4.0 CONTAINMENT

This section identifies the 3-60B package containment system and describes how it complies with the containment requirements of 10 CFR Part 71.

4.1 DESCRIPTION OF CONTAINMENT SYSTEM

4.1.1 Containment Boundary

Containment Vessel

The containment vessel for the 3-60B is shown on Figure 2-2. It consists of the cask inner shell, base and lid, along with associated O-rings, seals, welds, and fasteners. The inner shell, base, and lid are constructed of stainless steel. The top rim of the containment shell includes a bolting ring, also of stainless steel, that is welded to the inner (containment) cavity wall and exterior shell of the cask. This bolting ring contains the threaded holes into which the closure lid bolts are threaded.

Containment Penetrations

Containment vessel penetrations, also shown on Figure 2-2, consist of the (1) closure lid, (2) vent port, and (3) drain port. The closure lid is constructed of several stainless steel disks with a total thickness of 10 ½″. The steel plate fits inside a protective lip on the bolting ring and has holes through which sixteen 1 ½″ diameter hex head bolts are threaded into the bolting ring for attaching and sealing the lid. The bottom surface of the steel plate also has welded into it a seal ring in which two O-ring grooves are machined. Two solid, elastomer O-rings are placed in the grooves, and when the lid is bolted shut these O-rings compress against a polished sealing surface on the cask bolting ring to form the containment seal. The inner of the two O-rings is the containment boundary seal. A test port hole is provided through the seal ring plate between the O-rings that is used to perform the periodic and pre-shipment leak tests to verify proper seal closure.

The cask drain port is located at the bottom side of the cask and is used primarily to drain water from the cavity. It consists of a 1” opening through the floor of the cavity turns 90^{o} and exits the cask through an opening in the outer wall. During transport a socket head, cylindrical rod is threaded into the exterior opening and seals the drain port shut. The rod is torqued shut as shown in Table 4.1, and is sealed tight with a Parker Lock-O-Seal (or equivalent). The threaded rod is long enough to fill the horizontal length of the drain line to preclude loss of shielding in the region.

The cask vent port is located in the closure lid and primarily used when draining the cask cavity of water. It consists of a stepped, cylindrical hole which penetrates the lid. During transport of the cask the vent port is sealed shut by bolting into it a plug assembly consisting of a cylindrical plug and seal plate with o-rings. The cylindrical plug fits into the vent port opening to provide shielding. The seal plate has welded into it a seal ring with two O-ring grooves similar to the closure lid. The seal plate bolts into holes in the cask closure lid using six ½” diameter hex head bolts, which compresses the O-rings against a sealing surface on the lid. The bolts are torqued shut as shown in Table 4.1. The inner O-ring is the containment boundary seal on the vent port. A test port hole is provided through the seal ring and plate between the o-rings that is used to perform the periodic and pre-shipment leak tests to verify proper seal closure.

Welds

Containment boundary welds are shown on drawing C-002-165024-001 (Appendix 1.3). All containment boundary welds are non-destructively examined. Refer to Section 8.1.2 for weld examination requirements.

Closure

Secure closure of the containment boundary penetrations is assured by the threaded fasteners described under “Containment Penetrations” earlier in this section. These fasteners will be torqued as prescribed in Table 4.1 below. The containment penetrations will be covered by the impact limiters during transport, which will prevent inadvertent operation of the fasteners. The structural analysis in Section 2 shows that the threaded fasteners remain securely closed if subjected to pressure that could arise inside the package.

The 3-60B is not continuously vented.

Table 4.1
Containment Boundary Closure Torque Requirements

		Torque ± 10% (Lubricated)
Location	Size	Ft-Lb
Lid Bolts	1 ½”	300
Vent Port Bolts	½”	20
Drain Port Plug	1”	20

4.2 CONTAINMENT UNDER NORMAL CONDITIONS OF TRANSPORT

The 3-60B package is designed, fabricated, and leak tested to preclude release of radioactive materials in excess of the limits prescribed in 10CFR71.51(a)(1).

Of the permitted contents discussed in Section 1, two are considered in the following calculations as representative of the various types and forms permitted in the 3-60B; powdered solids and irradiated hardware. In this section and Section 4.2.1 below, the maximum permitted reference leakage rates (as defined in ANSI N14.5 – 1997 [Ref. 4.1]) for normal and hypothetical accident conditions are calculated for powdered solids and irradiated hardware waste forms, and the most restrictive of these (ie, the smallest leakage rate permitted) is taken as the reference leakage rate for the 3-60B cask and the basis for the acceptance criteria for leak testing. It is shown that the reference leakage rate (L_R) for the 3-60B cask is 1.50×10^{-6} ref-cm^3/sec, and that the release limits specified in 10CFR 71.51(a) (1) are met by limiting the release rate of the 3-60B to less than this value.

As discussed above, the most limiting type of radioactive waste contents permitted in the 3-60B is either powdered solids or irradiated hardware. The maximum permitted volumetric and reference leakage rates for Normal Conditions of Transport (NCT) are calculated for powdered solids and irradiated hardware ($L_{R\_N\_PS}$ and $L_{R\_N\_IH}$, respectively). Similar calculations are performed in Section 4.3 for Hypothetical Accident Conditions (HAC) ($L_{R\_A\_PS}$ and $L_{R\_A\_IH}$, respectively). The most restrictive of these four values is taken to be the maximum permitted reference leakage rate, L_R.

4.2.1 Maximum Permitted Leak Rate

In this section the maximum permitted leakage rate under Normal Conditions of Transport is calculated for the 3-60B package. 10CFR71.51(a)(1) states that the containment requirements for normal conditions of transport are:

> *…no loss or dispersal of radioactive contents, as demonstrated to a sensitivity of $10^{-6}A_2$ per hour, no significant increase in external radiation levels, and no substantial reduction in the effectiveness of the packaging.*

ANSI N14.5-1997 (Ref 4.1) states that the permissible leak rate shall be determined by Equation 4-1 below:

$$L := \frac{R}{C} \cdot \frac{cm^3}{sec} \qquad \text{Eqn. 4-1}$$

Where:

L = permissible volumetric leak rate (cm^3/sec)
R = package containment requirements (Ci/sec)
C = activity per unit volume of the medium that could escape from the containment system (Ci/cm^3)

For normal conditions of transport:

$$R_N := A_2 \cdot 10^{-6} \cdot \frac{1}{hr} \quad \Rightarrow \qquad R_N = 2.78 \times 10^{-10} \frac{A_2}{sec} \qquad \text{10CFR71}$$

Determine the volume of the 3-60B cavity using dimensions from Figure 1-1 in Section 1:

$$L_{cavity} \equiv 109.375 \cdot in \qquad D_{cavity} \equiv 35 \cdot in$$

Assume empty void volume of the cask cavity is 25% of the total cavity volume. Therefore,

$$V_{cavity} := \frac{(.25)\pi \cdot D_{cavity}{}^2 \cdot L_{cavity}}{4} \qquad V_{cavity} = 4.31 \times 10^5 cm^3$$

In Sections 4.2.2 and 4.2.3 below, the maximum permitted volumetric leak rates under normal conditions of transport (L_N) are calculated for powdered solids and irradiated hardware respectively, and each is then converted into a reference leak rates (L_{R_N}).

4.2.2 Containment Under Normal Conditions of Transport (Powdered Solids)

Note: the following calculation for L_{N_PS} follows the methodology in NUREG/CR-6487 (Ref. 4.2)

C_{NPS} = concentration of releasable material during normal conditions of transport, C_i/cm^3

ρ = density of powder aerosol, g/cm^3

ρ = 1 x 10^{-6} g/cm^3 from NUREG/CR-6487 (Ref. 4.2)

S_A = specific activity of the releasable material, C_i/g; therefore,

$$C_{NPS} := S_A \cdot \rho \cdot \frac{C_i}{cm^3}$$

Using Eqn. 4-1:

$$L_{N\_PS} := \frac{R_N}{C_{NPS}} \qquad L_{N\_PS} = 2.78 \times 10^{-4} \frac{A_2 \cdot cm^3}{S_A \cdot sec}$$

If L_{N_PS} = 2.78 x 10^{-4} cm^3/sec — Maximum permitted volumetric leakage rate, normal conditions, powdered solids.

Then,

$$\frac{A_2}{S_A} \geq 1.0$$

This will be a condition of the Certificate of Compliance if L_{N_PS} is determined to be the controlling leakage rate.

