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CHAPTER 7

CONFINEMENT

7.1 Confinement Boundary

The confinement boundary consists of the inner shell and bottom plate, shell flange, lid outer plate, lid bolts, penetration cover plate and bolts and the inner metallic O-rings of the lid seal and the two lid penetrations (vent and drain). The confinement boundary is shown in Figure 1.2-1. The construction of the confinement boundary is shown on drawings 972-70-1, 2 and 3 provided in Section 1.5. The confinement vessel prevents leakage of radioactive material from the cask cavity. It also maintains an inert atmosphere (helium) in the cask cavity. Helium assists in heat removal and provides a non-reactive environment to protect fuel assemblies against fuel cladding degradation which might otherwise lead to gross rupture.

7.1.1 Confinement Vessel

The TN-68 confinement vessel consists of: an inner shell which is a welded, carbon steel cylinder with an integrally-welded, carbon steel bottom closure; a welded flange forging; a flange and bolted carbon steel lid with bolts; and vent and drain covers with bolts. The overall confinement vessel length is 189.0 in. with a wall thickness of 1.5 in. The cylindrical cask cavity has a diameter of 69.5 in. and a length of 178 in.

The confinement shell and bottom closure materials are SA-203 Grade E and the shell flange is SA-350 Grade LF3. The confinement lid material is SA-203 Grade E or SA-350 Grade LF3.

The cask design, fabrication and testing are performed under Transnuclear's Quality Assurance Program which conforms to the criteria in Subpart G of 10CFR72.

The materials of construction meet the requirements of Section III, Subsection NB-2000 and Section II, Material specifications or the corresponding ASTM Specifications. The materials used in the confinement boundary conform to the requirements of NB-2121 and NB-2130. The confinement vessel is designed to the ASME Code, Section III, Subsection NB, Article 3200. The confinement vessel is fabricated and examined in accordance with NB-2500, NB-4000 and NB-5000. Welding materials used in confinement welds or welds to the confinement components conform to the requirements of NB-2400 and to the material specification requirements of Section II, Part C of the ASME B&PV Code.

The confinement vessel is hydrostatically tested in accordance with the requirements of the ASME B&PV Code, Section III, Article NB-6200 with the exception that the confinement vessel is installed in the gamma shield shell during testing. The confinement vessel is supported by the gamma shield during all design and accident events.

Even though the code is not strictly applicable to storage casks, it is the intent to follow Section III, Subsection NB of the Code as closely as possible for design and construction of the

confinement vessel. The casks may, however, be fabricated by other than N-stamp holders and materials may be supplied by other than ASME Certificate Holders. Thus the requirements of NCA are not imposed. TN's quality assurance requirements, which are based on 10CFR72 Subpart G and NQA-1 are imposed in lieu of the requirements of NCA-3850. This SAR is prepared in place of the ASME design and stress reports. Surveillances are performed by TN and utility personnel rather than by an Authorized Nuclear Inspector (ANI).

The weld of the bottom inner plate to the confinement shell is a Category C, Type 2 corner weld in accordance with Figure NB-4243-1 of the ASME Code. In accordance with NB-5231, Type 2 Category C full penetration corner welded joints require the fusion zone and the parent metal beneath the attachment surface to be ultrasonically examined after welding. If this weld is performed on the confinement vessel after assembly with the outer shell, the UT inspection will be performed on a best efforts basis. It may not be possible to do a complete UT inspection, since the outer diameter of the shell is inaccessible. The joint will be examined by the radiographic method and either the liquid penetrant or magnetic particle methods in accordance with the ASME Code Subsection NB.

Paragraph NB-4213 requires the rolling process used to form the inner vessel be qualified to determine that the required impact properties of NB-2300 are met after straining by taking test specimens from three different heats. If the plates are made from less than three heats, each heat will be tested to verify the impact properties.

7.1.2 Confinement Penetrations

There are two penetrations through the confinement vessel, both in the lid. One is the drain port and the other is the vent port. A double O-ring seal mechanical closure is provided for each penetration. Each penetration contains a quick disconnect coupling for ease of operation.

7.1.3 Seals and Welds

The confinement boundary welds consist of the circumferential welds attaching the bottom closure and the top flange to the vessel shell. Also, the longitudinal weld(s) on the rolled plate, closing the cylindrical vessel shell, and the circumferential weld(s) attaching the rolled shells together are confinement welds.

Double metallic seals are utilized on the lid and the two lid penetrations. Helicoflex HND or equivalent seals may be used. The seals are shown in Figure 7.1-3. The internal spring and lining maintain the necessary rigidity and sealing force, and provide some elastic recovery capability. The outer aluminum jacket provides a ductile material against the sealing surfaces. The jacket also provides a connecting sheet between the inner outer seals. Holes in this sheet allow for attachment screws and for communication between the overpressure system and the space between the seals. This sheet, which is about 0.020 inch thick, has insufficient strength to transmit radial forces great enough to overcome the axial compressive forces on the seals, which are over 1000 lb/inch of seal length. Additional information on the seals is provided in Section 2.3.2. The overpressure port seal is a single metallic seal of the same design, Helicoflex HN200 or equivalent.

All TN-68 surfaces which mate with the metallic seals are stainless steel.

The use of a double seal system allows the TN-68 cask to have a pressure monitoring of the interspace between the seals (See Section 2.3.2). This combined cover-seal pressure monitoring system always meets or exceeds the requirement of a double barrier closure which guarantees tight, permanent confinement. When the cask is placed in storage, a pressure greater than that of the cavity is set up in the gaps (interspace) between the double metallic seals of the lid and the lid penetrations. A decrease in the pressure of the monitoring system would be signaled by a pressure transducer/switch in the overpressure system.

The lid and penetration seals described above are contained in grooves. A high level of sealing over the storage period is assured by utilizing seals in a deformation-controlled design. The deformation of the seals is constant since bolt loads assure that the mating surfaces remain in contact. The seal deformation is set by the original diameter and the depth of the groove.

The nominal diameter of the lid seal is 6.6 mm, and the nominal groove depth is 5.6 mm. At 1 mm compression, the sealing force is 245 N/mm (1399 lb/inch)(11). The total force of the double seal is 633,800 lb. The total preload of the 48 lid bolts is 2,897,000 lb, which is greater than the combined force of the seals and internal pressure, 1,141,000 lb (Section 3A.3).

The nominal diameter of the port seals is 4.1 mm, and the nominal groove depth is 3.2 mm. At 0.9 mm compression, the sealing force is 200 N/mm (1142 lb/inch). The total force of the double seal is 37,900 lb. The total preload of the 8 cover bolts is 63,700 lb, which is greater than the combined force of the seals and internal pressure, 40,000 lb.

The sealing force is maintained by the seal's internal spring. Due to creep, the sealing pressure decreases with increasing temperature as shown in the following table(11). The ratios P_T/P_{20} compare the seal pressure at temperature T °C to the seal pressure at 20°C. The long-term temperature limit is the point at which the sealing pressure becomes zero due to creep (P_{Tmax}=0). The maximum normal temperature experienced by the seals in the TN-68 is 212 °F (Table 4.3-1), below the 119°C evaluated in the following table.

Seal	$P_{119\ C}/P_{20\ C}$ (119 °C = 247 °F)	$P_{200\ C}/P_{20\ C}$ (200 °C = 392 °F)	Temperature limit T_{max}
Lid, 6.6 mm	(439/670) = 66%	(250/670) = 37%	340 °C (644 °F)
Ports, 4 mm	(364/600) = 61%	(170/600) = 28%	280 °C (536 °F)

$P_{20\ C}$ and $P_{200\ C}$ from Reference 11; $P_{119\ C}$ by linear interpolation; sealing pressure P in N/mm^2 (referred to as "Intrinsic Power Pu" in reference 11)

The maximum radial force on the seals is from the 6.0 atm abs overpressure system. Using the compressed seal height of 5.6 mm, this results in a force per unit seal length of about

5.0 atm gage*14.7 psi/atm*(5.6/25.4)inch = 16 lb/inch

which is negligible compared to the compressive (axial) forces of over 1000 lb/inch. Because the maximum pressure is between the two seals, the direction of this force is such that the seals

are supported by the walls of the seal groove. However, the seals are designed to retain pressure in either direction.

Helicoflex metallic seals are all capable of limiting leak rates to less than 1 x 10^{-7} ref cm^3/s. After loading, all lid and cover seals are leak tested in accordance with ANSI N14.5. The acceptable total cask leakage (both inner and outer seals combined) is 1 x 10^{-5} ref cm^3/s.

7.1.4 Closure

The confinement vessel contains an integrally-welded bottom closure and a bolted and flanged top closure (lid). The flanged lid plate is attached to the cask body with 48 bolts. The bolt torque required to seal the metallic seals located in the lid and maintain confinement under normal and accident conditions is provided in Drawing 972-70-1. The closure bolt analysis is presented in Appendix 3A.3.

As previously mentioned, the lid contains two penetrations which are sealed by flanged covers fastened to the lid by 8 bolts each. The bolt torque required to seal the metallic seals in the penetration covers and maintain confinement under normal and accident conditions is provided in Drawing 972-70-1.

7.1.5 Monitoring of System Confinement

An overpressure monitoring system is part of the TN-68 design. The pressure in the monitoring system is greater than that of the cask cavity and the cask cavity pressure is greater than ambient. In this configuration, neither in-leakage of air nor out-leakage of cavity gas is possible.

If a leak existed in the seals, the design of the TN-68 overpressure system is such that the leak will either be to the atmosphere or to the cask cavity. Leakage from the cask cavity past the higher pressure of the overpressure system is physically impossible.

