Enclosure 1

MFN 16-001

ABWR COPS Redesign - ABWR DCD Revision 5 Markups

Table 6.2-7 Containment Isolation Valve Information Atmospheric Control System

Valve No.	T31-F001	T31-F002	T31-F003	T31-F004	T31-F005	T31-F006	T31-F007
Tier 2 Figure	6.2-39 (Sheet 1)	6.2-39 (Sheet 1)	6.2-39 (Sheet 1)	6.2-39 (Sheet 1)	6.2-39 (Sheet 1)	6.2-39 (Sheet 1	6.2-39 (Sheet 1)
Applicable Basis	GDC 56	GDC 56	GDC 56	GDC 56	GDC 56	GDC 56	GDC 56
Fluid	Air	Air or N_2	Air or N_2	Air or N_2	Air or N_2	Air or N_2	Air or N_2
Line Size	550A	550A	550A	550A	50A	550A	~~250A~~350A
ESF	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Leakage Class	(b)	(b)	(b)	(b)	(b)	(b)	(b)
Location	O	O	O	O	O	O	O
Type C Leak Test	Yes	Yes(e)	Yes(e)	Yes(e)	Yes(e)	Yes(e)	Yes(e)
Valve Type	Butterfly	Butterfly	Butterfly	Butterfly	Globe	Butterfly	Butterfly
Operator	Pneumatic	Pneumatic	Pneumatic	Pneumatic	Pneumatic	Pneumatic	Pneumatic
Primary Actuation	Electric	Electric	Electric	Electric	Electric	Electric	Electric
Secondary Actuation	Manual	Manual	Manual	Manual	Manual	Manual	Manual
Normal Position	Close	Close	Close	Close	Close	Close	Open
Shutdown Position	Close	Close	Close	Close	Close	Close	Open
Post-Accident Position	Close	Close	Close	Close	Close	Close	Open
Power Fail Position	Close	Close	Close	Close	Close	Close	Open
Containment Isolation Signal (c)	A, K, XX, YY	A, K, XX, YY	A, K, XX, YY	A, K, XX, YY	A, K, XX, YY	A, K, XX, YY	RM
Closure Time (s)	<20	<20	<20	<20	<15	<20	<20
Power Source (Div)	I	II	II	II	II	II	II

See page 6.2-167 for notes

Table 6.2-7 Containment Isolation Valve Information Atmospheric Control System

Valve No.	T31-F731	T31-F033A/B	T31-F035A-D	T31-F010	T31-F011
Tier 2 Figure	6.2-39 (Sheet 3)	6.2-39 (Sheet 3)	6.2-39 (Sheet 3)	6.2-39 (Sheet 1)	6.2-39 (Sheet 1)
Applicable Basis	RG 1.11	RG 1.11	RG 1.11	GDC 56	GDC 56
Fluid	DW Atmosphere	DW Atmosphere	DW Atmosphere	Air or N_2	Air or N_2
Line Size	20A	20A	20A	~~250A~~350A	550A
ESF	No	No	No	Yes	Yes
Leakage Class	(a)	(a)	(a)	(a)	(a)
Location	O	O	O	O	O
Type C Leak Test	No(m)	No(m)	No(m)	Yes(e)	Yes(e)
Valve Type	Gate	Gate	Gate	Butterfly	Butterfly
Operator	Solenoid	Solenoid	Solenoid	Pneumatic	Pneumatic
Primary Actuation	Electric	Electric	Electric	Electric	Electric
Secondary Actuation	N/A	N/A	N/A	Manual	Manual
Normal Position	Open	Open	Open	Open	Close
Shutdown Position	Open	Open	Open	Open	Close
Post-Accident Position	Open	Open	Open	Open	Close
Power Fail Position	Open	Open	Open	Open	Close
Containment Isolation Signal [(c)]	RM	RM	RM	RM	A, K XX, YY
Closure Time (s)	N/A	N/A	N/A	<20	<20
Power Source (Div)	N/A	N/A	N/A	I	III

