71-9204

CHEM-NUCLEAR SYSTEMS, LLC

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5 January, 2001
E&L-002-01

Mr. E. William Brach
Director, Spent Fuel Project Office
Office of Nuclear Material Safety and Safeguards, NMSS
U.S. Nuclear Regulatory Commission
Washington, DC 20555

Dear Mr. Brach:

Subj: Safety Analysis Report for the CNS 10-160B, C of C 9204, Rev. 15

Enclosed is our application for the revision to the Safety Analysis Report (SAR) for the CNS 10-160B, Certificate of Compliance (CofC) No. 9204. We request that the maximum radioactive contents for the CNS 10-160B be increased from 2000 times the Type A quantity to 3000 times a Type A quantity, which per Regulatory Guide 7.11, is the radioactivity limit for a Category II package. The changes to the SAR include the following:

- Revision to Chapter 1 of the SAR to specify the maximum radioactive contents for the CNS 10-160B as 3000 times a Type A quantity.
- Revision to the containment leak rate calculations of Chapter 4 to reflect an increase in the source term from 2000 to 3000 times a Type A quantity.
- Revision to Chapter 4 incorporating a number of editorial changes to correctly identify penetrations of the containment boundary and describe the lid seals.

All changes are indicated by a revision bar in the margin.

There are two attachments to this letter. The following is a discussion of the content and purpose of each attachment.

Attachment 1: The replacement pages for the SAR

- Cover Page
- Table of Contents
- Chapter 1, page 1-4
- Chapter 4, pages 4-1 through 4-28

Attachment 2: A justification for the requested change including a section by section discussion of the affect on the SAR.

We request completion of action on this request for Rev. 17 by April 2001. One user of the cask plans to ship TRU wastes (the subject of the submittal for Revision 16) in the second quarter of 2001 to meet their decommissioning schedule. NRC action on this application is requested in early 2001 to allow sufficient time for development of alternative shipping options should the requested revision be denied. The request for Rev. 16 to the CNS 10-160B SAR is currently under NRC review.

Should you or members of your staff have any questions about the application, please contact Mark Whittaker at (803)758-1898.

Sincerely,

Patrick L. Paquin
General Manager – Engineering & Licensing

Attachments:
1. Rev. 17 Change Pages
2. Justification for change

NMSS01 Public

ATTACHMENT 1

Revision 17 Changed Pages

Cover
Table of Contents
1-4
4-1 – 4-28

*Please replace current revision pages with the attached pages

SAFETY ANALYSIS REPORT

FOR

CHEM-NUCLEAR SYSTEMS

MODEL CNS 10-160B

TYPE B RADWASTE SHIPPING CASK

REVISION 17

January 2001

CHEM-NUCLEAR SYSTEMS
CORPORATE HEADQUARTERS
140 STONERIDGE DRIVE
COLUMBIA, SOUTH CAROLINA 29210

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LIST OF FIGURES (Continued)

FIGURE NO. DESCRIPTION

LIST OF FIGURES (Continued)

The contents of the cask will consist of:

1) Greater than Type A quantities (up to a maximum of 3000 A_2) of radioactive material in the form of solids or dewatered materials in secondary containers.

2) Greater than Type A quantities (up to a maximum of 3000 A_2) of radioactive material in the form of activated reactor components or segments of components of waste from a nuclear power plant.

3) That quantity of any radioactive material which does not exceed 3000 A_2 and which does not generate spontaneously more than 100 thermal watts of radioactive decay heat.

4) The weight of the contents in the cask cavity will be limited to 14,500 lbs. If an insert is installed in the cavity, the maximum payload is reduced by the weight of the insert.

1.2.3.2 Waste Forms

The type and form of waste material will include:

1) By-product, source, or special nuclear material consisting of process solids or resins, either dewatered, solid, or solidified in secondary containers. (See Section 4.2.1 for specific limitations). TRU wastes are limited as described in Appendix 4.10.2, Transuranic (TRU) Waste Compliance Methodology for Hydrogen Gas Generation.

2) Neutron activated metals or metal oxides in solid form.

3) Miscellaneous radioactive solid waste materials.

4. CONTAINMENT

This chapter describes the containment configuration and test requirements for the CNS 10-160B Cask. Both normal conditions of transport and hypothetical accident conditions are discussed.

4.1 Containment Boundary

4.1.1 Containment Vessel

The package containment vessel is defined as the inner shell of the shielded transport cask and the primary and secondary lids together with the associated o-ring seals and lid closure bolts. The inner shell of the cask, or containment vessel, consists of a right circular cylinder of 68 inches inner diameter and 77 inches inside height (nominal dimensions). The shell is fabricated of an outer shell of 2-inch thick steel plate, a 1 7/8 inch layer of lead, and an inner shell of 1 1/8 – inch thick steel. The cylindrical shell is attached at the base to a circular end plate construction with full penetration welds. The primary lid is attached to the cask body with 24, 1 ¾ inch 8 UN bolts. A secondary lid covers the 31 inch opening in the primary lid and is attached to the primary lid using 12, 1¾ inch 8 UN bolts. See Section 4.1.4 for closure details.

4.1.2 Containment Penetrations

There are two penetrations of the containment vessel. These are (1) an optional drain line, and (2) an optional cask vent port located in the secondary lid. The drain line is located at the cask base and consists of a ½ inch diameter hole drilled into the stainless steel cask bottom. The drain line is sealed by a plug with a seal at its outer opening. An optional vent port penetrates the secondary lid into the main cask cavity. The vent and drain port penetrations are sealed with silicone Parker Stat-o-Seals or self-sealing type Teflon-coated hex socket plugs.

4.1.3 Welds

The containment vessel is fabricated from steel using full penetration welds.

4.1.4 Closure and Seals

The primary lid closure consists of a two layer steel plate construction, stepped to fit over and within the top edge of the cylindrical body. The lid is supported at the perimeter of the cylindrical body by a 3.00-inch thick plate (bolt ring) welded to the top of the inner and outer cylindrical body walls. The lid confines two (2) solid, high temperature silicone o-rings (Parker or equivalent) in machined grooves. Groove dimensions prevent over-compression of the o-rings by the lid closure bolt preload forces and hypothetical accident preload forces. The primary lid is attached to the cask body by 24 bolts. The primary lid is fitted with a secondary lid of similar construction attached with 12 bolts. The secondary lid is also sealed with two (2) solid, high temperature silicone o-rings (Parker or equivalent) in machined grooves. Only the inner o-ring of each lid is part of the containment boundary.

The optional vent penetration, test ports, and drain penetrations are sealed as described in Section 4.1.2. The seal plugs in these penetrations are lockwired prior to each shipment. Table 4.1 gives the torque values for bolts and cap screws.

Table 4.1
Bolt and Cap Screw Torque Requirements

Location	Size	Torque Values +/- 10% (Lubricated)	
		In-lb	Ft-lb
Test Ports (2)	1/2 NPT	144	12
Primary Lid	1-3/4 inch, 8 UN	3600	300
Second Lid	1-3/4 inch, 8 UN	3600	300
Vent Port*	1/2 - 20 UNF	240	20
Drain Port*	1/2 - 20 UNF	240	20

*Optional - These ports may not be installed on cask.

