19EE Suppression Pool Bypass

19EE.1 Suppression Pool Bypass

As shown in Subsection 19E.2.3.3.3(4), the only mode of suppression pool bypass that presents any significant risk during a severe accident is vacuum breaker leakage. Vacuum breaker leakage is the passage of gas from the drywell into the wetwell air space. Vapor suppression and fission product scrubbing by the suppression pool are not available to the gas and vapor which pass through the vacuum breakers.

The ABWR contains eight vacuum breakers. ABWR vacuum breakers are swing check valves which begin to open passively when wetwell pressure exceeds drywell pressure by 0.0014 MPa and are fully open at 0.0035 MPa. When the pressure differential is less than this, or drywell pressure exceeds wetwell pressure, the vacuum breakers should be completely seated and no flow should be passing through them. A large drywell to wetwell pressure differential will produce a large force tending to close the vacuum breaker valves. A pressure differential of +0.048 MPa is typical in a severe accident after core damage occurs and the passive flooder opens. This pressure differential produces a closing force of 9810 N (2200 lbf) on the valves. For severe accident scenarios in which the firewater system is actuated, the pressure differential is about +0.096 MPa which produces a closing force of 19600 N (4400 lbf) on the valves. These large closing forces, as well as routine inspection, maintenance, and testing, ensure the probability of vacuum breaker leakage after the actuation of the passive flooder or the drywell spray system is extremely low.

Large amounts of leakage can occur as a result of catastrophic failure of valve components or a valve sticking open. Lesser amounts of leakage can result from normal wear and tear including degradation of the valve seating surfaces or retaining magnets. For sufficiently large amounts of leakage during a severe accident, the time to rupture disk opening or containment failure can be reduced and the amount of fission products released can be increased.

A study utilizing decomposition event trees and deterministic modeling was performed to assess the impact of vacuum breaker leakage on the performance of the ABWR during a severe accident. The event tree analysis is contained in Subsection 19EE.2. Subsection 19EE.3 contains the deterministic evaluation.

19EE.2 Description of Decomposition Event Tree Analysis

The suppression pool bypass decomposition event tree analysis consists of one decomposition event tree (DET), Figure 19EE-1. The DET considers the major phenomena which influence accident consequences. The first two events on the DET sort out vacuum breaker leakage area. Plugging of vacuum breaker leakage pathways by aerosols is considered in the third event. If leakage exists but the pathway is not very large, aerosol plugging can significantly diminish the consequences of suppression pool bypass through the vacuum breakers. The last event assesses the amount of suppression pool bypass.

The probabilities for each sequence pathway with similar end states were summed and these results transferred as the branch probabilities of the main containment event tree.

19EE.2.1 Vacuum Breaker Stuck Open (VB)

When a vacuum breaker sticks open or fails catastrophically, a large pathway is established between the drywell and wetwell. The deterministic analysis described in Subsection 19EE.3 demonstrates that pathway areas greater than 41 cm^2 (opening widths greater than 0.9 cm) can significantly affect accident consequences.

The suppression pool bypass scoping analysis presented in Subsection 19E.2.3.3 assumed a failure probability for vacuum breaker full reverse flow based on pre-1970 U.S. BWR operating history of general check valves. This failure rate is highly conservative because:

(1) The ABWR vacuum breaker design is based on current knowledge which is substantially improved over earlier check valve designs.

(2) The ABWR vacuum breaker environment is significantly less severe than general check valves—the working fluid is gas rather than liquid and the ABWR vacuum breakers will not experience chugging loads.

The failure probability used in this analysis was based on BWR operating experience from April 1981 to March 1991 as contained in a database of Licensing Event Reports. The database was queried for abnormal wetwell-to-drywell vacuum breaker operation. Information about the valves connecting the containment and reactor building were not included because some of these valves are not swing, check valves. The database query provided a short narrative of each abnormal operation as well as the total component operating time.

The database query included BWR Mark I, II and III containments. The vacuum breakers in these containments are similar in design to the ABWR vacuum breakers (passive, flapper-type valves attached to horizontal piping). The ABWR vacuum breakers will be slightly different in size than some of those currently in operation, but this does not undermine the applicability of the data. Only flapper-type vacuum breakers were represented in the data. The motor-operated valves (MOVs) used in the vacuum relief systems of Mark III containments were not considered.