See page 6.2-167 for notes

Table 6.2-7 Containment Isolation Valve Information Atmospheric Control System

Valve No.	T31-F805A/B	T31-D001	T31-D002
Tier 2 Figure	6.2-39 (Sheet 3)	6.2-39 (Sheet 1)	6.2-39 (Sheet 1)
Applicable Basis	RG 1.11	GDC 56	GDC 56
Fluid	WW Atmosphere	WW Atmosphere	WW Atmosphere
Line Size	20A	~~250A~~350A	~~250A~~350A
ESF	No	Yes	Yes
Leakage Class	(a)	N/A	N/A
Location	O	O	O
Type C Leak Test	No(m)	No(P)	No (P)
Valve Type	Gate	Rupture Disk	Rupture Disk
Operator	Solenoid	Self	Self
Primary Actuation	Electric	N/A	N/A
Secondary Actuation	N/A	N/A	N/A
Normal Position	Open	Close	Close
Shutdown Position	Open	Close	Close
Post-Accident Position	Open	Open	Open
Power Fail Position	Open	N/A	N/A
Containment Isolation Signal(c)	RM	N/A	N/A
Closure Time (s)	N/A	N/A	N/A
Power Source (Div)	N/A	N/A	N/A
See page 6.2-167 for notes			

pool surface and carried into the COPS piping. Calculation of entrainment at the surface of the suppression pool is considered using the work of Rozen, et. al. (Reference 19E.2-17) and is found to have an insignificant impact on fission product release.

19E.2.3.5.1 Response of Suppression Pool Surface to Decompression Wave

19E.2.3.5.1.1 Summary

Sudden opening of the containment overpressure protection system (COPS) rupture disk causes a gas discharge from the ABWR pool airspace. The associated decompression wave which enters the airspace spreads to the pool surface. It is necessary to determine how the pool surface responds to the arriving decompression. If the decompression wave causes pool pressure to fall below the saturation pressure, rapid vapor formation would cause the pool to swell as a flashing steam/water mixture. However, if the arriving decompression does not cause the pool pressure to fall below its saturation value, flashing would not occur, and the pool would respond as a compressed liquid.

The theoretical modeling used to determine pool response from operation of the COPS includes prediction of:

- The gas discharge rate
- The velocity and decompression disturbances originating where the COPS enters the airspace
- Expansion of the decompression into the airspace, and its attenuation with distance
- Decompression transmission from the airspace into the pool at the water surface
- The pool water dynamic and thermodynamic response

It was found that the originating decompression wave entering the containment airspace was ~~38.8~~61.4 kPa, dropping below the initial 721 kPa air pressure. The decompression wave leaving the COPS pipe of 0.275 m (0.9 ft) radius would reach the pool surface a distance of 4 m (13.12 ft) away, attenuating from ~~38.8~~61.4 kPa to ~~2.67~~4.2 kPa. Since sound speed and density of water are much higher than corresponding values in air, a decompression wave entering the water is nearly twice that arriving in the air, or about ~~5.34~~8.4 kPa. The decompression is not large enough to cause pool pressure to drop below its saturation pressure of 330 kPa at its initial temperature of 410 K, or 137°C (738 R or 278°F). The pool surface would move upward at only ~~0.0044 m/s (0.014 fps)~~0.0069 m/s (0.022 fps) for the transmitted decompression.

19E.2.3.5.1.2 The Gas Discharge Rate

The COPS pipe has a radius R and area A. The open COPS rupture disk has a flow area a. Since the airspace pressure P_o is 721 kPa and discharge is into the atmosphere at 101 kPa, the initial air flow is expected to be choked in the valve throat at a choked mass flux of (Reference 19E.2-37)

$$G_{gc} = \left(\frac{2}{k+1}\right)^{(k+1)/2(k+1)} \sqrt{kg_0P_0\rho_{g0}} \quad (19E.2\text{-}41a)$$

The quasi-steady mass flow rate through the pipe and valve is expressed as

$$m = G_{gc}a \quad (19E.2\text{-}41b)$$

Assuming isentropic flow from the airspace to the throat, and expressing the airspace sound speed as:

$$C_{g0} = \sqrt{(kg_0P_0)/\rho_{g0}} \quad (19E.2\text{-}41c)$$

the discharging mass flow rate is obtained in the form,

$$\frac{m}{AC_{g0}\rho_{g0}} = \left(\frac{2}{k+1}\right)^{(k+1)/2(k+1)} \frac{a}{A} \quad (19E.2\text{-}41d)$$

19E.2.3.5.1.3 Disturbance Entering the Airspace

It is assumed that the COPS valve opens instantly, causing an instantaneous quasi-steady flow in the attachment pipe. This assumption gives the maximum pipe velocity, which corresponds to a maximum initial decompression wave.

