GE Nuclear Energy

ABWR

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Subject Bypass Leakage

Message

ABWR CONTAINMENT STEAM BYPASS CAPABILITY

BACKGROUND

Currently, a steam bypass leakage capability ($A/K^{(1/2)}$) of 0.05 ft^2 is specified for the ABWR design. And consistent with the SRP requirements, the ABWR Technical Specifications will define and require that maximum leakage during periodic leakage rate tests shall be less than 10% of the design maximum bypass leakage capability.

During the October '91 and December '91 meetings with the staff in San Jose, GE described and explained the basis for specifying an allowable steam bypass leakage capability of 0.05 ft^2 for the ABWR design. The staff understood and recognized the basis of the currently defined bypass capacity of 0.05 ft^2. However, the staff requested GE to confirm that 0.05 ft^2 is not at the high point of cliff, considering a full spectrum of primary system break sizes.

GE, in response to this staff's request, undertook a task to perform sensitivity study evaluating steam bypass leakage capability over a full spectrum of pipe breaks and confirm that 0.05 ft^2 is not the high point of cliff. Additional objectives of this sensitivity study were to assess feasibility of achieving leakage capability greater than 0.05 ft^2 at both the containment design pressure as well as the overpressure protection set point values.

The following paragraphs describe and discuss results from this sensitivity study.

STEAM BYPASS LEAKAGE

If a direct leakage path were to exist between the drywell and the wetwell airspace during a loss-of-coolant accident (LOCA) event, the leaking steam bypassing the wetwell suppression pool would produce rapid pressurization of the wetwell airspace. To mitigate the consequences of any steam which bypasses the suppression pool, the ABWR design provides safety grade drywell and wetwell spray systems. Emergency Procedure Guidelines (EPGs) defining operator actions for controlling containment pressure, as necessary, have specified for the ABWR design.

For a given primary system break area, the maximum allowable leakage capacity can be determined when the containment pressure reaches the design pressure at the end of reactor blowdown. The most limiting conditions would occur for those primary system break sizes which do not cause rapid reactor depressurization enabling low pressure ECCS systems to start providing reactor vessel inventory makeup.

1. ABWR DESIGN FEATURES

A. ECCS Configuration

The ABWR ECCS design configuration, as a minimum, comprises of the following:

1 Reactor Core Isolation Cooling (RCIC) Loop
2 High Pressure Core Flooder (HPCF) Loops
3 Low Pressure Flooder (LPFL) mode of Residual Heat Removal (RHR) Loops. Two loops (RHR(B) and RHR(C)) have provision to operate in drywell/wetwell spray mode to remove heat from the

containment.

1 Automatic Depressurization system (ADS)
(Independent of any other ECCS)

The ECCS is separated into three independent functional divisions as follow:

Division A:	RCIC + 1 RHR(LPFL)	(RHR injects into FWL)
Division B:	1 HPCF + 1 RHR(LPFL/Spray	(Separate RHR injection nozzle)
Division C:	1 HPCF + 1 RHR(LPFL/Spray)	(Separate RHR injection nozzle)

In the event of a break in a pipe that is not part of the ECCS and allowing for single active component failure, the available combination of ECCS equipment shall be as follow:

(a) One HPCF + RCIC + two LPFL + all ADS valves; or
(b) Two HPCF + three LPFL + all ADS valves; or
(c) Two HPCF + RCIC + three LPFL + all ADS valves minus one

In the event of a break in a pipe that is a part of ECCS, and allowing for a single active component failure, the combination of ECCS equipment available shall be the ECCS equipment listed above minus the ECCS in which the break is assumed.

B. Emergency Procedure Guidelines

Emergency Procedure Guidelines (EPGs) defining operator actions to control containment pressure under LOCA conditions have been specified for the ABWR design in Chapter 18 of the SSAR. These guidelines specify operator actions and the conditions under which those actions can be undertaken, if that becomes necessary to control containment pressure under LOCA conditions. These actions, which are primarily symptom oriented, include actuation of drywell/wetwell sprays and emergency depressurization of the reactor pressure vessel, as shown in Figure 1. The ABWR design has provision for initiating drywell/wetwell sprays independent of RHR system by using Firewater Addition System.

C. Drywell/Wetwell Sprays

In the current design, each RHR pump has a rated flow capacity of 4200 gpm. When operating in spray mode the pump flow is split between the wetwell and drywell sprays. The ABWR design limits wetwell spray sparger flow to 500 gpm and drywell sparger flow to 3700 gpm. The pump maximum runout flow is 5000 gpm.

2. ANALYSES

Engineering analyses to evaluate steam bypass capability of the ABWR design were performed using approved engineering computer program. Steam bypass capability at both the containment design pressure value as well as the overpressure protection set point value was evaluated.

