affect the Divisional Separation Zones. The RB/SC HVAC will be, of course, isolated and the SGTS will be operated. External Secondary Containment barriers (doors) are expected to be closed. Secondary Containment is required (due to potential radiological effects) and automatically assured by isolation valve closures.

- Breaks inside the Main Steam Tunnel will not effect the Divisional Separation Zones. However, Secondary Containment is not required (due to low potential radiological effects) but probably will be available. The event does not result in core damage or core uncovery. Radiological releases are momentary (5.5 seconds). Residual radiation is extremely low. Break effects (release of steam and water) will be confined to MS tunnel, Turbine Building and outside site environs.

- Breaks outside Primary Containment but inside the Secondary Containment (e.g., CUW and/or RCIC breaks) are treated rather uniquely. Since the events do not result in core damage nor core uncovery throughout these events (similar for Main Steam Line Break inside the Main Steam Tunnel), there is no need for Secondary Containment during the blowdown or recovery phase. Although the subject valve closures are longer, coolant release is less and release pathways to the environs are more torturous. Environmental effects on the Secondary Containment and enclosed Divisional Separation Zones are taken into account. Equipment qualifications are defined by the worst break, worst-pressurization analysis. Little credit is assumed for non-affected DSZ areas. Existing barriers are conservatively treated. CUW break pressurization analysis (Chapter 6.2.3) limits the affected Secondary Containment volumes used in the analysis in order to maximize the blowdown effects. It then, however, applies the peak effects results to all Divisional Separation Zone areas. (Refer to Appendix 3I). Realistic analysis shows a significant reduction in break pressurization effects when using reasonable blowdown volumes (complete non divisional corridor plus upper levels of secondary containment). The further use of other available volumes (divisional zones themselves) would result in even lower break effects.

- The design and justification of softened versus hardened Divisional Separation Zones and barriers for extremely low probability breaks outside containment has been thoroughly examined and evaluated in a later paragraph.

- The above evaluation assumes that most of the Divisional Separation Zone barriers—except structural walls—are neglected or ignored in the pressurization and effects analysis. This is a very, very conservative assumption. Some access doors and penetration pathways are all assumed to be open. In realistic situations some will remain closed. Where

conservative analysis might require their closure for worst case pressurization analysis, they are assumed closed.

3.13.4.5 Harsh Environs

Divisional Separation Zones are maintained during harsh environs events. Events other than the above cited that events can occur individually or collectively (e.g., SBO—no HVAC) have been evaluated for abnormal or compromising effects. Required Divisional Separation Zone requirements were examined (e.g., restoration of one division HVAC for safe shutdown requirements without the availability of other the divisional HVACs). Most of these have been evaluated throughout Tier 2. For most such events, divisional barriers do not play a significant role in these localized environmental events. That is, these events are not extremely important relative to divisional separation functions.

Loss of RB/SC HVAC due to an inadvertent isolation is accommodated by the operation of the individual Divisional Separation Zone equipment compartment emergency HVAC coolers. This event can affect all the divisional zones at once but divisionalized cooling mitigates the event initial effects. Likewise, loss of an Emergency HVAC system will only affect one divisional zone area.

Divisional barriers appear to be less important for operationally harsh environs threats.

3.13.4.6 Divisional Separation Aspects Throughout the Plant

Divisional Separation Areas exist outside the Reactor Building–Secondary Containment Structures (e.g., in Control Building, RSWS Pump House, Pipe Chases and Tunnels, etc.). Both structural and operational feature barriers exist in these divisional separation areas. Separation criteria or requirements have been established in the Tier 2 sections addressing these divisional separation areas.

3.13.4.7 Divisional Separation Assurance

Most divisional separated systems are shown on separate drawings; powered by divisional sources; housed in divisional areas; and supported by divisional auxiliary systems. Most divisional separation structures are shown in identified areas on plant layout drawings. Most divisional separation barriers requirements are analyzed and justified in separate event evaluations. The documentation locations of these analysis are spread throughout Tier 2.

3.13.4.8 Soft vs. Hardened Divisional Separation Zones – Outside Breaks

The Secondary Containment, the Divisional Separation Zones, and both of their barriers provide rather robust and hardened inter- and intra-protection for most plant design basis events. They even provide under some extremely low probability and high consequence events a sustained level of total independence.