Next, determine the Reference Leakage Rate, $L_{R\_N\_PS}$, normal conditions, powdered solids, for a volumetric leak rate L_{N_PS}:

$\mu_{air} := 0.0185 \cdot cP$ $\qquad M_{air} := 29.0 \cdot \frac{gm}{mole}$ $\qquad$ Ref. 4.1

$a := 0.6 \cdot cm$ assumed length for hole leaking air (equals o-ring diameter)

For normal conditions of transport:

T_N = 183 deg F $\qquad$ from Chapter 3

MNOP = P_{u_N} = 35 psig

$P_{u\_N} := 3.38$ atm

$$P_{d\_N} := 1.0 \cdot atm$$

$$P_{a\_N} := \frac{P_{u\_N} + P_{d\_N}}{2} \qquad\qquad P_{a\_N} = 2.05\,atm$$

Use Eqn. B.3, B.4, and B.5 in ANSI N14.5 - 1997. Determine the diameter of a hole, D_{max1} that would leak L_{N_PS}.

$$L_{N\_PS} := 2.78 \cdot 10^{-4} \cdot \frac{cm^3}{sec}$$ From above.

$$F_{mn}(D_{max}) := \frac{\left[3.8 \cdot 10^3 \cdot (D_{max} \cdot cm)^3 \cdot \sqrt{\frac{T_N \cdot gm}{M_{air} \cdot K \cdot mole}}\right] \cdot cm}{a \cdot P_{a\_N} \cdot sec}$$ Eqn B.3 from ANSI N14.5 - 1997

Simplify this as follows:

$$F_{mn}(D_{max}) \rightarrow 10809.202742622231767 \cdot D_{max}{}^3 \cdot \frac{cm^3}{atm \cdot sec}$$

Also,

$$F_{cn}(D_{max}) := \frac{2.49 \cdot 10^6 \cdot (D_{max} \cdot cm)^4 \cdot cP}{a \cdot \mu_{air} \cdot atm \cdot sec}$$ Eqn B.4 from ANSI N14.5 - 1997

Simplify this as follows:

$$F_{cn}(D_{max}) \rightarrow 224324324.32432432432 \cdot D_{max}{}^4 \cdot \frac{cm^3}{atm \cdot sec}$$ Eqn. 4-2

Use Eqn. B.5 from ANSI N14.5 - 1997. Let D_{max1} represent the diameter of the hole that will leak L_{N_PS}:

Solve Eqn. 4-2 for D_{max1}:

$$L(D_{max1}) := \left[\left(F_{cn}(D_{max1}) + F_{mn}(D_{max1})\right) \cdot (P_{u\_N} - P_{d\_N}) \cdot \frac{P_{a\_N}}{P_{u\_N}}\right] - L_{N\_PS}$$

$$L(D_{max1}) \text{ solve}, D_{max1} \rightarrow \begin{pmatrix} -.98421362290715430626e\text{-}3 \\ -.12042699610461935498e\text{-}4 - .97171560521297481805e\text{-}3 \cdot i \\ -.12042699610461935498e\text{-}4 + .97171560521297481805e\text{-}3 \cdot i \\ .96011341954048509588e\text{-}3 \end{pmatrix}$$

$$D_{max1} := 9.6 \cdot 10^{-4} \qquad cm$$

Now calculate $L_{R\_N\_PS}$ based on D_{max1}. At standard conditions:

$$P_{u\_S} := 1.0 \cdot atm \qquad P_{d\_S} := 0.1 \cdot atm$$

Eqns B.3, B.4, and B.5 at standard conditions become:

$$F_{mstd}(D_{max}) := \frac{3.81 \cdot 10^{3} \cdot (D_{max} \cdot cm)^{3} \cdot \sqrt{\frac{T_S \cdot gm}{M_{air} \cdot K \cdot mole}} \cdot cm}{a \cdot P_{a\_S} \cdot sec} \qquad P_{a\_S} = 0.55\, atm \qquad T_S := 298 \cdot K$$

Simplify this equation:

$$F_{mstd}(D_{max}) \rightarrow 37010.092359370447894 \cdot D_{max}^{3} \cdot \frac{cm^3}{atm \cdot sec}$$

$$F_{cstd}(D_{max}) := \frac{2.49 \cdot 10^{6} \cdot D_{max}^{4} \cdot cm^{4} \cdot cP}{a \cdot \mu_{air} \cdot atm \cdot sec}$$

Simplify this equation:

$$F_{cstd}(D_{max}) \rightarrow 224324324.32432432432 \cdot D_{max}^{4} \cdot \frac{cm^3}{atm \cdot sec}$$

Therefore, Eqn. B.5 at standard conditions and a hole diameter D_{max1} is:

$$L_{R\_N\_PS}(D_{max1}) := \left(F_{cstd}(D_{max1}) + F_{mstd}(D_{max1})\right) \cdot \left(P_{u\_S} - P_{d\_S}\right) \cdot \frac{P_{a\_S}}{P_{u\_S}}$$

Eqn B.5 from ANSIN14.5 - 1997

Thus,

$$L_{R\_N\_PS}(D_{max1}) = 1.11 \times 10^{-4} \frac{cm^3}{sec}$$

Standard leak rate, normal conditions, powdered solids.

4.2.3 Containment Under Normal Conditions of Transport (Irradiated Hardware)

Assume that the worst case source term for irradiated hardware is control rod blades having the same type and level of surface contamination as spent fuel, and that the potentially releasable contents from the control rod blades is entirely from this surface contamination. The surface contamination on the control rod blades that is equivalent to spent fuel is characterized in NUREG/CR-6487 (Ref. 4.2).

The following information was derived from Ref. 4.2:

- bounding value for surface activity; worst case is for BWR fuel, S_B = 1254 x 10^{-6} Ci/cm^2
- surface area of control rod blade, SA_B = 44,500 cm^2
- A_2 for BWR fuel crud, normal transport conditions = 11.0 Ci
- fraction of surface activity that can spall off the surface of a blade and therefore is potentially releasable, normal transport conditions, f_N = .15

In addition, assume the weight of control rod blade = 200 lbs

Given:

- weight capacity of 3-60B cask = 9500 lbs.(Chapter 1)
- number of control rod blades that can be transported in the 3-60B; assume 100% packing efficiency; N
- C_{NIH} = activity concentration in the cavity that could potentially escape during normal conditions of transport, irradiated hardware, C_i/cm^3
- total surface activity available for release on the surface of the control rod blades, normal transport conditions, RL_N:
- number of control rod blades in the cavity = N

$N := \frac{9500}{200}$ $\quad N = 47.5\,\text{blades}$ $\quad$ assume $N := 50 \cdot \text{blades}$

$f_N := .15$

$S_B := 1254 \cdot 10^{-6} \cdot \frac{C_i}{cm^2}$

$SA_B := 44500 \cdot cm^2$

.

$RL_N := N \cdot S_B \cdot SA_B \cdot f_N$ $\quad RL_N = 4.19 \times 10^2 C_i$

$C_{NIH} := \frac{RL_N}{V_{cavity} \cdot (11.0)}$ $\quad C_{NIH} = 8.83 \times 10^{-5} \frac{A_2 \cdot C_i}{cm^3}$

from Eqn. 1-1 above:

$L_{N\_IH} := \frac{R_N}{C_{NIH}}$ $\quad L_{N\_IH} = 3.15 \times 10^{-6} \frac{cm^3}{sec}$

Maximum permitted volumetric leakage rate, normal conditions of transport, for irradiated hardware.

Next, determine the Reference Leakage Rate, $L_{R\_N\_IH}$, normal conditions, irradiated hardware, for a volumetric leak rate L_{N_IH}:

Follow the same steps used above. First, determine a D_{max2} that would leak L_{N_IH}:

$$L_{N\_IH} := 3.19 \cdot 10^{-6} \cdot \frac{cm^3}{sec}$$

Use Eqn. 4-2:

$$L(D_{max2}) := \left[\left(F_{cn}(D_{max2}) + F_{mn}(D_{max2})\right) \cdot \left(P_{u\_N} - P_{d\_N}\right) \cdot \frac{P_{a\_N}}{P_{u\_N}} \right] - L_{N\_IH}$$

Solve this equation for D_{max2}:

$$L(D_{max2}) \text{ solve}, D_{max2} \rightarrow \begin{pmatrix} -.330875268502487938240\text{e-3} \\ -.120118508801274755360\text{e-4} - .317425778760664379640\text{e-3} \cdot i \\ -.120118508801274755360\text{e-4} + .317425778760664379640\text{e-3} \cdot i \\ .306713367675149807940\text{e-3} \end{pmatrix}$$

$$D_{max2} := 3.06 \cdot 10^{-4} \ cm$$

Now substitute D_{max2} into Eqn. B.5 and determine $L_{R\_N\_IH}$ at standard conditions:

$$L_{R\_N\_IH}(D_{max2}) := \left(F_{cstd}(D_{max2}) + F_{mstd}(D_{max2})\right) \cdot \left(P_{u\_S} - P_{d\_S}\right) \cdot \frac{P_{a\_S}}{P_{u\_S}}$$

$$L_{R\_N\_IH}(D_{max2}) = 1.50 \times 10^{-6} \frac{cm^3}{sec}$$

Standard leak rate, normal conditions, irradiated hardware.

4.3 CONTAINMENT UNDER HYPOTHETICAL ACCIDENT CONDITIONS OF TRANSPORT (TYPE B PACKAGES)

In this section the maximum permitted leakage rates under Hypothetical Accident Conditions are calculated for the 3-60B package. 10CFR71.51(a)(2) states that the containment requirements for Hypothetical Accident Conditions are:

> *…no escape of krypton-85 exceeding 10A_2 in 1 week, no escape of other radioactive material exceeding a total amount A_2 in 1 week, and no external radiation dose rate exceeding 10 mSv/h (1 rem/h) at 1 m (40 in) from the external surface of the package.*

Following the methodology from Section 4.2 in Sections 4.3.1 and 4.3.2 below, the maximum permitted volumetric leakage rates under Hypothetical Accident Conditions are calculated for powdered solids and irradiated hardware, L_{A_PS} and L_{A_IH} respectively. In Section 4.3.1 the reference leakage rate corresponding to L_{A_PS}, $L_{R\_A\_PS}$, is calculated, and in Section 4.3.2 the reference leakage rate corresponding L_{A_IH}, $L_{R\_A\_IH}$, is calculated.

