RTL-001-CALC-CN-0101 Rev 6_Redacted

ENERCON FEDERAL SERVICES, INC.	CALCULATION COVER SHEET	CALC. NO. RTL-001-CALC-CN-0101 REV. 6 PAGE NO. 1 of 24

Title:	Containment Evaluation for the RT-100	Client: Robatel Technologies Project: RT-100 Transport Package

Item	Cover Sheet Items	Yes	No
1	Does this calculation contain any open assumptions that require confirmation? (If **YES**, Identify the assumptions) ______	☐	☒
2	Does this calculation serve as an "Alternate Calculation"? (If **YES**, Identify the design verified calculation.) **Design Verified Calculation No.** ______	☐	☒
3	Does this calculation Supersede an existing Calculation? (If **YES**, identify the superseded calculation.) **Superseded Calculation No.** ______	☐	☒

Scope of Revision:

Editorial correction made to equation on page 17 (added parenthesis around ($F_C + F_m$) terms). Updated Figure 7.4 based on revision of reference drawings.

Revision Impact on Results:

Revision 6 changes: No impact on results of calculation.

Study Calculation ☐ **Final Calculation** ☐

Safety-Related ☒ **Non-Safety Related** ☐

(Print Name and Sign)

Originator: David Hartmangruber [signature]	**Date:** 01/03/2014
Design Verifier: Curt Lindner [signature]	**Date:** 1/3/14
Approver: Nand Lambha [signature]	**Date:** 1/3/14

CALCULATION REVISION STATUS

REVISION	DATE	DESCRIPTION
0	09/27/12	Initial Issue
1	10/02/12	O-ring groove width (assumption 5) was changed from 1.1 cm to 0.49 cm to reflect updated drawings. This altered the standard leakage rates of the cask. These leakage rates were recalculated and updated. Added references for drawings used in Figures 7.1 and 7.2. Added reference for assumption 5. Updated table of contents, list of figures, and list of tables to reflect this addition of references. Renumbered references throughout text to reflect updated references list. Updated equations to reflect new O-ring groove width. Revised section 7.6 to include a calculation of the leak rate acceptance criteria using helium as a fill gas for fabrication, periodic, and maintenance tests.
2	07/31/13	Adjusted methodology and updated results in order to satisfy RAI questions. Leaktight criterion established for RT-100 Transport Cask. Corrected Calculation Number in document.
3	08/28/13	Provided test leakage rates between partial helium pressures of 0.25 atm to 1.0 atm. Update based on information provided by Robatel, Appendix A. Removed ANSI viscosity value for helium at a temperature of 298 Kelvin. Data point seemed excessive due to proximity of 300 Kelvin value.
4	09/04/13	Client comment incorporation. Removed no longer necessary assumptions from Section 4, added Section 5.1.1, and updated discussion in Sections 5.1.2, 5.1.3, 5.1.5, 6, and 7.2. Appendix A removed based on client comment.
5	09/11/13	Client comment incorporation and Figures 5.1, 7.3, and 7.4 updated.
6	01/03/14	Corrected equation on page 17. Updated revision of reference drawings and calculations.

PAGE REVISION STATUS

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All	6		

APPENDIX REVISION STATUS

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ENERCON FEDERAL SERVICES, INC.	CALCULATION DESIGN VERIFICATION CHECKLIST	CALC. NO. RTL-001-CALC-CN-0101
		REV. 6
		PAGE NO. 3 of 24

Item	CHECKLIST ITEMS	Yes	No	N/A
1	**Design Inputs** - Were the design inputs correctly selected, referenced (latest revision), consistent with the design basis, and incorporated in the calculation?	✓		
2	**Assumptions** - Were the assumptions reasonable and adequately described, justified and/or verified, and documented?	✓		
3	**Quality Assurance** - Were the appropriate QA classification and requirements assigned to the calculation?	✓		
4	**Codes, Standards, and Regulatory Requirements** - Were the applicable codes, standards, and regulatory requirements, including issue and addenda, properly identified and their requirements satisfied?	✓		
5	**Construction and Operating Experience** - Have applicable construction and operating experience been considered?			✓
6	**Interfaces** - Have the design-interface requirements been satisfied, including interactions with other calculations?	✓		
7	**Methods** - Was the calculation methodology appropriate and properly applied to satisfy the calculation objective?	✓		
8	**Design Outputs** - Was the conclusion of the calculation clearly stated, did it correspond directly with the objectives, and are the results reasonable compared to the inputs?	✓		
9	**Radiation Exposure** - Has the calculation properly considered radiation exposure to the public and plant personnel?			✓
10	**Acceptance Criteria** - Are the acceptance criteria incorporated in the calculation sufficient to allow verification that the design requirements have been satisfactorily accomplished?	✓		
11	**Computer Software** - Is a computer program or software used, and if so, are the requirements of CSP 3.02 met?			✓