The failures were culled to exclude failures other than those that could lead to a vacuum breaker sticking open or catastrophically failing. Failures to open were excluded because mechanical binding was never the root cause. Most failures to open (10 out of 12) were attributed to either the setpoint drift or worn retaining magnets. Neither of these conditions would prevent the vacuum breaker from closing once it had opened, albeit at a differential pressure outside the normal range. The remaining failures were due to:

(1) a loose set screw on the flapper pivot pin, and

(2) excessive clearance between the valve shaft and disk.

Both of these conditions led to opening forces greater than technical specification limits and greater than the forces required to open the other vacuum breakers tested in the same sequence. In the ABWR design, only seven of the eight vacuum breakers are required to accommodate the most rapid drywell depressurization. Therefore, if either of the these two failure conditions existed during an accident, the affected valves would probably not open because the other vacuum breakers would open and relieve high differential wetwell pressure before the force required to open the affected valves was achieved.

Failures to pass leak rate tests during refueling and maintenance outages when the vacuum breaker proximity switch indicated "closed" were also excluded because they represent small leakage paths. These failures were included in the probability for VB_LEAK as described in Subsection 19EE.2.2. A "closed" indication will be given only when the vacuum breaker disk is seated or very nearly so. Failures to close were included, as were cases in which excessive force was required to cycle a vacuum breaker during stroke capability testing.

The database query provided the following results:

Abnormal operation which could lead to failure to close	18 (N_{close})
Cumulative vacuum breaker operating time	2.66E7 hours (T_{close})

The ability of vacuum breakers to open and close in current plants is demonstrated monthly during stroke capability tests (T_{stroke} = 720 hours). Therefore, the probability that one of the eight ABWR vacuum breakers will fail to close on demand and a large leakage path will be established between the wetwell and drywell can be approximated.

This failure probability conservatively over-estimates the probability that one of the ABWR vacuum breakers will fail to close during accident conditions because the closure forces during an accident will be at least an order of magnitude greater than those present during testing and normal operation. Additional closure force will enhance sealing and overcome some, if not all of the closing resistance.

The vacuum breakers in the ABWR will not be stroke tested every month as are those in current operation. This is expected to improve vacuum breaker reliability because the monthly stroking increases wear, increases galling potential, imparts impact loads to the valve components, loads the valves in a non-uniform manner, and decreases the sealing ability of the soft seats. Reliability will also be increased by improvements made possible by the operational experience of vacuum breakers currently in BWRs with Mark I, II and III containments. These improvements will include material selection, valve assembly techniques and maintenance procedures. Corrosion on ABWR vacuum breaker load bearing components will be negligible because of material selection and operating environment (nearly pure nitrogen). Since reliability is improved and corrosion will be negligible, the failure probability determined during monthly testing of current vacuum breakers provides a conservative over-estimation of ABWR vacuum breaker reliability.

19EE.2.2 Vacuum Breaker Leaks (VB_LEAK)

The consequences of small leakage paths between the drywell and wetwell are less severe than those for a vacuum breaker sticking open. The small leakage area cutoff was determined to be 41 cm^2 in the sensitivity study contained in Subsection 19EE.3. The BWR operating history described in Subsection 19EE.2.1 was also used to determine the probability of small leakage.

BWRs with Mark I containments have a single passive, flapper-type valve attached to the end of each vacuum breaker line. Mark II containments have two passive, flapper-type valves in series in each vacuum breaker line. Mark III containments have a single, flapper-type valve in series with a motor operated valve (MOV) in each line. All of the valves are attached to horizontal piping in the wetwell air space. Since the ABWR has a single, flapper-type valve on the end of each line in the wetwell air space, the operating experience of BWRs with Mark I containments provides the best indication of ABWR vacuum breaker leakage. Actual ABWR vacuum breakers will perform better than those in Mark I containments because:

(1) The ABWR vacuum breaker materials—especially those of the seating surfaces—will be improved because they will be based on the many years accumulated vacuum breaker experience of current BWRs.

(2) The ABWR vacuum breakers will not experience chugging loads.

(3) The ABWR vacuum breakers will not be cycled every month.

