GE Nuclear Energy

May 26, 1994

Docket No. 52-001

Tom Boyce, Senior Project Manager
Standardization Project Directorate
Associate Directorate for Advanced Reactors
and License Renewal
Office of the Nuclear Reactor Regulation

Subject: Submittal Supporting Accelerated ABWR Schedule - **ABWR Containment Sprays**

References: Letter, R. W. Borchardt to Joseph Quirk, Remaining Actions on the Advanced Boiling Water Reactor (ABWR), May 13, 1994

Dear Tom:

In response to the Reference Letter, we have performed additional analyses to assess the impact of drywell spray actuation following a LOCA to ensure that the bounding scenario was evaluated. In addition, we have re-assessed the drywell spray initiation limit curve and have determined the impact of drywell spray actuation on the differential pressure capability of the containment. Results of these analyses show no adverse impact of the drywell spray actuation on the differential pressure capability of the containment.

Please provide a copy of this transmittal to John Monninger.

Sincerely,

Jack Fox

Jack Fox
Advanced Reactor Programs

cc:	Alan Beard	(GE)
	Norman Fletcher	(DOE)
	Joe Quirk	(GE)
	Umesh Saxena	(GE)
	Cal Tang	(GE)

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ABWR CONTAINMENT SPRAYS

Reference: Letter, 5/13/94, Borchardt (NRC) to Quirk (GE): REMAINING ACTIONS ON THE ADVANCED BOILING WATER REACTOR (ABWR) REVIEW

INTRODUCTION

Two of the RHR loops in the ABWR design provide containment spray cooling subsystems. In the normal, or the preferred, mode of operation drywell (DW) and wetwell (WW) sprays actuate simultaneously. In addition, the system design allows for independent operation of wetwell or drywell sprays through a series of operator actions. Compared to simultaneous actuation of drywell and wetwell sprays, independent actuation of drywell spray only will result in somewhat higher drywell depressurization. In view that independent actuation of drywell spray (and no wetwell spray) will require series of operator actions, independent actuation of drywell spray is intended for surveillance testing of system equipment such as pumps and valves.

After reviewing SSAR Amendment 34 (Reference letter), Staff has requested GE to consider and assess the impact of drywell spray actuation on the SSAR containment depressurization analyses. It is perceived that actuation of drywell spray only may result in undesirable negative DW to WW and DW/WW to RB differential pressure results. The two analyses identified for further assessment in reference letter are:

1. Sizing of the WW to DW vacuum breakers (in SSAR Section 6.2.1).
2. Drywell Spray Initiation Limit (DSIL) curve (in SSAR Section 18A).

In response to staff request, additional analyses were performed to assess the impact of drywell spray actuation on these two analyses. Though a very low probability event, it is postulated that upon start of the preferred mode of containment spray operation wetwell spray injection valve failed to open resulting in actuation of drywell spray only and no wetwell spray.

ANALYSES

1. Sizing of the WW to DW vacuum Breakers

A. SSAR Analysis

The primary requirement for the sizing basis of the wetwell-to-drywell vacuum breaker system (WDVBS) is to limit the drywell-to-wetwell negative pressure differential below its allowable value during the drywell depressurization events. The drywell depressurization is primarily caused by two major events:

1. post-LOCA ECCS flow
2. inadvertent actuation of DW/WW sprays.

Following the break of a FWL, the drywell air is purged into the wetwell air space leaving the drywell full of steam. Subsequent condensation of this steam by cold ECCS flow out of the break results in depressurization of the drywell. Likewise, actuation of DW/WW sprays will condense the steam in the drywell resulting in depressurization of the drywell. A higher and colder flow into the drywell will result in higher depressurization in the drywell.

The sizing of the WDVBS was determined and based on the post-LOCA ECCS flow event. As a conservative assumption, a maximum combination of ECCS (HPCF/LPFL/RCIC) flow of 2,642 lb/sec (4,316 m^3/hr), at CST temperature of 60 °F, was assumed in the sizing analysis. This assumption of ECCS flow into the drywell at 60 °F is excessively conservative since it neglects heating of the ECCS flow inside the vessel before it flows out of the break. In contrast, drywell/wetwell spray (maximum flow rate of 584 lb/sec or 950 m^3/hr) should be expected to result in substantially much lower drywell depressurization.