4.2 Containment Requirements for Normal Conditions of Transport

4.2.1 Leak Test Requirements

The CNS 10-160B cask is designed, fabricated, and leak tested to preclude a release of radioactive material in excess of the limits prescribed in NRC Regulatory Guide 7.4, paragraph C and 10CFR71.51(a)(1). The limits on leakage during normal conditions of transport are defined by 10CFR71.51(a)(1).

The leak test procedure must be able to detect leaks of $3.25\text{x}10^{-6}$ atm-cm^3/sec (based on dry air at 25°C with a pressure differential of one atmosphere) to assure compliance with 10CFR71.51(a)(1). A description of the calculational procedure used to determine this value follows.

10CFR71.51(a)(1) states the containment requirements for normal conditions of transport as:

> ...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 (Reference 4) states that the permissible leak rate shall be determined by equation 1 (below):

(Equation 1) $$L = \frac{R}{C}$$

where:

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

In Section 3.4.4, it is noted that the saturated water vapor in equilibrium at 168 degrees-F and 8.4 psig could exist within the internal shipping containers (liners or drains). It is assumed that these conditions exist within the cask cavity. The containment must limit the leakage of this water vapor to that prescribed in ANSI N14.5. It is very conservative to assume that the concentration of nuclides in the free liquid is equal to that of the solids which comprise the vast majority of material being transported in the cask. This value is determined below:

$$C = \frac{\text{Total Curie Content of Vapor}}{\text{Minimum Void Volume in Cask Cavity}}$$

- Cask curie content = 3000 x A_2 or less
- Free water is limited to restriction of one-percent of solid volume
- Hence the curie content = 0.01 x 3000 A_2
- The minimum void volume occurs when the largest liner is shipped

(Equation 2) $$V\ (\text{cask cavity}) = \frac{\pi}{4} \times 67.25^2 \times 75.75 = 269{,}064\ \text{in}^3$$

The largest liner will have at least ¾ inch of radial clearance and a 1½ inch of height difference, giving a volume,

(Equation 3)

$$V\ (\text{liner}) = \frac{\pi}{4} \times (67.25 - 2 \times 0.75)^2 \times (75.75 - 1.5)\ \text{in}^3$$
$$= 252{,}103\ \text{in}^3$$

Void Volume $= 269{,}064 - 252{,}103 = 16{,}961\ \text{in}^3$

$= 16{,}961\ \text{in}^3 \times 16.4\ \text{cm}^3/\text{in}^3$

$= 278{,}161\ \text{cm}^3$

Hence,

(Equation 4)

$$C = \frac{30 A_2\ \text{Ci}}{278{,}161\,\text{cm}^3} = 1.08 \times 10^{-4}\ A_2\ \text{Ci/cm}^3$$

And,

(Equation 5)

$$Ln = \frac{Rn}{C} = \frac{2.78 \times 10^{-10}\ A_2\ \text{Ci/sec}}{1.08 \times 10^{-4}\ A_2\ \text{Ci/cm}^3} \qquad \text{Eqn. 3, Ref. 4}$$
$$= 2.57 \times 10^{-6}\ \text{cm}^3/\text{sec}$$

A leak rate at standard conditions will be calculated which is equivalent to a volumetric leak rate of 2.57×10^{-6} cm^3/sec.

EquationsB.3, B.4,and B.5 are used to determine the diameter of hole that would give a leak rate of 2.57×10^{-6} cm^3/sec.

$$Lu = (Fc + Fm)(Pu - Pd)\left(\frac{Pa}{Pu}\right) \qquad \text{Eqn. B.5, Reference 4}$$

$$Fm = \frac{3.81 \times 10^3 D^3 \sqrt{\frac{T}{M}}}{a\ Pa} \qquad \text{Eqn. B.4, Reference 4}$$

$$Fc = \frac{2.49\text{x}10^6 D^4}{a\ \mu} \qquad \text{Eqn. B.3, Reference 4}$$

where:

L_u = upstream leakage rate, cm^3/sec

$\mu_{air} = 0.0185cP$

T = 168°F = 349°K Section 3.4.4

P_u = 8.4 psig = 1.57 atm

P_d = 1.0 atm

P_a = (1.57 + 1.0)/2 = 1.28 atm

M_{water} = 18 g/gmole

a = length of hole; assume 0.6 cm

Substituting into Eqns. B.3, B.4, and B.5:

$$Fc = \frac{2.49x10^6 D^4}{(0.6)(0.0185)} = 2.24 \text{ x } 10^8 D^4$$

$$Fm = \frac{3.81x10^3 D^3 \sqrt{\frac{349}{18}}}{(0.6)(1.28)} = 2.18 \text{ x } 10^4 D^3$$

$$2.57x10^{-6} = (2.24x10^8 D^4 + 2.18x10^4 D^3)(1.57 - 1.0)\left(\frac{1.28}{1.57}\right) \qquad \text{Solve for D}$$

D = 3.74 x 10^{-4} cm

Next, using Equation B.5 from Reference 4, determine the flow of air at standard conditions through a hole of this size. Where:

a = 0.6 cm

M_{air} = 29 g/gmole

μ_{air} = 0.0185 cP

P_u = 1.0 atm

P_d = 0.01 atm

P_a = (1.0 + 0.01)/2 = 0.505 atm

T = 298°K

$$Fc = \frac{(2.49x10^6)(3.74x10^{-4})^4}{(0.6)(0.0185)} = 4.38 \text{ x } 10^{-6} \frac{cm^3}{atm - sec}$$

$$F_m = \frac{(3.81x10^3)(3.74x10^{-4})^3\sqrt{\frac{298}{29}}}{(0.60)(0.505)} = 2.11\,x\,10^{-6} = \frac{cm^3}{atm - sec}$$

Substituting into B.5:

$$L_{std} = (4.38x10^{-6} + 2.11x10^{-6})(1.0 - 0.01)\left(\frac{0.505}{1.0}\right) = 3.25\,x\,10^{-6}\ \frac{atm - cm^3}{sec}$$

4.2.2 Pressurization of the Containment Vessel

Section 2.4.4 summarizes normal condition temperatures and pressures within the containment vessel. These pressures and associated temperatures are used to evaluate the integrity of the CNS 10-160B package. None of these conditions reduce the effectiveness of the package containment.

4.2.3 Coolant Containment

Not applicable; there are no coolants in the CNS 10-160B package.

4.2.4 Coolant Loss

Not applicable; there are no coolants in the CNS 10-160B package.

4.3 Containment Requirements for Hypothetical Accident Conditions

4.3.1 Leak Test Requirements

Section 2.7 demonstrates that the CNS 10-160B cask will maintain its containment capability throughout the hypothetical accident conditions. Fission gas products will not be carried within the cask so there can be no release of fission gases. The CNS 10-160B cask is designed, fabricated, and leak tested to preclude a release of radioactive material in excess of the limits prescribed in NRC Regulatory Guide 7.4, paragraph C and 10CFR71.51(a)(2). The limits on leakage during normal conditions of transport are defined by 10CFR71.51(a)(2).