A full spectrum of primary system break sizes (0.01 through 1.0 ft^2) was considered and evaluated, including both steam and liquid breaks. It is to be noted that 1.0 ft^2 is the largest primary system break area for the ABWR design. Operator actions, as permissible by the EPGs, were factored into these analyses. These actions included actuation of wetwell sprays (when wetwell airspace pressure reaches 0.728 kg/cm^2 g or 25 psia) and emergency depressurization of the reactor pressure vessel (when wetwell airspace pressure reaches 1.54.kg/cm^2 g or 36.6 psia), see Figure 1. For each case analyzed, available ECCS combination was determined considering a worst single active component failure.

Heat loss at the upper drywell and wetwell airspace concrete walls was modeled in the analysis. Heat loss at the lower drywell walls and suppression pool boundary walls was neglected.

A minimum time delay of 800 seconds for actuation of wetwell spray was assumed. Drywell sprays were not considered and modeled, because the calculated LOCA conditions in the drywell happened to be outside the EPGs specified drywell spray initiation range.

3. RESULTS

3.1 Containment Design Bypass Capability

Analyses were performed to determine maximum allowable leakage capacity of the ABWR design. For a given primary system break area, the maximum allowable leakage capacity is determined when the containment pressure remains below the design pressure (60 psia) at the end of blowdown. These analyses considered and evaluated breaks in Feedwater line, in Main steam line, in LPFL injection line, and in HPCF injection line.

Results from these analyses which were performed to determine the allowable leakage between the drywell and the wetwell airspace during a primary system pipe break are shown in Figure 2. These results show the allowable leakage capacity ($A/K^{(1/2)}$) as a function of primary system break area. A is the actual area of the leakage flow path and K is the total geometric loss coefficient associated with the leakage flow path.

As seen from Figure ..., the maximum allowable leakage capacity is at $A/K^{(1/2)} = 0.1$ ft^2. Since a typical geometric loss factor would be 3 or greater, the maximum allowable leakage flow path area would be

$0.173\ ft^2$.

3.2 Containment Bypass Capability At Rupture Disc Set Point

The maximum allowable leakage capacity is determined when for a given primary system break area the containment pressure remains below the rupture disc set point pressure (105 psia). Both liquid and steam breaks were considered and analyzed. A maximum allowable leakage capacity at $A/K^{(1/2)} = 0.35\ ft^2$ was determined. Taking a value of 3 or greater for K, the maximum allowable leakage path area would be 0.6 ft^2.

STEAM BYPASS CAPABILITY INCREASE

Various alternatives which would assist in increasing the current bypass capability limit were assessed for their merit and demerit. The alternatives which were assessed are:

Alternative A: Vessel Cooldown Rate Greater Than 100°F/h

Alternative B: Single vs Two Valves in Series per Penetration

Alternative C: Increasing DW/WW Spray Capacities

Alternative D: Less Restrictive DW Spray initiation range

Alternative A was considered and factored into the sensitivity study described above. Vessel cooldown rates ranging from 100°F/h to full ADS actuation were modeled and analyzed.

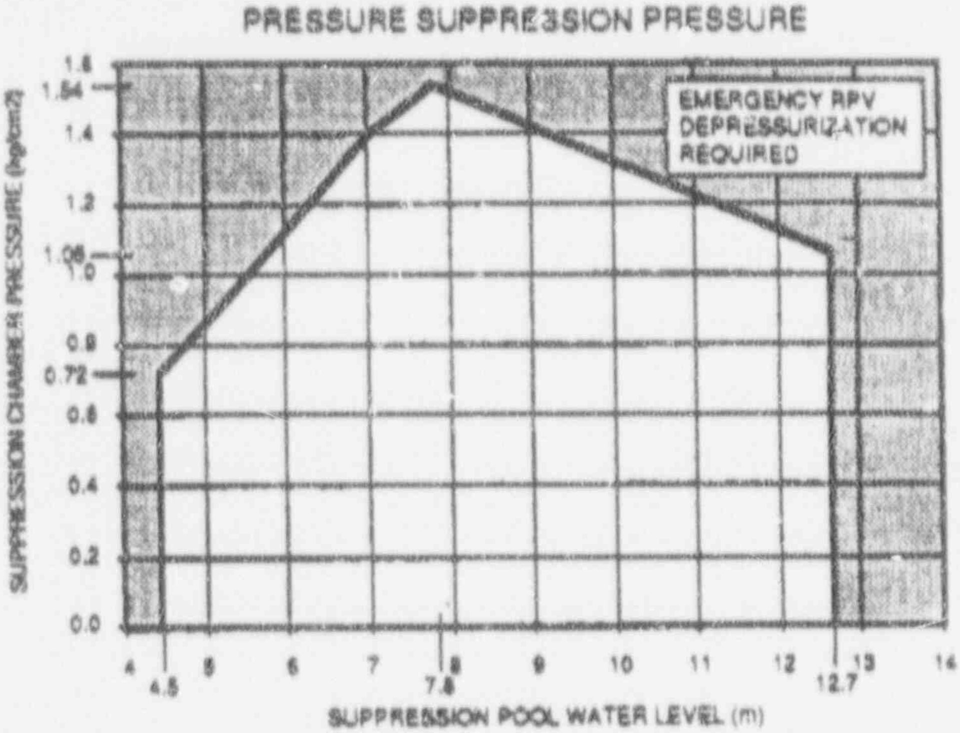
Alternative B was assessed for its merit and demerit for increasing the bypass capability. It is believed that two (simple check) valves in series are not expected to provide any significant improvement in the leakage area when compared to that with a single (simple check) valve. On the other hand, two valves in series will make valve inspection and maintenance routine more time consuming which would have significant impact on plant outage schedule and plant maintenance cost.