The seals are collectively leak tested to 1 x 10^{-5} ref cm^3/s. Using the methodology of ANSI N14.5[(2)], an equivalent maximum hole size is estimated based upon test conditions of equivalent air leaking from 1 atm abs to 0.01 atm abs in ambient temperature conditions (77°F or 25°C) and the maximum acceptable leak of 1 x 10^{-5} ref cm^3/s. The leakage hole length is assumed to be the same as the metal seal width, 0.5 cm. The equivalent maximum hole size is calculated below.

$$L_u = (F_c + F_m)(P_u - P_d)(P_a/P_u) \text{ cc/sec at } T_u, P_u$$

Other definitions:

- L_u = upstream volumetric leakage rate, cc/sec = 1 x 10^{-5} ref cm^3/s (Test Leak Rate)
- F_c = coefficient of continuum flow conductance per unit pressure, cc/atm-sec
- F_m = coefficient of free molecular flow conductance per unit pressure, cc/atm-sec
- P_u = fluid upstream pressure, atm abs = 1.0 atm abs
- P_d = fluid downstream pressure, atm abs = 0.01 atm abs
- D = leakage hole diameter, cm

a = leakage hole length, cm = 0.5 cm (assuming leak path length is on the order of the metal seal width)

μ = fluid viscosity, cP = 0.0185 cP (from ANSI N14.5, Table B.1)

T = fluid absolute temperature, °K = 298°K

M = molecular weight, g/mol = 29.0 g/mol (from ANSI N14.5, Table B.1)

P_a = average stream pressure = ½ (P_u + P_d), atm abs = 0.505 atm abs

$L_u = (F_c + F_m)(P_u - P_d)(P_a/P_u)$ cc/sec

where:

$F_c = (2.49x10^6 \times D^4)/(a\mu)$ cc/atm-sec

$F_m = \{3.81x10^3 \times D^3 \times (T/M)^{0.5}\} / \{aP_a\}$ cc/atm-sec

Substituting:

$F_c = (2.49x10^6 \times D^4)/(0.5 \times 0.0185) = 2.69 \text{ x } 10^8 D^4$

$F_m = \{3.81x10^3 \times D^3 \times (298/29.0)^{0.5}\} / \{0.5 \times 0.505) = 4.84 \text{ x } 10^4 D^3$

$L_u = (F_c + F_m)(P_u - P_d)(P_a/P_u)$ cc/sec

$1 \text{ x } 10^{-5} = (F_c + F_m)(1.0 - 0.01)(0.505 / 1.0)$

$F_c + F_m = 2 \text{ x } 10^{-5}$

Solving the simultaneous equations, the equivalent hole diameter, D, is 4.825 x 10^{-4} cm.

During operations, the overpressure system is initially back filled with 6 atm abs (73.5 psig) of Helium at standard temperature. The temperature of the helium in the O.P. tank at equilibrium is assumed to be 174°F (79°C)*. The pressure in the overpressure system at this temperature will be 7.09 atm abs (89 psig). Assuming the overpressure system is leaking to the atmosphere, the leak rate is defined using the equations of ANSI N14.5:

$L_{u,He} = (F_c + F_m)(P_u - P_d)(P_a/P_u)$ cc/sec

$F_c = (2.49x10^6 \times D^4)/(a\mu)$ cc/atm-sec

$F_m = \{3.81x10^3 \times D^3 \times (T/M)^{0.5}\} / \{aP_a\}$ cc/atm-sec

Where:

$L_{u,He}$ = helium volumetric leakage rate

P_u = 7.09 atm abs

P_d = 1.0 atm abs

D = 4.825 x 10^{-4} cm

a = 0.5 cm

μ = 0.0223 cP (for helium at 352 K)

* The assumed OP temperature is based on thermal analysis for 21.2 kW heat load. Since the axial heat transfer in the TN-68 cask from the basket to the OP system is not significant, the OP system temperature at thermal equilibrium for 30 kW heat load would not differ much from the value assumed for the 21.2 kW case.

T = 352°K
M = 4.0 g/mol
P_a = ½ (P_u + P_d) = 4.04 atm abs

Substituting:

$$F_c = \{2.49E{+}06 \times (4.825E{-}04)^4\}/(0.5 \times 0.0223) = 1.21E{-}05$$
$$F_m = \{3.81E{+}03 \times (4.825E{-}04)^3 \times (352/4)^{0.5}\} / (0.5 \times 4.04) = 1.99E{-}06$$

$$L_{u,He} = (F_c + F_m)(P_u - P_d)(P_a/P_u)$$
$$L_{u,He} = (1.21E{-}05 + 1.99E{-}06)(7.09 - 1.0)(4.04/7.09)$$
$$L_{u,He} = 4.9E{-}05 \text{ cc/sec of Helium}$$

Over the first year, the maximum volume leaked from the overpressure system is:

$$V = 4.9E{-}05 \text{ cc/sec} \times (365 \text{ days/year} \times 24 \text{ hrs/day} \times 3600 \text{ sec/hr}) = 1544 \text{ cc at } T_u, P_u$$

The OP system tank basically consists of a 6” diameter schedule 80 pipe (27” long) and two 6” diameter schedule 80 end caps. The volume of the tank is 835 in^3. The volume of the OP system is increased to 900 in^3 (14750 cc) to include the OP system tubing and the space between the metallic seals in the lid and penetrations. Corresponding, the pressure is reduced by the following in the first year:

$$P_{OP\ released} = P_{OP\ Sys,\ Initial} \times \{V_{released} / V_{OP\ Sys}\}$$
$$P_{OP\ released} = 6.53 \text{ atm } (1544cc / 14750cc) = 0.74 \text{ atm}$$

The overpressure system pressure is also corrected for the corresponding drop in temperature over the first year. At the end of the first year, the overpressure system pressure is 6.34 atm abs (78.5 psig). These calculations are repeated every year for the 20 year life of the cask. Figure 7.1-1 illustrates the pressure drop from the overpressure system to the atmosphere. Figure 7.1-1 also illustrates the pressure drop in the cask cavity due to fuel cooling.

If a leak is to the cask cavity rather than the atmosphere, the pressure drop in the overpressure system is calculated using a downstream pressure of 2.2 atm abs (17.64 psig). Figure 7.1-1 also illustrates the results of this analysis. In this scenario, the corresponding increase in the cask cavity pressure is negligible.

As shown above, the monitoring system pressure is greater than the cask cavity or atmospheric pressure assuming a leak based on the conservative initial acceptance test leak rate of 1 x 10^{-5} ref cm^3 /s. Typically, helicoflex metallic seals result in joints with much lower leak rates than the acceptance criteria. Therefore, no leakage will occur from the cask cavity during the storage period.

The pressure in the overpressure system will be monitored over the lifetime of the cask. To allow time to diagnose and correct any problems, the overpressure monitoring system is set to alarm if the overpressure system drops below 3.0 atm abs (29.4 psig). This alarm setpoint

ensures that pressure decreases in the overpressure monitoring system are identified well before any potential out leakage from the cask cavity occurs.

7.2 Requirements for Normal Conditions of Storage

7.2.1 Release of Radioactive Material

The TN-68 dry storage cask is designed to provide storage of spent fuel for at least 40 years. The cask cavity pressure is always above ambient during the storage period as a precaution against the in-leakage of air which might be harmful to the fuel. Since the confinement vessel consists of a steel cylinder with an integrally-welded bottom closure, the cavity gas can escape only through the lid closure system. In order to ensure cask leak tightness, two systems are employed. First, all bolted closures are provided with double seals. Second, the interspace between the seals is pressurized to provide a positive pressure gradient. If the inner seals were to leak, helium would flow into the cask cavity and radioactive material would not be released. If the outer seals were to leak, helium would leak from the overpressure system to the exterior, and no radioactive material would be released.

The cask loadings for normal conditions of storage are given in Section 2.2.5. It is shown that the seals are not disturbed by any of the loadings and thus, the cask confinement is maintained.

7.2.2 Pressurization of Confinement Vessel

The TN-68 cask cavity's equilibrium pressure during normal storage conditions with no fuel rod rupture is 2.2 atm abs (17.6 psig). The internal pressure is determined on the basis that a minimum of 1 atm pressure must exist on the coldest day at the end of life. Pressure variations due to daily and seasonal changes in ambient temperature conditions will be small due to the large thermal capacity of the cask. The initial pressure of 2.2 atm abs assures that at the end of 40 years, on the coldest day (–20°F ambient), the internal pressure of the cask is:

$$P_{cavity} = 2.20 \text{ atm abs} \times (596°R / 862°R) = 1.5 \text{ atm abs (7.7 psig)}^{\dagger}$$

Therefore, the internal pressure of the cask is above the 1 atm minimum.

7.2.2.1 Pressure at Helium Backfill

The maximum normal operating pressure is 2.2 atm abs. A steady state run of the full cask model described in Section 4.5.1 determines the average cavity gas temperature after completion of the helium backfilling. An ambient temperature of 70°F is considered for this run. The average gas cavity temperature is 350°F (810°R), and is retrieved from the model using the methodology described in Section 4.7.1.

† 596°R is the average gas cavity temperature after 40 years of storage assuming an external ambient temperature of -20°F and 21.2 kW initial heat load.

Section 4.7.1 shows, once the cask reaches thermal equilibrium, the average cavity gas temperature with 100°F ambient air and maximum solar load is 402°F (862°R). Therefore, the pressure at helium backfill should be equal to or less than:

2.2 atm abs (810°R / 862°R) = 2.07 atm abs (15.7 psig)

7.2.2.2 Pressure under 100°F Ambient Air Temperature, Maximum Insolation, 10% Fuel Rod Failure

See Section 4.7 for calculation of the cask cavity pressure under normal, off-normal, and accident conditions.