Most of these events are dictated by the need for Secondary Containment due to severe radiological considerations caused by inside containment breaks. Others involved the need to assure immediate and sustained safe and orderly shutdown capabilities for plant internal events within the Secondary Containment. Fire or flood events require complete isolation of the event effects. Environmental rather than radiological effects governed these mitigation requirements. Barrier performance is critical to the event impact and outcome of all of the above. The timely response of the mitigation engineered safety features also determined the significance of the event effects. Primary Containment radiological barrier isolation valves closed per design, fire doors were closed or closed, flood leak detection actuated alarms and isolations, etc. To most extent the containment features or barriers are inherent, hardened, mostly passive, uni-directional and predisposited.

However, some events are better serviced and mitigated by circumventing conventional barriers or utilizing the barriers for another function. A rapid pressurization is better served by a rapid venting through barriers rather than bottling within the barriers. This is the softened approach to barriers. This is the technique used for breaks outside containment in RB/SC/DSZs. The barrier shortcomings are utilized and engineered for other purposes.

3.13.5 Hardened–Softened Barrier Concept Approach– Special Critique

3.13.5.1 General

The Secondary Containment and Divisional Separation Zone Barriers are subject to wide spectrum of events, accident effects, and performance objectives. Some of these often require diametrically opposed response functions. (e.g., in case of Secondary Containment: maintain integrity or provide a ventable pathway). Each function cited here depends on location of the specific pipe break. That is, whether its inside or outside containment. Whether the outside containment break isolatable or unisolatable. Whether steam or water release is finite or infinite. The current design contains provisions to address all of the barriers functions for all of the design basis events and to also address less frequent and higher consequence events as well. The net result is that the ABWR design has both hardened divisional separation objectives and softened objectives. The hardened objectives demand the robust maintenance of integrity of barriers or boundaries between Divisional Separation Zones in the Secondary Containment for most events. The softened objectives allow more relaxed communication between the zones for a negligible number of unique events. Fire analysis demands strict separation and time maintenance of barriers. Breaks inside CUW areas allow depressurization throughout the Secondary Containment, Non-Divisional Corridor, Stairwells, Vertical HVAC and pipe chases, etc. to the site environs.

The inside containment break demands Secondary Containment full and complete isolation and integrity. The inside flood event in a DSZ compartment allows flooding outside the affected compartment into a non-divisional corridor but no to other DSZ rooms.

3.13.5.2 Specific Critique

The Secondary Containment, the Divisional Separation Zones, and their respective barriers could be viewed as being somewhat softer in protection for pipe breaks occurring within themselves. The barriers do not appear to be designed to sustain the same separation capabilities exhibited above for other areas and events.

There are a number of reasons for considering breaks outside containment, harsh environment occurrences and barrier design basis differently. The reasons include:

- Secondary Containment does not have specific safety function for outside containment breaks.
- Breaks outside containment are less frequent; they result in less consequences; and they are more readily preventable by frequent periodic inspection, increased monitoring and more sensitive leak before break detection.
- Breaks outside containment are more likely to be isolatable and terminated by automatic, timely and responsive break detection and isolation valve closure actions.
- Breaks of the type designed for HELB events (e.g., CUW and RCIC) do not result in core damage, core uncovery or appreciable radiological or environmental effects.
- These breaks result in immediate but short term environmental effects. Their effects are not curtailable by rapid valve closure, early break detections, etc. or even reasonable barrier considerations.
- The most effective and efficient means to accommodate such sudden and momentary energy releases is to provide a large blowdown volume and a large ventable pathway for the released effluents to the outside environs.
- Safe shutdown event mitigation equipment can be and is sheltered out of the direct effects of the break blowdown. Residual effects of the blowdown are included in the equipment qualifications. It is essentially engineering the blowdown pathway.
- Many of the current DSZ barriers, have conflicting missions when used for other events (e.g., fire and flood door closures are rigid barrier features). For pressurization events, door opening are very helpful. They provide additional blowdown pathways.
- The failure modes and effects of most barriers tend to assist the depressurization objective rather than resist it. Door openings are more predictable than door closures.
- Sensitivity of most barrier performances have minimal effects on the depressurization/ event outcome. Blowout panels go over a wide range of pressures. Ventilation dampers closure characteristics are very hard to protect and predict.

- The risk to plant and public is a very small percentage of the total risk for the CUW and RCIC breaks. Refer to Section 15.6.6, 19.8 and 19.9, and Appendix 19E for specific information relative to these breaks and their treatment both deterministically and probabilistically.