The leak test procedure which assures compliance with leakage during normal conditions of transport will also be sufficient to assure compliance during hypothetical accident conditions. A description follows of the calculational procedure which demonstrates that the maximum leakage requirement during normal conditions of transport is more stringent than the maximum leakage requirement during the hypothetical accident.

10CFR71.51(a)(2) states the containment requirements for the hypothetical accident conditions as:

> ...no escape of krypton-85 exceeding 10,000 curies in one week, no escape of other radioactive material exceeding a total amount of A_2 in one week, and no external radiation dose rate exceeding one rem per hour at one meter from the external surface of the package.

Since the cask does not carry fission products or radioactive gases, only the A_2 per week requirement is limiting. A release of A_2 in one week is equivalent to the activity release rate, R_a, given by equation 9.

(Equation 9)
$$\begin{aligned} Ra &= (A2/\text{week})(1\ \text{week}/168\ \text{hr}) \\ &= 5.952 \times 10^{-3}\ A2/\text{hr} \end{aligned}$$

In Section 3.5.4, it is noted that the saturated water vapor in equilibrium at 243 degrees-F and 31.2 psig could exist within the internal shipping containers (liners or drains). It is assumed that these conditions exist within the cask cavity. The containment must limit the leakage of this water vapor to that prescribed in ANSI N14.5. It is very conservative to assume that the concentration of nuclides in the free liquid is equal to that of the solids which comprise the vast majority of material being transported in the cask. This value is determined below:

$$C = \frac{\text{Total Curie Content of Vapor}}{\text{Minimum Void Volume in Cask Cavity}}$$

- Cask curie content = 3000 x A_2 or less
- Free water is limited to restriction of one-percent of solid volume
- Hence the curie content = 0.01 x 3000 A_2
- The minimum void volume occurs when the largest liner is shipped

(Equation 10)
$$V(\text{cask cavity}) = \frac{\pi}{4} \times 67.25 \times 75.75 = 269{,}064$$

The largest liner will have at least ¾ inch of radial clearance and a 1½ inch of height difference, giving a volume, (Equation 11) $$V\,(\text{liner}) = \frac{\pi}{4} \times (67.25 - 2 \times 0.75)^2 \times (75.75 - 1.5)\ \text{in}^3$$

$$= 252{,}103\ \text{in}^3$$

Void Volume $= 269{,}064 - 252{,}103 = 16{,}961$

$= 16{,}961\ \text{in}^3 \times 16.4\ \text{cm}^3/\text{in}^3$

$= 278{,}161\ \text{cm}^3$

Hence,

(Equation 12) $$C = \frac{30 A_2\ \text{Ci}}{278{,}161\,\text{cm}^3} = 1.08 \times 10^{-5}\ A_2\ \text{Ci/cm}^3$$

The corresponding volumetric leak rate, L, is calculated by substituting C given by equation 12 and R_a given by equation 9 into equation 1. Equation 13 results from these substitutions.

(Equation 13) $$La = \frac{5.952 \times 10^{-3} A_2\ \text{Ci/hr}}{1.08 \times 10^{-5}\ A_2\ \text{Ci/cm}^3}\ \frac{1\,\text{hr}}{3600\,\text{sec}}$$

$$= 1.53 \times 10^{-2}\ \text{cm}^3/\text{sec}$$

The allowable leak rate during the hypothetical accident is larger than during the normal conditions of transport, 3.25×10^{-6} atm-cm^3/sec. Thus, the leak rate for normal conditions of transport is limiting and will determine the maximum permissible leak rate during tests.

4.4 Determination of Test Conditions for Preshipment Leak Test

4.4.1 Maximum Permissible Leak Rate at Standard Conditions

The preshipment leak test is performed by pressurizing the annulus between the O-ring seals of the primary and secondary lids (or if used, the vent or drain ports) with air. Pressure is read on a pressure gauge which is readable without estimation and which is calibrated to a maximum error of 1% full scale.

The test pressure shall be 35 PSIG and the test shall last for ½ hour (10 minutes for vent or drain ports) with an allowable pressure drop of 1 PSIG. Any condition which results in a pressure drop of more than 1 PSIG shall be corrected.

ANSI N14.5 - 1997 states (Reference 4, Table 1) that the permitted leak rate shall be either less than the reference air leakage rate, L_R, or no detected leakage when tested to a sensitivity of 1×10^{-3} ref-cm^3/sec. The following sections demonstrate that the sensitivity of the assembly verification test is equal to 10^{-3} atm-cm^3/sec is achieved with the preshipment leak test described above..

4.4.2 Detector Sensitivity - Test Conditions

The test performed is a pressure drop test. The annulus between the O-ring seals is pressurized with air. The annulus is a 1/8 inch deep groove, 1/8 inch in width, centered between O-rings, with a minimum inner diameter of 68 15/16 inches. The minimum volume of the annulus is 55 cm^3. The leak rate at test conditions is determined from equation B.14 of ANSI N14.5-1997 which is given as equation 15. Note that the same test is used for both the primary and secondary lid annulus. The secondary lid annulus is on a minimum 35½ inch diameter with a 1/8 x 1/8 inch groove. Since its minimum volume is about 28 cm^3 (which is less than the primary lid volume), the test sensitivity is greater for this test and is acceptable.

(Equation 15)

$$LR = \frac{V\,Ts}{3600\,HPs}\left[\frac{P1}{T1} - \frac{P2}{T2}\right]$$

Eqn B.14, Reference 4

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

4.4.3 Required Charge Pressure at the Test Pressure

Equation B.16 of Reference 4 states that:

$S \leq L/2$

Therefore the maximum permitted leak rate for the preshipment leak test is 2×10^{-3} atm-cm^3/sec. Substituting this in Eqn. B-14, determine the required leak test pressure, where:

$V = 55\ \text{cm}^3$
$H = 0.5\ \text{hr}$
$T_s = T_1 = T_2 = 298^\circ\text{K}$
$P_1 = 35\ \text{psig} = 3.38\ \text{atm}$

$$2\text{x}10^{-3} = \frac{(55\,\text{cm}^3)(298^\circ\,\text{K})}{3600(0.5\,\text{hr})(1\,\text{atm})}\left(\frac{3.38\,\text{atm}}{298^\circ\,\text{K}} - \frac{P_2}{298^\circ\,\text{K}}\right) \quad \text{Solve for } P_2\text{:}$$

$P_2 = 3.31\ \text{atm} = 34\ \text{psig}$

Therefore, the 1 psig pressure drop test starting at 35 psig meets the preshipment test requirement for a minimum sensitivity of 10^{-3} atm-cm^3/sec.

4.5 Periodic Verification Leak Rate Determination Using R-12 Test Gas

This section contains calculations to determine the periodic verification test measurement that is equivalent to the maximum permissible leak rate as determined using ANSI N14.5-1997 (Reference 4).

The purpose of this calculation is to determine the allowable leak rate using the R-12 halogen gas that may be used to perform the annual verification leak tests on the CNS 10-160B cask.

4.5.1 Introduction

The text of this document is prepared using Mathcad, Version 6.0, software. Most conventions used in the text are the same as normal practice. A benefit of the Mathcad code is that is automatically carries all units with the variables used in the calculations. The code also allows output of variables in any form of the fundamental units (length, mass, time, etc.), allowing for automatic conversions between unit systems without the need for conversion factors. All Mathcad calculations in this Section 4.5 have been verified by hand calculations.