Alternative C which would result in more steam quenching capacity, obviously, will be helpful in improving the ABWR steam bypass capability. It was determined that a sizeable upgrading of the current RHR design hardware will be necessary, in order for achieving any substantial increase in the DW/WW spray capacities.

Alternative D was judged to have a strong potential for providing a substantial increase in the steam bypass leakage capability with very minimum, or no impact, on the current ABWR RHR hardware design. The DW spray initiation region currently defined in the EPGs is based on somewhat overly conservative initial conditions and assumptions. It appeared feasible to make the current DW spray initiation region less restrictive, by reviewing and eliminating any undue conservatism. This alternative could be further evaluated for its effectiveness in increasing the bypass leakage capability, if that becomes desirable.

CONCLUSION

The sensitivity study results presented and discussed above demonstrate that the currently specified bypass leakage capability of 0.05 ft^2 is not at the high point of cliff, and there is substantial margin in the ABWR design steam bypass capability.


PRESSURE SUPPRESSION PRESSURE
EMERGENCY RPV DEPRESSURIZATION REQUIRED
SUPPRESSION CHAMBER PRESSURE (kg/cm2)
1.6
1.54
1.4
1.2
1.06
1.0
0.8
0.72
0.6
0.4
0.2
0.0
4
4.5
5
6
7
7.8
8
9
10
11
12
12.7
13
14
SUPPRESSION POOL WATER LEVEL (m)

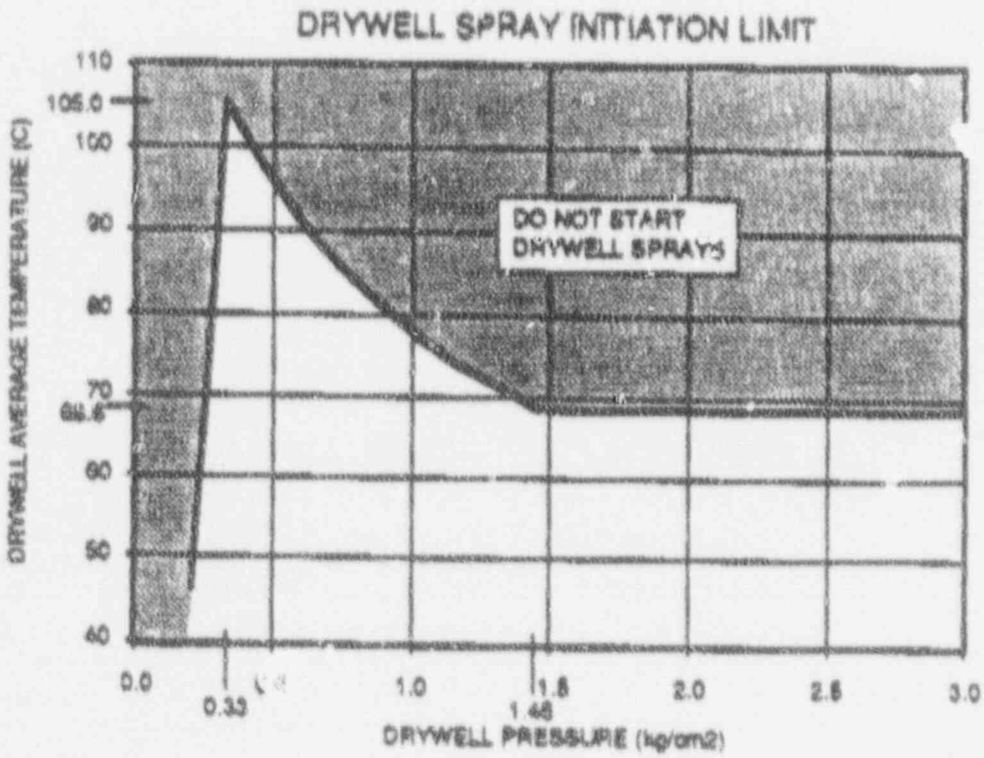

DRYWELL SPRAY INITIATION LIMIT
DO NOT START DRYWELL SPRAYS
DRYWELL AVERAGE TEMPERATURE (C)
110
105.0
100
90
80
70
60
50
40
0.0
0.33
1.0
1.5
1.46
2.0
2.5
3.0
DRYWELL PRESSURE (kg/cm2)