COMMENTS:

	(Print Name and Sign)	
Design Verifier:	Curt Lindner [signature]	**Date:** 1/3/14
Others:		**Date:**

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1. Purpose and Scope

The purpose of this calculation is to provide an analysis that demonstrates compliance with the permitted activity release limits specified in 10 CFR 71 [1] for the Robatel Technologies RT-100 cask. Satisfaction of the containment criteria, expressed in this analysis as the design basis leakage rate, ensures that the package will not exceed the allowable radionuclide release rate. Leakage rates are determined using NUREG/CR-6487, *Containment Analysis for Type B Packages Used to Transport Various Contents* [2] and the NRC's Regulatory Guide 7.4, *Leakage Tests on Packages for Shipment of Radioactive Materials* [3] as guides. These calculations must also be in accordance with the requirements of ANSI N14.5 [4].

The RT-100 cask's maximum allowable leakage rate ensures that the requirements of 10 CFR 71.51 are met. The containment boundary for the RT-100 cask consists of the inner cask shell, the inner bottom plate, the upper flange, the primary lid and inner O-ring, the secondary lid and inner O-ring, and the vent port cover plate and associated O-ring.

Due to the variety of inventories, diversity in both isotopic composition and in total activity concentration, the RT-100 cask has been established as a leaktight container. Leaktight is a degree of package containment that in a practical sense precludes any significant release of radioactive materials. This degree of containment is achieved by demonstration of a leakage rate less than or equal to 1×10^{-7} ref·cm^3/s, of air at an upstream pressure of 1 atmosphere absolute and a downstream pressure of 0.01 atmosphere absolute or less [4].

2. Summary and Conclusion

The RT-100 cask is to be certified for shipment of Category II radioactive material as defined in NUREG/CR-6487 [2]. Inventory within the RT-100 cask will be maintained below a total activity of 3000 A_2 within accordance the maximum specified in NUREG/CR-6487 [2]. Containment acceptance criteria for transport casks shall be leaktight or determination of an allowable standard leakage rate limit using normal and accident conditions. The RT-100 Transport Cask has been set to leaktight standards. This precludes the necessity of calculating individual release rates for normal and accident conditions and converting to allowable standard leakage rates. The allowable standard leakage for leaktight condition rates and sensitivity, for both helium and air media, are provided in Table 2.1.

Table 2.1 Allowable Standard Leakage Rates

	Allowable Leakage Rate [ref-cm^3/sec]	Sensitivity [ref-cm^3/sec]
Air	1.00E-07	5.00E-08
Helium	2.00E-07	1.00E-07

3. References

1. 10 CFR 71, "Packaging and Transport of Radioactive Material," 2010.
2. NUREG/CR-6487, UCRL-ID-124822, *Containment Analysis for Type B Packages Used to Transport Various Contents*, B.L. Anderson et al., Lawrence Livermore National Laboratory, November 1996.
3. NRC's Regulatory Guide 7.4, Leakage Tests on Packages for Shipment of Radioactive Materials.
4. ANSI N14.5-1997, "American National Standard for Radioactive Material Leakage Tests on Packages for Shipment."
5. RT100-PE-1001-1, Sheet 1, Rev. H, "General Assembly".
6. RT100-PE-1001-2, Sheet 2, Rev. H, "General Assembly".
7. "Particle-size distribution and packing fraction of geometric random packings." H. J. H. Brouwers, Physical Review E 74, 031309, 2006.
8. RTL-001-CALC-TH-0102, Rev. 6, "RT-100 Cask Maximum Normal Operating Pressure Calculation."
9. RTL-001-CALC-TH-0202, Rev. 6, "RT-100 Cask Hypothetical Accident Condition Maximum Pressure Calculation."
10. Lamarsh, J. & Baratta, A., "Introduction to Nuclear Engineering", 3rd Edition, 2001.
11. Munson, B., Young, D., & Okiishi, T., "Fundamentals of Fluid Mechanics", 5th Edition, 2006.
12. Brookhaven National Laboratory, "Selected Cryogenic Data Notebook", August 1980.
13. RTL-001-CALC-SH-0201, Rev 5, "Shielding Evaluation for the RT-100 Transport Cask."
14. NUREG-1465, "*Accident Source Terms for Light-Water Nuclear Power Plants*", L. Soffer et al., February 1995.
15. "Nuclear Chemical Engineering", M. Benedict, T. H. Pigford, and H. W. Levi, 1981.