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

4.5.2 Detector Sensitivity Calculation – Test Conditions

This section determines the sensitivity necessary for a leak test performed with R-12 halogen gas. This test is performed using a General Electric Model H-25 leak detector, along with a Yokogawa Model LS-20 leak standard containing R-12 halogen gas. The leak standard is used to calibrate the leak detector to alarm at the maximum allowable test leak rate. The test is performed by filling the region between the O-rings with 25 psig of R-12 halogen gas.

$L_{std} := 3.25\,10^{-6}\cdot std\cdot\frac{cm^3}{sec}$ Section 4.2.1 of 10-160B SAR

Where, for air at standard conditions:

$P_a := .505\cdot atm$

$T := 298\cdot K$

$P_u := 1.0\cdot atm$

$M_{air} := 29\cdot\frac{gm}{mole}$

$P_d := .01\cdot atm$

$\mu_{air} := 0.0185\cdot cP$

Assume a, which is the length of the hole in the o-ring, is

$a := 0.6\cdot cm$ From 4.2.1

The maximum possible diameter of hole in the O-ring is:

$D_{max} := 3.74\cdot 10^{-4}\cdot cm$ From Section 4.2.1

$$L_{std}(D) = (F_c(D) + F_m(D) \bullet (P_u - P_d) \bullet \frac{P_a}{P_d}$$ Eqn. B5 – ANSI N14.5 - 1997

Determine the equivalent air/R12 mixture (L_{mix}) that would leak from D_{max} during a leak test. Assume the O-ring void is pressurized to 25 psig (2.7 atm) with an air/R12 mixture.

$P_{mix} = 2.7 \cdot atm$

$P_{air} = 1.0 atm$

$P_{R12} = 1.7 \cdot atm$

$P_a := \frac{P_{mix} + P_{air}}{2} \Rightarrow P_a = 1.85 \cdot atm$

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

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

$M_{mix} := \frac{M_{R12} P_{R12} + M_{air} P_{air}}{P_{mix}}$ Eqn. B7 ANSI N14.5 - 1997

$\Rightarrow M_{mix} = 86.93 \cdot \frac{gm}{mole}$

$\mu_{mix} := \frac{\mu_{air} \cdot P_{air} + \mu_{R12} \cdot P_{R12}}{P_{mix}}$ Eqn. B8 ANSI N14.5 - 1997

$\Rightarrow \mu_{mix} = 0.015 \cdot cP$

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

$T := 273 \cdot K, 278 \cdot K .. 318 \cdot K$ Temperature range for test: 32°F to 113°F

$F_c := \frac{2.49 \cdot 10^6 \cdot D_{max}^4 \cdot cP \cdot std}{a \cdot \mu_{mix} \cdot sec \cdot atm} \Rightarrow F_c = 5.539 \cdot 10^{-6} \cdot \frac{cm^3}{sec \cdot atm}$

$$F_m(T) := \frac{3.81\cdot 10^{3}\cdot D_{ma}^{3}\cdot\sqrt{\frac{T}{M_{mi}}}\cdot cmgm^{0.5}}{a\cdot P_a\cdot K^{0.5}\cdot mole^{0.5}\cdot sec}$$

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

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

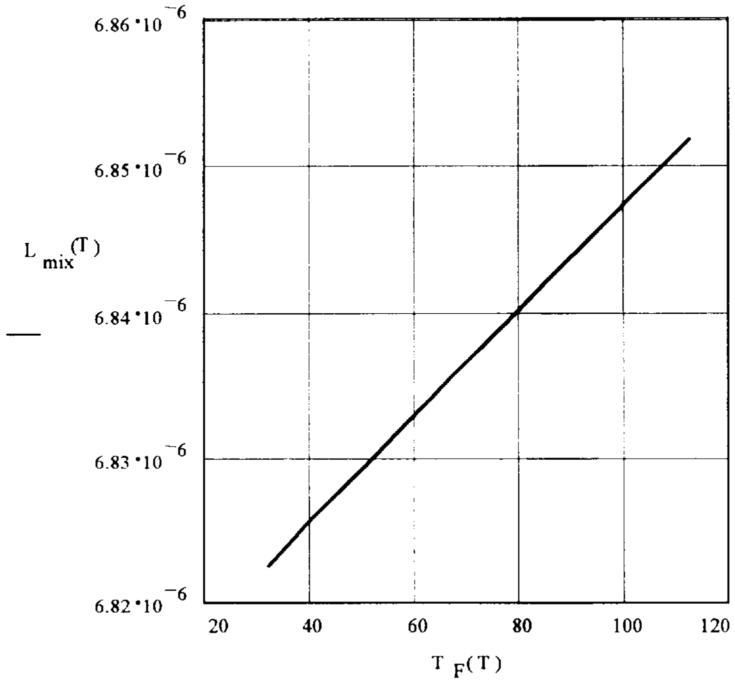

Fig.4.1 - Allowable R-12 Gas/Air Mixture Test Leakage, cm^3/sec, versus test temperature, deg.F

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.

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

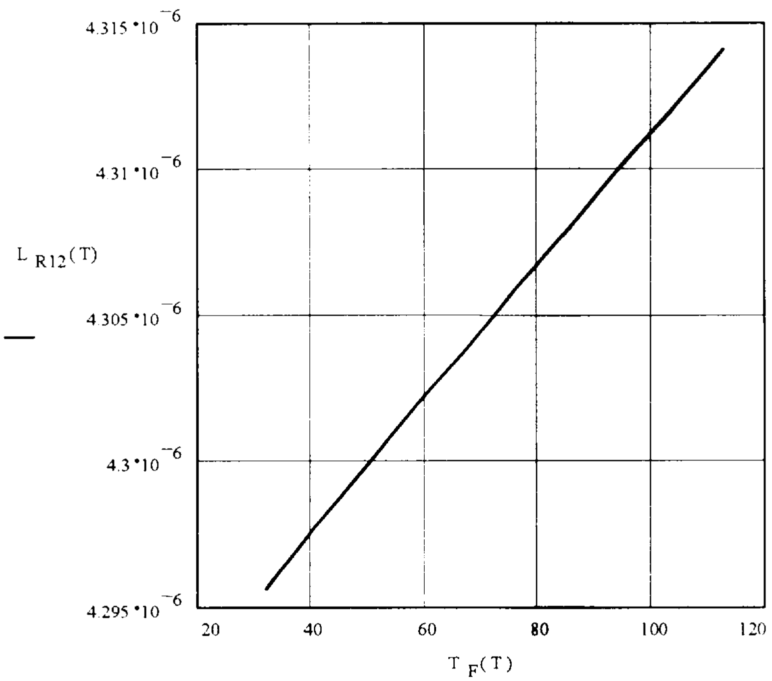

Fig.4.2 - Allowable R-12 test leakage, cm^3/sec versus test temperature, deg.F

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

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

where,

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

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.