In calculating the drywell depressurization, 100% of the ECCS break flow was mixed with the drywell atmosphere. This assumption of 100% mixing of the ECCS flow will result in conservative depressurization effect, considering that in reality a portion of the ECCS flow will fall directly on to the floor without mixing with the drywell steam. The gravity settling of the ECCS flow was mechanistically calculated. As reported in SSAR, the design-calculated sizing of the WDVBS (an effective flow area of ≥8.3 ft^2 or 0.77 m^2) limited the negative pressure differential values below the design value of 2.0 psid. The drywell-to-wetwell maximum negative pressure differential was calculated to be 1.4 psid, and the drywell/wetwell-to-reactor building negative differential was calculated to be 0.85 psid.

B. Additional Evaluation

An additional study was performed to evaluate the impact of the drywell spray following a LOCA on drywell-to-wetwell negative pressure differential. For comparison purpose with the drywell spray case, the ECCS break flow was re analyzed and modeled as spray flow. The gravity settling of spray flow was mechanistically calculated. Assuming a spray efficiency of 100% (a conservative assumption) and a CST temperature of 60 °F, the ECCS flow of 2,642 lb/sec produced drywell-to-wetwell maximum negative pressure differential of about 1.72 psid. For the purpose of sensitivity study only, a CST temperature of 40 °F resulted in a maximum negative pressure differential of about 1.84 psid.

For the purpose of this analysis, drywell spray flow rate of 612 lb/sec (1,000 m^3/hr) was assumed, instead of the maximum expected flow rate of 584 lb/sec, for an added conservatism. In addition, a constant spray temperature of 40 °F was assumed for additional conservatism. Analysis results showed a maximum negative pressure differential of about 0.52 psid, which is substantially lower than that produced by the ECCS break flow case. These results suggest no adverse impact of drywell spray actuation following a LOCA.

C. Conclusion

The drywell-to-wetwell negative pressure differential is limited by the conservative analysis based on the full ECCS flow out of the break. The drywell spray following a LOCA will have no adverse impact on the WDVBS sizing analysis.

2. DSIL Curve of the EPGs

Additional analyses were performed to evaluate the impact of drywell spray actuation on the Drywell Spray Initiation Limit (DSIL) curve of the EPGs contained in SSAR Amendment 34, Appendix 18A. A range of drywell and wetwell initial conditions pertaining to the DSIL curve were analyzed. The allowable negative pressure differential is 3.0 psid to preclude failure of the containment liner.

A. Analysis Description

It is postulated that upon start of the RHR subsystem in its preferred spray mode wetwell spray injection valve failed to open. This would lead to and result in actuation of drywell spray only. A summary description of initial conditions for this analysis and their basis are shown in Exhibit A. The key modeling assumptions are described as below:

a. A constant spray flow rate of 612 lb/sec (1,000 m^3/hr) is ascumed. Considering that the RHR pump maximum flow rate is 584 lb/sec (954 m^3/hr), this assumption of drywell spray flow rate of 612 lb/sec provides additional margin in the analysis.

b. Spray efficiency of 100%. This implies instantaneous heating of the spray flow to the drywell temperature condition.

c. Assume a total of six (6) wetwell-to-drywell vacuum breakers are operable. This allows for one single failure and one out of service. This is a conservative assumption since failure of one vacuum breaker will require a plant shutdown within 72 hours by Tech. Specs.

d. A constant spray temperature of 60 °F.

e. Vacuum breakers are full open at a wetwell-to-drywell pressure differential of 0.5 psid.

f. Structural heat sinks in the drywell and wetwell are ignored for conservatism.

g. Heat and mass interaction between suppression pool and the wetwell airspace are ignored.