The ability of vacuum breakers to remain leak tight is demonstrated during wetwell-to-drywell leakage tests performed as part of each refueling and maintenance outage. During these tests, the drywell is pressurized with respect to the wetwell and the pressure decay rate measured. If the pressure differential decreases too rapidly indicating excessive leakage, the root cause is found and corrected. The instances when a vacuum breaker was found to be the leakage pathway are reported in Licensing Event Reports and included in the operating experience database. The pressurization rate used in the leakage tests are generally slower than those experienced during accident conditions. Increased pressurization rates improve the sealing capability of soft seats and reduce leakage.

All failures reported in the selected operating history of wetwell-to-drywell vacuum breakers in Mark I containments, except failures to open and those used to determine vacuum breaker stuck open, were included in the determination of small leakage probability. The database query provided the following results:

Number of Mark I wetwell-to-drywell vacuum breaker abnormal operations which could lead to small leakage	42 (N_{leak})
Cumulative Mark I vacuum breaker operating time	2.37E7 hours (T_{leak})

The actual amount of leakage was not reported in the database and is generally not available. However, the vacuum breaker leakage area can be roughly characterized. Currently, wetwell-to-drywell vacuum breakers are verified to be closed by indication lights in the control room every seven days. Position is determined by proximity switches which are generally accurate to within the 0.9 cm disk opening, corresponding to the 41 cm^2 cutoff area. The proximity switches used in conjunction with the ABWR vacuum breakers will have even closer tolerances because of the increased importance placed on bypass leakage. None of the leakage failures included failure of “closed” indication. Therefore, leakage was occurring when the valve was open less than the cutoff amount.

During the operating period selected in the database query, refueling and maintenance outages were conducted every twelve to eighteen months. Thus, taking the test time to be eighteen months (T_{test} = 13,140 hours) is conservative. The probability that one of the eight ABWR vacuum breakers develops a small leakage path can be approximated.

This probability is a conservative over-estimation since wetwell-to-drywell leakage test are conducted at differential pressures much lower than those expected during accident conditions. The additional differential pressures will greatly enhance sealing.

19EE.2.3 Aerosols Plug Leakage Path (LEAK_PLUG)

The consequences of leakage pathways between the drywell and wetwell can be greatly diminished if aerosols plug the path. The Vaughan aerosol plugging model (Reference 19EE-1) was used with MAAP-ABWR to determine if and at what time plugging occurred. A full description of this methodology can be found in Subsection 19EE.3.1.

The sensitivity study contained in Subsection 19EE.3.2 predicts that if plugging is allowed to occur in small leakage paths (opening widths $\leq$ 0.9 cm), accident consequences are not effected by the presence of leakage paths. Even though plugging may reduce the consequences of larger opening widths, no credit was taken in the DET. The sensitivity study predicted plugging for opening widths up to 1.25 cm. Therefore, a high probability was given to plugging of opening widths up to 0.9 cm.

19EE.2.4 Suppression Pool Bypass (POOL_BP)

This heading on the DET summarizes the amount of suppression pool bypass. “No Pool Bypass” indicates that either no leakage, an insignificant amount of leakage, or a plugged leakage pathway exists. The consequences of a particular accident scenario will be unaffected by pool bypass for this condition. “Small Leak” indicates that a small amount of pool bypass is present. Small amounts of bypass will have marginal impact on accident consequences. Large amounts of pool bypass are indicated by “Large Leakage”. Accident consequences will increase in severity when large amounts of pool bypass exist.

19EE.3 Deterministic Analysis

A sensitivity study was performed with MAAP-ABWR to access the impact of suppression pool bypass during severe accident conditions.

19EE.3.1 Method

The dominant severe accident sequence [Loss of all core Cooling with vessel failure occurring at Low Pressure (LCLP)] was chosen to evaluate plant performance. MAAP-ABWR runs were made with effective vacuum breaker area, $A/\sqrt{K}$, varying from 0 to 2030 cm^2 (315 in^2). The upper bound corresponds to one fully open vacuum breaker with no flow resistance. Five variations were analyzed. In each case the overpressure relief rupture disk opened when the wetwell pressure reached 0.72 MPa. The five scenarios were:

(1) Bypass leakage begins after passive flooder activation, aerosol plugging is neglected.

(2) Bypass leakage is present from the beginning of the accident, aerosol plugging is neglected.