Acoustic theory can be applied if pressure disturbances do not create Mach numbers much greater than 0.2. An area ratio of a/A = ~~0.132~~0.207 (diameter ratio of d/D = ~~0.364~~0.5) with an airspace state described by

P_0 = 721 kPa

T_0 = 410 K (278°F)

g_0 = 6.16 kg/m^3 (0.384 lbm/ft^3)

C_{g0} = 406 m/s (1332 fps)

yields a gas velocity in the pipe of ~~31 m/s (102 fps)~~49 m/s (161 fps). The corresponding mach number is ~~31/406 = 0.076~~49/406 = 0.121, which justifies treating the decompression as an acoustic wave.

It is further assumed that the discharge begins suddenly, imposing the pipe flow velocity of 31 m/s at its entrance. In order to employ spherical propagation of the acoustic wave, an imaginary hemisphere of pipe radius R = D/2 = 0.55/2 m = 0.275 m (0.902 ft) has twice the pipe flow area, reducing the entrance velocity on the hemisphere to ~~31/2 = 15.5 m/s (50.8 fps)~~49/2 = 24.5 m/s (81 fps). The acoustic equation,

$$\delta P_0 = \frac{C_\rho \delta V}{g_0} \tag{19E.2-41e}$$

can be employed to show that the corresponding decompression disturbance is P_0 = ~~38.8 kPa (5.6 psid)~~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,

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

with the boundary and initial conditions at r = R of

$$P = P_0 - \delta P_0 \tag{19E.2-41g}$$

a boundary condition as r approaches infinity of

$$P = P_0 \tag{19E.2-41h}$$

and initial conditions at t = 0 of

$$P = P_0 \tag{19E.2-41i}$$

$$\frac{\partial P}{\partial r} = 0 \tag{19E.2-41j}$$

A solution for the outgoing decompression wave is given by

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

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

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

It is seen from Equation (~~00.1-41k~~19E.2-41k) that even after the decompression arrives at r, its amplitude decays exponentially with time. This feature is excluded from the analysis for conservatism.

If the water surface is a distance r = 4 m away from the COPS pipe, the arriving decompression wave will have an amplitude of only ~~2.67~~4.2 kPa.

19E.2.3.5.1.5 Transmission into the Pool

The arriving decompression wave undergoes both simultaneous transmission and reflection at the pool surface interface. Acoustic theory for a plane wave arriving at a flat surface discontinuity of density and sound speed gives the ratio of transmitted to oncoming pressure disturbances as

$$\frac{\delta P_{transmitted}}{\delta P_{oncoming}} = \frac{2}{1+\rho_1 C_1/\rho_2 C_2} \tag{19E.2-41l}$$

where subscripts 1 and 2 refer to the airspace and water in this case. A water density and sound speed of 1000 kg/m3 and 1220 m/s yields a transmitted/oncoming pressure of

$$\frac{\delta P_{transmitted}}{\delta P_{oncoming}} = 1.99$$

That is, the decompression wave arriving at the pool surface nearly doubles from the oncoming value to ~~5.34~~8.4 kPa. The plane wave analysis employed here is based on left and right traveling waves which add to satisfy continuity and energy conservation at the interface (Reference 19E.2-38). A similar analysis for spherical waves is obtained from the method of images to provide a plane surface of symmetry. The local pressure transmission and reflection amplitudes are the same as those obtained from the plane wave analysis (Reference 19E.2-38).

19E.2.3.5.1.6 Water Dynamic and Thermodynamic Response

The ~~5.34~~8.4 kPa decompression wave transmitted into the water pool does not lower the initial 721 kPa pressure anywhere near the 330 kPa saturation pressure. Therefore, the arriving decompression cannot cause rapid pool flashing and swelling. Steam formation will occur in the pool later when continued decompression of the airspace lowers the pressure below saturation.

The water is expected to respond acoustically to the arriving decompression, taking on a velocity obtained from Equation ~~00.1-41e~~19E.2-41e, written for the liquid as

$$\delta V_L = \frac{g_0 \delta P}{\rho_L C_L} \tag{19E.2-41m}$$

where subscript L refers to the water, and δP is the transmitted pressure disturbance. The resulting pool velocity is only ~~0.0044 m/s (0.014 fps)~~.0069 m/s (0.022 fps).