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

$\frac{gm}{sec} = 1.113 \cdot 10^{6} \cdot \frac{oz}{yr}$ Conversion of gm/sec to oz/yr

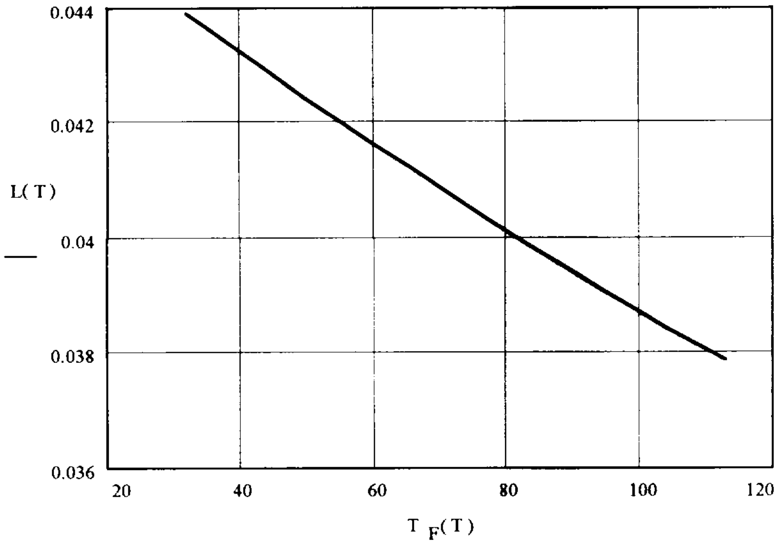

Fig.4.3 - Allowable R-12 test leakage, oz/yr, versus test temperature, deg.F

The graph above 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:

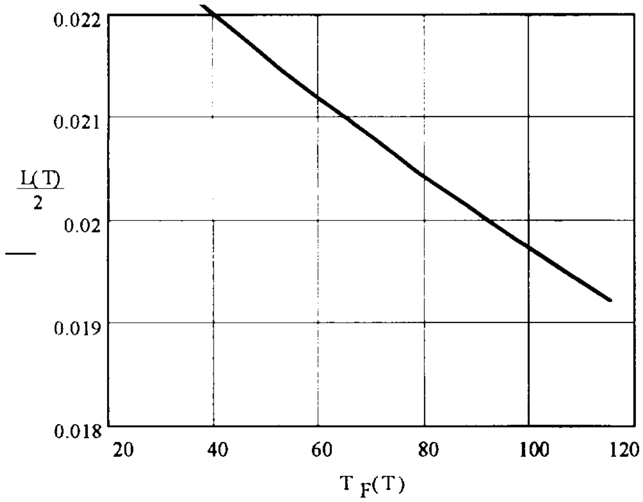

Fig.4.4 - Allowable R-12 test leakage sensitivity, oz/yr, versus test temperature, deg.F

The values presented in Figure 4.4 should be used to determine the sensitivity to calibrate the leak detector prior to the test.

4.6 Periodic Verification Leak Rate Determination Using Helium Test Gas

This section contains calculations to determine the periodic verification test measurement that is equivalent to the maximum permissible leak rate as determined using ANSI N14.5-1997 (Reference 4).

4.6.1 Introduction

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 CNS 10-160B cask.

The text of this document is prepared using Mathcad, Version 6.0, software. Most conventions used in the text are the same as normal practice. A benefit of the Mathcad code is that it automatically carries all units with the variables used in the calculations. The code also allows output of variables in any form of the fundamental units (length, mass, time, etc.), allowing for automatic conversions between unit systems without the need for conversion factors. All Mathcad calculations in this Section 4.6 have been verified by hand calculations.

4.6.2 Detector Sensitivity – Test Conditions

In Section 4.2.1, it was determined that the maximum possible diameter hole in the cask O-ring (D_{max}) that would permit the standard leak rate ($L_{std} = 3.25\times10^{-6}$ std cm^3/sec) is:

$$D_{max} = 3.74\cdot10^{-4}\cdot cm$$

Next, determine the equivalent air/He mixture (L_{mix}) that would leak from D_{max} during a leak test. Assume the O-ring void is pressurized to 25 psig (2.7 atm) with an air/He mixture.

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

$$P_{air} = 1.0\cdot atm$$

$$P_{He} = 1.7\cdot atm$$

$$P_a = \frac{P_{mix} + P_{air}}{2}$$

$$P_a = 1.85\cdot atm$$

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

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

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

$\Rightarrow$ $M_{mix} = 13.26\cdot\frac{gm}{mole}$

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

$\Rightarrow$ $\mu_{mix} = 0.019\cdot cP$

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:

$:= 273\cdot K, 278\cdot K .. 318\cdot K$ Temperature range for test: 32°F to approx. 113°F

$$F_c := \frac{2.49\,10^{6}\cdot D_{max}{}^{4}\cdot cP\cdot std}{a\cdot\mu_{mix}\cdot sec\cdot atm}$$

$\Rightarrow$ $F_c = 4.203\cdot 10^{-6}\cdot\frac{cm^{3}}{sec\cdot atm}$

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

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

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

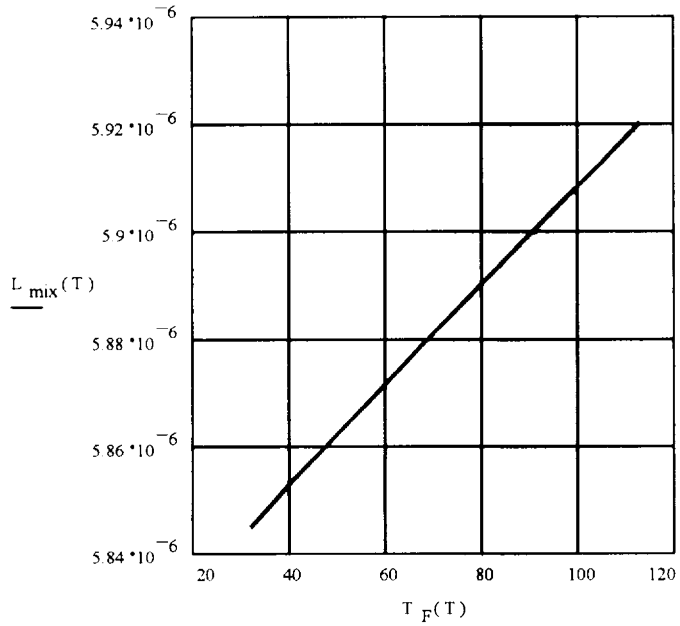

Fig.4.5 - Allowable He/Air Mixture Test Leakage, cm^3/sec, versus test temperature, deg.F

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.