7.3 Confinement Requirements for Hypothetical Accident Conditions

7.3.1 Fission Gas Products

Table 5.2-5 lists the activity representing the fission gases, volatiles, and fines contributing more than 0.1% of the activity contained in the 68 fuel assemblies, plus Iodine 129.

The releasable source term is first determined. The release fractions applied to the source term are provided below (developed from References 3 and 4).

Variable	Off-Normal Conditions	Accident Conditions
Fraction of crud that spalls off rods, f_C	0.15	1.0
Fraction of Rods that develop cladding breaches, f_B	0.10	1.0
Fraction of Gases that are released due to a cladding breach, f_G	0.3	0.3
Fraction of Fines that are released due to a cladding breach, f_F	3×10^{-5}	3×10^{-5}
Fraction of Released fines that remain airborne following a cladding breach, $F_{f,a}$ *	0.10	0.10
Fraction of Volatiles that are released due to a cladding breach, f_V	2×10^{-4}	2×10^{-4}

* 0.003% of the fuel in a rod is released from the rod during a cladding failure in the form of fines. However, only 10% of the fuel fines ejected from the rod during a cladding failure remain airborne (Reference 10).

The releasable source term also depends on the leak rate from the TN-68. Under off-normal conditions, it is assumed that the overpressure system is not functioning properly. In this case, the cask cavity gas is free to leak out at a rate of 1×10^{-5} std cc /sec. Assuming the cask cavity gas acts like helium (including the gases, volatiles, fines and crud), the leak rate is adjusted to a helium leak rate at cask cavity conditions using the equations of ANSI N14.5. This calculation is shown below.

P_u = 2.47 atm abs , 36.3 psig (off-normal cask cavity pressure assuming 10% of the fuel rods have failed – Section 4.7.5)
P_d = 1.0 atm abs
D = 4.825×10^{-4} cm
a = 0.5 cm
μ = 0.0279 cP (for helium at 479K)
T = fluid absolute temp = average cavity gas temp = 402°F = 479 K
M = 4.0
$P_a = \frac{1}{2} (P_u + P_d)$ = 1.735 atm abs

Substituting:

F_c = 9.674E-06
F_m = 5.399E-06

$L_{u,he}$ = 1.556E-05 cc/sec (conservatively 1.66E-05) of Helium for off-normal conditions

Similarly, under hypothetical accident conditions, it is assumed that the overpressure system has stopped functioning and fire conditions exist.

P_u = 5.89 atm abs, 71.7 psig (cask cavity pressure following hypothetical fire and assuming 100% fuel rod failure –Section 4.7.5)
P_d = 1.0 atm abs
D = 4.825 x 10^{-4} cm a = 0.5 cm
μ = 0.0296 cP (for helium at 573K)
T = fluid absolute temp = average cavity gas temp following fire = 572°F = 593K
M = 4.0
$P_a = ½ (P_u + P_d)$ = 3.44 atm abs

Substituting in to the equations of ANSI N14.5:

F_c = 9.119E-06
F_m = 2.978E-06
$L_{u,he}$ = 3.454E-05 cc/sec (conservatively 3.54E-05) of Helium for hypothetical accident conditions.

The releasable contents from the TN-68 during off-normal and hypothetical accident conditions are provided in Tables 7.3-1 and 7.3-2, respectively.

7.3.2 Release of Contents

Two scenarios are considered:

- Off-Normal Conditions – This condition exists over a one year period, seals are leaking at the test leak rate of 1 x 10^{-5} ref cm^3/s and the fraction of rods that have failed is 10%. Stability category D and 5 m/s wind speed is used for this analysis. This scenario assumes one cask is in off-normal condition at the ISFSI.

- Hypothetical Accident Conditions – This condition exists over a 30 day period, seals are leaking at the test leak rate of 1 x 10^{-5} ref cm^3/sec, the fraction of rods that have failed is 100%, and the temperature inside the cask is comparable to the fire accident conditions. Stability category F and 1 m/s wind speed is used for this analysis. This scenario assumes one cask is in the hypothetical accident condition at the ISFSI.

In the first scenario, the release is assumed to occur for more than a 20 minute period. The methodology of Reg Guide 1.145(5) is applied. The atmospheric diffusion from a ground level point source at 100 meters is based on the following parameters.

Wind speed = 5 meter/second
σ_y = 8 meters from Ref 5, Figure 1
σ_z = 5 meters from Ref 5, Figure 2

$M = 1.1$, from Ref 5, Figure 3
$\Sigma_y = M\sigma_y = 8.8$ meters
A = is cross sectional area of the TN-68 = $12.6m^2$

Using the methodology of Reg Guide 1.145, $\{\chi/Q\}_{100\ meters}$ during off-normal conditions is 1.45E-03 sec/m^3. Similarly, the atmospheric diffusion for 500 meters during off- normal conditions is calculated using the following parameters.

Wind speed = 5 meter/second
$\sigma_y = 40$ meters
$\sigma_z = 20$ meters
$M = 1.1$
$\Sigma_y = M\sigma_y = 44$ meters

During off normal conditions$\{\chi/Q\}_{500\ meters}$ is 7.23E-05 sec/m^3.

In the second scenario the release is assumed to be a short term ground level release (occurring however over a 30 day period) assuming the methodology of Regulatory Guide 1.25[(6)]. The atmospheric stability classification of F and a wind speed of 1 m/sec is used. The atmospheric diffusion from a ground level point source at 100 meters is calculated below.

Wind speed = 1 meter/second
$\sigma_y = 4$ meters (Ref 5, Figure 1)
$\sigma_z = 2.3$ meters (Ref 5, Figure 2)

Substituting into the equations of Reference 6:
$\chi/Q = 1 / 1 (\pi \times 4 \times 2.3) = 3.46E\text{-}02$ sec/m^3 for hypothetical accident conditions

Similarly, the atmospheric diffusion for 500 meters is:

Wind speed = 1 meter/second
$\sigma_y = 20.0$ meters (from reference [2.13], Figure 1)
$\sigma_z = 8.4$ meters (from reference [2.13], Figure 2)
$\{\chi/Q\}_{500\ meters} = 1.90E\text{-}03$ sec/m^3 for hypothetical accident conditions.

7.3.2.1 Dose Calculations

Dose components are calculated following the method of Regulatory Guide 1.109[(7)] and utilizing dose conversion factors from EPA Federal Guidance Reports Numbers 11 and 12[(8,9)]. (Note: Two sets of DCFs depending upon the chemical state of Sr-90 are reported in Federal Guidance Report Number 11. One set of DCF values is for Sr in the form of $SrTiO_3$ and the other set is for Sr in all other forms. The Sr-90 fission product should not form $SrTiO_3$ within the storage cask and therefore the DCF for this compound was not used.)

To determine the committed doses (from air inhalation), the following equation is used:

$Dose_{inhalation} = R \times \chi/Q \times Q \times DCF_{inhalation} \times Time$

Where:
R = Inhalation Rate = 8,000 m^3/year = 2.54E-04 m^3/sec
χ/Q = Short term average centerline value of atmospheric diffusion for a ground level release (sec/m^3)
Q = amount of material released (μCi/sec)
$DCF_{inhalation}$ = Exposure Dose Conversion Factor (mrem/μCi), from reference 8.
Time = Time of Exposure (Seconds)

To determine the deep doses (from air immersion), the following equation is used:

$Dose_{air\ immersion} = \{\chi/Q \times Q \times DCF_{air\ immersion}\} \times Time$

Where:

χ / Q = Short term average centerline value of atmospheric diffusion for a ground level release (sec/m^3)
Q = amount of material released (μCi/sec)
$DCF_{immersion}$ = Exposure Dose Conversion Factor (mrem/year per $\mu Ci/cm^3$), from ref 9
Time = Time of Exposure (Seconds)

Section 5.2.4 provides the definitions and source terms for three combinations of burnup, enrichment, and cooling time for 8x8 fuel: design basis (DBF-68), medium burnup (MBF-68) and high burnup (HBF-68). For off-normal conditions, the estimated annual airborne doses (internal and external) at 100 meters from a single TN-68 cask are provided in Table 7.3-3. Since the DBF-68 fuel provides for the maximum source term (Co60 dominates the releases) for off-normal conditions, only the DBF-68 fuel is evaluated for confinement calculations. The deep dose (external) and the committed dose (internal) on an organ basis and total effective dose for distances of 100 and 500 meters are summarized below:

	Dose at 100 meters (mrem/yr)	Dose at 500 meters (mrem/yr)
Gonad	5.96E-01	2.97E-02
Breast	1.21E+00	6.02E-02
Lung	**2.25E+01**	**1.12E+00**
Red Marrow	3.14E+00	1.56E-01
Bone Surface	1.78E+01	8.88E-01
Thyroid	1.07E+00	5.36E-02
Remainder	2.87E+00	1.43E-01
Effective	**5.39E+00**	**2.69E-01**
Skin	5.16E-02	2.57E-03

The values presented in bold print above demonstrate that the criteria of 72.104(a) are met under off-normal conditions.

For hypothetical accident conditions, the committed doses (internal) and the deep doses (external) at 100 meters from a single TN-68 cask for a 30 day exposure are provided in Table 7.3-4. The total effective dose equivalent at 100 m and at 500 m from the TN-68 cask due to the three sources DBF-68, MBF-68 and HBF-68 is summarized in the tables below.