Figure 1

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ALLOWABLE STEAM BYPASS LEAKAGE CAPACITY

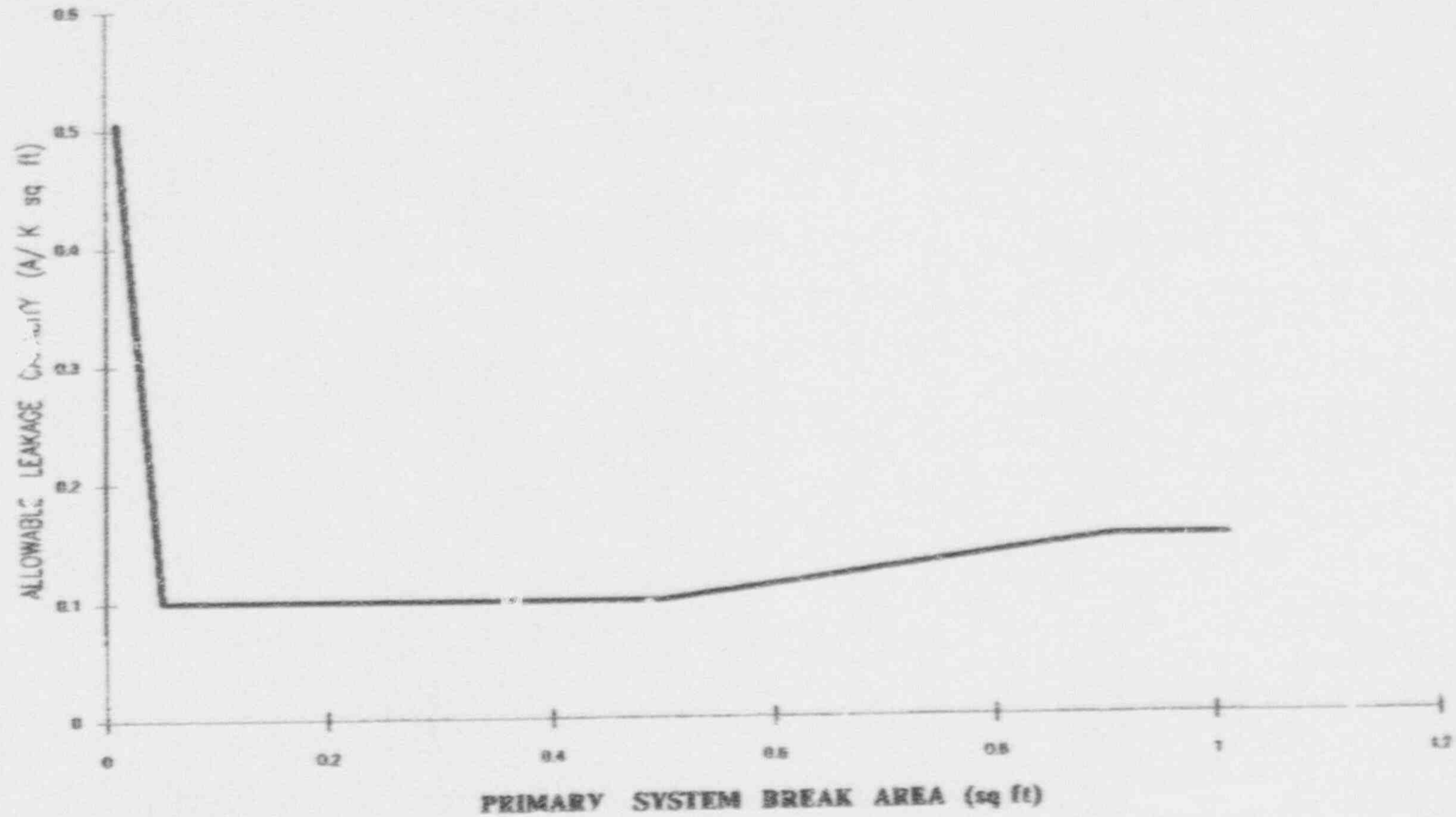

Figure 2