4. Assumptions

The following assumptions are employed in determining the allowable leakage rates:

1. The flow is un-choked for all analyses because the un-choked flow correlations better approximate the true measured flow rate for the leakage rates associated with transportation packages. Per NUREG/CR-6487 Section 2.2.5, page 6, "it was found that the continuum and molecular flow equation provided good agreement with the experimental results for flow rates less than about 1 atm·cm^3/s." Since the gas flow rate of interest for this radioactive material transportation container is less than 1 atm·cm^3/s, the un-choked correlations are chosen. [2]

2. The O-ring contact surface or seating width with the smallest diameter will determine the allowable leakage rates of the cask. This width can be assumed as the groove width for the O-ring in the vent port cover plate (0.49-cm) [6, Section H-H, Detail 1] since it is smaller than the O-

rings in the primary and secondary lids, and this is the value which will be used as the capillary length.

3. The maximum allowable activity is set at 3000 A_2. This is the upper limit of Category II radioactive material [2].

5. Design Inputs

5.1 Description of Containment System

5.1.1 Containment Boundary

The containment boundary of the RT-100 transport cask consists of the inner shell, inner bottom plate, the primary lid connected to the upper flange with the primary lid's inner O-ring, the secondary lid connected to the primary lid with the secondary lid's inner O-ring, and the vent port cover plate and the vent port cover plate's inner O-ring. An illustration of the RT-100 transport cask containment boundary is provided in Figure 5.1. The inner shell and the inner bottom plate are stainless steel. At the base, the cylindrical shell is attached to a circular end plate with full penetration welds. The primary lid is bolted to the upper flange which has full penetration welds to the top of the inner and outer cylindrical shells of the cask body. The secondary lid is bolted to the primary lid [5]. The vent port cover plate is also bolted to the primary lid [6]. The primary lid, secondary lid, and vent port cover plate each have two (2) solid, elastomeric O-rings retained in machined grooves. The inner O-rings of each lid are considered part of the containment boundary.

The RT-100 transport cask does not rely on any valve or pressure relief device to meet the containment requirements. The quick disconnect valve is protected by the vent port cover plate which protects the valve from unauthorized operation and provides a sealed enclosure to retain any leakage from the device.

Proprietary Information Content Withheld Under 10 CFR 2.390

5.1.2 Containment Vessel

The package containment system is defined as the inner shell of the shielded transport cask, together with the associated lid, O-ring seals, and lid closure bolts. The inner shell of the cask or containment vessel consists of a right circular cylinder of 1730 mm inner diameter and 1956 mm (~196.0 cm) inside height [6]. The shell is fabricated of stainless steel. The inner shell is 30 mm (3.0 cm) thick and the inner bottom plate is 50 mm (5.0 cm) thick stainless steel. At the base, the cylindrical shell is attached to a circular end plate with full penetration welds. The primary lid is supported at the perimeter of the cylindrical body by a thick flange (upper forging) which is welded to the top of the inner and outer cylindrical shells. The primary lid is attached to the cask body with thirty-two (32) equally spaced M48 hex head bolts. A secondary lid covers an opening in the primary lid and is attached to the primary lid using eighteen (18) equally spaced M36 hex head bolts. The vent port cover plate covers the vent port and is attached to the primary lid using six (6) M10x30 socket hex head bolts. See Section 5.1.5 for closure details.

5.1.3 Containment Penetration

There are three penetrations of the containment vessel. These are (1) the primary lid with the containment boundary of the primary lid's inner O-ring; (2) the secondary lid with the containment boundary of the secondary lid's inner O-ring; and (3) the cask vent port located in the primary lid. The vent port penetrates the primary lid into the main cask cavity. The vent penetration contains a quick disconnect valve and is sealed with the vent port cover plate and the vent port cover plate's inner O-ring. The primary and secondary lids are sealed with elastomeric O-rings.