(3) Bypass leakage begins after passive flooder activation, aerosol plugging of the vacuum breaker opening is considered.

(4) Bypass leakage is present from the beginning of the accident, aerosol plugging of the vacuum breaker opening is considered.

(5) Bypass leakage is present from the beginning of the accident and the operator initiates the firewater spray system.

MAAP-ABWR uses the MAAP 3.0B aerosol plugging model developed by E.U. Vaughan (Reference 19EE-1). The model predicts the mass of aerosol required to flow through the leak path in order to form a plug as a function of the size of the opening. MAAP conservatively assumes that the flow rate through the vacuum breaker opening is not affected by the growing aerosol plug until the aerosol mass required to plug the leak completely has passed through the opening. For a circular opening, the mass is proportional to the cube of the diameter; and, for a rectangular opening, the mass is proportional to the product of the length and the square of its width. The proportionality constant has been experimentally determined to range from 10,000 to 50,000 kg/m^3 (130 to 640 lbm/ft^3), and varies with aerosol size, aerosol mass flow rate, and leak path geometry. The MAAP-ABWR runs for scenarios 3 and 4 used a conservative proportionality constant of 50,000 kg/m^3 (640 lbm/ft^3).

Although the Vaughan aerosol plugging model does not suggest an upper bound on the size of leak paths which can be plugged, there is some question about the applicability of the model for leak paths greater than 1 cm (0.39 in) in diameter. In NRC/IDCOR Technical Issue 13A (Reference 19EE-2), the NRC asserted that the data cited by Morewitz (Reference 19EE-3) in support of the Vaughan plugging model for pathways greater than 1 cm diameter does not adequately simulate severe accident conditions. The experiments cited with pathways greater than 1 cm (0.39 in) in diameter involved straight ducts with lengths greater than 10 meters (32.8 ft). Therefore, due to the lack of appropriate experimental data, the NRC has accepted the Vaughan aerosol plugging model only for leak pathways smaller than 1 cm (0.39 in). The NRC’s position on this issue is stated in the resolution of NRC/IDCOR Technical Issue 13A (Reference 19EE-2).

The applicability of the Vaughn Plugging Model to the conditions of the vacuum breakers was examined by consideration of various test data provided by Morewitz (Reference 19EE-3). The data surveyed includes a variety of experiments involving orifices as well as pipes. The data for orifice plugging indicates that the plugging coefficient is comparable to that for small piping.

Morewitz also discusses the impact of steam on the plugging of leakpaths. He indicates test data which indicated that “leak paths quickly plugged when steam was introduced in the containment atmosphere”. He also notes that densification effects such as condensation of water on hygroscopic deposits could increase the rate of plug formation. In the ABWR, hygroscopic CsOH particles form a significant fraction of the aerosol. A large portion of the aerosol mass is expected to be made up of tin (Sn) which is released during the core degradation phase of the accident. Tin is insoluble in water (Reference 19EE-4) and therefore, any plug created with tin would not be expected to be affected by the presence of steam. If continued core-concrete interaction is predicted, a major contributor to the aerosol mass would be SiO2 which is also insoluble in water (Reference 19EE-4).

Most of the experimental evidence cited by Morowitz involves systems with very high pressure differences across the plug. For example, in the orifice test data noted above, the differential pressures ranged from 0.21 MPa to 6.9 MPa. Morowitz indicates that “either solid or porous plugs formed” in these experiments. Reference 19EE-3 also describes a test of a small, concrete, tilt-up-panel building at Atomics International in the early 1960’s. The building was overpressurized and cracked so that it leaked badly. In order to plug the leaks, a sodium fire was lit inside the building and observers were stationed around the outside. No smoke was seen issuing from the building. Upon pressure testing of the building, no gas leaks could be detected. Reference 19EE-3 describes several other situations with lower pressure differences in which termination (or significant reduction) in gas flow rates was observed. In the ABWR the maximum pressure difference across the plug will be limited to the head of water above the first row of horizontal vents [about 0.02 MPa assuming normal water level]. Therefore a complete blockage is expected. Any small gas leakage would have an insignificant affect on the wetwell pressurization.

