Enclosure 2

MFN 16-001, Revision 1, Supplement 2

ABWR COPS Redesign - ABWR DCD Revision 6 Markups

reducing the entrance velocity on the hemisphere to 49/2 = 24.5 m/s (81 fps). The acoustic equation,

$$\delta P_0 = \frac{\rho C \delta V}{g0} \qquad (19E.2\text{-}41e)$$

can be employed to show that the corresponding decompression disturbance is δP_0 = 61.4 kPa (8.9 psid).

19E.2.3.5.1.4 Expansion Into Airspace

The acoustic decompression wave propagation is governed by the spherical wave ~~Equation 19E.2–41b~~,

Reference 19E.2-38

$$\frac{\partial^2 P}{\partial t^2} - \frac{C^2}{r^2}\frac{\partial}{\partial r}\left(r^2 \frac{\partial P}{\partial r}\right) = 0 \qquad (19E.2\text{-}41f)$$

with the boundary and initial conditions at r = R of

$$P = P_0 - \delta P_0 \qquad (19E.2\text{-}41g)$$

a boundary condition as r approaches infinity of

$$P = P_0 \qquad (19E.2\text{-}41h)$$

and initial conditions at t = 0 of

$$P = P_0 \qquad (19E.2\text{-}41i)$$

Ct/R - (r-R)/R

$$\frac{\partial P}{\partial r} = 0 \qquad (19E.2\text{-}41j)$$

A solution for the outgoing decompression wave is given by

$$\frac{\delta P}{\delta P_0} = \frac{R}{r} e^{-(Ct/r - r/R + 1)} H_s\left(t - \frac{r - R}{C}\right) \qquad (19E.2\text{-}41k)$$

where H_s is the Heaviside step function, which is zero for negative arguments, and 1.0 for positive arguments. A pressure disturbance in the airspace will travel from r = R to another r at the acoustic speed C, which requires a time (r - R)/C. When it does arrive, H_s is 1.0, and the arriving magnitude is

$$\delta P = \frac{R}{r}\delta P_0$$

6.2.5.2.1

containment (see Item (3) Shutdown-Deinerting below this subsection). The system has the following features:

(1) Atmospheric mixing is achieved by natural processes. Mixing will be enhanced by operation of the containment sprays, which are used to control pressure in the primary containment.

(2) The ACS primary containment nitrogen makeup maintains an oxygen-deficient atmosphere (≤3.5% by volume) in the primary containment during normal operation.

(3) The redundant oxygen analyzer system (CAMS) measures oxygen in the drywell and suppression chamber. Oxygen concentrations are displayed in the main control room. Description of safety-related display instrumentation for containment monitoring is provided in Chapter 7. Electrical requirements for equipment associated with the combustible gas control system are in accordance with the appropriate IEEE standards as referenced in Chapter 7.

In addition, the ACS provides overpressure protection to relieve containment pressure, as required, through a pathway from the wetwell airspace to the stack. The pathway is isolated during normal operation by a rupture disk.

The following modes of ACS operation are provided:

(1) **Startup**—Inerting: Liquid nitrogen is vaporized with steam or electric heaters to a temperature greater than -7°C and is injected into the wetwell and the drywell. The nitrogen will be mixed with the primary containment atmosphere by the drywell coolers in the drywell and, if necessary, by the sprays in the wetwell.

(2) **Normal**—Maintenance of Inert Condition: A nitrogen makeup system automatically supplies nitrogen to the wetwell and upper drywell to maintain a slightly positive pressure in the drywell and wetwell to preclude air leakage from the secondary to the primary containment. An increase in containment pressure is controlled by venting through the drywell bleed line.

(3) **Shutdown**—Deinerting: Air is provided to the drywell and wetwell by the Reactor Building HVAC purge supply fan. Exhaust is through the drywell and wetwell exhaust lines to the plant vent, through the HVAC or SGTS, as required. During shutdown, purge air provides containment access ventilation.