In Section 4.4, $L_{R\_A\_PS}$ and $L_{R\_A\_IH}$ are compared to the reference leakage rates for Normal Conditions of Transport calculated in Section 4.2.1 to determine the most restrictive, and thus the reference air leakage rate for the 3-60.

$R_A := 1 \cdot \frac{A_2}{week}$ $\qquad R_A = 1.65 \times 10^{-6} \frac{A_2}{sec}$ $\qquad$ 10CFR71

4.3.1 Containment Under Hypothetical Accident Conditions (Powdered Solids)

Use the same parameters as Section 4.2.2:

C_{APS} = concentration of releasable materials during hypothetical accident conditions, C_i/cm^3

$$C_{APS} := C_{NPS}$$

Using Eqn 1-1:

$L_{A\_PS} := \frac{R_A}{C_{APS}}$ $\qquad L_{A\_PS} = 1.65 \frac{A_2 \cdot cm^3}{S_A \cdot sec}$

assume $L_{A\_PS} = 1.65\ cm^3/sec$ $\qquad$ Volumetric leakage rate, hypothetical accident conditions, powdered solids

Therefore,

$\frac{A_2}{S_A} \geq 1.0$ $\qquad$ This will be a condition of the Certificate of Compliance if L_{A_PS} is determined to be the controlling leakage rate.

Next, determine the reference leakage rate, $L_{R\_A\_PS}$, accident conditions, powdered solids, for a volumetric leak rate L_{A_PS}:

$P_{d\_A} := 1 \cdot atm$ $\qquad \mu_{air} := 0.0185 \cdot cP$ $\qquad M_{air} := 29.0 \cdot \frac{gm}{mole}$ $\qquad$ Ref. 4.1

$a := 0.6 \cdot cm$ $\qquad$ assumed length for hole leaking air (equals o-ring diameter)

For accident conditions:

$$T_A := 380 \cdot K$$

$P_{u\_A} := 55\,psig$ From Section 3

$P_{u\_A}(x) := (x \cdot psig + 14.7) \cdot psi$

$P_{u\_A} := 4.74 \cdot atm$

$P_{d\_A} := 1 \cdot atm$

$P_{a\_A} := \frac{P_{u\_A} + P_{d\_A}}{2}$ $P_{a\_A} = 2.87\,atm$

Equations B.3 and B.4 at accident conditions are as follows:

$$F_{mA}(D_{max}) := \frac{3.8 \cdot 10^3 \cdot (D_{max} \cdot cm)^3 \cdot \sqrt{\frac{T_A \cdot gm}{M_{air} \cdot K \cdot mole}} \cdot cm}{a \cdot P_{a\_A} \cdot sec}$$

Eqn B.3 from ANSI N14.5 - 1997

$$F_{mA}(D_{max}) \rightarrow 8131.2196492499283502 \cdot D_{max}^{3} \cdot \frac{cm^3}{atm \cdot sec}$$

$$F_{cA}(D_{max}) := \frac{2.49 \cdot 10^6 \cdot (D_{max} \cdot cm)^4 \cdot cP}{a \cdot \mu_{air} \cdot atm \cdot sec}$$

$$F_{cA}(D_{max}) \rightarrow 224324324.32432432432 \cdot D_{max}^{4} \cdot \frac{cm^3}{atm \cdot sec}$$ Eqn B.4 from ANSI N14.5 - 1997

Let D_{max3} represent the diameter of the hole that will leak L_{A_PS}:

$$L_{A\_PS} := 1.653 \cdot \frac{cm^3}{sec}$$

$$L(D_{max3}) := \left[\left(F_{cA}(D_{max3}) + F_{mA}(D_{max3})\right) \cdot \left(P_{u\_A} - P_{d\_A}\right) \cdot \frac{P_{a\_A}}{P_{u\_A}} \right] - L_{A\_PS}$$

Solve this equation for D_{max3}:

$$L(D_{max3}) \text{ solve}, D_{max3} \rightarrow \begin{pmatrix} -.75705681405315851791e\text{-}2 \\ -.90618753863883870832e\text{-}5 - .75614736329755221612e\text{-}2 \cdot i \\ -.90618753863883870832e\text{-}5 + .75614736329755221612e\text{-}2 \cdot i \\ .75524442856390309474e\text{-}2 \end{pmatrix}$$

$$D_{max3} := 7.55 \cdot 10^{-3} cm$$

Substitute this value of D_{max3} into Eqn B.3 at standard conditions:

$$L_{R\_A\_PS}(D_{max3}) := \left(F_{cstd}(D_{max3}) + F_{mstd}(D_{max3})\right) \cdot \left(P_{u\_S} - P_{d\_S}\right) \cdot \frac{P_{a\_S}}{P_{u\_S}}$$

$$L_{R\_A\_PS}(D_{max3}) = 0.369 \frac{cm^3}{sec}$$ **Standard leak rate, normal conditions, irradiated hardware**.

4.3.2 Containment Under Hypothetical Accident Conditions (Irradiated Hardware)

(see Section 4.4 for the basic assumptions regarding control rod blades and irradiated hardware.)
For accident conditions:

- A_2 for BWR fuel, accident conditions = 11.0 Ci (Ref. 4.2)
- fA = 1.0 (Ref. 4.2) fraction of surface activity potentially that can spall off surface of a blade and therefore is potentially releasable under accident conditions,

C_{AIH} = activity concentration in the cavity that could potentially escape during accident conditions, irradiated hardware, C_i/cm^3

$$RL_A := N \cdot S_B \cdot SA_B \cdot f_A \qquad RL_A = 2.79 \times 10^3 C_i$$

$$C_{AIH} := \frac{RL_A}{V_{cavity} \cdot (11.0)} \qquad C_{AIH} = 5.88 \times 10^{-4} \frac{A_2 \cdot C_i}{cm^3}$$

$$L_{A\_IH} := \frac{R_A}{C_{AIH}} \qquad L_{A\_IH} = 2.81 \times 10^{-3} \frac{cm^3}{sec}$$

Volumetric leak rate, Hypothetical Accident Conditions, Irradiated hardware

Next, determine the reference leakage rate, $L_{R\_A\_IH,}$ accident conditions, irradiated hardware, for a volumetric leak rate L_{A_IH}:

Follow the same steps used in Section 4.3.1 above. First, determine a D_{max4} that would leak L_{A_IH}:

$$L_{A\_IH} := 2.81 \cdot 10^{-3} \cdot \frac{cm^3}{sec}$$

From above.

$$L(D_{max4}) := \left[\left(F_{cA}(D_{max4}) + F_{mA}(D_{max4})\right) \cdot \left(P_{u\_A} - P_{d\_A}\right) \cdot \frac{P_{a\_A}}{P_{u\_A}} \right] - L_{A\_IH}$$

Solve this equation for D_{max4}

$$L(D_{max4}) \text{ solve}, D_{max4} \rightarrow \begin{pmatrix} -.15499570546177480809\text{e-}2 \\ -.90612745322633546887\text{e-}5 - .15407346406477229144\text{e-}2 \cdot i \\ -.90612745322633546887\text{e-}5 + .15407346406477229144\text{e-}2 \cdot i \\ .15318319980169437844\text{e-}2 \end{pmatrix}$$

$$D_{max4} := 1.53 \cdot 10^{-3} \quad cm$$

Now substitute D_{max4} into Eqn B.5 and determine $L_{R\_A\_IH}$ at standard conditions:

$$L_{R\_A\_IH}(D_{max4}) := \left(F_{cstd}(D_{max4}) + F_{mstd}(D_{max4})\right) \cdot \left(P_{u\_S} - P_{d\_S}\right) \cdot \frac{P_{a\_S}}{P_{u\_S}}$$

$$L_{R\_A\_IH}(D_{max4}) = 6.74 \times 10^{-4} \frac{cm^3}{sec}$$

Standard leak rate, normal conditions, irradiated hardware.