Target	**Dose at 100 meters (mrem)**		
	DBF-68	**MBF-68**	**HBF-68**
Gonad	2.04E+01	1.97E+01	1.87E+01
Breast	3.44E+01	2.36E+01	1.86E+01
Lung	6.49E+02	4.56E+02	3.69E+02
Red Marrow	1.16E+02	1.20E+02	1.20E+02
Bone Surface	**7.33E+02**	**8.98E+02**	**9.27E+02**
Thyroid	3.07E+01	2.12E+01	1.68E+01
Remainder	8.88E+01	7.53E+01	6.64E+01
Effective (TEDE)	**1.75E+02**	**1.50E+02**	**1.39E+02**
Skin	1.67E+00	1.26E+00	1.12E+00
Lens Dose (Skin + TEDE)	**1.76E+02**	**1.51E+02**	**1.40E+02**

Target	**Dose at 500 meters (mrem)**		
	DBF-68	**MBF-68**	**HBF-68**
Gonad	1.12E+00	1.08E+00	1.03E+00
Breast	1.89E+00	1.30E+00	1.02E+00
Lung	3.56E+01	2.50E+01	2.03E+01
Red Marrow	6.37E+00	6.57E+00	6.61E+00
Bone Surface	**4.02E+01**	**4.93E+01**	**5.09E+01**
Thyroid	1.69E+00	1.17E+00	9.22E-01
Remainder	4.88E+00	4.13E+00	3.65E+00
Effective (TEDE)	**9.60E+00**	**8.24E+00**	**7.64E+00**
Skin	9.18E-02	6.94E-02	6.15E-02
Lens Dose (Skin + TEDE)	**9.69E+00**	**8.31E+00**	**7.70E+00**

The maximum 30-day TEDE value of 175 mrem is due to the DBF-68 fuel. The corresponding 10CFR 72.106 limit is 5 rem.

The maximum 30-day Lens Dose Equivalent value of 176 mrem is also due to the DBF-68 fuel. The corresponding 10CFR 72.106 limit is 15 rem.

The maximum 30-day dose to any organ / tissue is 927 mrem and it occurs at the bone surface due to the HBF-68 fuel. The corresponding 10CFR 72.106 limit is 50 rem.

Therefore all the criteria of 72.106 are met at 100m.

For the accident conditions, the DBF-68 fuel provides for the maximum annual dose except bone surface and red marrow. For these organs, the Pu-238 and Cm-244 are important isotopes and their concentrations are higher at higher burnup.

A summary of the doses at 100m and their corresponding regulatory limits is shown below

Off-Normal Conditions		
Organ	**10CFR72.104(a) Limit (mrem)**	**Dose (mrem)**
Whole Body (TEDE)	25	5.39
Thyroid	75	1.07
Other Critical Organ	25	22.5 (Lung)
Accident Conditions		
Organ	**10CFR72.106(b) Limit (mrem)**	**Dose (mrem)**
Whole Body (TEDE)	5000	175
Organ (TODE)	50000	927 (Bone Surface)
Lens of Eye (LDE)	15000	176
Skin (SDE)	50000	1.67

7.3.2.2 Pressurization of Confinement Vessel

The cask cavity pressure for normal, off-normal, and accident conditions is calculated in Section 4.7.

7.3.3 Latent Seal Failure

By design the overpressure monitoring system does not immediately alarm if there is a leak in a seal or the overpressure system. The time period from when a leak begins to occur and when the overpressure system alarm is activated is dependent on the size of the leak. Two conditions which could exist within the TN-68 confinement system are:

(1) The outer seal (or the overpressure system) is leaking to the atmosphere. In this case the inner seal is intact and there is no release of the contents of the cask cavity to the atmosphere.

(2) The inner seal is leaking (or the overpressure system is leaking into the cask cavity). In this case the outer seal is still intact and there is no release of the cask cavity contents to the atmosphere.

If a latent seal leak has occurred, the tables below provide some examples of the time to alarm based on assumed leakage rates (and based on the conditions presented in Section 7.1.5).

Case 1 - Leakage of Overpressure System to the Atmosphere

Leak Rate (ref cm^3/s)	Estimated Time to Alarm (from Start of Latent Seal Failure)	Estimated Time to Loss of OP System Pressure (from Start of Latent Seal Failure)
1×10^{-3}	15 days	31 days
1×10^{-4}	160 days	326 days
5×10^{-4} (see Figure 7.1-2)	1 year	2.5 years
1×10^{-5} (see Figure 7.1-1)	11 years	over 20 years

Case 2 – Leakage of Overpressure System to Cask Cavity

Leak Rate (ref cm^3/s)	Estimated Time to Alarm (from Start of Latent Seal Failure)	Estimated Time to Equalize OP System Pressure with Cask Cavity Pressure (from Start of Latent Seal Failure)
1×10^{-3}	16 days	21 days
1×10^{-4}	175 days	220 days
5×10^{-4} (see Figure 7.1-2)	1.5 years	10 years
1×10^{-5} (see Figure 7.1-1)	15 years	over 20 years

As shown in the tables above, the alarm is set such that for any credible leak, there is time to evaluate the leaking condition and correct the condition provided that the overpressure system remains pressurized. This period can be extended by repressurizing the overpressure tank.

Another condition which has been considered is that a latent seal failure has occurred and the overpressure system is removed due to an accident.

(1) If the outer seal has the latent failure and the OP system is removed then there is no release of cask cavity contents to the atmosphere.

(2) If the inner seal has a latent failure and the OP system is removed then the table below provides the time before 10 CFR 72.106(b) limits will be exceeded (based on accident conditions presented in Section 7.2).

Standard Leak Rate (ref cm^3/sec)	Time to exceed 10 CFR 72.106(b) Limits
1×10^{-3}	8.5 days
1×10^{-4}	85 days
5×10^{-5}	171 days
1×10^{5}	857 days

The times above demonstrate that a latent failure up to 100 times greater than the test value could occur and recovery is possible.

The time to reach the accident release rates is dependent on the size of the leak. Due to the reliability of the metallic o-rings used in static applications, it is not considered credible that the inner seals could leak at a rate significantly higher than the test leak rate. The probability that a gross leak of an inner seal in combination with a gross leak in an outer seal or the overpressure system, such that the overpressure system could not hold pressure, is not considered a credible event.

However, if the overpressure system is not functional, the overpressure system can be replaced with a blind flange. The replacement of the overpressure system with the blind flange is described under contingency actions in Chapter 8, Section 8.4. The estimated operational dose due to this operation is provided in Chapter 10.

7.4 References

1. American Society of Mechanical Engineers, ASME Boiler and Pressure Vessel Code, Section III, Division 1 - Subsection NB, 1995 with Addenda through 1996.

2. ANSI N14.5-1997, “Leakage Tests on Packages for Shipment,” February 1998.

3. NUREG-1536, “Standard Review Plan for Dry Storage Casks, Final Report,” US Nuclear Regulatory Commission, January 1997.

4. NUREG-1617, “Standard Review Plan for Transportation Packages for Spent Nuclear Fuel, Draft Report for Comment” US Nuclear Regulatory Commission, March 1998.

5. USNRC Regulatory Guide 1.145,"Atmospheric Dispersion Models for Potential Accident Consequence Assessment at Nuclear Power Plants," Rev 1, 1983.

6. USNRC Regulatory Guide 1.25, “Assumptions Used for Evaluating the Potential Radiological Consequences of a Fuel Handling Accident in the Fuel Handling Storage Facility for Boiling and Pressurized Water Reactors.”

7. USNRC Regulatory Guide 1.109, "Calculation of Annual Doses to Men from Routing Releases of Reactor Effluent for the Purpose of Evaluating Compliance with 10CFR50, Appendix I," Rev 1, 1977.

8. USEPA Federal Guidance Report No 11, "Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion and Ingestion," EPA-520/1-88-0202, September 1988.

9. USEPA Federal Guidance Report No 12, "External Exposure to Radionuclides in Air, Water, and Soil," EPA-402-R-93-081, September, 1983.

10. SAND90-2406, “A Method for Determining the Spent Fuel Contribution to Transport Cask Containment Requirements,” Sandia National Laboratories, November 1992.

11. Helicoflex Catalog ET 507 E5930

Table 7.3-1
TN-68 Releasable Source Term for Off-Normal Conditions (Design Basis 8x8 Fuel)

Isotope	Activity (Ci/assembly)	Release Fraction	Concentration in Void Space of TN-68[1] (Ci/cm^3)	Material Released[2] Q (μCi/sec)
H 3	8.89E+01	0.30	3.02E-05	5.02E-04
Co 60[3]	5.04E+01	1.50E-01	8.57E-05	1.42E-03
Pu238	9.72E+02	3.00E-06	3.30E-09	5.49E-08
Pu239	5.15E+01	3.00E-06	1.75E-10	2.91E-09
Pu240	1.24E+02	3.00E-06	4.22E-10	7.00E-09
Pu241	1.90E+04	3.00E-06	6.46E-08	1.07E-06
Am241	2.78E+02	3.00E-06	9.45E-10	1.57E-08
Am243	1.35E+01	3.00E-06	4.59E-11	7.62E-10
Cm243	7.08E+00	3.00E-06	2.41E-11	4.00E-10
Cm244	2.22E+03	3.00E-06	7.55E-09	1.25E-07
Kr 85	1.28E+03	0.30	4.35E-04	7.22E-03
Sr 90	1.46E+04	2.00E-04	3.31E-06	5.49E-05
Y 90	1.46E+04	3.00E-06	4.96E-08	8.24E-07
Ru106	1.29E+03	2.00E-04	2.92E-07	4.85E-06
Rh106	1.29E+03	3.00E-06	4.39E-09	7.28E-08
Sb125	3.68E+02	3.00E-06	1.25E-09	2.08E-08
Te125m	8.98E+01	3.00E-06	3.05E-10	5.07E-09
I129	8.94E-03	0.30	3.04E-09	5.05E-08
Cs134	4.92E+03	2.00E-04	1.12E-06	1.85E-05
Cs137	2.47E+04	2.00E-04	5.60E-06	9.29E-05
Ba137m	2.33E+04	3.00E-06	7.92E-08	1.32E-06
Ce144	3.91E+02	3.00E-06	1.33E-09	2.21E-08
Pr144	3.91E+02	3.00E-06	1.33E-09	2.21E-08
Pm147	4.52E+03	3.00E-06	1.54E-08	2.55E-07
Eu154	1.04E+03	3.00E-06	3.54E-09	5.87E-08
Eu155	3.15E+02	3.00E-06	1.07E-09	1.78E-08

1. Values are based on 10% failure of the fuel rods and cask free volume of 6 m^3.

2. Values are based on 1.6E-05 cm^3 / sec helium leak from confinement.

3. The Co-60 source is calculated using the methodology of Reference 3. It is based on a 7x7 fuel assembly with surface area of 1829 cm^2/rod and a crud surface concentration of 1254 μCi /cm^2 at the time of discharge. (The value listed above includes a minimum cooling time of ten years.)