3.13.5.3 Conclusions

The Secondary Containment—Divisional Separation Zone Barriers serve both hardened and softened objectives very well. They rigidly resist integrity loss for most plant internal and external influenced events and flexibly relax and allow depressurization pathways for a small number of internally generated events. In essence, they inherently can serve two masters at once successful.

A series of comprehensive evaluations of means to further harden the SC and DSZ barriers was carried out. Blast dampers for HVAC ducting were considered. Increased venting via blowout panels to the MSL tunnel was examined. Faster valve closures on CUW, separate and hardened HVAC subsystems to each DSZ, containment-like DSZ penetrations, etc. were evaluated. However, risk evaluations failed to indicate any appreciable risk reduction by incorporating totally hardened barriers (such as the above).

3.13.6 Specific Barrier Design Basis and Safety Evaluation

The following subsection singles out important individual barriers and provide a brief design basis and safety evaluation of them.

3.13.6.1 Divisional Structural Walls

All the structural load bearing, etc. walls are designed to building code structural requirements. Structural integrity will be assured during all DBA events. These are discussed in Subsection 3.8.

The Reactor Building exterior walls and the divisional walls used for flood protection on the –8,200 mm elevation of the Reactor Building will be designed to withstand the differential pressure resulting from a HELB that is vented only into the corridor spaces within the division on that elevation. Credit could be taken for all the non-divisional corridor volume at –8,200 mm. The Secondary Containment and divisional walls on elevation –1,700 mm and above in the Reactor Building will be designed to withstand the resulting differential pressure from HELB that is assumed to expand into the volumes of these elevations.

Appendix 3H.4 provides the Secondary Containment and Divisional Separation Zone wall design thickness and capabilities. Lower level walls are shown to be capable of maintaining their structural integrity for the pressurization analysis pressures cited.

Divisional structural walls can maintain their structural integrity for internal design loads for fire and flood conditions cited in Section 3.4 and Appendix 9A.

3.13.6.2 Divisional Access Doors

Lower corridor divisional compartment water tight doors are expected to maintain their leak tight closed position during design basis internal flood events.

Fire doors at all levels are expected to maintain their integrity for 3 hours during internal design basis fire events.

Lower corridor doors are expected to open on breaks outside primary containment but inside secondary containment pressurization events.

Non-affected lower divisional doors are expected to stay closed during similar events.

Upper divisional level doors are expected to be less affected by break outside containment venting pressures. They may or may not open depending on vent pressure pathways.

Secondary Containment external access doors are expected to maintain their closed position during fire, flood and break events.

Blowout Panels will not become missiles but will be retained in place.

Elevator Shaft will not be affected pressurization transient.

Equipment Hatches will leak but will be retained in place.

Vertical HVAC and Piping Chimneys are expected to be available as a vent pathway.

3.13.6.3 Divisional Penetrations

Lower corridor divisional penetrations (water, power, I&C) are expected to maintain their integrity under all internal design basis fire and flood conditions.

Lower corridor to divisional compartment penetrations are expected to leak under breaks outside containment pressurization events. However, divisional flooding will not occur.

Division compartment HVAC are expected to maintain their integrity under inside DBA events and internal fire and flood event conditions but not function after an outside break.

Divisional compartment HVAC penetrations are expected to leak or open upon outside break pressurization events.

3.13.6.4 Divisional Safe Shutdown Equipment

Divisional safe shutdown equipment is designed and will be procured for the very conservative normal and accident conditions cited in Appendix 3I. Reasonable and/or realistic analysis show that these requirements are indeed conservative and far beyond anticipated barrier performance and equipment qualification needs. Subsection 6.2.3 analysis shows that for the most limiting

events—CUW or RCIC system breaks outside containment—the required safe shutdown equipment in the DSZs are maintained within their environmental qualification limits by wide margins.

3.13.6.5 Pressurization Analysis

The subject analysis conservatively bounds break outside containment event effects. Refer to Subsection 6.2.3. The basis and results of the CUW or RCIC break evaluations are described there. The resulting environmental effects are the most limiting conditions for Secondary Containment and Divisional Separation Zone safe shutdown equipment. The event conditions are momentary as shown by the time at temperature analysis. The conditions cited are used as their equipment qualification requirements. Refer to Appendix 3I.