B. Analysis Calculations

The pressure/temperature state conditions which were evaluated are shown in Exhibit B. In order to cover a broader range of state conditions, some cases happened to have non-mechanistically higher than the nominal mass of total noncondensibles. For the purpose of sensitivity study only, a few cases were analyzed assuming a constant spray temperature of 40 °F.

The wetwell-to-drywell maximum negative pressure differential was determined by taking the difference of the drywell and wetwell pressure values calculated by the code. The drywell/wetwell-to-reactor building negative pressure differential was determined through end-point calculation. In the long term the drywell and wetwell will come to common pressure and temperature equilibrium conditions. At equilibrium condition, the drywell and wetwell atmosphere will be saturated air at the spray temperature. The end-point equilibrium pressure, P_e, will be given by the sum of partial pressures of air and water vapor. That is,

$$P_e = P_a + P_v$$

P_a = $(M_t \times R \times T_e)/(V_t)$, and
P_v = saturation vapor pressure at T_e.
M_t = combined sum of drywell and wetwell noncondensibles
R = specific gas constant
T_e = end-point equilibrium temperature, equal to spray temperature
V_t = combined volume of drywell and wetwell air space

Example:

Let M_t = 32,600 lb_m,
T_e = 500 °R (i.e., 40 °F spray temperature)
V_t = 470,060 ft^3
R_{air} = 53.3 $ft\text{-}lb_f/lb_m\text{-}°R$

For these given values, the final equilibrium pressure in both drywell and the wetwell air space is

$$P_e = 12.84 + 0.1216 = 12.96 \text{ psia.}$$

Assuming the reactor building (RB) pressure of 14.7 psia, the DW/WW-to-RB negative pressure differential is given by

$$\Delta P = 12.96 - 14.7 = -1.74 \text{ psid.}$$

C. Analysis Results

The analysis results for the cases evaluated are summarized and presented in Exhibit C. These results show that the negative pressure differentials due to the drywell spray actuation will remain below the allowable value of -3.0 psid for the state conditions in the spray region of the DSIL curve (see Exhibit B).

D. Conclusion

The results presented in Exhibit C show no adverse impact of drywell spray actuation on the differential pressure capability of the containment. Based on our evaluation of these results, we conclude that there are no limitations for initiation of containment sprays from conditions on the right region of the DSIL curve of the EPGs given in SSAR Amendment 34. Further, we believe that the pressure/temperature conditions analyzed in this evaluation study are representative of and bound the entire range of pressure/temperature conditions expected on the right region of the DSIL curve.

CONCLUSION

Additional analyses were performed assessing the impact of drywell spray actuation on wetwell-to-drywell negative pressure differential and the DSIL curve of the EPGs as given in SSAR Amendment 34. Results from these analyses show no adverse impact of the drywell spray actuation on the differential pressure capability of the containment.