5.1.4 Welds and Seals

The containment vessel is fabricated using full penetration groove welds. Seals are described in Sections 5.1.3 and 5.1.5.

5.1.5 Closure

The primary lid closure consists of a partially recessed, 210 mm-thick stainless steel plate. The lid is supported at the perimeter of the cylindrical body by a thick plate (upper forging) which is welded to the top of the inner and outer cylindrical shells. The lid is attached to the cask body by thirty-two (32) equally spaced M48 hex head bolts. Two (2) solid, elastomeric O-rings are retained in machined grooves at the lid perimeter. Groove dimensions prevent over-compression of the O-rings by the closure bolt pre-load forces and hypothetical accident impact forces. The cask is fitted with a secondary lid of similar construction attached to the primary lid with eighteen (18) equally spaced M36 hex head bolts. The secondary lid is also sealed with two (2) solid, elastomeric O-rings in machined grooves.

The vent penetration is sealed by the vent port cover plate and its inner O-ring. Table 5.1 gives the torque values for the cap screws.

Table 5.1 Bolt and Cap Screw Torque Requirements

Location	Size	Torque Values (N-m) ± 10% Lubricated
Primary Lid	M48	850
Secondary Lid	M36	350

5.2 Cavity Volume, Conditions, and Contents

The cavity dimensions are displayed in Table 5.2:

Table 5.2 Cask Cavity Dimensions

	Inches	Centimeters
L_{cavity}	77.2	196
D_{cavity}	68.1	173

Thus, the volume of the cylindrical cavity is:

$$V_{cavity} = (\pi \cdot D_{cavity}^2 \cdot L_{cavity})/4$$

Table 5.3 Cask Cavity Volume

Total Cavity Volume [cm^3]	4.60E+06

The temperatures under normal and accident conditions are determined based on the maximum internal cavity temperatures for normal and accident situations. Pressures and temperatures are provided by References 8 and 9 for normal and accident conditions, respectively. The standard leakage rate is the leakage rate of dry air when it is leaking from 1-atm (upstream pressure) to 0.01-atm (downstream pressure) at 298 K [4]. Dynamic viscosity values were generated based on the Sutherland equation [11], Table IV.4 in Reference 10, Table B-1 in Reference 4, Table B.4 in Reference 11, and viscosity of gaseous helium table in Reference 12.

Table 5.4 Parameters for Normal Transport and Accident Conditions

Parameter	Normal Conditions [8]	Accident Conditions [9]	Standard Conditions
P_u [atm]	3.38	6.8	1
P_d [atm]	1	1	0.01
P_a [atm]	2.19	3.9	0.505
T [°F]	176 (353 K, 80 °C)	302 (423 K, 150 °C)	76.7 (298 K, 25 °C)
M [g/mol]	29 (air), 4 (He)	29 (air), 4 (He)	29 (air), 4 (He)
μ [cP]	0.0207 (air), 0.0224 (He)	0.0236 (air), 0.0254 (He)	0.0185 (air), 0.0198 (He)
a [cm]	0.49	0.49	0.49

6. Methodology

Due to the variety of inventories, diversity in both isotopic composition and in total activity concentration, the RT-100 cask has been established as a leaktight container. Leaktight is a degree of package containment that in a practical sense precludes any significant release of radioactive materials. This degree of containment is achieved by demonstration of a leakage rate less than or equal to 1×10^{-7} ref·cm^3/s, of air at an upstream pressure of 1 atmosphere absolute and a downstream pressure of 0.01 atmosphere absolute or less [4]. Under the same conditions, the helium leakage rate is approximately 2×10^{-7} cm^3/s.

Using the leaktight standard leakage rate limit of 1×10^{7} ref·cm^3/s, allowable leakage rates for a helium/air mixture and helium leak test rates at various temperatures are provided in Section 7.2.

6.1 Allowable Leakage Rates at Test Conditions

For conservatism, un-choked flow correlations are used as they better approximate the true measured flow rate for the leakage rates associated with transportation packages. Using the equations for molecular and continuum flow provided in NUREG/CR-6487 [2], the corresponding leak hole diameter is calculated for the RT-100 cask for standard test conditions by solving Equation 6.1 for *D*, the leak hole diameter. The capillary length required for Equation 6.1 for the containment system is conservatively chosen as the vent port cover plate groove width, which is 0.49 cm.