4.4 Reference Air Leakage Rate

The following table summarizes results in Sections 4.2 and 4.3 above:

	Max. Volumetric Leak Rate (cm^3/sec)	Max. Hole Diameter (cm)	Reference Leak Rate (cm^3/sec)
Normal Conditions of Transport, Powdered Solids	$L_{N\_PS} = 2.78 \times 10^{-4}$	$D_{max1} = 9.06 \times 10^{-4}$	$L_{R\_N\_PS} = 1.11 \times 10^{-4}$
Normal Conditions of Transport, Irradiated Hardware	$L_{N\_IH} = 3.15 \times 10^{-6}$	$D_{max2} = 3.06 \times 10^{-4}$	$L_{R\_N\_IH} = 1.50 \times 10^{-6}$
Hypothetical Accident Conditions, Powdered Solids	$L_{A\_PS} = 1.65$	$D_{max3} = 7.55 \times 10^{-3}$	$L_{R\_A\_PS} = 0.369$
Hypothetical Accident Conditions, Irradiated Hardware	$L_{A\_IH} = 2.81 \times 10^{-3}$	$D_{max4} = 1.53 \times 10^{-3}$	$L_{R\_A\_IH} = 6.74 \times 10^{-4}$

The most restrictive reference leak rate is $L_{R\_N\_IH}$, for normal conditions of transport, irradiated hardware, and will be the reference leak rate for the cask. Therefore, for the 3-60B cask:

$$L_R := 1.50 \cdot 10^{-6} \cdot \frac{ref \cdot cm^3}{sec}$$ **3-60B cask reference air leakage rate**

4.5 Leakage Rate Tests for Type B Packages

The following leakage tests are conducted on the 3-60B package as required by ANSI N14.5:

Table 4.2
Leakage Tests of the 3-60B Package

<table>
<tr><th>Test</th><th>Frequency</th><th>Test Gas</th><th>Acceptance Criteria</th></tr>
<tr><td>Maintenance</td><td>After maintenance, repair (such as weld repair), or replacement of components of the containment system.</td><td rowspan="3">R-12, R-134a, or helium (optional)</td><td rowspan="3">$\leq L_R$*</td></tr>
<tr><td>Fabrication</td><td>Prior to first use of the 3-60B.</td></tr>
<tr><td>Periodic</td><td>Within 12 months prior to each shipment.</td></tr>
<tr><td>Pre-Shipment</td><td>Before each shipment, after the contents are loaded and the package is closed.**</td><td>nitrogen or air (optional)</td><td>sensitivity $\leq 10^{-3}$ ref-cm^3/sec</td></tr>
</table>

* Adjusted for the individual properties of the test gas.
**The pre-shipment leak test is not required for contents that meet the definition of low specific activity material or surface contaminated objects in 10CFR71.4, and also meet the exemption standard for low specific activity material and surface contaminated objects in 10CFR71.14(b)(3)(i).

As shown in Table 4.2, the Maintenance, Fabrication, and Periodic leakage tests may be performed using R-12, R-134a, or helium as the tracer gas. The acceptance criteria for these tests is the reference air leakage rate, L_R, which is calculated in Section 4.4 above. An equivalent maximum permissible leakage rate to L_R has been calculated in Sections 4.5.1, 4.5.2, and 4.5.3 below for each of the possible test gases, adjusting for individual properties for the gas plus the test pressure and temperature. The equivalent leakage becomes the acceptance criteria for the particular gas being used to perform the test.

The Maintenance, Fabrication, and Periodic leakage tests are performed on the closure lid, plus the vent and drain ports. The detailed procedure for performing these test is given in Section 8, but generally they will be conducted as follows:

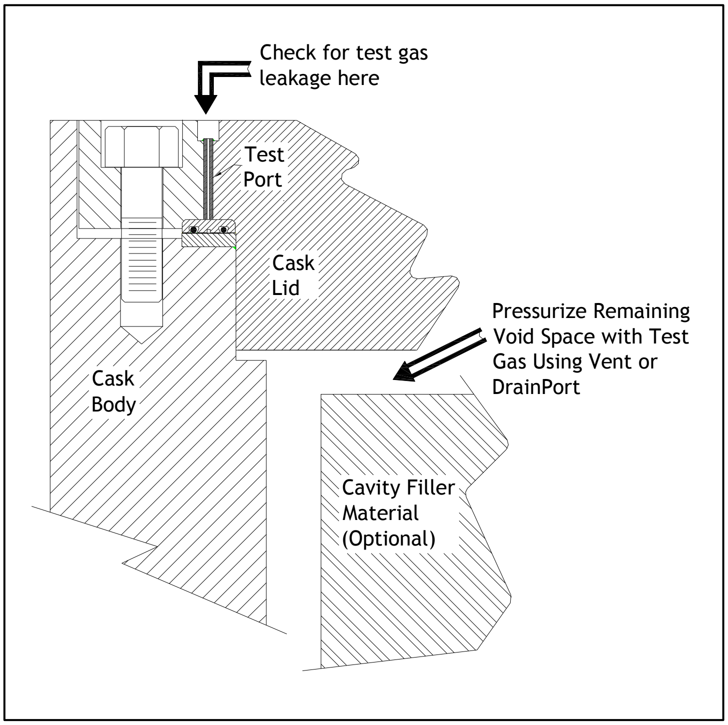

Fig. 4.1
Periodic Leak Test of Closure Lid

- Pressurize the void space in the cavity with a test gas using the vent port in the lid. Some of the volume of the cavity may be temporarily filled to reduce the volume of test gas required to conduct the test. (Dunnage must not cover the drain opening)
- Check for leaks of the inner (containment boundary) O-ring using the test port in the lid.

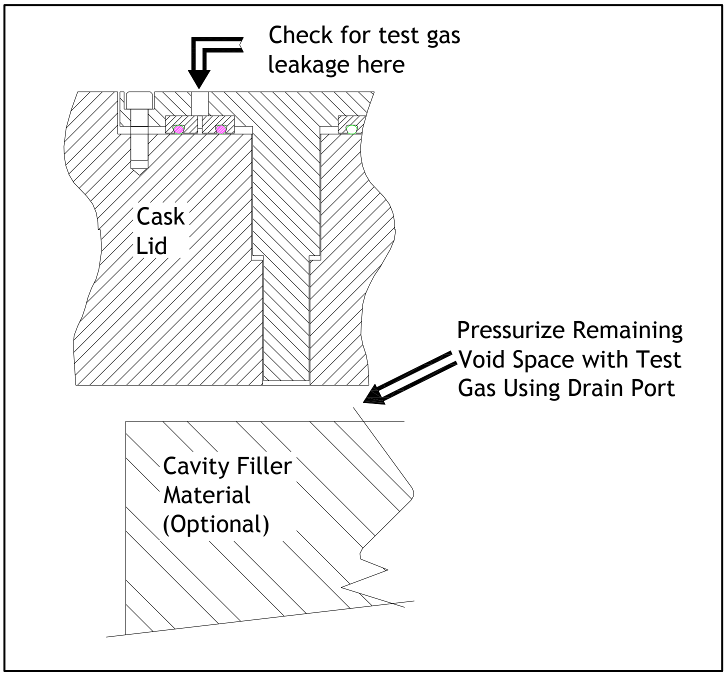

Fig. 4.2
Periodic Leak Test of Vent Port

- Pressurize the void space in the cavity with a test gas using the drain port. Some of the volume of the cavity may be temporarily filled to reduce the volume of test gas required to conduct the test.
- Check for leaks of the inner (containment boundary) vent port cover plate O-ring

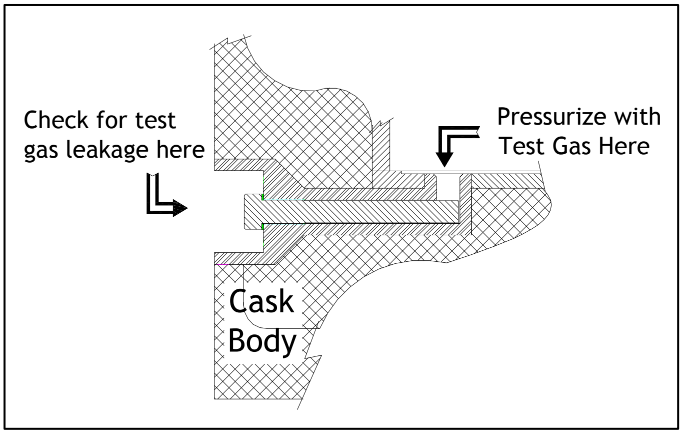

Fig. 4.3
Periodic Leak Test of Drain Port

- Pressurize inlet to drain port
- Check for leaks at head of drain port plug and seal

4.5.1 Determination of Equivalent Reference Leakage Rate for R-12 Gas

The purpose of this calculation is to determine the maximum allowable leak rate for R-12 halogen gas that may be used to perform the annual verification leak tests on the 3-60B cask..

This calculation uses formulas presented in ANSI N14.5 - 1997 (4.1).

$$L_R = 1.5 \times 10^{-6} \mathrm{ref} \cdot \frac{\mathrm{cm}^3}{\mathrm{sec}}$$ from 4.4 above

The maximum diameter hole through the O-ring corresponding to this leakage rate is:

$$D_{MAX} := D_{max2} \cdot \mathrm{cm} \qquad D_{MAX} = 3.06 \times 10^{-4} \mathrm{cm}$$

from 4.4 above

Next, determine the equivalent air/R12 mixture (L_{mix}) that would leak from D_{MAX} during a leak test. Assume the cask void is first evacuated to 20" Hg vacuum (9.92" Hg abs) and pressurized to 25 psig (2.7 atm) with an air/R12 mixture.

$$P_{mix} := 2.7 \cdot \mathrm{atm}$$

$$P_{air} := 9.92 \cdot \mathrm{in\_Hg} \qquad P_{air} = 0.33\,\mathrm{atm}$$

$$P_d := 1.0 \cdot \mathrm{atm}$$

$$P_{R12} := P_{mix} - P_{air} \qquad P_{R12} = 2.37\,\mathrm{atm}$$

$$P_a := \frac{P_{mix} + P_d}{2} \qquad P_a = 1.85\,\mathrm{atm}$$

$M_{R12} := 121 \cdot \frac{gm}{mole}$ ANSI N14.5 - 1997

$\mu_{R12} := 0.0124 \cdot cP$ ANSI N14.5 - 1997

$$M_{mix} := \frac{M_{R12} \cdot P_{R12} + M_{air} \cdot P_{air}}{P_{mix}} \qquad M_{mix} = 109.7 \frac{gm}{mole}$$ Eqn. B7 - ANSI N14.5

$$\mu_{mix} := \frac{\mu_{air} \cdot P_{air} + \mu_{R12} \cdot P_{R12}}{P_{mix}} \qquad \mu_{mix} = 0.0131\,cP$$ Eqn. B8 - ANSI N14.5