In order to accurately simulate aerosol flow through open vacuum breaker valves in the ABWR, experiments should be conducted with ducts of less than 2 cm (0.79 in) in length. However, the trends of the experimental data do not suggest that the Vaughan plugging model is invalid for openings only slightly larger than 1 cm. Unfortunately, no definitive conclusions can be reached regarding the applicability limit without additional experimental data. For this reason, studies were performed with and without plugging for vacuum breaker bypass widths up to 1.6 cm (0.63 in) corresponding to an effective area of 75 cm^2 (11.6 in^2). This information is used to indicated the conservatisms which may exist in the analysis.

The opening of a stuck-open vacuum breaker is neither circular nor rectangular. Rather it is a crescent shape formed by two circular disks separating while remaining hinged at one point. The leak path width used for the Vaughan plugging model is conservatively assumed to be the maximum crack width. The length of opening is approximated as the effective area divided by the width. For vacuum breaker opening widths of up to 1 cm (0.39 in), corresponding to bypass effective areas of up to 46 cm^2 (7.1 in^2), use of the plugging model provides the best estimate of containment response. As discussed above, additional calculations were run for widths up to 1.6 cm (0.63 in).

19EE.3.2 Results

A series of bypass flow areas was analyzed using MAAP-ABWR for each of the assumed scenarios. A summary of the time and magnitude of fission product releases for each scenario is presented in Table 19EE-1. It was not necessary to run all of the variations in bypass area for each of the five scenarios for this analysis. Thus, Table 19EE-1 contains some blanks. The characteristics of each scenario is discussed below.

19EE.3.2.1 Late Suppression Pool Bypass with no Plugging

For the scenario 1 accident sequence, the passive flooder opens [based on the gas temperature in the lower drywell reaching 533 K (500°F)] at 5.5 hours. The pressure in the drywell decreases as cold water floods into the suppression pool from the lower drywell. Fifteen minutes later, the drywell starts to repressurize and the suppression pool bypass is presumed to begin. If there is no bypass leakage, the elapsed time before rupture disk opening and fission product release is about 20 hours. MAAP predicts that the time to rupture disk opening is not affected for effective vacuum breaker bypass areas of up to 5 cm^2 (0.78 in^2). As the effective area increases from 5 to 50 cm^2 (0.775 to 7.75 in^2), the time to rupture disk opening steadily decreases to about 10 hours. Above 50 cm^2 (7.75 in^2), the time asymptotically approaches 9 hours and remains at 9 hours even for a fully open vacuum breaker valve.

As expected, fission product releases are much higher for cases with bypass leakage than for the case without bypass leakage. For non-bypass cases, the release fraction of CsI at 72 hours is less than 1E-7. The release fractions of CsI at 24 and 72 hours approach asymptotes as the effective bypass area increases. For cases with effective areas greater than 400 cm^2, the 24 hour CsI release fractions are about 6% and the 72-hour release fractions are about 17%. Most of the releases occur late in the sequences as fission products revaporize from the vessel surfaces.

19EE.3.2.2 Pre-existing Suppression Pool Bypass with no Plugging

Bypass leakage was assumed to be present from the beginning of the accident sequence for the cases in scenario 2. As with the scenario 1 cases, the elapsed time before rupture disk opening is not affected by effective bypass areas smaller than 5 cm^2 (0.775 in^2). Unlike the scenario 1 cases, however, the elapsed time did not reach a 9-hour asymptote. Instead, the elapsed time continued to decrease to a value of 2.2 hours for a fully open vacuum breaker valve.

The 24- and 72-hour CsI release fractions asymptotically approached a maximum value for large effective areas. The CsI release fractions for the scenario 2 cases are very similar to those for the cases of scenario 1. The variations in release are caused by changes in revaporization behavior due the slight differences in thermal hydraulic performance.

19EE.3.2.3 Late Suppression Pool Bypass with Plugging

For the scenario 3 cases, bypass leakage was assumed to begin after the actuation of the passive flooder. Plugging of the vacuum breaker opening before the wetwell pressure reached the rupture disk setpoint was predicted for all widths below 1.25 cm. After the leak plugs, all flow from the drywell is directed through the drywell connecting vents into the suppression pool. There is then a period in which little steam is generated in the wetwell vapor space. The wetwell gas temperature decreases during this time due to condensation on the walls. This in turn causes the containment pressure to decrease for a short time. Steam generation in the drywell eventually causes the suppression pool to heat up and the containment pressure increases again. For cases with vacuum breaker opening widths up to 1 cm (0.39 in), the elapsed time to rupture disk actuation is about 20 hours, the same as for the case with no bypass leakage. MAAP-ABWR predicts CsI releases of less than 1E-7 at 72 hours for all of the opening widths less than 1 cm.