Equation 6.1

$$L_{@P_a} = \left[\frac{2.49\times10^6\, D^4}{a\cdot\mu} + \frac{3.81\times10^3 D^3 \sqrt{\frac{T}{M}}}{a\cdot P_a}\right] \times [P_u - P_d]$$

where:

$L_{@Pa}$ is the allowable leakage rate at the average pressure for standard conditions [cm^3/s],
a is the capillary length [0.49 cm],
T is the temperature for standard conditions [K],
M is the gas molecular weight [g/mol] = 29.0 for air, 4.0 for He from ANSI N14.5, Table B1,
μ is the dynamic viscosity for helium or air [cP],
P_u is the upstream pressure [atm],
P_d is the downstream pressure [atm],
P_a is the average pressure; $P_a = (P_u + P_d)/2$ for standard conditions [atm], and
D is the capillary diameter [cm].

The leak hole diameter is determined using the parameters for standard conditions presented in Table 5.4.

The allowable leakage rate for leaktight conditions is at the upstream pressure, the ratio presented in Equation 6.2 is used to convert Equation 6.1 to upstream leakage rate so that the capillary diameter can be determined.

Equation 6.2

$$L_{@Pa} = L_{@P_u} \frac{P_u}{P_a}$$

where:

$L_{@Pa}$ is the allowable leakage rate at the average pressure [cm^3/s] for standard conditions,
$L_{@Pu}$ is the allowable leakage rate at the upstream pressure [cm^3/s] for standard conditions,
P_u is the upstream pressure [atm],
P_d is the downstream pressure [atm], and
P_a is the average pressure; $P_a = (P_u + P_d)/2$ [atm].

6.2 Leak Test Sensitivity

The sensitivity (S) for the leakage test procedures is established by ANSI N14.5-1997 [4] as shown in Equation 6.3.

Equation 6.3

S = ½·*Leakage Rate*[1]

[1] Leakage rate in this case is the upstream pressure leakage rate at standard conditions.

7. Calculations

For the calculation of the reference helium leak rate for test acceptance criteria, the Microsoft Excel workbook *Helium test rate.xlsx* is used.

7.1 Containment Boundary Test Requirements for Maintenance, Fabrication, Periodic, and Pre-Shipment

The following leakage tests are conducted on the RT-100 package as required by ANSI N14.5:

Table 7.1 Leakage Tests of the RT-100 Package

Test	Frequency	Test Gas	Acceptance Criteria
Maintenance	After maintenance, repair (such as weld repair), or replacement of components of the containment system	Helium	$\leq L_{He}^{*}$
Fabrication	Prior to the first use of the RT-100		
Periodic	Within 12 months prior to each shipment		
Pre-Shipment	Before each shipment, after the contents are loaded and the package is closed	Nitrogen or air (optional)	No Leakage at a sensitivity $\leq 10^{-3}$ ref-cm^3/sec

*Adjusted for the individual properties of the test gas; sensitivity is $\leq L_{He}/2$

As shown in Table 7.1, the maintenance, fabrication, and periodic leakage tests may be performed using helium as the tracer gas. The acceptance criterion for these tests is the reference helium leakage rate, L_{He}, which is calculated in Section 7.2.

7.2 Determination of Equivalent Reference Leakage Rate for Helium Gas

Helium leak tests are performed prior to initial use, periodically, and after maintenance work is performed. The inner containment O-ring seals in the primary lid, the secondary lid, and the vent port cover plate are tested for helium leakage. This section determines the allowable leakage rate using the helium gas which may be used to perform the annual verification leakage tests summarized in Table 7.1. This calculation uses formulas presented in ANSI N14.5 [4].

It is known that the reference air leakage rate, L_R, is 1.00×10^{-7} ref-cm^3/sec based on leaktight criteria.

Using Equation 6.1 and Equation 6.2, the maximum capillary diameter, D_{max}, was determined:

$$L_{@P_u}=\left(\left(\frac{2.49x10^6D_{max}^4}{(0.49cm)(0.0185cP)}+\frac{3.81x10^3D_{max}^3\sqrt{\frac{298K}{\frac{29g}{mole}}}}{(0.49cm)(0.505atm)}\right)(1atm-0.01atm)\right)\left(\frac{0.505atm}{1atm}\right)$$

$$=1x10^{-7}cm^3/s$$

This equation was entered into the "Diameter" worksheet of Excel workbook *Helium test rate.xlsx* and diameter values, D_{max}, are inputted into the equation until it is roughly equivalent to $1x10^{-7}$ cm^3/s.