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(4) Overpressure Protection: If the wetwell pressure increases to about 617.8 kPaG(Subsection 19E.2.8.1), the rupture disk will open. The overall containment pressure decreases as venting continues. Closing the two ~~250~~A air-operated butterfly valves re-establishes containment isolation as required.

to a leaking, fractured or improperly sealed rupture disk, the two valves upstream of the disk can be closed. These valves are safety-related and are subjected to all testing required for normal isolation valves. The solenoids in these valves are DC powered. These valves are capable of closing against pressures up to 617.8 kPaG.

(7) The piping material is carbon steel. The design pressure is 1030 kPaG, and the design temperature is 171°C.

6.2.5.2.6.2 Containment Overpressure Protection System

ABWR has a very low core damage frequency. Furthermore, in the unlikely event of an accident resulting in core damage, the fission products are typically trapped in the containment and there is no release to the environment. Nonetheless, in order to mitigate the consequences of a severe accident which results in the release of fission products and to limit the effects of uncertainties in severe accident phenomena, ABWR is equipped with a containment overpressure protection system (COPS). This system is intended to provide protection against the rare sequences in which structural integrity of the containment is challenged by overpressurization. It has been determined that these rare sequences comprise a small percentage of the hypothesized severe accident sequences.

The COPS is part of the atmospheric control system and consists of two ~~200~~ 250 mm diameter overpressure relief rupture disks mounted in series on a ~~250~~ 350A line which connects the wetwell airspace to the stack. The second rupture disk, located at the inlet to the plant stack, has a very low set point, less than 0.03 MPaD. The setpoint of the inner rupture disk, located near the containment boundary, will be selected such that the COPS opens when the wetwell pressure is 0.72 MPaA. The COPS provides a fission product release point at a time prior to containment structural failure. Thus, the containment structure will not fail. By engineering the release point in the wetwell airspace, the escaping fission products are forced through the suppression pool. In a core damage event initiated by a transient in which the vessel does not fail, fission products are directed to the suppression pool via the SRVs, scrubbing any potential release. In a severe accident with core damage and vessel failure or in a LOCA which leads to core damage, the fission products will be directed from the vessel and drywell through the drywell connecting vents and into the suppression pool again ensuring any release is scrubbed. Eventually, if containment pressure cannot be controlled, the rupture disk opens. Any fission product release to the environment is greatly reduced by the scrubbing provided by the suppression pool.

In the absence of the COPS, unmitigated overpressurization of the containment will result in failure of the drywell head for most severe accident scenarios (some high-pressure core melt sequences result in fission product leakage through the moveable penetrations in the drywell rather than drywell head failure). To compare the consequences of severe accidents resulting in fission product releases via drywell head failure to those with releases through the COPS, MAAP was used to simulate a series of severe accident sequences for both release mechanisms. These severe accident sequences are described in Section 19E.2.2. Failure pressure of the drywell head was assumed to be equal to its median failure pressure 1.025 MPa. The results of these runs show releases of volatile fission products, after 72 hours, for the COPS cases to be

6.2.5.2.6.5

hand, if the rupture disk is too large, level swell in the suppression pool could introduce water into the COPS piping. If this were to occur, the piping could be damaged or there could be carryover of waterborne fission products from the containment.

A ~~200A~~ 250 mm rupture disk was selected. This is sufficient to allow ~~35~~ 33.7 kg/s of steam flow at the opening pressure of 0.72 MPaA and corresponds to an energy flow of about ~~2.4~~ 2.3% rated power. The minimum acceptable flow rate is 28 kg/s of steam flow at the same pressure. For virtually all severe accident sequences, the rupture disk would not be called upon until about 20 hours after scram. The decay heat level at this time is less than 0.5%. Thus, there is ample margin in the sizing of the rupture disk for severe accidents.