Table 7.3-2
TN-68 Releasable Source Term for Off-Normal Conditions (Design Basis 8x8 Fuel)

Isotope	Activity (Ci/assembly)	Release Fraction	Concentration in Void Space of TN-68[1] (Ci/cm^3)	Material Released[2] Q (μCi/sec)
H3	8.89E+01	0.30	3.02E-04	1.07E-02
Co60[3]	5.04E+01	1.00E-00	5.71E-04	2.02E-02
Pu238	9.72E+02	3.00E-06	3.30E-08	1.17E-06
Pu239	5.15E+01	3.00E-06	1.75E-09	6.20E-08
Pu240	1.24E+02	3.00E-06	4.22E-09	1.49E-07
Pu241	1.90E+04	3.00E-06	6.46E-07	2.29E-05
Am241	2.78E+02	3.00E-06	9.45E-09	3.35E-07
Am243	1.35E+01	3.00E-06	4.59E-10	1.62E-08
Cm243	7.08E+00	3.00E-06	2.41E-10	8.52E-09
Cm244	2.22E+03	3.00E-06	7.55E-08	2.67E-06
Kr85	1.28E+03	0.30	4.35E-03	1.54E-01
Sr90	1.46E+04	2.00E-04	3.31E-05	1.17E-03
Y90	1.46E+04	3.00E-06	4.96E-07	1.76E-05
Ru106	1.29E+03	2.00E-04	2.92E-06	1.04E-04
Rh106	1.29E+03	3.00E-06	4.39E-08	1.55E-06
Sb125	3.68E+02	3.00E-06	1.25E-08	4.43E-07
Te125m	8.98E+01	3.00E-06	3.05E-09	1.08E-07
I129	8.94E-03	0.30	3.04E-08	1.08E-06
Cs134	4.92E+03	2.00E-04	1.12E-05	3.95E-04
Cs137	2.47E+04	2.00E-04	5.60E-05	1.98E-03
Ba137m	2.33E+04	3.00E-06	7.92E-07	2.80E-05
Ce144	3.91E+02	3.00E-06	1.33E-08	4.71E-07
Pr144	3.91E+02	3.00E-06	1.33E-08	4.71E-07
Pm147	4.52E+03	3.00E-06	1.54E-07	5.44E-06
Eu154	1.04E+03	3.00E-06	3.54E-08	1.25E-06
Eu155	3.15E+02	3.00E-06	1.07E-08	3.79E-07

1 Values are based on 100% failure of the fuel rods and cask free volume of 6 m^3.

2 Values are based on 2.76E-05 cm^3 / sec helium leak from confinement.

3 The Co-60 source is calculated using the methodology of Reference 3. It is based on a 7x7 fuel assembly with surface area of 1829 cm^2/rod and an initial crud surface concentration of 1254 μCi / cm^2 at the time of discharge. (The value listed above includes a minimum cooling time of ten years).

Table 7.3-3
Off-Site Airborne Doses From Off-Normal Conditions at 100 M
From the TN-68 Cask

Design Basis 8x8 Fuel (DBF-68), Committed Doses (Internal) + Deep Dose (External)
mrem/year

Isotope	Gonad	Breast	Lung	R. Marrow	B. Surface	Thyroid	Remainder	Effective
H3	3.73E-04	3.73E-04	3.73E-04	3.73E-04	3.73E-04	3.73E-04	3.73E-04	3.73E-04
Co60	3.21E-01	1.16E+00	2.11E+01	1.08E+00	8.68E-01	1.02E+00	2.23E+00	3.64E+00
Pu238	6.60E-02	2.36E-06	7.54E-01	3.58E-01	4.48E+00	2.27E-06	1.66E-01	2.50E-01
Pu239	3.97E-03	1.15E-07	4.03E-02	2.11E-02	2.64E-01	1.13E-07	9.44E-03	1.45E-02
Pu240	9.56E-03	2.86E-07	9.71E-02	5.08E-02	6.35E-01	2.72E-07	2.27E-02	3.49E-02
Pu241	3.14E-02	1.41E-06	1.47E-01	1.55E-01	1.94E+00	5.71E-07	6.04E-02	1.03E-01
Am241	2.19E-02	1.80E-06	1.24E-02	1.17E-01	1.46E+00	1.08E-06	5.27E-02	8.09E-02
Am243	1.07E-03	4.98E-07	5.83E-04	5.66E-03	7.11E-02	2.72E-07	2.53E-03	3.90E-03
Cm243	3.55E-04	1.08E-07	3.33E-04	2.03E-03	2.52E-02	6.62E-08	9.89E-04	1.43E-03
Cm244	8.56E-02	5.60E-06	1.04E-01	5.05E-01	6.30E+00	5.44E-06	2.57E-01	3.61E-01
Kr85	1.43E-04	1.64E-04	1.39E-04	1.33E-04	2.69E-04	1.44E-04	1.33E-04	1.46E-04
Sr90	6.23E-03	6.23E-03	8.81E-03	7.93E-01	1.72E+00	6.23E-03	1.35E-02	8.29E-01
Y90	3.63E-07	3.68E-07	3.30E-04	9.90E-06	9.91E-06	3.63E-07	1.37E-04	8.08E-05
Ru106	2.88E-03	2.86E-03	2.17E-01	2.86E-03	2.86E-03	2.86E-03	3.53E-03	2.69E-02
Rh106	1.25E-07	1.43E-07	1.25E-07	1.20E-07	2.12E-07	1.27E-07	1.19E-07	1.28E-07
Sb125	3.91E-07	4.51E-07	1.94E-05	6.45E-07	2.56E-06	3.60E-07	1.36E-06	3.02E-06
Te125m	2.75E-08	2.40E-08	2.27E-06	6.56E-07	6.99E-06	2.20E-08	1.47E-07	4.29E-07
I129	1.93E-07	4.59E-07	6.83E-07	3.05E-07	3.09E-07	3.38E-03	2.58E-07	1.02E-04
Cs134	1.06E-02	8.86E-03	9.62E-03	9.61E-03	9.13E-03	9.07E-03	1.13E-02	1.02E-02
Cs137	3.50E-02	3.13E-02	3.52E-02	3.31E-02	3.17E-02	3.17E-02	3.64E-02	3.45E-02
Ba137m	6.28E-06	7.17E-06	6.24E-06	6.08E-06	1.03E-05	6.41E-06	5.97E-06	6.41E-06
Ce144	1.83E-06	1.87E-06	7.50E-04	2.53E-05	4.31E-05	1.79E-06	9.77E-05	9.58E-05
Pr144	7.10E-09	8.05E-09	9.62E-08	7.07E-09	1.13E-08	7.30E-09	8.20E-09	1.84E-08
Pm147	2.38E-10	4.36E-10	8.49E-04	8.95E-05	1.12E-03	2.46E-10	6.46E-05	1.16E-04
Eu154	3.01E-05	3.98E-05	2.00E-04	2.68E-04	1.32E-03	1.86E-05	2.86E-04	1.96E-04
Eu155	2.79E-07	4.78E-07	9.10E-06	1.09E-05	1.16E-04	1.91E-07	8.49E-06	8.56E-06
Total	5.96E-01	1.21E+00	2.25E+01	3.14E+00	1.78E+01	1.07E+00	2.87E+00	5.39E+00

Table 7.3-3
Off-Site Airborne Doses From Off-Normal Conditions at 100 M
From the TN-68 Cask