19E.2.3.5.2 Critical Time Constants for Blowdown Response

The time constant for the depressurization of the wetwell airspace is calculated from critical flow considerations. Comparing this value to the time constant for propagation of a pressure wave around the wetwell annulus allows one to determine if non-uniform effects in the suppression need to be considered in calculating the suppression pool response.

The depressurization time constant for the wetwell airspace is estimated based on the critical flow through the rupture disk opening and the ideal gas law. There are two sources of steam to the wetwell airspace: the blowdown through the vent system of steam and non-condensable gas from the drywell, and the boiling or steaming of the suppression pool which results from the pressure decrease. If both of these sources are neglected, the time constant for the depressurization of the wetwell will conservatively be underestimated. If one further neglects the effects of any temperature change which results from the blowdown (a second order effect), the rate of depressurization is:

$$\frac{dP}{dt} = \frac{0.665 ART\sqrt{P\rho_g}}{V_w M_{a,W}} \tag{19E.2-42}$$

where:

P	=	pressure
A	=	rupture disk flow area
R	=	universal gas constant
ρ_g	=	density of gas
V_w	=	volume of wetwell airspace
$M_{a,w}$	=	molecular weight of gas species in wetwell.

Conservatively assuming the wetwell vapor space has only steam, for a blowdown from 0.65 MPa to atmospheric conditions, the assumptions above yield a time constant on the order of ~~9~~5.7 minutes. A typical time constant for a pressure wave going around the torus which comprises the wetwell is about 0.5 seconds. Comparison of these two numbers indicates clearly that the entire suppression pool will participate in the blowdown. Thus, two dimensional effects may be neglected.

of the ABWR rupture disk, a sensitivity study was performed in which the pressure setpoint of the rupture disk was varied.

The nominal pressure setpoint of the rupture disk is 0.72 MPa at 366 K (200°F). Two cases were examined using MAAP-ABWR in this sensitivity study. For both cases the LCLP-PF-R sequence was used as the base case. First, the rupture disk pressure setpoint was reduced to 0.708 MPa which corresponds to a rupture disk temperature of 422 K (300°F); and, second, the pressure setpoint was increased to 0.735 MPa which corresponds to a temperature of 311 K (100°F). This temperature range, from 311 to 422 K (100 to 300°F), bounds all anticipated rupture disk temperatures.

The elapsed time to rupture disk opening was within 0.8 hours of the base case value of 20.2 hours for both cases tested. Higher rupture disk temperatures (i.e. lower pressure setpoints) reduce the time to rupture disk opening and lower rupture disk temperatures (i.e. higher pressure setpoints) increase the time to rupture disk opening. There were no significant changes in fission product release. For both cases the CsI release fraction at 72 hours remained less than 1E-7.