Determine L_{mix} as a function of temperature. Assume the viscosities of air and R12 do not change significantly over the range of temperatures evaluated:

$T := 273, 278 .. 328$ ^oK Temperature range for test: 32^oF to 130^oF

$$F_c := \frac{2.49 \cdot 10^6 \cdot D_{MAX}{}^4 \cdot cP \cdot ref}{a \cdot \mu_{mix} \cdot sec \cdot atm}$$ then, $$F_c = 2.77 \times 10^{-6} \frac{cm^3}{sec \cdot atm}$$

$$F_m(T) := \frac{3.81 \cdot 10^3 \cdot D_{MAX}{}^3 \cdot \sqrt{\frac{T}{M_{mix}}} \cdot cm \cdot gm^{0.5}}{a \cdot P_a \cdot mole^{0.5} \cdot sec}$$

$$L_{mix}(T) := \left[\left(F_c + F_m(T)\right) \cdot \left(P_{mix} - P_d\right) \cdot \frac{P_a}{P_{mix}} \right]$$

$$T_F(T) := \left[(T - 273) \cdot \frac{9}{5} + 32 \right] \cdot F$$

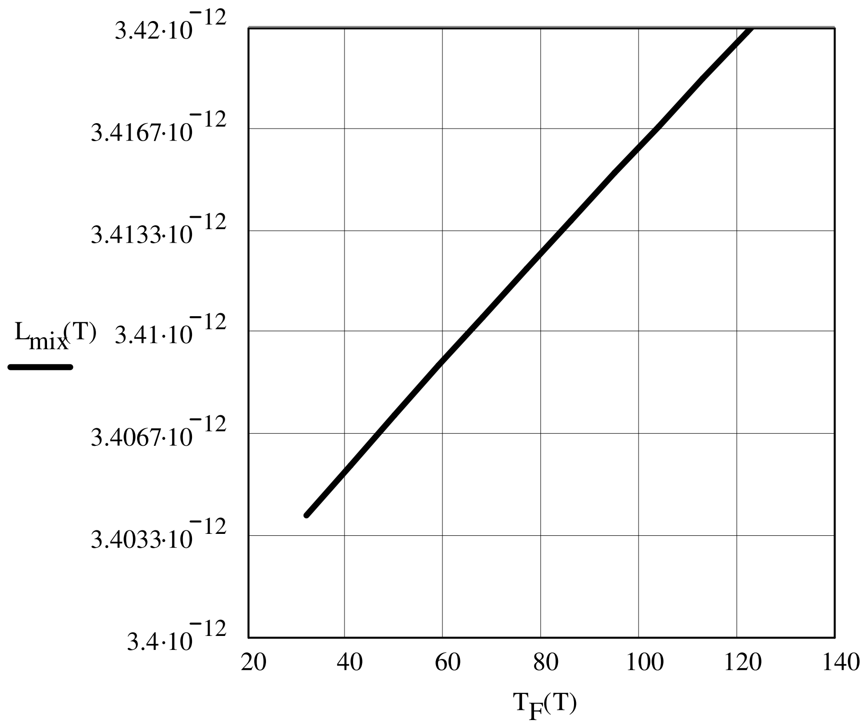

Fig. 4.4 Allowable R-12/Air Mixture Test Leakage, m^3/sec, versus Test Temperature, ^oF

The R-12 component of this leak rate can be determined by multiplying the leak rate of the mixture by the ratio of the R-12 partial pressure to the total pressure of the mix, as follows.

$$L_{R12}(T) := L_{mix}(T)\cdot\frac{P_{R12}}{P_{mix}}$$

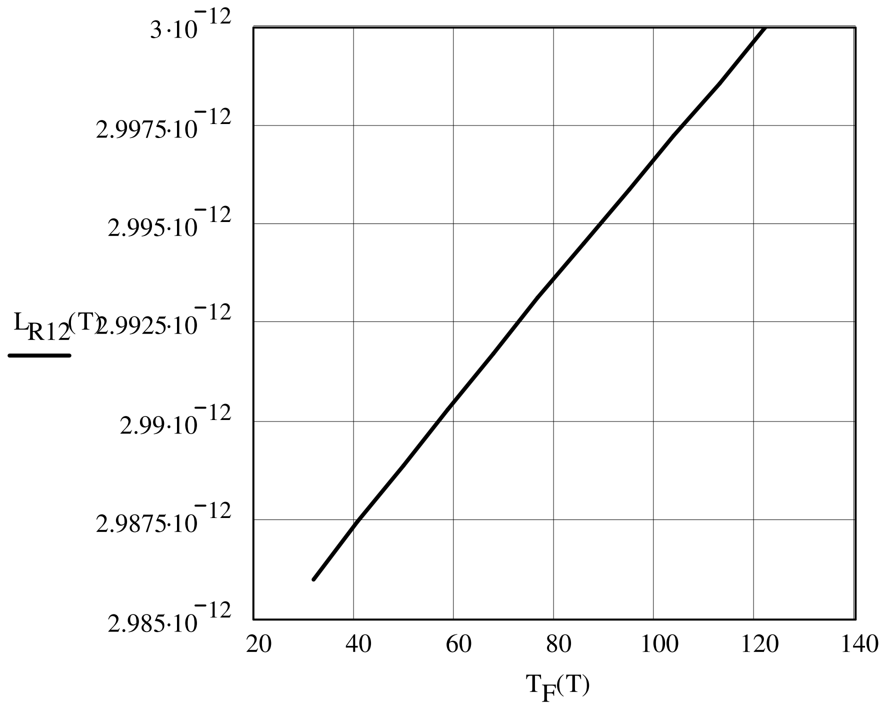

Fig. 4.5 Allowable R-12 Test Leakage, m^3/sec, versus Test Temperature, ^oF

Determine the equivalent mass flow rate for L_{R12} in oz/yr:

$$N(T) := \frac{P_{R12}\cdot V}{R_o\cdot T}$$ Ideal Gas Law

where,

$$R_o := \frac{82.05\cdot cm^3\cdot atm}{mole} \qquad V := 1\cdot cm^3$$

This data can then be used to convert the volumetric leak rate for R-12 calculated above to a mass leak rate. By dividing N by V, the number of moles per unit volume can be multiplied by the molecular weight of the gas and the maximum allowable volumetric leak rate to determine the maximum allowable mass leak rate, as a function of test temperature as shown in the graph below. The conversion from grams per second to ounces per year is also shown below.

$$\frac{gm}{sec} = 1.11\times10^{6}\frac{oz}{yr}$$ Conversion of gm/sec to oz/yr

$$L(T) := L_{R12}(T)\cdot\frac{N(T)}{V}\cdot M_{R12}$$

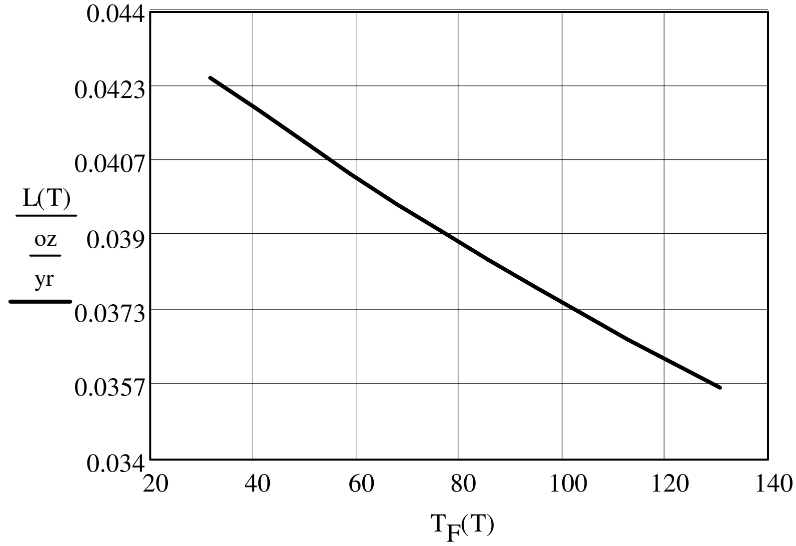

Fig. 4.6 Allowable R-12 Test Leakage, oz/yr, versus Test Temperature, °F

Figure 4.6 can be used to determine the allowable leak rate based on the temperature at the time of the test. According to ANSI N14.5 methodology, the maximum allowable leak rate must be divided by 2 to determine the minimum sensitivity for the test. A graph of the required sensitivity in oz/yr is presented below:

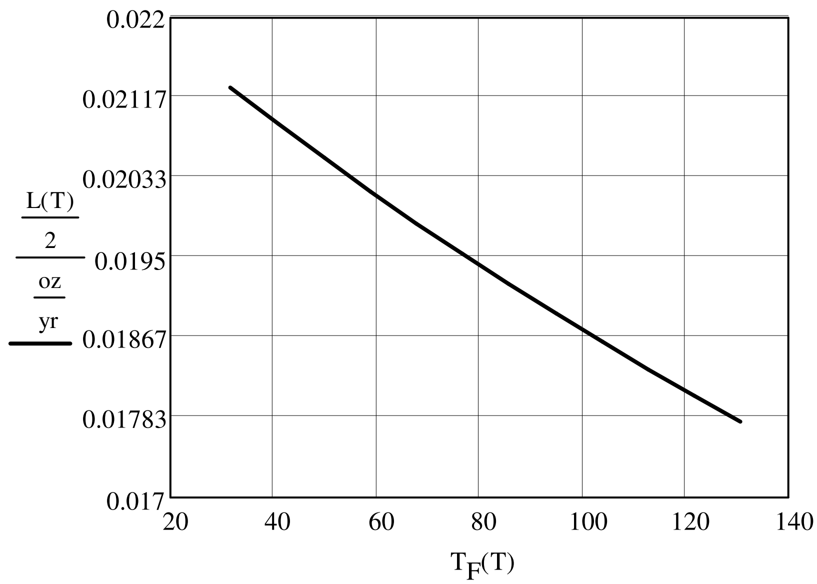

Fig. 4.7 Allowable R-12 Test Leakage sensitivity, oz/yr, versus Test Temperature, °F

4.5.2 Determination of Equivalent Reference Leakage Rate for R-134a Gas

The purpose of this calculation is to determine the allowable leak rate using the R-134a halogen gas that will be used to perform the annual verification leak tests on the 3-60B cask. This halogen gas is now in widespread use as a replacement gas for R-12 in many industrial applications.

This calculation uses formulas presented in ANSI N14.5 - 1997.

$L_R = 1.50 \times 10^{-6} \frac{cm^3}{sec}$ from 4.4 above

$D_{MAX} = 3.06 \times 10^{-4} cm$ from 4.4 above

Determine the equivalent air/R134a mixture (L_{mix}) that would leak from D_{MAX} during a leak test. Assume the cask void is first evacuated to 20" Hg vacuum (9.92" Hg abs) and then pressurized to 25 psig (2.7 atm) with an air/R134a mixture.

$P_{mix} = 2.70\,atm$

$P_{air} = 0.33\,atm$ $P_{R134a} := P_{mix} - P_{air}$ $P_{R134a} = 2.37\,atm$ $P_d = 1.00\,atm$

$P_a := \frac{P_{mix} + P_d}{2}$ $P_a = 1.85\,atm$

The properties of R134a are :

$M_{R134a} := 102 \cdot \frac{gm}{mole}$

$\mu_{R134a} := 0.012 \cdot cP$

$M_{mix} := \frac{M_{R134a} \cdot P_{R134a} + M_{air} \cdot P_{air}}{P_{mix}}$ $M_{mix} = 93.04 \frac{gm}{mole}$ Eqn. B7 - ANSI N14.5

$\mu_{mix} := \frac{\mu_{air} \cdot P_{air} + \mu_{R134a} \cdot P_{R134a}}{P_{mix}}$ $\mu_{mix} = 0.0128\,cP$ Eqn. B8 - ANSI N14.5

Determine L_{mix} as a function of temperature. Assume the viscosities of air and R134a do not change significantly over the range of temperatures evaluated:

$T := 273, 278 .. 328 \quad {}^oK$ Temperature range for test: 32^oF to 130^oF

$$F_c := \frac{2.49 \cdot 10^6 \cdot D_{MAX}^{\;4} \cdot cP \cdot ref}{a \cdot \mu_{mix} \cdot sec \cdot atm} \qquad \text{then,} \qquad F_c = 2.84 \times 10^{-6} \frac{cm^3}{sec \cdot atm}$$

$$F_m(T) := \frac{3.81 \cdot 10^3 \cdot D_{MAX}^{\;3} \cdot \sqrt{\frac{T}{M_{mix}}} \cdot cm \cdot gm^{0.5}}{a \cdot P_a \cdot mole^{0.5} \cdot sec}$$

$$L_{mix}(T) := \left(F_c + F_m(T)\right) \cdot \left(P_{mix} - P_d\right) \cdot \frac{P_a}{P_{mix}}$$

$$T_F(T) := \left[(T - 273) \cdot \frac{9}{5} + 32\right] \cdot F$$

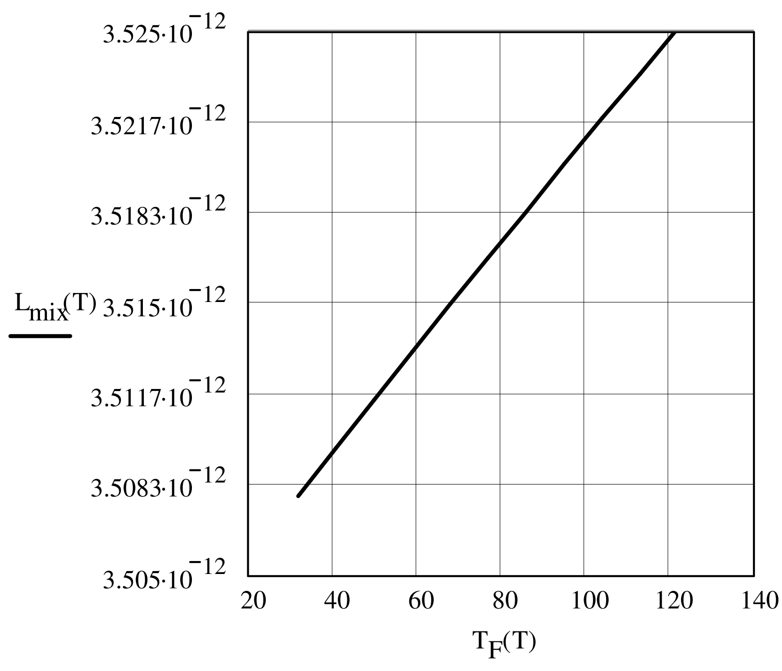

Fig. 4.8 Allowable R-134a/Air Mixture Test Leakage, m^3/sec, versus Test Temperature, ^oF

The R-134a component of this leak rate can be determined by multiplying the leak rate of the mixture by the ratio of the R-134a partial pressure to the total pressure of the mix, as follows.

$$L_{R134a}(T) := L_{mix}(T) \cdot \frac{P_{R134a}}{P_{mix}}$$

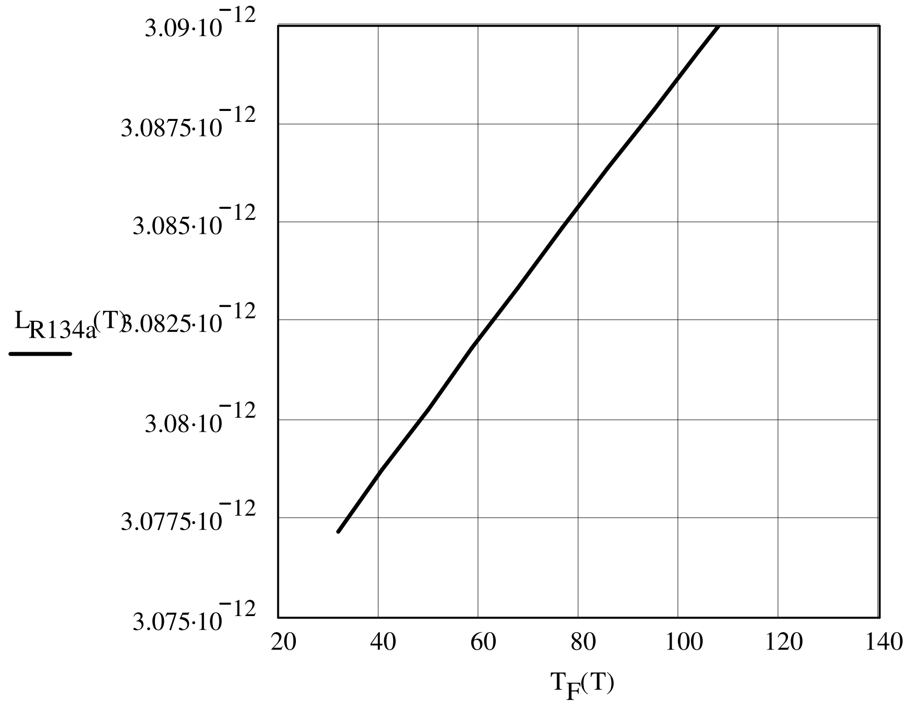

Fig. 4.9 Allowable R-134a Test Leakage, m^3/sec, versus Test Temperature, ^oF

Determine the equivalent mass flow rate for L_{R134a} in oz/yr:

$$N(T) := \frac{P_{R134a} \cdot V}{R_o \cdot T}$$ Ideal Gas Law

where,

$$V := 1 \cdot cm^3$$

$$R_o := \frac{82.05 \cdot cm^3 \cdot atm}{mole}$$

This data can then be used to convert the volumetric leak rate for R-134a calculated above to a mass leak rate. By dividing N by V, the number of moles per unit volume can be multiplied by the molecular weight of the gas and the maximum allowable volumetric leak rate to determine the maximum allowable mass leak rate, as a function of test temperature as shown in the graph below. The conversion from grams per second to ounces per year is also shown below.