Solving for the D_{max} iteratively yields:

D_{max} = 1.3261E-04 [cm]

The equivalent air/helium mixture that would leak from D_{max} during a leak test as described in Table 7.1 is determined. The leakage tests are performed with an air/helium mixture. The helium partial pressures can vary from 0.25 atm to 1.0 atm. An example with a helium partial pressure of 0.7 atm has been provided to illustrate the process used to determine the value of the variables used to determine the acceptable test leakage rates.

Assume the cask void is evacuated to 0.3 atm and then pressurized to 1.0 atm with an air/helium mixture.

$P_{void} = P_{air} = 0.3$ atm

$P_{mix} = 1.0$ atm

$P_{He} = P_{mix} - P_{air} = 0.7$ atm

The downstream pressure, P_d, under standard conditions is 0.01 atm.

$P_a = 0.5 \times (P_{mix} + P_d) \rightarrow P_a = 0.505$ atm

From ANSI N14.5- 1997 Table B.1:

$M_{He} = 4.0$ g/mol $\quad M_{air} = 29.0$ g/mol
$\mu_{He} = 0.0198$ cP $\quad \mu_{air} = 0.0185$ cP

The mass of the mixture of air/helium gases is then determined:

$$M_{mix} = \frac{M_{He}P_{He} + M_{air}P_{air}}{P_{mix}} \rightarrow M_{mix} = 11.5 \text{ g/mol}$$ Equation B.7- ANSI N14.5

$$\mu_{mix} = \frac{\mu_{He}P_{He} + \mu_{air}P_{air}}{P_{mix}} \rightarrow \mu_{mix} = 0.0194 \text{ cP}$$ Equation B.8- ANSI N14.5

Change in viscosity as a function of temperature was taken into consideration by using the values listed in Table 7.2, and performing linear interpolation. Mixture viscosity was determined for each temperature using the same methodology described above.

Table 7.2 Helium and Air Viscosity

Temperature (Kelvin)	Helium Viscosity (cP)
250	0.0178 [2]
275	0.0191 [2]
300	0.0201 [3]
350	0.0223 [3]

Temperature (Kelvin)	Air Viscosity (cP)
273.15	0.0171 [4]
278.15	0.0173 [4]
283.15	0.0176 [4]
288.15	0.0180 [4]
293.15	0.0182 [4]
298.15	0.0185 [4]
303.15	0.0186 [4]
313.15	0.0187 [4]
323.15	0.0195 [4]
333.15	0.0197 [4]

Determine L_{mix} as a function of temperature.

Temperature range for test = T = 273 to 328 K, or equivalently 31.73°F to 130.73°F.

$$F_c(D_{max}) = \frac{2.49 \cdot 10^6 \cdot D_{max}^4}{a \cdot \mu_{mix}}$$ Equation B.3 from ANSI N14.5-1997

$$F_m(T) = \frac{3.81 \cdot 10^3 \cdot D_{max}^3 \sqrt{\frac{T}{M_{mix}}}}{a \cdot P_a}$$ Equation B.4 from ANSI N14.5-1997