The maximum vacuum breaker opening width for which MAAP predicts that the leak path will plug before the rupture disk opens was determined to be 1.25 cm (0.49 in). Even if the rupture disk opens before an aerosol plug forms, reductions in source term can be observed. After the rupture disk opens, aerosols will continue to flow through the vacuum breaker opening and can eventually form a plug. This essentially terminates fission product release. The CsI release fractions at 72 hours for cases with late bypass and credit for aerosol plugging are significantly less than for the cases in which no plugging is assumed.

19EE.3.2.4 Pre-existing Suppression Pool Bypass with Plugging

The scenario 4 cases, in which suppression pool bypass flow was present from the beginning of the accident, show similar results to those of the scenario 3 cases. For cases with vacuum breaker opening widths up to 0.9 cm (0.35 in), the bypass leak plugged before the rupture disk opened and the elapsed time to fission product release was the same as the case with no bypass (about 20 hours). Also, the fission product release for these cases at 72 hours was less than 1E-7, as in the case with no bypass.

The case with an effective bypass area of 46 cm^2 (7.1 in^2), opening width of 1 cm (0.39 in), exhibited a different response. The mass of aerosol passing through the opening was not sufficient to plug the leak before the wetwell pressure reached 0.72 MPa and the rupture disk opened. However, the leak did plug about 30 minutes after the rupture disk opened which reduced the amount of fission products that was released to the environment. MAAP predicts a CsI release fraction of 0.04% at 72 hours for this case, which is about two orders of magnitude less than the corresponding case in which no plugging is assumed. The same behavior was observed for the slightly larger 50 cm^2 case.

19EE.3.2.5 Suppression Pool Bypass with Drywell Spray

The last scenario examined the effects of the drywell spray on cases with bypass leakage present from the beginning of the accident. The firewater addition system was used for these cases since its flow rate is smaller than the drywell spray function of the RHR system. Assuming the operator initiates the firewater spray within 2 hours of the start of the accident, the elapsed time to rupture disk opening can be delayed to nearly 30 hours. This time is comparable to the base case, LCLP-FS-R-N, with no bypass leakage (Subsection 19E.2.2.1).

The fission product releases for all bypass areas analyzed are on the same order of magnitude as the releases for the cases of scenarios 1 and 2 (with no plugging or firewater addition), but the elapsed time to release is much longer. The long times to release allow for a great deal of fission product decay which leads to a substantial reduction in risk as compared to cases in which the drywell spray is not actuated.

19EE.3.3 Conclusions of Deterministic Analysis

Suppression pool bypass can lead to a significant increase in fission product release. Releases can be on the order of 10% for a fully stuck-open vacuum breaker. For sequences in which the firewater addition system is used in spray mode, the time to release is not significantly affected by bypass. However, for sequences without sprays, the time from the beginning of the accident until the onset of the release can be significantly reduced. The use of the Morewitz blockage model results in a significant improvement in the calculated risk associated with suppression pool bypass. Nonetheless, there is a substantial increase in consequences associated with large bypass areas.

19EE.4 Summary of Results

19EE.4.1 Quantification of DET

The event tree is shown in Figure 19EE-1. The probabilities for different leakage areas are transferred to containment event trees.

19EE.4.2 Impact of Release Fractions

MAAP-ABWR predicts the release fraction of CsI for the LCLP case without bypass leakage is less than 1E-7. The effect of leakage on the CsI release fraction (f) is shown below.

Amount of Leakage	Release Fraction of CsI
None	f < 1E-7
Small	1% < f < 10%
Large	f > 10%

19EE.4.3 Impact on Time to Rupture Disk Opening

The sensitivity study contained in Subsection 19EE.3 focused on the Loss of all core Cooling with vessel failure occurring at Low Pressure (LCLP) accident sequence. This is the dominant sequence and its response to suppression pool bypass should be typical of the other accident sequences.