(Continued)
Design Basis 8x8 Fuel (DBF-68), Deep Doses (External)
mrem/year

Isotope	Gonad	Breast	Lung	R. Marrow	B. Surface	Thyroid	Remain-der	Effective	Skin
H3	0.00E+00	0.00E+00	2.34E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.81E-08	0.00E+00
Co60	2.96E-02	3.35E-02	2.99E-02	2.96E-02	4.29E-02	3.06E-02	2.89E-02	3.04E-02	3.49E-02
Pu238	6.09E-11	1.18E-10	9.85E-12	1.56E-11	8.64E-11	3.73E-11	1.85E-11	4.53E-11	3.80E-10
Pu239	2.38E-12	3.72E-12	1.30E-12	1.31E-12	4.66E-12	1.91E-12	1.41E-12	2.09E-12	9.16E-12
Pu240	7.54E-12	1.46E-11	1.29E-12	1.96E-12	1.10E-11	4.65E-12	2.32E-12	5.63E-12	4.65E-11
Pu241	1.31E-11	1.57E-11	1.18E-11	1.02E-11	3.98E-11	1.27E-11	1.11E-11	1.32E-11	2.12E-11
Am241	2.28E-09	2.84E-09	1.79E-08	1.38E-09	7.63E-09	2.08E-09	1.68E-09	2.17E-09	3.40E-09
Am243	2.83E-10	3.37E-10	2.48E-10	2.00E-10	9.64E-10	2.70E-10	2.31E-10	2.81E-10	3.55E-10
Cm243	3.90E-10	4.52E-10	3.72E-10	3.38E-10	1.02E-09	3.90E-10	3.51E-10	3.98E-10	6.63E-10
Cm244	1.46E-10	2.82E-10	1.50E-11	3.10E-11	1.87E-10	8.89E-11	3.84E-11	1.04E-10	8.30E-10
Kr85	1.43E-04	1.64E-04	1.39E-04	1.33E-04	2.69E-04	1.44E-04	1.33E-04	1.46E-04	1.62E-02
Sr90	7.24E-08	8.83E-08	5.99E-08	5.06E-08	2.12E-07	6.82E-08	5.68E-08	7.01E-08	8.56E-05
Y90	2.64E-08	3.07E-08	2.47E-08	2.26E-08	6.20E-08	2.61E-08	2.34E-08	2.65E-08	8.71E-06
Ru106	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rh106	1.25E-07	1.43E-07	1.25E-07	1.20E-07	2.12E-07	1.27E-07	1.19E-07	1.28E-07	1.34E-06
Sb125	6.96E-08	7.98E-08	6.86E-08	6.58E-08	1.24E-07	7.07E-08	6.54E-08	7.11E-08	9.32E-08
Te125m	5.12E-10	7.28E-10	1.91E-10	1.60E-10	1.05E-09	3.98E-10	2.22E-10	3.89E-10	1.67E-09
I129	4.13E-09	5.69E-09	1.83E-09	1.40E-09	9.40E-09	3.30E-09	1.97E-09	3.25E-09	9.40E-09
Cs134	2.32E-04	2.64E-04	2.31E-04	2.25E-04	3.76E-04	2.37E-04	2.21E-04	2.37E-04	2.96E-04
Cs137	1.25E-07	1.52E-07	1.05E-07	8.97E-08	3.60E-07	1.19E-07	9.98E-08	1.22E-07	1.36E-04
Ba137m	6.28E-06	7.17E-06	6.24E-06	6.08E-06	1.03E-05	6.41E-06	5.97E-06	6.41E-06	8.31E-06
Ce144	3.19E-09	3.77E-09	2.87E-09	2.50E-09	9.31E-09	3.11E-09	2.70E-09	3.19E-09	1.10E-08
Pr144	7.10E-09	8.04E-09	7.10E-09	6.99E-09	1.12E-08	7.29E-09	6.88E-09	7.29E-09	3.15E-07
Pm147	3.23E-11	4.13E-11	2.35E-11	1.93E-11	9.42E-11	2.92E-11	2.27E-11	2.99E-11	3.50E-08
Eu154	5.96E-07	6.77E-07	5.95E-07	5.84E-07	9.37E-07	6.11E-07	5.72E-07	6.10E-07	8.24E-07
Eu155	7.50E-09	8.88E-09	6.68E-09	5.57E-09	2.44E-08	7.26E-09	6.23E-09	7.50E-09	1.02E-08
Total	3.00E-02	3.39E-02	3.02E-02	3.00E-02	4.35E-02	3.10E-02	2.93E-02	3.07E-02	5.16E-02

Table 7.3-4
Off-Site Airborne Doses From Accident Conditions at 100 M
From the TN-68 Cask

Design Basis 8x8 Fuel (DBF-68), mrem/30 Days, Committed Doses (Internal)

Isotope	Gonad	Breast	Lung	R. Marrow	B. Surface	Thyroid	Remainder	Effective
H3	1.56E-02	1.56E-02	1.56E-02	1.56E-02	1.56E-02	1.56E-02	1.56E-02	1.56E-02
Co60	8.11E+00	3.14E+01	5.88E+02	2.93E+01	2.30E+01	2.76E+01	6.14E+01	1.01E+02
Pu238	2.76E+00	9.86E-05	3.16E+01	1.50E+01	1.87E+02	9.49E-05	6.92E+00	1.05E+01
Pu239	1.66E-01	4.82E-06	1.69E+00	8.83E-01	1.10E+01	4.72E-06	3.95E-01	6.06E-01
Pu240	4.00E-01	1.20E-05	4.06E+00	2.13E+00	2.65E+01	1.14E-05	9.51E-01	1.46E+00
Pu241	1.31E+00	5.90E-05	6.13E+00	6.48E+00	8.10E+01	2.39E-05	2.52E+00	4.30E+00
Am241	9.17E-01	7.53E-05	5.19E-01	4.91E+00	6.12E+01	4.51E-05	2.21E+00	3.38E+00
Am243	4.46E-02	2.08E-05	2.44E-02	2.37E-01	2.97E+00	1.14E-05	1.06E-01	1.63E-01
Cm243	1.49E-02	4.52E-06	1.39E-02	8.48E-02	1.06E+00	2.75E-06	4.14E-02	5.96E-02
Cm244	3.58E+00	2.34E-04	4.35E+00	2.11E+01	2.63E+02	2.27E-04	1.08E+01	1.51E+01
Kr85	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sr90	2.61E-01	2.61E-01	3.68E-01	3.32E+01	7.18E+01	2.61E-01	5.66E-01	3.47E+01
Y90	1.41E-05	1.41E-05	1.38E-02	4.13E-04	4.12E-04	1.41E-05	5.73E-03	3.38E-03
Ru106	1.20E-01	1.20E-01	9.07E+00	1.20E-01	1.20E-01	1.20E-01	1.47E-01	1.13E+00
Rh106	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sb125	1.34E-05	1.55E-05	8.10E-04	2.42E-05	1.02E-04	1.21E-05	5.41E-05	1.23E-04
Te125m	1.13E-06	9.75E-07	9.47E-05	2.74E-05	2.92E-04	9.05E-07	6.15E-06	1.79E-05
I129	7.88E-06	1.90E-05	2.85E-05	1.27E-05	1.25E-05	1.41E-01	1.07E-05	4.25E-03
Cs134	4.33E-01	3.59E-01	3.93E-01	3.93E-01	3.66E-01	3.69E-01	4.63E-01	4.16E-01
Cs137	1.46E+00	1.31E+00	1.47E+00	1.39E+00	1.33E+00	1.32E+00	1.52E+00	1.44E+00
Ba137m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ce144	7.66E-05	7.81E-05	3.14E-02	1.06E-03	1.80E-03	7.46E-05	4.09E-03	4.01E-03
Pr144	9.56E-11	4.16E-10	3.73E-06	3.20E-09	5.35E-09	3.36E-10	5.55E-08	4.64E-07
Pm147	8.62E-09	1.65E-08	3.55E-02	3.74E-03	4.68E-02	9.08E-09	2.70E-03	4.86E-03
Eu154	1.23E-03	1.64E-03	8.36E-03	1.12E-02	5.52E-02	7.53E-04	1.19E-02	8.16E-03
Eu155	1.14E-05	1.96E-05	3.80E-04	4.57E-04	4.86E-03	7.67E-06	3.55E-04	3.58E-04
Total	1.96E+01	3.34E+01	6.48E+02	1.15E+02	7.31E+02	2.98E+01	8.80E+01	1.74E+02

Table 7.3-4
Off-Site Airborne Doses From Accident Conditions at 100 M
From the TN-68 Cask

(Continued)
HBF-68 Fuel, mrem/30 Days, Committed Doses (Internal)

Isotope	Gonad	Breast	Lung	R. Marrow	B. Surface	Thyroid	Remainder	Effective
H3	1.45E-02	1.45E-02	1.45E-02	1.45E-02	1.45E-02	1.45E-02	1.45E-02	1.45E-02
Co60	4.20E+00	1.62E+01	3.04E+02	1.52E+01	1.19E+01	1.43E+01	3.18E+01	5.22E+01
Pu238	3.78E+00	1.35E-04	4.32E+01	2.05E+01	2.56E+02	1.30E-04	9.47E+00	1.43E+01
Pu239	1.71E-01	4.96E-06	1.74E+00	9.09E-01	1.13E+01	4.86E-06	4.06E-01	6.24E-01
Pu240	4.29E-01	1.28E-05	4.36E+00	2.28E+00	2.85E+01	1.22E-05	1.02E+00	1.57E+00
Pu241	1.11E+00	4.97E-05	5.16E+00	5.45E+00	6.82E+01	2.01E-05	2.13E+00	3.62E+00
Am241	1.45E+00	1.19E-04	8.19E-01	7.75E+00	9.66E+01	7.13E-05	3.48E+00	5.34E+00
Am243	6.15E-02	2.87E-05	3.36E-02	3.26E-01	4.09E+00	1.56E-05	1.46E-01	2.25E-01
Cm243	1.71E-02	5.21E-06	1.61E-02	9.77E-02	1.22E+00	3.17E-06	4.77E-02	6.87E-02
Cm244	5.00E+00	3.27E-04	6.07E+00	2.95E+01	3.68E+02	3.18E-04	1.50E+01	2.11E+01
Kr85	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sr90	2.86E-01	2.86E-01	4.04E-01	3.64E+01	7.87E+01	2.86E-01	6.20E-01	3.80E+01
Y90	1.55E-05	1.55E-05	1.51E-02	4.53E-04	4.51E-04	1.55E-05	6.28E-03	3.70E-03
Ru106	4.83E-03	4.79E-03	3.64E-01	4.79E-03	4.79E-03	4.79E-03	5.91E-03	4.51E-02
Rh106	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sb125	4.57E-06	5.28E-06	2.75E-04	8.23E-06	3.46E-05	4.11E-06	1.84E-05	4.18E-05
Te125m	3.82E-07	3.30E-07	3.21E-05	9.28E-06	9.90E-05	3.06E-07	2.08E-06	6.08E-06
I129	9.61E-06	2.31E-05	3.47E-05	1.55E-05	1.53E-05	1.72E-01	1.30E-05	5.19E-03
Cs134	1.11E-01	9.20E-02	1.01E-01	1.01E-01	9.37E-02	9.46E-02	1.18E-01	1.07E-01
Cs137	1.62E+00	1.45E+00	1.63E+00	1.53E+00	1.47E+00	1.46E+00	1.68E+00	1.59E+00
Ba137m	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ce144	1.05E-06	1.07E-06	4.29E-04	1.45E-05	2.46E-05	1.02E-06	5.59E-05	5.48E-05
Pr144	1.31E-12	5.70E-12	5.10E-08	4.39E-11	7.33E-11	4.60E-12	7.60E-10	6.35E-09
Pm147	2.42E-09	4.64E-09	9.97E-03	1.05E-03	1.31E-02	2.55E-09	7.59E-04	1.37E-03
Eu154	1.06E-03	1.40E-03	7.16E-03	9.58E-03	4.73E-02	6.45E-04	1.02E-02	6.99E-03
Eu155	6.75E-06	1.16E-05	2.26E-04	2.71E-04	2.88E-03	4.55E-06	2.11E-04	2.12E-04
Total	1.82E+01	1.81E+01	3.68E+02	1.20E+02	9.26E+02	1.63E+01	6.60E+01	1.39E+02