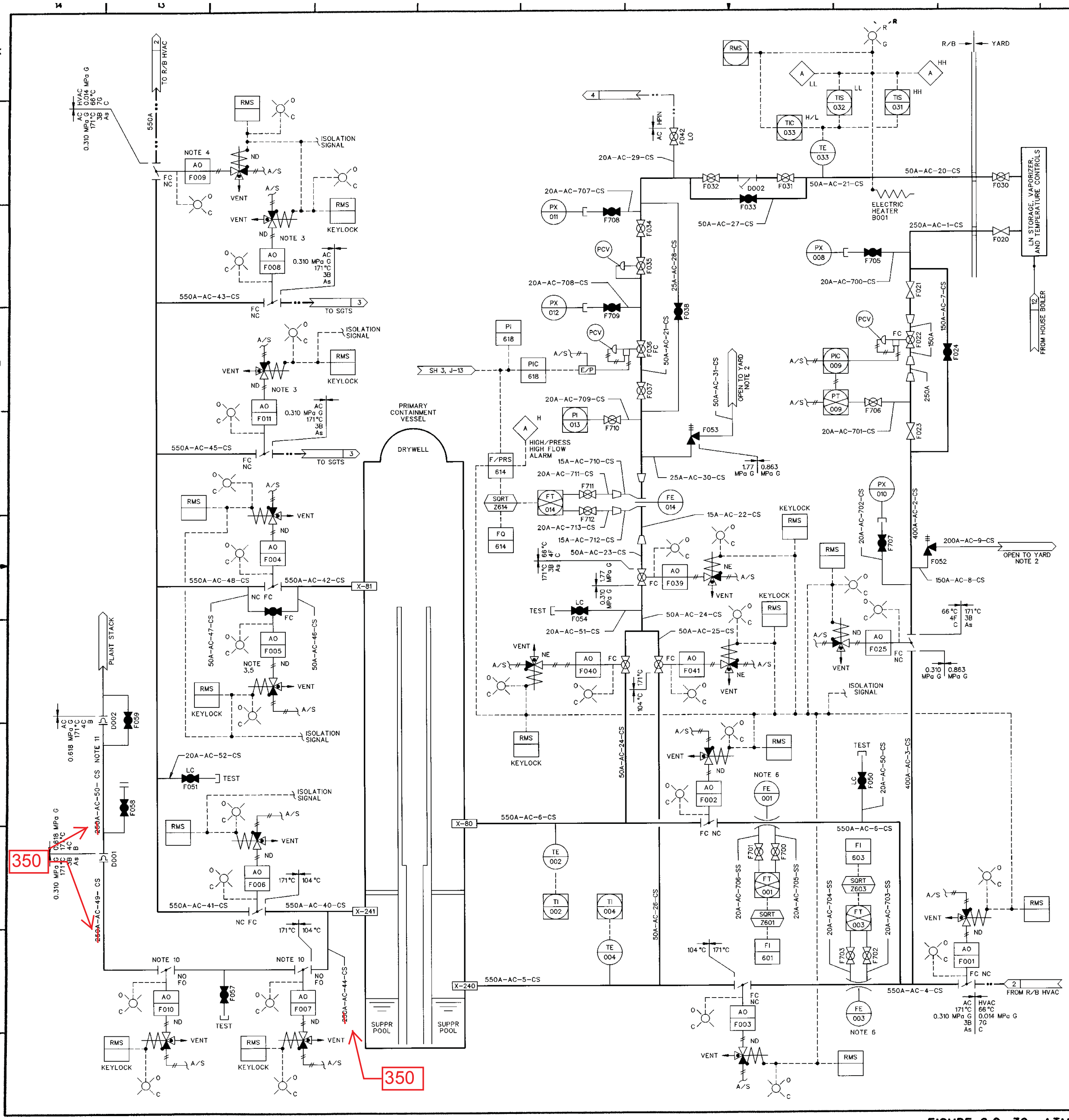
Another parameter affected by the variation in the rupture disk temperature is the probability of drywell head failure prior to rupture disk opening in a severe accident. Using the rupture disk and drywell head failure distributions, it was determined that the probability of drywell head failure prior to rupture disk opening increased slightly for the case with the rupture disk temperature of 311 K (100°F). With a rupture disk temperature of 422 K (300°F), the probability decreased slightly. The rupture disk temperature variation has a similar effect on the severe accident sequences in which the firewater spray system is activated. The probability of drywell head failure prior to rupture disk opening increases slightly for the case with the rupture disk temperature of 311 K (100°F) and decreases slightly for the case with the rupture disk temperature of 422 K (300°F).

The results of this sensitivity study show that variations in rupture disk temperature, which cause small variations in rupture disk opening pressure, have a minor effect on the performance of the ABWR Containment Overpressure Protection System.

19E.2.8.1.3 Sizing of Rupture Disk

The size of the rupture disk has also been optimized. If the rupture disk is too small, it could be incapable of venting enough steam to prevent further containment pressurization. On the other 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 ~~200~~250A (~~8~~10-inch) 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 a 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



NOTES:

1. QUALITY CONTROL GROUP AND QUALITY GROUP CLASSIFICATION ARE PROVIDED IN FOLLOWING TABLE.

ITEM		QUALITY CLASSIFICATION	DESIGN CLASSIFICATION
AC SYS EXCEPT FOR FOLLOWING ITEMS		F	4
PCV BOUNDARY		B	3
HVAC SYS		G	7
TEST TAP	UPSTREAM OF VALVE	SAME AS PROCESS LINE	
	DOWNSTREAM OF VALVE	G	7
DRAIN	UPSTREAM OF VALVE	SAME AS PROCESS LINE	
	DOWNSTREAM OF VALVE	G	7
INSTRUMENT PIPING		SAME AS PROCESS LINE	
TEST TAP (FROM VALVE TO CAP)		G	7

2. THE EXHAUST TO THE YARD SHALL BE LOCATED AWAY FROM NORMALLY OCCUPIED AREAS. THE EXHAUST SHALL HAVE A STRUCTURE THAT PREVENTS ENTRY OF RAIN.