Without suppression pool bypass, rupture disk opening is predicted to occur at approximately 20 hours into the accident for cases with passive flooder operation. The effect of leakage on time to rupture disk opening, *t*, is summarized below.

Amount of Leakage	Time to Rupture Disk Opening
None	~20 hours
Small	6 < *t* < 16 hours
Large	*t* < 6 hours

19EE.4.4 Not Used

19EE.5 Conclusions

Suppression pool bypass (the passage of gas and vapor from the drywell directly into the wetwell air space) can lead to increased fission product releases. As shown in Subsection 19E.2.3.3.3(4), the only mode of suppression pool bypass that has the possibility of significantly increasing risk is vacuum breaker leakage. This attachment determined the probabilities and consequences for vacuum breaker leakage areas from zero to that corresponding to one vacuum breaker stuck fully open.

Fission product release fractions were determined with MAAP-ABWR using the dominant accident sequence [Loss of all core Cooling with vessel failure occurring a Low Pressure (LCLP)] modified to include a path between the drywell and the wetwell air space. Plugging of leakage paths by fission products was considered for small pathways. Leakage probabilities were determined by reviewing recent operating experience of wetwell to drywell vacuum breakers in BWRs with Mark I, II and III containments.

Suppression pool bypass does not significantly add to the risk associated with the ABWR because the bypass areas resulting in increased releases are offset by low probabilities of occurrence. No leakage and, correspondingly, no impact on plant risk is expected to occur for almost all of the accident demands. Small amounts of leakage have a small probability, and can result in medium volatile fission product releases (one to 10% of initial inventory). Volatile fission product releases on the order of 10–20% of initial inventory can result when large amounts of suppression pool bypass are present. However, the impact on plant risk is still negligible because the probability of large leakage is very small.

19EE.6 References

19EE-1 Vaughan, E.U., “Simple Model for Plugging of Ducts by Aerosol Deposits”, Trans. Am. Nuclear. Soc., 28, 507, 1978.

19EE-2 “Technical Support for Issue Resolution”, IDCOR Technical Report 85.2, July 1985.

19EE-3 Morewitz, H.A, “Leakage of Aerosols from Containment Buildings”, Health Physics, Vol. 42, No. 2, 1982, pp. 195-207.

19EE-4 “Handbook of Chemistry and Physics”, 53rd Edition, CRC Press, 1972-1973.

19EE-5 "ABWR Severe Accident Evaluations," Toshiba UTLR-0014.

Table 19EE-1 Summary of Volatile Fission Product Releases for Severe Accidents with Suppression Pool Bypass Leakage through Vacuum Breaker Valves

Eff. Area (cm^2)	0	5	20	41	46	50	58	75	100	400	2030
Leak Width (cm)	0	0.11	0.44	0.90	1.00	1.09	1.25	1.63	2.17	8.70	*
Scenario	**Time to Fission Product Release (h)**										
1	19.9	19.8	15.4	*	*	9.9	*	9.1	9.1	9.0	9.0
2	19.9	20.0	13.1	*	*	5.5	*	4.0	3.5	2.7	2.2
3	19.9	20.2	20.2	*	*	20.3	20.4	9.2	†	†	†
4	19.9	20.2	20.2	20.4	5.9	5.6	*	*	†	†	†
5	31.1	*	*	*	*	29.7	*	*	*	*	28.9
Scenario	**CsI Release Fraction at 72 Hours**										
1	< 1E-7	0.38%	1.6%	*	*	3.6%	*	6.3%	8.5%	18%	17%
2	< 1E-7	0.55%	1.7%	*	*	4.2%	*	6.5%	8.5%	16%	18%
3	< 1E-7	< 1E-7	< 1E-7	*	*	< 1E-7	< 1E-7	0.06%	†	†	†
4	< 1E-7	< 1E-7	< 1E-7	< 1E-7	0.04%	0.06%	*	*	†	†	†
5	< 1E-7	*	*	*	*	4.8%	*	*	*	*	14%

* Not calculated

† Plugging presumed to be ineffective

Table 19EE-2 Not Used

Figure 19EE-1 Containment Event Evaluation DET for Suppression Pool Bypass

Not Part of DCD (Refer to Reference 19EE-5)

Figure 19EE-2 Not Used