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

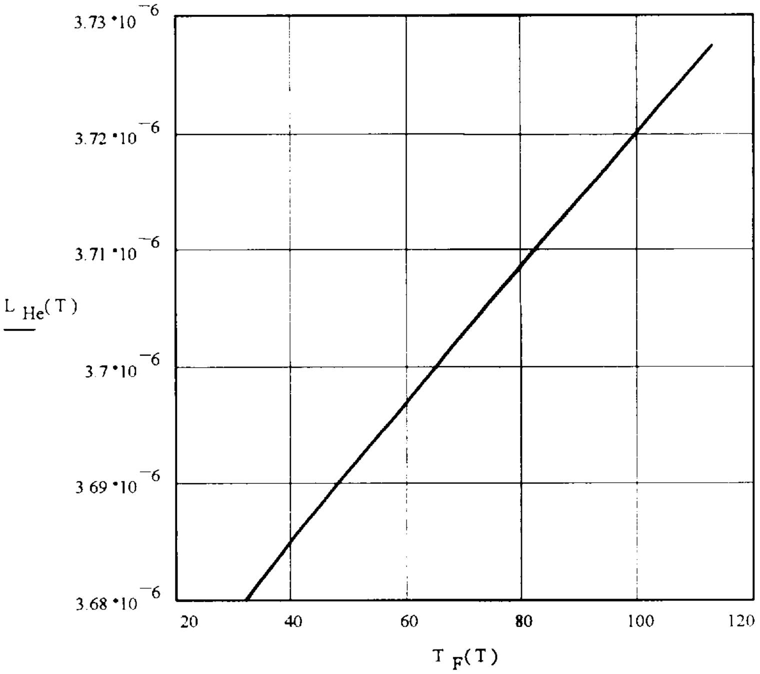

Fig.4.6 - Allowable Helium test leakage, cm^3/sec versus test temperature, deg.F

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

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

where,

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

This data can then be used to convert the volumetric leak rate for Helium 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.

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

$$\frac{gm}{sec} = 1.113 \cdot 10^6 \cdot \frac{oz}{yr} \qquad \text{Conversion of gm/sec to oz/yr}$$

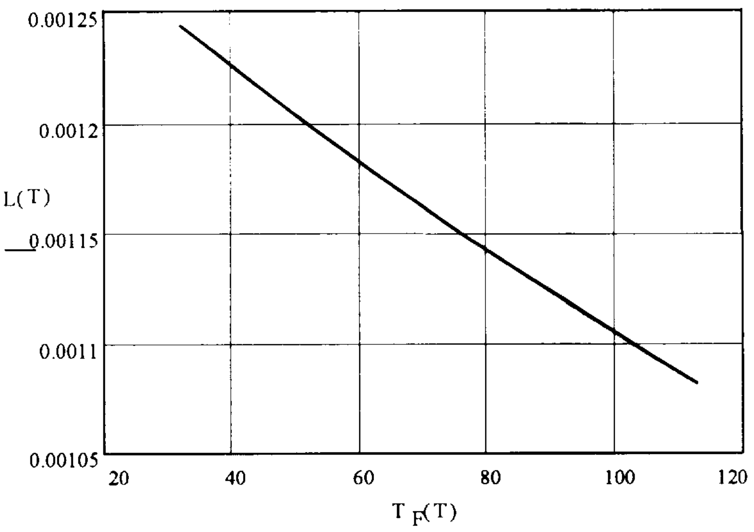

Fig.4.7 - Allowable helium test leakage, oz/yr, versus test temperature, deg.F

The graph above 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:

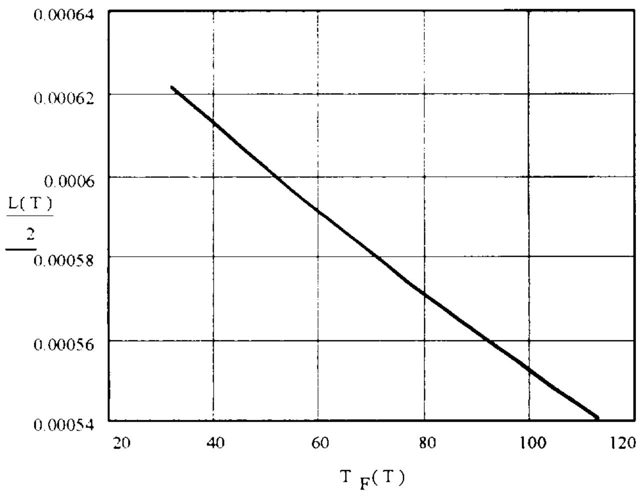

Fig.4.8 - Allowable helium test leakage sensitivity, oz/yr, versus test temperature, deg.F

The values presented in Figure 4.8 should be used to determine the sensitivity to calibrate the leak detector prior to the test.

4.7 Periodic Verification Leak Rate Determination Using R-134A Test Gas

This section contains calculations to determine the periodic verification test measurement that is equivalent to the maximum permissible leak rate as determined using ANSI N14.5-1997 (Reference 8).

4.7.1 Introduction

The purpose of this calculation is to determine the allowable leak rate using the R-134a halogen gas that will be used as an alternative to perform the annual verification leak tests on the CNS 10-160B cask. This halogen gas is now in widespread use as a replacement gas for R-12 in many industrial applications. Properties for R134a are included in Appendix 4.1.

The text of this document is prepared using Mathcad, Version 6.0, software. Most conventions used in the text are the same as normal practice. A benefit of the Mathcad code is that it automatically carries all units with the variables used in the calculations. The code also allows output of variables in any form of the fundamental units (length, mass, time, etc.), allowing for automatic conversions between unit systems without the need for conversion factors. All Mathcad calculations in this Section 4.7 have been verified by hand calculations.

4.7.2 Detector Sensitivity Calculation - Test Conditions

This section determines the sensitivity necessary for a leak test performed with R-134a halogen gas. This test is performed using a General Electric Model H-25 leak detector, along with a Yokogawa Model LS-20 leak standard containing R-134a halogen gas. The leak standard is used to calibrate the leak detector to alarm at the maximum allowable test leak rate. The test is performed by filling the region between the o-rings with 25 psig of R-134a halogen gas. In section 4.2.1, it was determined that the maximum possible diameter hole in the cask O-ring (D_{max}) that would permit the standard leak rate ($L_{std} = 3.25 \times 10^{-6}$) is:

$D_{max} = 3.74 \cdot 10^{-4} \cdot cm$

Next, determine the equivalent air/R134a mixture (L_{mix}) that would leak from D_{max} during a leak test. Assume the O-ring void is pressurized to 25 psig (2.7 atm) with an air/R134a mixture.

$P_{mix} = 2.7 \cdot atm$

$P_{air} = 1.0 \cdot atm$

$P_{R134a} = 1.7 \cdot atm$

$$P_a = \frac{P_{mix} + P_{air}}{2}$$

$$P_a = 1.85 \cdot atm$$

The properties of R134a are given in the attached literature (Appendix 4.1):

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

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

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

$$\Rightarrow \quad M_{mix} = 74.96 \cdot \frac{gm}{mole}$$

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

$$\Rightarrow \quad \mu_{mix} = 0.014cP$$

Next, 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:

$T = 273 \cdot K, 278 \cdot K .. 318 \cdot K$ Temperature range for test: 32°F to 113°F

Substitute these properties for the air/R134a mixture and the maximum diameter hole (D_{max}) into equations B.3, B.4, and B.5 from ANSI N14.5:

$$F_c = \frac{2.49 10^6 \cdot D_{max}^4 \cdot cP \cdot std}{a \cdot \mu_{mix} \cdot sec \cdot atm}$$

$$\Rightarrow \quad F_c = 5.636 \cdot 10^{-6} \cdot \frac{cm^3}{sec \cdot atm}$$

$$F_m(T) = \frac{3.81 \cdot 10^3 \cdot D_{ma}{}^3 \cdot \sqrt{\frac{T}{M_{mi}}} \cdot cmgm^{0.5}}{a \cdot P_a \cdot K^{0.5} \cdot mole^{0.5} \cdot sec}$$