$$\frac{gm}{sec} = 1.11 \times 10^6 \frac{oz}{yr}$$ Conversion of gm/sec to oz/yr

$$L(T) := L_{R134a}(T)\cdot\frac{N(T)}{V}\cdot M_{R134a}$$

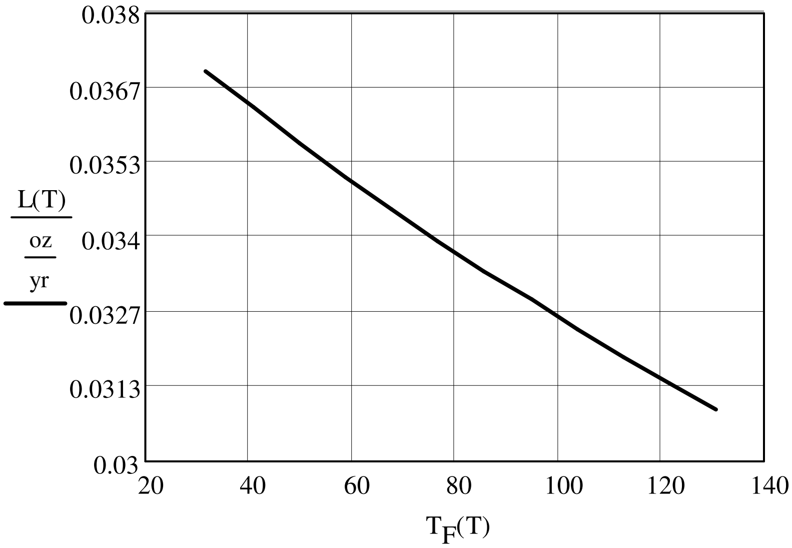

Fig. 4.10 Allowable R-134a Test Leakage, oz/yr, versus Test Temperature, °F

Figure 4.10 can be used to determine the allowable leak rate based on the temperature at the time of the test. According to ANSI N14.5 methodology, the maximum allowable leak rate must be divided by 2 to determine the minimum sensitivity for the test. A graph of the required sensitivity in oz/yr is presented below:

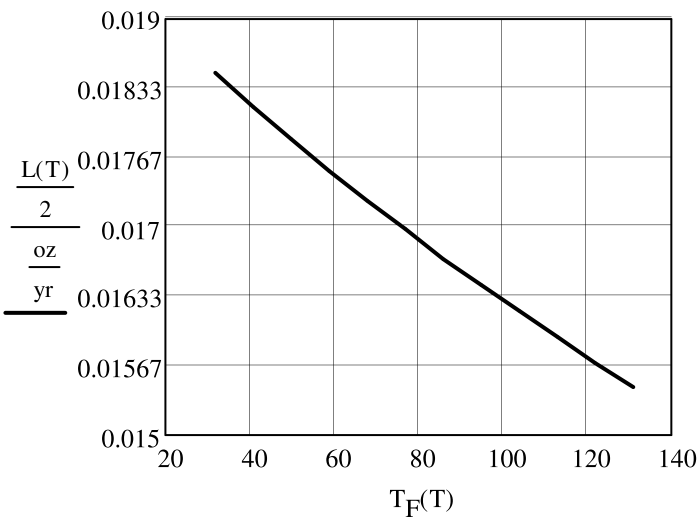

Fig.4.11 - Allowable R-134a test leakage sensitivity, oz/yr, versus test temperature, deg.F

4.5.3 Determination of Equivalent Reference Leakage Rate for Helium Gas

The purpose of this calculation is to determine the allowable leak rate using the Helium gas that may be used to perform the annual verification leak tests on the 3-60B cask.

This calculation uses formulas presented in ANSI N14.5 - 1997.

$D_{MAX} = 3.06 \times 10^{-4} \text{cm}$ from Section 4.4

Determine the equivalent air/helium mixture (L_{mix}) that would leak from D_{MAX} during a leak test. Assume the cask void is first evacuated to 20" Hg vacuum (9.92" Hg abs) and then pressurized to 1 psig (1.07 atm) with an air/helium mixture.

$P_{mix} = 1.07 \text{atm}$ $P_{air} = 0.33 \text{atm}$ $P_d = 0.01 \text{atm}$

$P_{He} := P_{mix} - P_{air}$ $P_{He} = 0.74 \text{atm}$

$P_a := \dfrac{P_{mix} + P_d}{2}$ $P_a = 0.54 \text{atm}$

$M_{He} := 4.0 \cdot \dfrac{\text{gm}}{\text{mole}}$ ANSI N14.5 - 1997

$\mu_{He} := 0.0198 \cdot \text{cP}$ ANSI N14.5 - 1997

$M_{mix} := \dfrac{M_{He} \cdot P_{He} + M_{air} \cdot P_{air}}{P_{mix}}$ $M_{mix} = 7.07 \dfrac{\text{gm}}{\text{mole}}$ Eqn. B7 - ANSI N14.5

$\mu_{mix} := \dfrac{\mu_{air} \cdot P_{air} + \mu_{He} \cdot P_{He}}{P_{mix}}$ $\mu_{mix} = 0.020 \text{cP}$ Eqn. B8 - ANSI N14.5

Determine L_{mix} as a function of temperature. Assume the viscosities of air and Helium do not change significantly over the range of temperatures evaluated:

$T := 273, 278 .. 328$ °K Temperature range for test: 32°F to 130°F

$F_c := \dfrac{2.49 \cdot 10^6 \cdot D_{MAX}^4 \cdot \text{cP} \cdot \text{std}}{a \cdot \mu_{mix} \cdot \text{sec} \cdot \text{atm}}$ then, $F_c = 1.85 \times 10^{-6} \dfrac{\text{cm}^3}{\text{sec} \cdot \text{atm}}$

$$F_m(T) := \frac{3.81 \cdot 10^3 \cdot D_{MAX}{}^3 \cdot \sqrt{\frac{T}{M_{mix}}} \cdot cm \cdot gm^{0.5}}{a \cdot P_a \cdot mole^{0.5} \cdot sec}$$

$$L_{mix}(T) := \left(F_c + F_m(T)\right) \cdot \left(P_{mix} - P_d\right) \cdot \frac{P_a}{P_{mix}}$$ Equation B5, ANSI N14.5-1997

$$T_F(T) := \left[(T - 273) \cdot \frac{9}{5} + 32\right] \cdot F$$

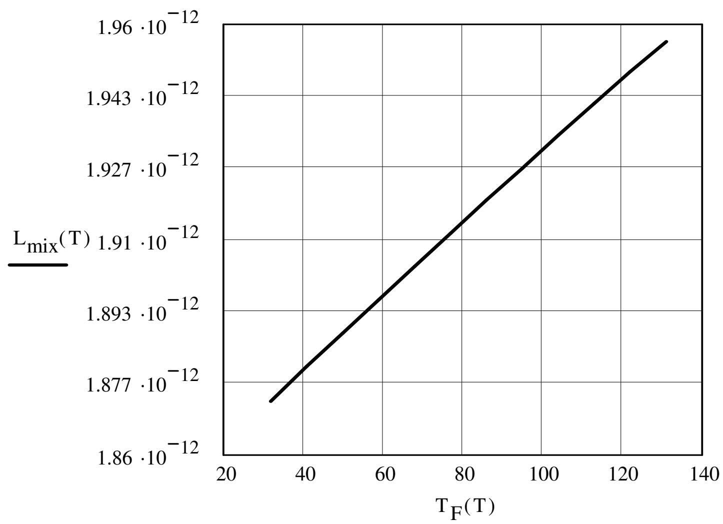

Fig.4.12 - Allowable He/Air Mixture Test Leakage, m^3/sec, versus test temperature, deg.F

The Helium component of this leak rate can be determined by multiplying the leak rate of the mixture by the ratio of the Helium partial pressure to the total pressure of the mix, as follows.

$$L_{He}(T) := L_{mix}(T) \cdot \frac{P_{He}}{P_{mix}}$$

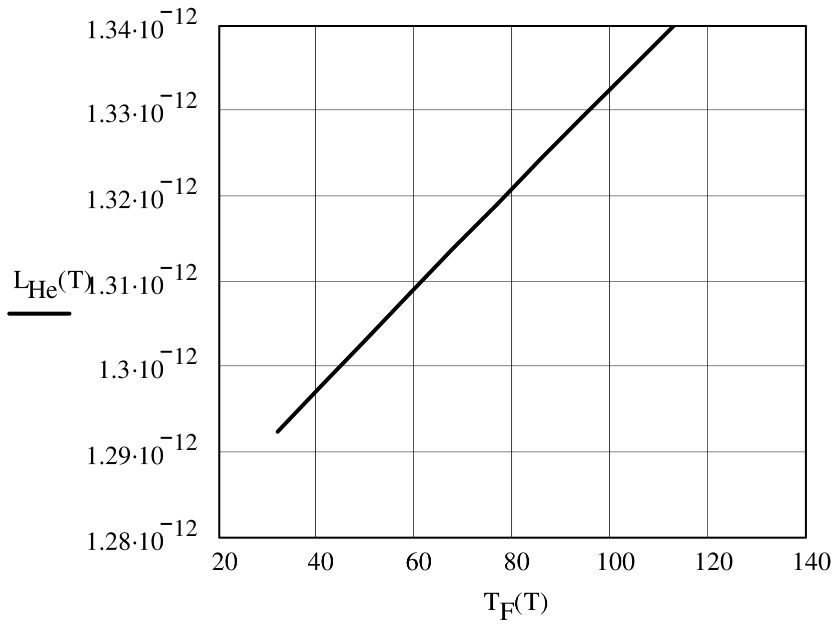

Fig.4.13 - Allowable He Test Leakage, m^3/sec, versus test temperature, deg.F

Figure 4.13 can be used to determine the allowable leak rate based on the temperature at the time of the test. According to ANSI N14.1 methodology, the maximum allowable leak rate must be divided by 2 to determine the minimum sensitivity for the test. A graph of the required sensitivity is presented below.