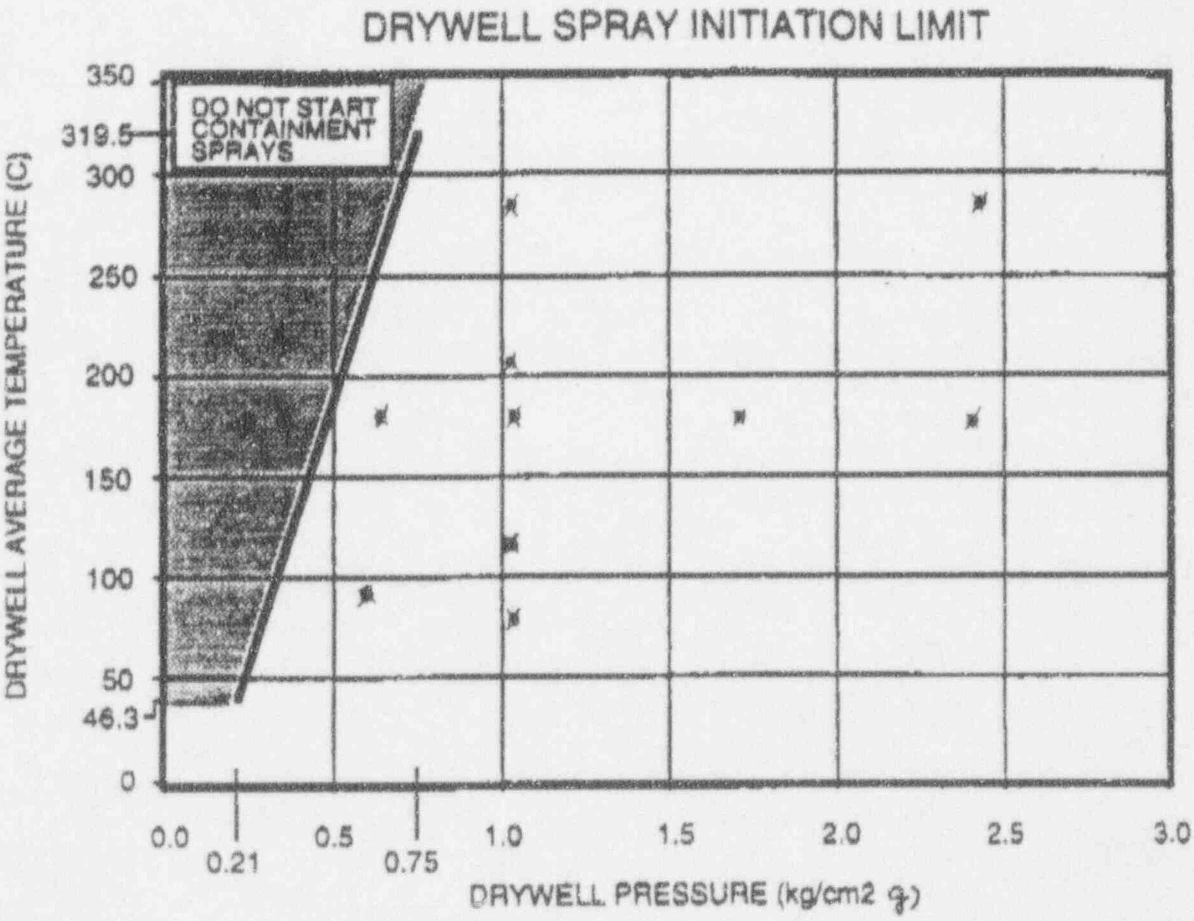
Initial Conditions for ABWR-Specific Drywell Spray Analysis

Item	EPG Assumption	ABWR Assumption	Basis
Spray temperature	40°F	60°F	Lowest reasonably achievable
Drywell humidity	0 %	approaching 0%	SHEX code will not perform calculations at 0% RH in the drywell
Drywell temperature	545°F	340°F	ADS qualification temperature; Sprays are initiated prior to reaching this temperature in Step DW/T-2
Drywell pressure range	0 to 20 psig	3 Points: 5, 10, and 15 psig	To address reasonable range of conditions
Drywell noncondensible mass	Entire mass from both drywell and wetwell	Mass that is predicted by Ideal Gas Law for the drywell volume, pressure, and temperature	Consistent with a mechanistic calculation

Wetwell humidity	Not considered	100%	Wetwell typically has a high relative humidity; consistent with mechanistic calculation
Wetwell temperature	Not considered	80°F and 280°F	Low temperature minimizes the wetwell depressurization rate, High temperature (taken from the low pressure endpoint of the HCTL) minimizes the mitigative effect of the wetwell-to-drywell vacuum breakers
Wetwell pressure range	Same as drywell pressure	Same as drywell pressure	Same
Wetwell-drywell ΔP	0 psid	0 psid	Same
Vacuum breaker operability	None until airspace saturated, then sufficient number (unspecified) to mitigate any further pressure decrease	One out of service	Consistent with Tech Spec requirements and mechanistic analysis
Spray efficiency	Instantaneous airspace saturation	100% spray efficiency	Maximize the depressurization rate for a mechanistic analysis