Table 7.3-4
Off-Site Airborne Doses From Accident Conditions at 100 M
From the TN-68 Cask

(Continued)
Design Basis 8x8 Fuel (DBF-68), mrem/30 Days, Deep Doses (External)

	Gonad	Breast	Lung	R. Marrow	B. Surface	Thyroid	Remain-der	Effective	Skin
H3	0.00E+00	0.00E+00	9.77E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.18E-06	0.00E+00
Co60	8.26E-01	9.34E-01	8.33E-01	8.26E-01	1.20E+00	8.53E-01	8.06E-01	8.46E-01	9.74E-01
Pu238	2.55E-09	4.94E-09	4.12E-10	6.53E-10	3.61E-09	1.56E-09	7.73E-10	1.90E-09	1.59E-08
Pu239	9.97E-11	1.55E-10	5.46E-11	5.50E-11	1.95E-10	7.99E-11	5.89E-11	8.73E-11	3.83E-10
Pu240	3.15E-10	6.10E-10	5.40E-11	8.18E-11	4.59E-10	1.94E-10	9.72E-11	2.35E-10	1.94E-09
Pu241	5.46E-10	6.59E-10	4.92E-10	4.28E-10	1.66E-09	5.30E-10	4.63E-10	5.51E-10	8.89E-10
Am241	9.54E-08	1.19E-07	7.49E-07	5.79E-08	3.19E-07	8.70E-08	7.05E-08	9.09E-08	1.42E-07
Am243	1.18E-08	1.41E-08	1.04E-08	8.37E-09	4.03E-08	1.13E-08	9.66E-09	1.18E-08	1.48E-08
Cm243	1.63E-08	1.89E-08	1.56E-08	1.42E-08	4.25E-08	1.63E-08	1.47E-08	1.66E-08	2.77E-08
Cm244	6.12E-09	1.18E-08	6.28E-10	1.30E-09	7.83E-09	3.72E-09	1.61E-09	4.36E-09	3.47E-08
Kr85	5.99E-03	6.86E-03	5.83E-03	5.58E-03	1.13E-02	6.04E-03	5.58E-03	6.09E-03	6.75E-01
Sr90	3.03E-06	3.69E-06	2.51E-06	2.12E-06	8.87E-06	2.85E-06	2.38E-06	2.93E-06	3.58E-03
Y90	1.10E-06	1.28E-06	1.03E-06	9.46E-07	2.59E-06	1.09E-06	9.81E-07	1.11E-06	3.64E-04
Ru106	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rh106	5.21E-06	5.98E-06	5.21E-06	5.03E-06	8.87E-06	5.31E-06	4.97E-06	5.36E-06	5.62E-05
Sb125	2.91E-06	3.34E-06	2.87E-06	2.75E-06	5.19E-06	2.96E-06	2.74E-06	2.97E-06	3.90E-06
Te125m	2.14E-08	3.04E-08	8.01E-09	6.68E-09	4.38E-08	1.67E-08	9.30E-09	1.63E-08	6.96E-08
I129	1.73E-07	2.38E-07	7.65E-08	5.86E-08	3.93E-07	1.38E-07	8.22E-08	1.36E-07	3.93E-07
Cs134	9.70E-03	1.11E-02	9.66E-03	9.43E-03	1.57E-02	9.93E-03	9.26E-03	9.93E-03	1.24E-02
Cs137	5.24E-06	6.37E-06	4.40E-06	3.75E-06	1.51E-05	4.97E-06	4.17E-06	5.10E-06	5.68E-03
Ba137m	2.63E-04	3.00E-04	2.61E-04	2.54E-04	4.31E-04	2.68E-04	2.50E-04	2.68E-04	3.47E-04
Ce144	1.33E-07	1.58E-07	1.20E-07	1.04E-07	3.89E-07	1.30E-07	1.13E-07	1.33E-07	4.58E-07
Pr144	2.97E-07	3.36E-07	2.97E-07	2.92E-07	4.67E-07	3.05E-07	2.88E-07	3.05E-07	1.32E-05
Pm147	1.35E-09	1.73E-09	9.85E-10	8.06E-10	3.94E-09	1.22E-09	9.51E-10	1.25E-09	1.47E-06
Eu154	2.49E-05	2.83E-05	2.49E-05	2.44E-05	3.92E-05	2.56E-05	2.39E-05	2.55E-05	3.45E-05
Eu155	3.14E-07	3.72E-07	2.80E-07	2.33E-07	1.02E-06	3.03E-07	2.61E-07	3.14E-07	4.27E-07
Total	8.42E-01	9.52E-01	8.49E-01	8.41E-01	1.22E+00	8.69E-01	8.21E-01	8.63E-01	1.67E+00

Table 7.3-4
Off-Site Airborne Doses From Accident Conditions at 100 M
From the TN-68 Cask

(Continued)
HBF-68 Fuel, mrem/30 Days, Deep Doses (External)

	Gonad	Breast	Lung	R. Marrow	B. Surface	Thyroid	Remain-der	Effective	Skin
H3	0.00E+00	0.00E+00	9.11E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.10E-06	0.00E+00
Co60	4.28E-01	4.83E-01	4.31E-01	4.28E-01	6.19E-01	4.42E-01	4.17E-01	4.38E-01	5.04E-01
Pu238	3.49E-09	6.75E-09	5.64E-10	8.93E-10	4.94E-09	2.13E-09	1.06E-09	2.59E-09	2.17E-08
Pu239	1.03E-10	1.60E-10	5.62E-11	5.66E-11	2.01E-10	8.22E-11	6.06E-11	8.98E-11	3.94E-10
Pu240	3.38E-10	6.54E-10	5.80E-11	8.77E-11	4.92E-10	2.08E-10	1.04E-10	2.53E-10	2.08E-09
Pu241	4.60E-10	5.55E-10	4.14E-10	3.60E-10	1.40E-09	4.46E-10	3.90E-10	4.64E-10	7.48E-10
Am241	1.51E-07	1.88E-07	1.18E-06	9.14E-08	5.04E-07	1.37E-07	1.11E-07	1.44E-07	2.25E-07
Am243	1.63E-08	1.94E-08	1.43E-08	1.15E-08	5.55E-08	1.55E-08	1.33E-08	1.62E-08	2.04E-08
Cm243	1.88E-08	2.18E-08	1.79E-08	1.63E-08	4.89E-08	1.88E-08	1.69E-08	1.92E-08	3.19E-08
Cm244	8.55E-09	1.65E-08	8.77E-10	1.81E-09	1.09E-08	5.19E-09	2.24E-09	6.09E-09	4.85E-08
Kr85	5.33E-03	6.11E-03	5.20E-03	4.97E-03	1.00E-02	5.38E-03	4.97E-03	5.42E-03	6.02E-01
Sr90	3.32E-06	4.05E-06	2.75E-06	2.32E-06	9.72E-06	3.13E-06	2.61E-06	3.21E-06	3.92E-03
Y90	1.21E-06	1.41E-06	1.13E-06	1.04E-06	2.84E-06	1.20E-06	1.07E-06	1.22E-06	3.99E-04
Ru106	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rh106	2.09E-07	2.40E-07	2.09E-07	2.02E-07	3.56E-07	2.13E-07	1.99E-07	2.15E-07	2.25E-06
Sb125	9.89E-07	1.13E-06	9.74E-07	9.35E-07	1.76E-06	1.00E-06	9.30E-07	1.01E-06	1.32E-06
Te125m	7.24E-09	1.03E-08	2.71E-09	2.26E-09	1.48E-08	5.64E-09	3.15E-09	5.51E-09	2.36E-08
I129	2.10E-07	2.90E-07	9.33E-08	7.15E-08	4.79E-07	1.68E-07	1.00E-07	1.66E-07	4.79E-07
Cs134	2.49E-03	2.83E-03	2.48E-03	2.41E-03	4.03E-03	2.54E-03	2.37E-03	2.54E-03	3.17E-03
Cs137	5.79E-06	7.04E-06	4.86E-06	4.15E-06	1.67E-05	5.49E-06	4.61E-06	5.63E-06	6.28E-03
Ba137m	2.91E-04	3.32E-04	2.89E-04	2.82E-04	4.78E-04	2.97E-04	2.76E-04	2.97E-04	3.85E-04
Ce144	1.82E-09	2.16E-09	1.64E-09	1.43E-09	5.33E-09	1.78E-09	1.55E-09	1.82E-09	6.27E-09
Pr144	4.06E-09	4.60E-09	4.06E-09	4.00E-09	6.40E-09	4.17E-09	3.94E-09	4.17E-09	1.80E-07
Pm147	3.80E-10	4.85E-10	2.77E-10	2.26E-10	1.11E-09	3.43E-10	2.67E-10	3.52E-10	4.12E-07
Eu154	2.14E-05	2.43E-05	2.13E-05	2.09E-05	3.36E-05	2.19E-05	2.05E-05	2.19E-05	2.95E-05
Eu155	1.86E-07	2.21E-07	1.66E-07	1.38E-07	6.05E-07	1.80E-07	1.55E-07	1.86E-07	2.53E-07
Total	4.36E-01	4.93E-01	4.39E-01	4.36E-01	6.34E-01	4.50E-01	4.25E-01	4.47E-01	1.12E+00