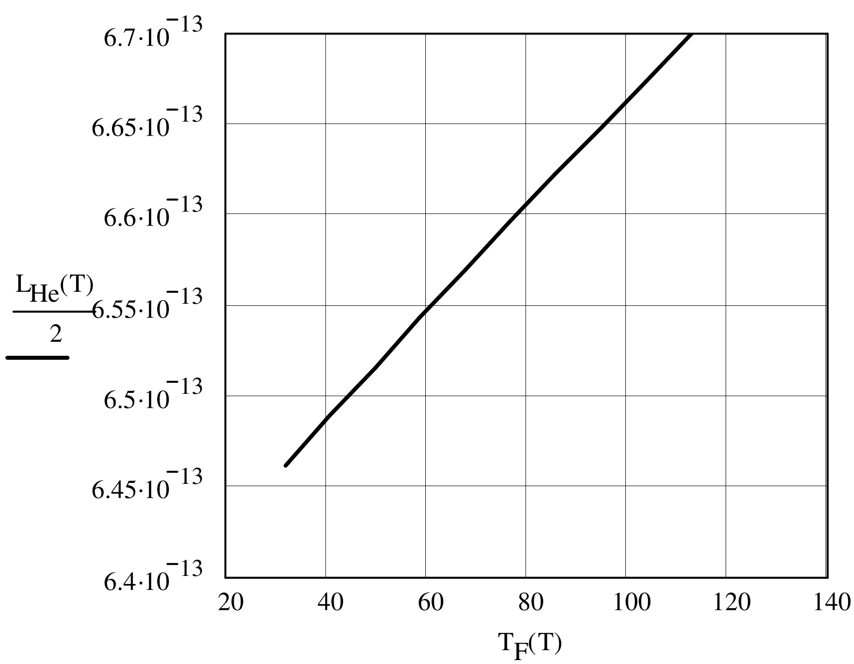

Fig.4.14 - Allowable helium test leakage sensitivity, m^3/sec, versus test temperature, deg.F

4.5.4 Determination of Test Conditions for Pre-Shipment Leakage Test

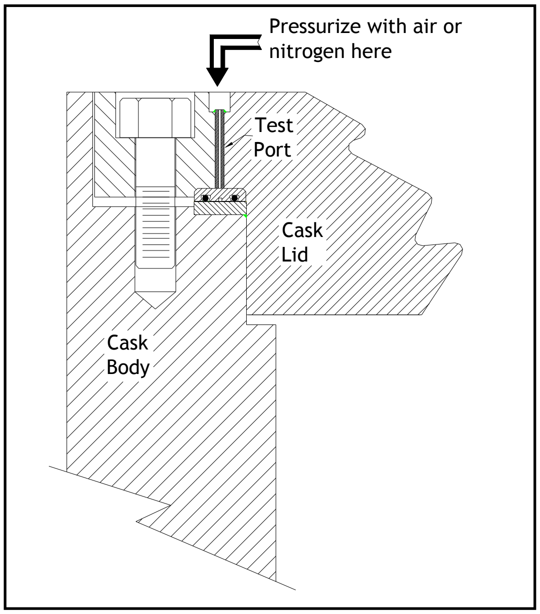

Fig. 4.15
Preshipment Leak Test of Closure Lid

The preshipment leak test is performed using the Gas Pressure Drop Method as shown in A.5.1, Table A-1 of ANSI N14.5-1997 Ref. (4.1)**.** The Gas Pressure Drop test is conducted on the closure lid of the 3-60B by pressurizing the annulus between the O-rings with dry air or nitrogen. The vent and drain ports are also tested by pressurizing them with dry air or nitrogen. In this section the minimum hold time for Gas Pressure Drop test for each of the three components is calculated using the methodology from ANSI N14.5.

As required by ANSI N14.5, the test is conducted by holding the test pressure on the component being tested for a prescribed period of time (calculated below) and monitoring for any detectable drop in pressure. ANSI N14.5 – 1997 states (Ref. 4.1, Table 1) that the acceptance criteria for the pre-shipment leak test is a leakage rate that is either less than the reference air leakage rate, L_R, or no detected leakage when tested to a sensitivity of $1x10^{-3}$ ref-cm^3/sec. This section will show that the requirement of ANSI N14.5 is met by testing to a sensitivity of $1x10^{-3}$ ref-cm^3/sec when performing the Gas Pressure Drop test for 15 minutes. The procedure for conducting the pre-shipment leak test on the 3-60 is given in Section 8.

The calculations below on the required charge pressure and hold time are performed assuming dry air is the test gas, although as indicated in the above paragraph and in Chapter 7, nitrogen may be used as well. If nitrogen is the test gas used, the calculations for the required charge time are conservative. Since air is primarily nitrogen, the physical properties of the two gases are very close. However, because the molecular weight and viscosity of nitrogen are slightly less than air's, the pressure drop experienced during the required charge time using nitrogen as the test gas will be slightly greater than for air.

	molecular wt	Viscosity (cP)	(Ref. 4.1)
air	29.0	.0185	
nitrogen	28.01	.0173	

<u>Determining Required Charge Time for Closure Lid:</u>

The pre-shipment leak test is performed by charging the annulus between the O-rings of the closure lid with air and holding the pressure for the prescribed time. Any pressure drop larger than the minimum detectable increment on the pressure measuring instrument shall be corrected. In this section the minimum hold time is determined.

When doing the pre-shipment leak test on the closure lid, the annulus between the O-rings is pressurized . The annulus is centered between O-rings and is 1/8" deep and 1/8" wide with an inner diameter of 39-1/8". Therefore, the volume of the annulus is 31.6 cm^3. To conservatively account for additional volume due to a test manifold, the volume of the test annulus will be doubled.

The required hold time for the Gas Pressure Drop test is determined using Equation B.14 of ANSI N14.5-1997 (Ref. 4.1):

$$L_R = \frac{V\,T_s}{3600\,HP_s}\left[\frac{P_1}{T_1} - \frac{P_2}{T_2}\right] \qquad \text{Eqn B.14, Reference 4.1}$$

where:

L_R = atm-cm^3/sec of air at standard conditions
V = gas volume in the test annulus cm^3
T_s = reference absolute temperature, 298°K
H = test duration, hours
P_1 = gas pressure in test item at start of test, atm, abs
P_2 = gas pressure in test item at end of test, atm, abs
P_s = standard pressure = 1 atm
T_1 = gas temperature in test item at start of test, °K
T_2 = gas temperature in test item at end of test, °K

As discussed above, the maximum sensitivity for the pre-shipment leak test as prescribed in ANSI N14.5-1997 is 10^{-3} ref-cm^3/sec. Further, ANSI N14.5-1997 states that in cases where the test sensitivity has been established and the Gas Pressure Drop test is used, the maximum permitted leak rate is:

$L \le S/2$ Equation B-17, Reference 4.1

Therefore the maximum permitted leak rate for the pre-shipment leak test is 5×10^{-4} ref-cm^3/sec. Substituting this in Eqn. B-17 above, determine the required hold time, where:

V = 63.2 cm^3
$T_s = T_1 = T_2$ = 298°K
$P_1 - P_2$ = pressure instrument sensitivity = 0.1 psig

$$5x10^{-4} = \frac{(63.2\,\text{cm}^3)(298^o K)}{3600(H\ hr)(1\,\text{atm})}\left(\frac{0.007\,\text{atm}}{298^o K}\right)$$

Solve for H:

H = 0.24 hr = 14.32 min.

<u>For conservatism, the test will be conducted for 15 minutes.</u>

<u>Determining Required Charge Time for Vent Port Cover and Drain Port:</u>

This calculation is similar to the one as in "Determining Required Charge Time for Closure Lid" above. The volume of the annulus for the vent port is 4.1 cm^3. The volume of the drain port cavity is 21.9 cm^3. Since the drain port cavity has the larger volume, the charge time will be calculated for the drain port and then used for both. As above a test manifold will be used with a volume conservatively assumed to be 31.6 cm^3. Using Eqn B.14, Reference 4-1

$$H = 0.20 \text{ hr} = 12.2 \text{ min}$$

For conservatism, the test on the vent port cover and the drain port will be conducted for 15 minutes minimum.

4.6 Appendix

4.6.1 References

4-1 ANSI N14.5, "American National Standard for Radioactive Materials – Leakage Tests on Packages for Shipment," 1997.