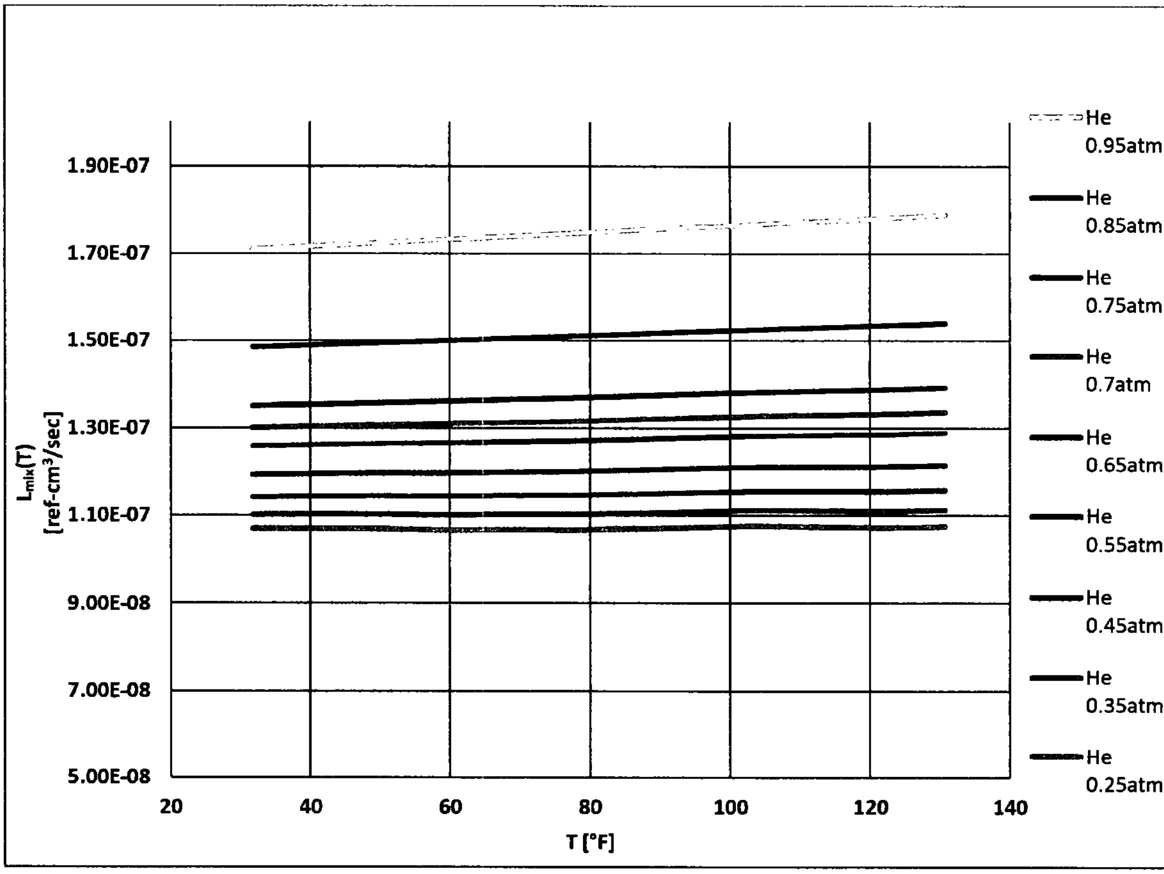
$$L_{mix}(T) = (F_c + F_m(T)) \cdot (P_{mix} - P_d) \frac{P_a}{P_{mix}}$$ Equation B.5 from ANSI N14.5-1997

Convert the test temperature to Fahrenheit: $T_F(T_K) = [(9/5)T_K - 459.67]$ °F

Figure 7.1 illustrates the air and helium mixture test leakage rate, L_{mix}, as a function of temperature in degrees Fahrenheit.

[2] Viscosity based on Reference 12.
[3] Viscosity based on Reference 10.
[4] Viscosity based on Reference 11

Figure 7.1 Allowable Air/Helium Mixture Test Leakage Rates



The helium component of this leak rate is determined by multiplying the leak rate of the mixture by the ratio of the helium partial pressure to the total mix pressure.