EXHIBIT A

EXHIBIT B



DRYWELL SPRAY INITIATION LIMIT
DO NOT START CONTAINMENT SPRAYS
DRYWELL AVERAGE TEMPERATURE (C)
350
319.5
300
250
200
150
100
50
46.3
0
0.0
0.21
0.5
0.75
1.0
1.5
2.0
2.5
3.0
DRYWELL PRESSURE (kg/cm2 g)

ABWR - SPECIFIC DRYWELL SPRAY ANALYSIS
INITIAL CONDITIONS AND SUMMARY RESULTS

Key Modeling Assumptions:

a. Spray efficiency of 100%
b. DW spray flow rate of 1,000 m^3/h (No WW Spray)
c. Spray temperature of 60 °F
d. WW-DW VBs operable, with one out of service

Containment Negative Differential Pressure Capability, ΔP = - 3.0 psid

Case #	DW Temp. (°F)	DW Rel. Humidity	DW Pressure (psia)	WW Temp. (°F)	WW Rel. Humidity	WW Pressure (psia)	DW/WW to RB $\Delta P^{(2)}$ (psid)	DW-WW ΔP (psid)	Drywell Air Mass (lb)	Wetwell Air Mass (lb)	Total Air Mass (lb)
1(4)	340.0	0.005(1)	15.0	80.0	1.0	15.0	-3.08	-2.00	12,490	15,380	27,870
2(4)	340.0	0.005	20.0	80.0	1.0	20.0	+0.87	-2.15	16,820	20,690	37,510
3.	340.0	0.005	25.0	80.0	1.0	25.0	+4.78	-2.25	21,150	25,990	47,140
4.	340.0	0.005	30.0	80.0	1.0	30.0	+9.62	-2.25	25,490	31,300	59,000
5(4)	340.0	0.005	15.0	200.0	1.0	15.0	-5.19	-1.75	12,490	3,020	15,510
6(4)	340.0	0.005	20.0	200.0	1.0	20.0	-4.58	-1.87	16,820	7,360	24,180
7.	340.0	0.005	30.0	200.0	1.0	30.0	+2.50	-1.99	25,490	16,040	41,530
8.	340.0	0.005	50.0	280.0	1.0	50.0	+3.27	-1.48	42,820	620	43,440
9(3)(4)	340.0	0.005	15.0	80.0	1.0	15.0	-3.[illegible]1	-2.20	14,380	13,480	27,860
10.	550.0	0.005	30.0	80.0	1.0	30.0	+5.33	-2.57	17,000	31,300	48,300
11.	400.0	0.005	30.0	80.0	1.0	30.0	+7.87	-2.45	23,190	31,300	54,490
12(3)	340.0	0.205	30.0	130.0	0.92	30.0	-1.70	-1.75	5,550	27,170	32,720
13.	550.0	0.048	50.0	205.0	1.0	50.0	-1.27	-2.48	90	32,080	32,170
14(3)	550.0	0.048	50.0	205.0	1.0	50.0	-1.91	-2.68	90	32,080	32,170
15	340.0	0.205	30.0	130.0	0.92	30.0	-1.56	-1.7	5,550	27,170	32,720
16(3)	170.0	0.118	30.0	250.0	1.0	30.0	-1.83	-0.55	32,240	140	32,380
17(3)	340.0	0.011	40.0	267.0	1.0	40.0	-1.37	-1.73	33,540	0	33,540
18(3)	550.0	0.003	50.0	280.0	1.0	50.0	-1.67	-2.50	32,170	620	32,790
19(3)	340.0	0.101	50.0	200.0	1.0	50.0	+11.61	-1.86	33,110	33,400	66,150
20	340.0	0.001	20.0	80.0	1.0	20.0	+1.08	-2.20	17,230	20,680	37,910
21(3)	250.0	1.0	30.0	80.0	0.396	30.0	-2.06	-0.50	170	31,620	31,790
22	170.0	0.118	30.0	250.0	1.0	30.0	-1.19	-0.50	32,240	140	32,380

(1) Code requires a minimum non-zero value (2) End-point equil. pressure at spray temperature. (3) Spray temperature of 40 °F
(4) State conditions lie in NO-SPRAY region

EXHIBIT C