3.13.6.6 Post Event Recovery

The cited DSZ barriers do not play a critical role in the post event recovery actions. Use of internally located equipment that assure safe shutdown and long-term recovery operations depend only on isolation valve closures within a reasonable length of time (0-1 hour). Externally located equipment that can assure safe shutdown (e.g. Feedwater) depends only on the supply of make-up water available and not on RB/SC/DSZ environmental conditions.

3.13.6.7 Divisional Equipment Reliability

The engineered safety feature equipment required for short term post event safe and orderly shutdown and for long term recovery have been evaluated for the break-environmental effects. Considerations are given both to the effects on the equipment operation and its reliability. Breaks outside containment will subject equipment to brief, momentary environmental conditions below the equipment qualification levels. Breaks inside containment will not subject the equipment to any abnormal conditions. Timely automatic or manual post recovery actions will significantly reduce these momentary conditions to levels significantly below their qualification or capability levels. The reliability of the equipment to these momentary conditions was taken into account. Decreases in equipment reliability is not expected.

3.13.7 Protection of Environmentally Sensitive Equipment

3.13.7.1 Overview

Special attention has been given to environmentally sensitive equipment, especially to equipment located with the Reactor Building, the Secondary Containment or the Divisional Separation Zones which are required or utilized in safe shutdown operations. Certain digital, solid-state electronic I&C equipment falls into this category, (e.g. safety-related remote digital logic controllers (RDLCs)).

Special protection precautions are incorporated in the ABWR design to address environmental sensitivities. These include:

(1) Locating the subject equipment in environmentally suitable and acceptable areas where mild environmental conditions already exists.

(2) Protecting the equipment from expected or potential plant abnormal plant events and their effects or locating the equipment at alternate locations.

(3) Providing alternative, diverse backup equipment which is less environmentally sensitive.

(4) Separating the equipment such that a single severe or challenging plant event or its effects will not be experienced by redundant components or functions.

(5) Providing reliable environmental controls to maintain acceptable conditions at all times even during abnormal events.

(6) Including environmental condition margins in the design and procurement of equipment.

(7) Being able to identify and discriminate between I&C outputs from equipment subjected to abnormal conditions and being able to operate or function around them.

(8) Monitoring and reacting to abnormal environmental conditions with timely remedial actions.

Normal and Accident Equipment Environmental Conditions are cited in Appendix 3I. The Appendix 3I tables contained in this appendix identify environmental conditions at various plant building and equipment locations for a wide spectrum of plant design bases conditions. Pipe breaks both inside and outside primary containment are the dominant contributors to the abnormal plant conditions cited in the tables. Plant impact aspects from design basis fire or flood, or harsh environmental conditions have less of an impact. Due to divisional separation requirements enough equipment is isolated from the single plant fire and flood sources to assure safe shutdown. That is, the event only affects a limited amount of equipment and plant area. Beyond design basis events plant effects like ATWS and SBO are enveloped by the above cited tables since the environmental conditions and effects of these events are less pronounced or momentary. Specific design requirements for these event demand inherent coping capabilities. A number of engineered safety features also mitigate the initial hostile conditions. Ultimately, other equipment is available to restore normal conditions, (e.g. CTG operation and restoration of HVAC). The subject Appendix 3I tables apply to safety-related equipment and their environmental qualifications. However, other equipment unaffected by these environmental conditions may also provide mitigation service (e.g., Turbine Building Feedwater).

3.13.7.2 Reactor Building Housed Equipment

The Reactor Building houses environmentally sensitive equipment in isolated and protected clean zones. These are areas which are not subject to design basis accident pipe break (inside or outside containment) effects. These clean rooms, areas or zones have their own independent and redundant component environmental control HVAC systems. The clean zones house a number of safety-related systems or related components (e.g. emergency electrical equipment rooms, the remote shutdown panel rooms, diesel generator rooms, etc.). The clean zones for redundant safety equipment are in themselves separated by divisional requirements related to fire, flood, and break aspects. Environmentally sensitive I&C equipment is housed in the Emergency Electrical Equipment (EEE) rooms. Not all equipment in clean zones are environmentally sensitive, In fact, only a small portion of the equipment are environmentally sensitive to changes in normal environmental conditions.

Safety-related RDLCs and other data communication equipment are housed in EEE rooms. Severe plant event effects do not effect their safety functions. They are inherently unaffected by their own heat sources. They are also capable of prolonged loss of HVAC services due to their environmental locations and their low self heatup characteristics. Since there are three I&C divisions, environmental effects in one will not negate any demanded safety functions from the other locations.