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

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

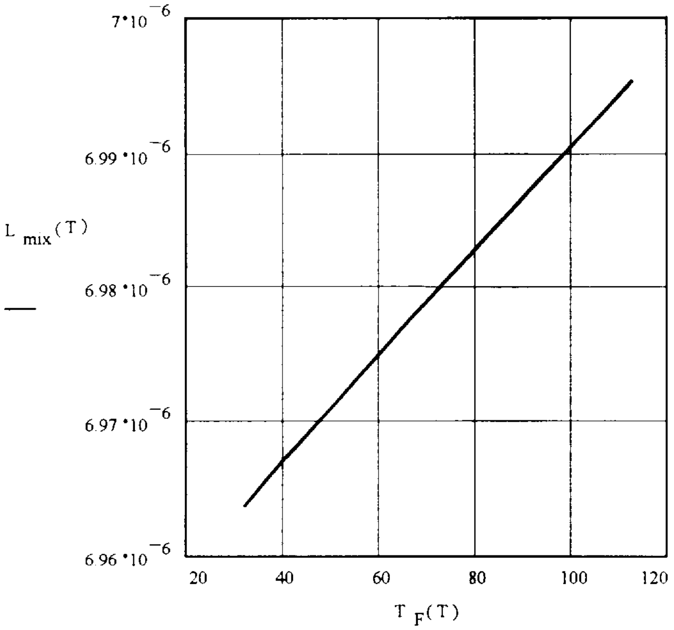

Fig.4.9 - Allowable R134a/Air Mixture Test Leakage, m^3/sec, versus test temperature, deg.F

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.

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

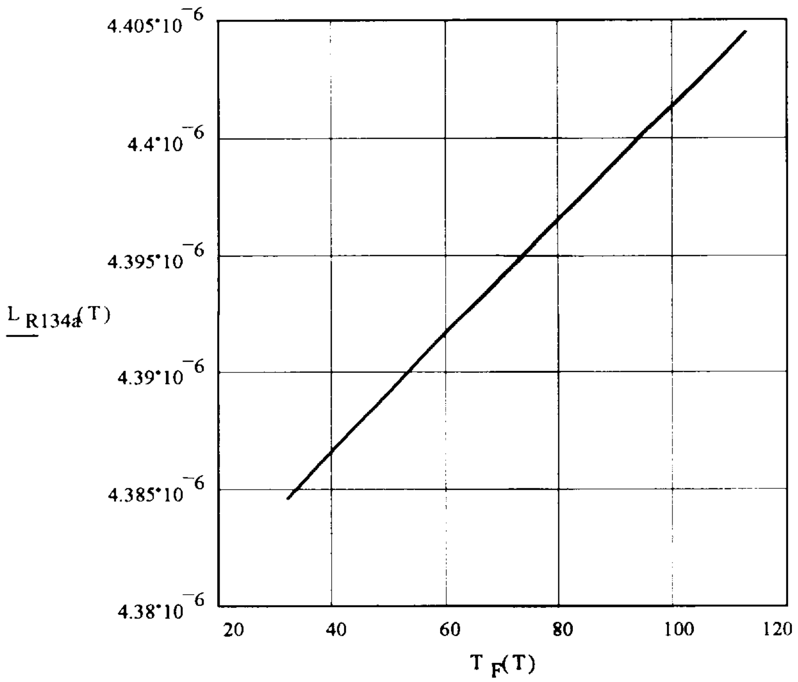

Fig.4.10 - Allowable R-134a test leakage, cm^3/sec versus test temperature, deg.F

Determine the equivalent mass flow rate for L_{R134a} in oz/yr, the measurement used by the detector:

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

where,

$$R_o = \frac{82.05\, cm^3 \cdot atm}{mole K}$$ Universal gas constant

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.

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

$$\frac{gm}{sec} = 1.113 \cdot 10^6 \cdot \frac{oz}{yr}$$ Conversion of gm/sec to oz/yr

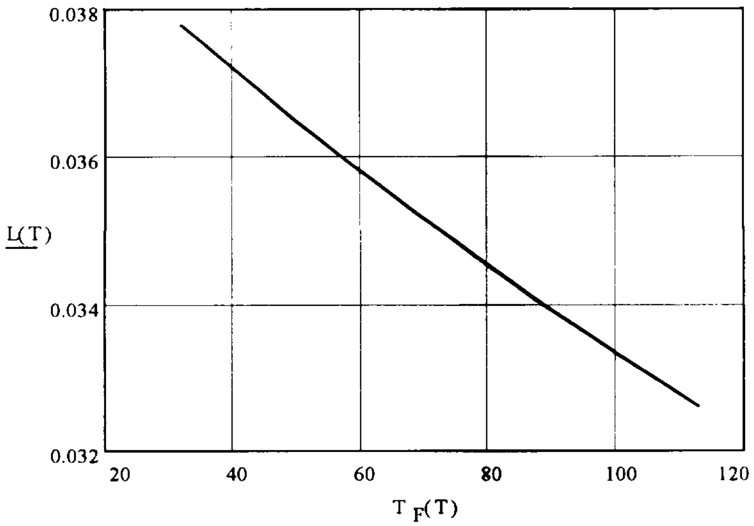

Fig.4.11 - Allowable R134a test leakage, oz/yr, versus test temperature, deg.F

The graph above 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:

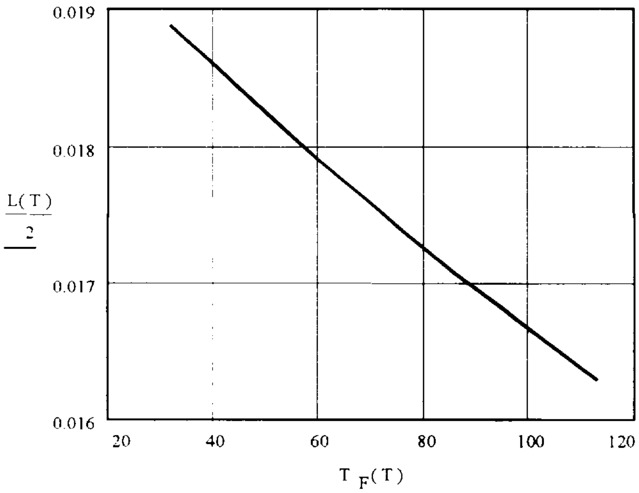

Fig.4.12 - Allowable R134a test leakage sensitivity, oz/yr, versus test temperature, deg.F

The values presented in Figure 4.12 should be used to determine the sensitivity to calibrate the leak detector prior to the test.

4.8 Combustible Gas Generation Safety Assurance

Assurance of safe shipment of vessels which may generate combustible gas is based on meeting the following criteria over the shipment period.

i) The quantity of hydrogen generated must be limited to a molar quantity that would be no more than 5% by volume at STP (or equivalent limits for other inflammable gases) of the secondary container gas void (i.e., no more than 0.063 gram moles/cubic foot, or

ii) The secondary container and the cask cavity (if required) must be inerted with a diluent to assure the oxygen, including that radiolytically generated, shall be limited to 5% by volume in those portions of the package which could have hydrogen greater than 5%.