Figure 7.1-1
Overpressure Monitoring System Pressure Drop With Time
(Assuming Acceptance Test Leak Rate of 1 x 10^{-5} ref cm^3 /s)

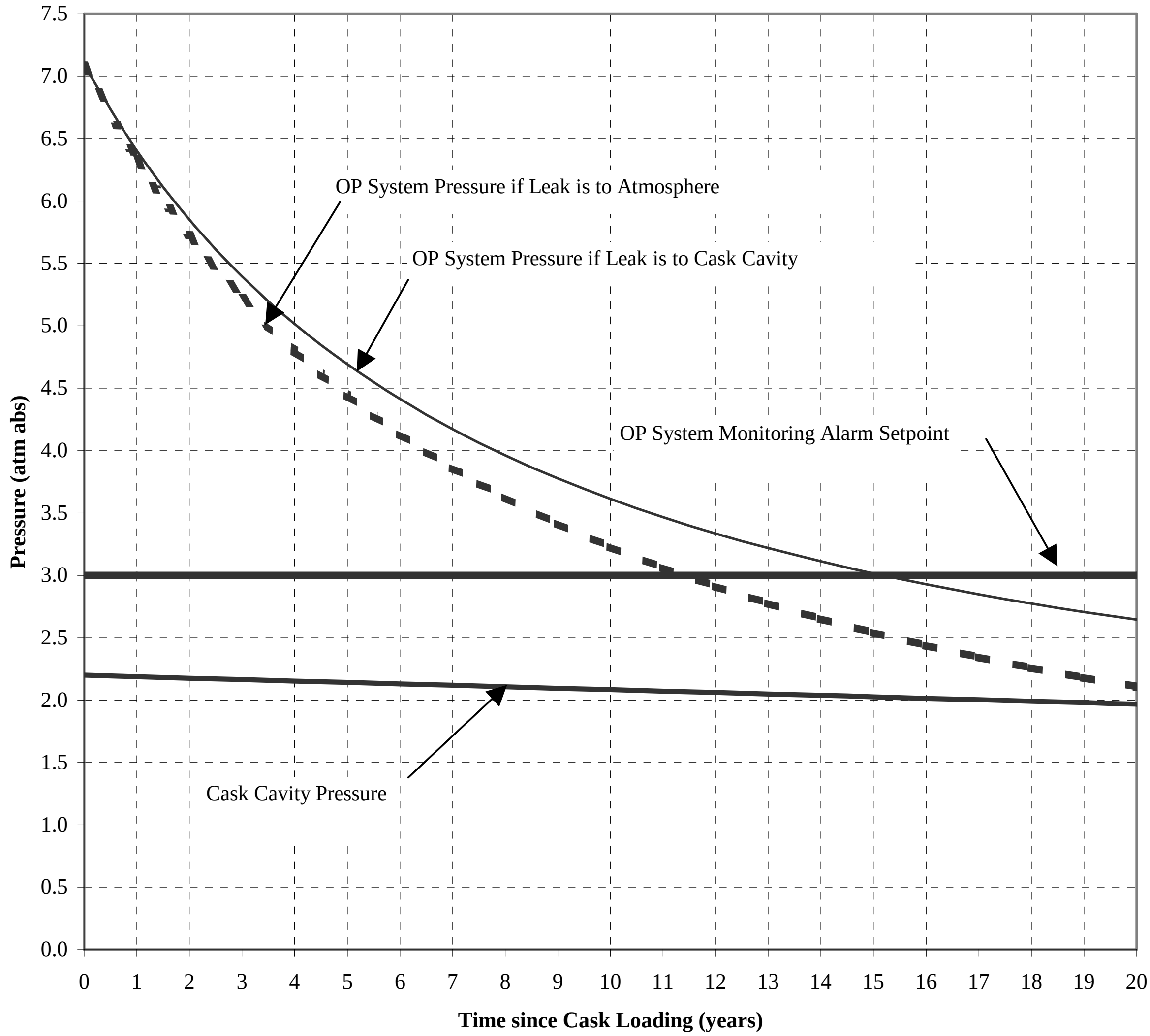

Figure 7.1-2
Overpressure Monitoring System Pressure Drop With Time
(Assuming a Latent Seal Leak Rate of 5×10^{-4} ref cm^3 /s)

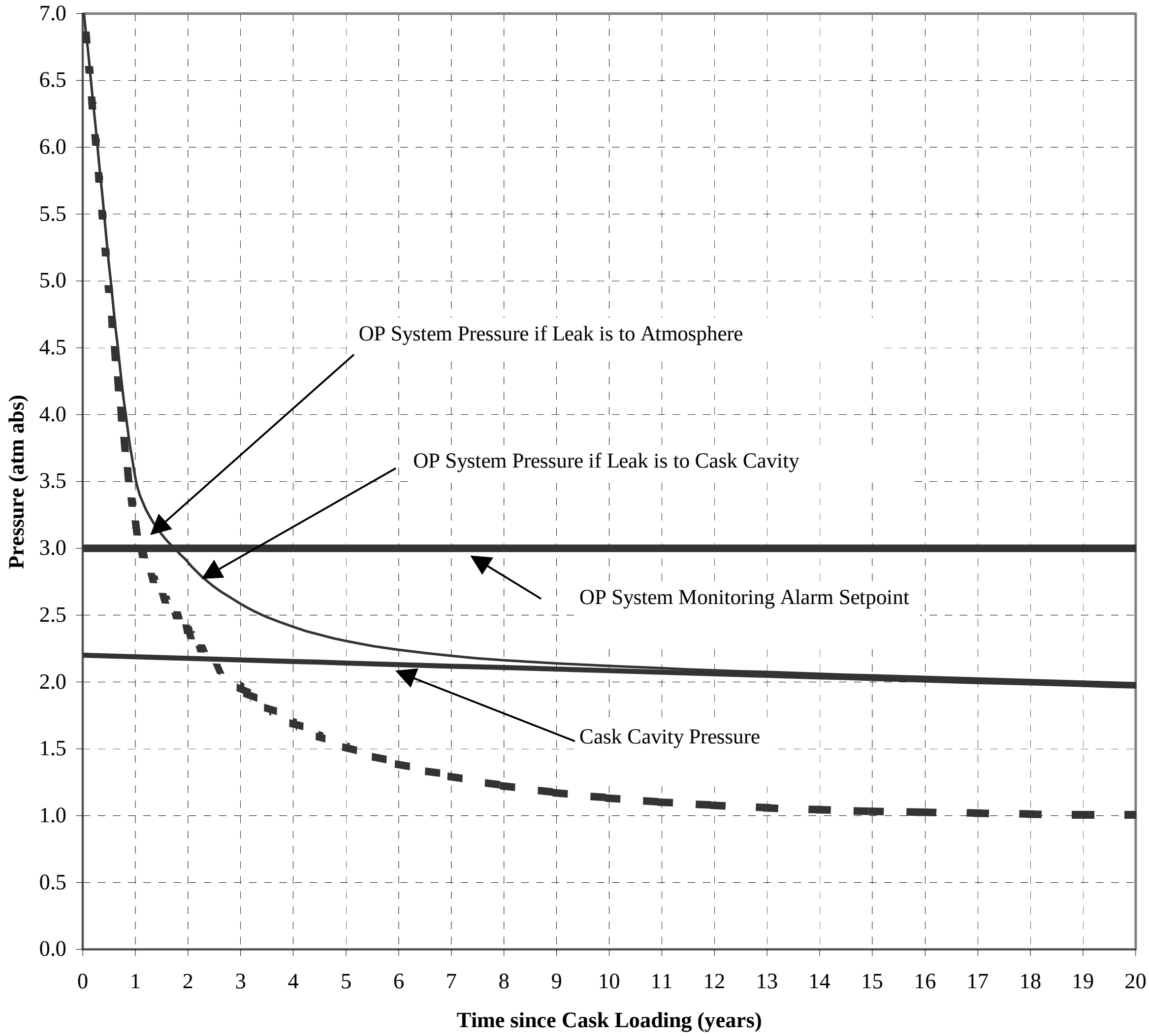

Figure 7.1-3
Lid, Vent Port and Drain Port Metal Seals