3.13.7.3 Secondary Containment Housed Equipment

The Secondary Containment houses both safety-related and non-safety-related equipment. Little environmentally sensitive equipment is located inside the Secondary Containment. Although all equipment is ultimately affected by beyond normal operation condition, the threshold EQ for most equipment is high and maximum event effect results are low to it. A limited number of potential pipe breaks inside the Secondary Containment require that housed safe shutdown equipment be designed and qualified for significantly elevated (above normal) environmental conditions. Even though these conditions are only momentary (a few seconds to a minute), equipment is qualified for them. The equipment is generally capable of operating for longer times at abnormal effect conditions than required by the design basis event effects.

No safety-related environmentally sensitive I&C equipment resides inside Secondary Containment (e.g. ECFs). Some non-safety related operational Plant Data Network (PDN) equipment is housed in the Secondary Containment. Their failure or mal-operation due to abnormal secondary containment conditions will not negate safety-related equipment abnormal event functions. The safety-related equipment in the RB/EEE rooms and the qualified safe shutdown equipment in the secondary containment will accomplish their safety function regardless of any non-safety system failures due to environmental conditions.

3.13.7.4 Divisional Separation Zones Housed Equipment

For most plant events and their effects the divisional separation zones generally afford another level of environmental protection and control. Each division has its own emergency HVAC

system. For fire, flood and breaks inside containment, the divisional separation barriers assure complete independence, electrical, physical, environmental, etc. A small number of outside containment breaks limit the barriers effectiveness in regards to environmental effects. The equipment qualification requirements are designed to take these low probability events into account.

Less pronounced abnormal environmental conditions (e.g. divisional pipe leaks, fires, floods, HVAC loss, etc.) are readily isolated to the affected divisional zone and not allowed to propagate to the other divisional zones. Even postulated beyond design basis long term environmental effects (total loss of HVAC, extended SBOs, unisolated breaks, etc.) are accommodated. They are accommodated in the short term by the current conservative equipment environmental qualifications and alternative heat removal capabilities and in the long term by power recoveries, valve closures and break isolations, HVAC restoration and alternate heat removal systems.

3.13.7.5 Control Building Housed Equipment

The same protection afforded the above equipment is provided in the Control Building. Control Building environmental effects are induced and self-correcting. (e.g., divisional separation, independent emergency HVAC systems, isolation capabilities.) No high energy related events can occur in the Control Building.

3.13.8 Summary Conclusions

The following overall summary conclusions are offered:

- The ABWR Design Containment structures, systems and barriers provide adequate protection to the plant and public for a wide spectrum of events—Design Basis Accidents, Special Events and Severe Accidents.
- The individual containment structures, systems and components including barriers comply with a wide spectrum of design basis and performance requirements.
- Plant Containment Structures will maintain their structural integrity for all postulated design basis events, (e.g. fire, floods, breaks, site-related events)
- The Secondary Containment and the Divisional Separation Zones will maintain their design basis barriers for all radiologically significant events—DBA breaks inside containment, core/fuel integrity anomalies and refueling accidents.
- Breaks within the Secondary Containment can be accommodated and safe shutdown achieved for a variety of event scenarios. The Divisional Separation Zone equipment will continue to operate after these breaks and will reliably assure safe and order shutdown.

- The Secondary Containment and Divisional Separation Zone envelope integrities are not required for breaks outside Primary Containment especially those within the Secondary Containment or the zones.
- The primary function of the Secondary Containment–Divisional Separation Zones is to assure physical, electrical, divisional and environmental separation during normal plant operations, plant transients and DBA events requiring secondary containment.
- Divisional Separation is most affected during plant design basis fire, flood, breaks inside containment and harsh environs, plant-related events and by site-related threats.
- The Hardened–Softened Barrier Concept utilized in this design is the most practical and effective means of addressing the wide spectrum of events cited.
- The ABWR Design containment systems meet all regulatory requirements and regulations.
- Environmentally sensitive equipment is afforded a significant amount of protection by the ABWR Reactor Building-Secondary Containment-Divisional Separation-Control Building physical configuration arrangements; by engineered safety features -- emergency HVAC system, alternative power supplies and heat removal techniques, by alternate hardwired I&C networks, and by divisional separation requirements; and by conservative fire, flood, break and harsh environs event evaluations, system interaction analysis and conservative EQ considerations.