An additional accident was considered in the selection of the rupture disk size. In the event of an ATWS with the additional failure of the standby liquid control system, the operator is directed to lower water level to control power. Analysis has shown that the RHR system is capable of removing the energy generated by the ATWS from the containment (Subsection 19.3.1.3.1). If the additional failure of containment heat removal is assumed, a simple calculation indicates that the rupture disk area is just sufficient to limit the containment pressure below service level C.

Calculations were also performed to investigate the potential effects of pool swell and fission product carryover at the time of COPS operation. These analyses (Subsection 19E.2.3.5) indicate that pool swell does not threaten the integrity of the COPS piping and that no significant entrainment of fission products will occur due to carryover.

6.2.5.2.6.6 Comparison of ABWR Performance With and Without COPS

The results of the MAAP ABWR calculations for the various accident scenarios were investigated in Section 19E.2.2. The releases are summarized in Table 19E.2-25. Comparisons of CsI release fraction at 72 hours show large differences between the COPS and drywell head failure cases. CsI release fraction at 72 hours for drywell head failures is on the order of 0.1% to 37%. For all cases with release via the COPS, MAAP ABWR predicts release fractions of less than 1E-7. Table 19E.2-26 summarizes several critical parameters for the dominate low pressure core melt scenario.

There is, of course, some reduction in the elapsed time to fission product release for the COPS cases when compared to the drywell head failure cases. For the dominant accident sequences in which the operator initiates the firewater spray system prior to overpressurization, the time difference between rupture disk opening and drywell head failure is only 3 to 4 hours. A typical example is the loss of all core coolant with vessel failure at low pressure with firewater spray addition sequence (LCLP-FS), as described in Subsection 19E.2.2.1. For this sequence the wetwell pressure will reach 0.72 MPaA and the rupture disk will open at 31.1 hours. Without the rupture disk, the drywell will reach 1.025 MPa at 35.0 hours.

(4) After a LOCA, the system is manually actuated from the control room when high oxygen levels are indicated by the containment atmospheric monitoring system (CAMS). (If hydrogen is not present, oxygen concentrations are controlled by nitrogen makeup.) Operation of either recombiner will provide effective control over the buildup of oxygen generated by radiolysis after a design-basis LOCA. Once placed in operation the system continues to operate until it is manually shut down when an adequate margin below the oxygen concentration design limit is reached.

6.2.5.3 Design Evaluation

The ACS is designed to maintain the containment in an inert condition except for nitrogen makeup needed to maintain a positive containment pressure and prevent air (0_2) leakage from the secondary into the primary containment.

The primary containment atmosphere will be inerted with nitrogen during normal operation of the plant. Oxygen concentration in the primary containment will be maintained below 3.5% by volume measured on a dry basis.

During normal operation, nitrogen makeup and containment pressure control are accomplished using only the 50A supply lines. The large valves (550A) in the containment ventilation lines are closed and flow to the plant stack through the overpressure protection line (~~250A~~) is prevented by the rupture disk. 350 A

The following conditions assure that the large (550A) containment purge and vent lines will be isolated following a LOCA:

(1) The valves remain closed at all times during normal operation and will only be opened for inerting or de-inerting at the beginning and end of a shutdown.

(2) The valves and piping provide redundancy such that no single failure can prevent isolation of the purge and vent lines.

(3) In the event of a LOCA, the valves receive an isolation signal.

(4) The valves fail in the closed position. If electrical power to the solenoids is lost or the pneumatic pressure fails, the valves will close.

Following an accident, hydrogen concentration will increase due to the addition of hydrogen from the specified design-basis metal-water reaction. Hydrogen concentration will also increase due to radiolysis. Any increase in hydrogen concentration is of lesser concern because the containment is inerted. Due to dilution, additional hydrogen moves the operating point (O_2 Concentration) of the containment atmosphere farther from the envelope of flammability.

Containment oxygen concentration also increases due to radiolysis. During plant operation, there are no other sources of oxygen in the containment.