3. THESE VALVES SHALL BE ABLE TO BE OPENED MANUALLY BY SWITCHES THAT OVERRIDE THE PCV ISOLATION SIGNAL.

4. THIS VALVE IS MANUALLY OPENED AFTER EACH PCV LEAK TEST BY THE HAND WHEEL.

5. THIS VALVE SHALL BE USED FOR LIMITING FLOW RATE DURING DEPRESSURIZATION FOLLOWING PCV INTEGRATED LEAK RATE TEST.

6. THIS FLOW ELEMENT SHALL BE ANNULAR-TYPE.

7. DESIGN CONDITIONS OF PIPING ARE AS FOLLOWS UNLESS OTHERWISE SPECIFIED.
   - A. MATERIAL --------- CARBON STEEL
   - B. SCHEDULE --------- 75A AND OVER – SCH 40; 50A AND LESS – SCH 80
   - C. RADIOACTIVE CONCENTRATION ------- PCV BOUNDARY AND EXHAUST LINE: $\geq 37 \times 10^{-6}$ μBq/cc : B.G.
   - D. SEISMIC CLASS ------ PCV BOUNDARY : As, COPS : B; OTHER AREAS : C
   - E. FLUID ----------- N2 OR AIR

8. DESIGN CONDITIONS OF TEST, DRAIN AND INSTRUMENT PIPING ARE AS FOLLOWS:

ITEM		MAX OPERATING PRESSURE	MAX OPERATING TEMPERATURE	MATERIAL
TEST TAP	UPSTREAM OF VALVE	SAME AS PROCESS LINE		
	DOWNSTREAM OF VALVE	SAME AS PROCESS LINE	66 °C	CS
DRAIN	UPSTREAM OF VALVE	SAME AS PROCESS LINE		
	DOWNSTREAM OF VALVE	ATMOSPHERIC PRESSURE	66 °C	CS
INSTRUMENT PIPING		SAME AS PROCESS LINE		
INSTRUMENT PIPING CONNECTED TO DRYWELL		0.310 MPa G	171 °C	SS
INSTRUMENT PIPING CONNECTED TO SUPPRESSION POOL		0.310 MPa G	104 °C	SS
TEST TAP	UPSTREAM OF VALVE	0.310 MPa G	171 °C	CS
	DOWNSTREAM OF VALVE	0.310 MPa G	66 °C	CS

9. SUPPRESSION POOL WATER TEMPERATURE MONITORING IS PROVIDED BY SPTM SYSTEM, REF 6.

10. THESE VALVES ARE NOT PROVIDED WITH AN ISOLATION SIGNAL. CONTROL SWITCHES SHOULD BE LOCKED OPEN.

11. MEANS SHALL BE PROVIDED FOR MAINTAINING INERT CONTAINMENT OVERPRESSURE PROTECTION SYSTEM (COPS) PIPING VOLUME BETWEEN THE RUPTURE DISKS. D001 IS LOCATED AS CLOSE AS PRACTICAL TO THE CONTAINMENT AND D002 TO THE STACK.

REFERENCE DOCUMENTS:	MPL NO.
1. PIPING AND INSTRUMENT SYMBOLS DIAGRAM	A10–3030
2. HVAC SYSTEM P&ID	U41–1010
3. STANDBY GAS TREATMENT SYSTEM P&ID	T22–1010
4. HIGH PRESS, NITROGEN GAS SUPPLY SYS P&ID	P54–1010
5. NUCLEAR BOILER SYSTEM P&ID	B21–1010
6. SUPPR POOL WATER TEMP MONITORING SYS IED	T53–1010
7. DRYWELL COOLING SYSTEM	T41–1010
8. REMOTE SHUTDOWN SYSTEM IED	C61–1010
9. HIGH PRESSURE CORE FLOODER SYS P&ID	E22–1010
10. REACTOR CORE ISOLATION COOLING SYS P&ID	E51–1010
11. SUPPRESSION POOL CLEANUP SYSTEM P&ID	G51–1010
12. HOUSE BOILER SYS P&ID	P62–1010

MPL NO. T31–1010

FIGURE 6.2–39 ATMOSPHERIC CONTROL SYSTEM P&ID (Sheet 1 of 3)