Criterion (i) essentially stipulates that the quantity of hydrogen shall be limited to 5% of the secondary container gas void at STP. This 5% hydrogen gas volume at standard conditions is equivalent to a hydrogen partial pressure of 0.735 psi or 0.063 gram moles/cubic foot. By actual experiment (Ref. 6), the produce an approximate 2.3 psi incremental pressure increase above a nominally atmospheric initial pressure. This is because 0.063 gram moles of hydrogen per cubic foot provides such a small source that the peak pressure rise resulting from ignition of this source is slight. (The pressure rise is independent of the total volume under test, i.e. the 0063 gram moles per cubic foot relationship to a 2.3 psi pressure rise is valid for one or many cubic feet of specimen volume). This incremental pressure rise is an inconsequential load on the cask structure.

(Ref. 7), Criteria (ii) is invoked to ensure that when a secondary container's hydrogen concentration potentially exceeds 5% volume, release of that hydrogen to the then existing total volume (secondary container void plus cask void) will not result in a total mixture of greater than 5% volume hydrogen in a greater than 5% oxygen atmosphere. Maintaining the oxygen concentration lower than five (5) volume % assures a nonflammable mixture.

4.9 References

1. Hansen Couplings, The Hansen Manufacturing Company, Cleveland, Ohio.

2. Mark's Standard Handbook for Mechanical Engineers, Theodore Baumeister, et. al., Eighth Edition, McGraw-Hill Book Company, New York, 1979.

3. Basic Engineering Thermodynamics, M. W. Zemansky and H. C. Van Ness, McGraw-Hill Book Company, New York, 1966.

4. American National Standard for Leakage Tests on Packages for Shipment of Radioactive Materials, American National Standards Institute, Inc., New York, ANSI N14.5-1997, 1998.

5. CRC Handbook of Chemistry and Physics, Robert C. Weast and Melvin J. Astle, eds., 62nd Edition, CRC Press, Inc., Boca Ration, Florida, 1981.

6. Flame and Detonation Initiation Area Propagation in Various Hydrogen - Air Mixtures With and Without Water Spray, L. W. Carlson, et. al., Atomic International Division of Rockwell International, Canoga Park, California, May 11, 1973.

7. Combustion, Flames and Explosions of Gases, B. Lewis and G. von Elbe, Academic Press, New York, 1961, Second Edition, Appendix B.

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ATTACHMENT 2

Justification for Revision
3 pages

ATTACHMENT 2

JUSTIFICATION FOR REVISION 16 TO THE CNS 10-160B SAR AND C OF C

The primary requested change is to increase the quantity limit to 3000 times a Type A quantity without a change in the currently authorized type of permitted content materials, material form, or other quantity limits. The currently authorized activity limit is "not to exceed 2000 times a Type A quantity".
No change is requested to the maximum quantity limits listed in 5(b)(2) of:
decay heat ≤ 100 watts and fissile material ≤ the mass limits of 10 CFR 71.53.
As the quantity limit is the basis for the containment leak rate calculations of Chapter 4, the leak rate calculations have been revised to reflect a limit of 3000 times a Type A quantity.

In addition, text changes have been made to Chapter 4 Containment, Section 4.1. Previously, the lid leak test ports were identified as penetrations of the containment boundary. However, since the ports are outside the inner o-ring (the inner o-ring was considered the containment boundary in all analyses), the ports do not penetrate the containment boundary. The text in Section 4.1.2 has been revised to correctly identify only two containment penetrations, the optional drain line and the optional vent port in the secondary lid. Also, in Section 4.1.4, the incorrect designator of "Stat-O-Seal" has been removed from the lid o-rings (the seals are not Stat-O-Seals but silicone o-rings) and the inner o-ring of each lid pair is identified as the containment boundary for clarity.

Evaluations of each section of the 10-160B SAR taking into consideration the requested change are presented below.

<u>CNS 10-160B Safety Analysis Report</u>

1.0 GENERAL INFORMATION

1.1 Introduction

The requested change has no impact on this section.

1.2 Package Description

1.2.1 Packaging

The requested change has no impact on this section.

1.2.2 Operational Features

The requested change has no impact on this section.

1.2.3 Contents of Packaging

1.2.3.1 Cask Contents

Items 1, 2, and 3 are revised to specify 3000 A_2 as the maximum allowed activity. Regulatory Guide 7.11 identifies the radioactivity limit for a Category II package as "Between 3,000 A_2 and 30 A_2" for Normal Form material. The impact of this change on the leak rate is discussed in Section 4, Containment

1.2.3.2 Waste Forms
The requested change has no impact on this section.

1.3 Appendix – CNS 10-160B Shipping Cask Drawing
The requested change has no impact on this section.

2.0 STRUCTURAL EVALUATION

The requested change to the quantity of radioactive material in the contents does not alter the cask structure or content weights previously approved by the NRC for the 10-160B. The requested change has no impact on this section.

3.0 THERMAL EVALUATION

The requested change to the quantity of radioactive material in the contents does not alter the thermal limit previously approved for the 10-160B. The requested change has no impact on this section.

4.0 CONTAINMENT

4.1 Containment Boundary

The text now reflects the existence of only two containment boundary penetrations, the optional drain line and the optional vent in the secondary lid. The lid seals are now correctly identified as silicone o-rings without the additional qualifier of "Stat-O-Seal" and the inner o-ring is identified as the containment boundary.

4.2 Containment Requirements for Normal Conditions of Transport

The calculations in this section have been revised using a source term of 3000 A_2.

4.3 Containment Requirements for Hypothetical Accident Conditions

The calculations in this section have been revised using a source term of 3000 A_2.

4.4 Determination of Test Conditions for Assembly Verification Leak Test

The requested change has no impact on this section.

4.5 Periodic Verification Leak Rate Determination Using R-12 Test Gas

The calculations in this section have been revised for a L_{STD} based on a source term of 3000 A_2.

4.6 Periodic Verification Leak Rate Determination Using Helium Test Gas

The calculations in this section have been revised for a L_{STD} based on a source term of 3000 A_2.

4.7 Periodic Verification Leak Rate Determination Using R-134a Test Gas
The calculations in this section have been revised for a L_{STD} based on a source term of 3000 A_2.

4.8 Combustible Gas Generation Safety Assurance
The requested change has no impact on this section.

4.9 References
The requested change has no impact on this section.

5.0 SHIELDING EVALUATION

The shielding evaluation is based on a gamma source limited by external dose rate not by total activity. As shown in the evaluation, a typical gamma source (^{60}Co is used) is limited by the external dose rate on the cask. The maximum ^{60}Co source, based on external dose rate, is less than the currently authorized activity limit of 2000 times a Type A quantity. The requested change to 3000 times a Type A quantity has no impact on this section.

6.0 CRITICALITY EVALUATION

The requested change does not alter the fissile material limit previously authorized. The requested change has no impact on this section.

7.0 OPERATING PROCEDURES

The requested change has no impact on this section.

8.0 ACCEPTANCE TESTS AND MAINTENANCE

The requested change has no impact on this section.