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

Figure 7.2 Allowable Helium Test Leakage Rates

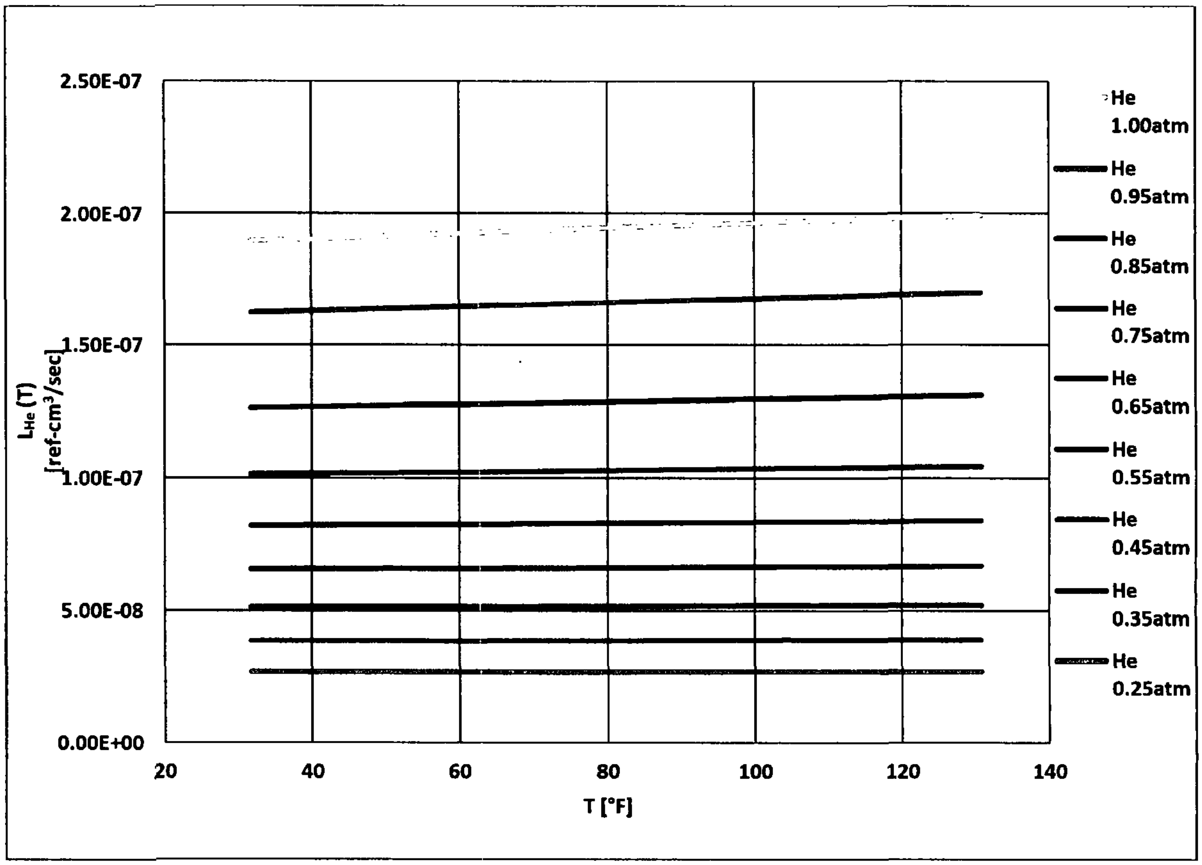


Figure 7.2 provides helium leakage rates at partial helium pressures of 0.25, 0.35, 0.45, 0.55, 0.65, 0.75, 0.85, 0.95, and 1.00 atm. Table 7.3 provides the helium leakage rates for several helium partial pressures at temperatures ranging from 31.73 °F (273 K) to 130.73 °F (328 K).

Table 7.3 Allowable Helium Test Leakage Rates, cm^3/sec

Temperature (°F)	Temperature (Kelvin)	Helium Leakage Rate P_{He}-1.0atm	Helium Leakage Rate P_{He}-0.85atm	Helium Leakage Rate P_{He}-0.65atm	Helium Leakage Rate P_{He}-0.45atm	Helium Leakage Rate P_{He}-0.25atm
31.73	273	1.897E-07	1.263E-07	8.185E-08	5.137E-08	2.672E-08
33.53	274	1.898E-07	1.263E-07	8.188E-08	5.138E-08	2.673E-08
35.33	275	1.900E-07	1.264E-07	8.191E-08	5.139E-08	2.673E-08
37.13	276	1.902E-07	1.265E-07	8.194E-08	5.141E-08	2.673E-08
38.93	277	1.903E-07	1.266E-07	8.198E-08	5.142E-08	2.673E-08
40.73	278	1.905E-07	1.267E-07	8.202E-08	5.144E-08	2.674E-08
42.53	279	1.907E-07	1.267E-07	8.205E-08	5.144E-08	2.673E-08
44.33	280	1.909E-07	1.268E-07	8.208E-08	5.144E-08	2.673E-08
46.13	281	1.911E-07	1.269E-07	8.211E-08	5.145E-08	2.672E-08
47.93	282	1.913E-07	1.270E-07	8.214E-08	5.145E-08	2.672E-08
49.73	283	1.914E-07	1.271E-07	8.217E-08	5.146E-08	2.671E-08
51.53	284	1.916E-07	1.272E-07	8.219E-08	5.145E-08	2.670E-08
53.33	285	1.918E-07	1.272E-07	8.221E-08	5.144E-08	2.668E-08
55.13	286	1.920E-07	1.273E-07	8.222E-08	5.144E-08	2.667E-08
56.93	287	1.922E-07	1.274E-07	8.224E-08	5.143E-08	2.666E-08
58.73	288	1.924E-07	1.275E-07	8.226E-08	5.142E-08	2.664E-08
60.53	289	1.925E-07	1.276E-07	8.230E-08	5.144E-08	2.665E-08
62.33	290	1.927E-07	1.277E-07	8.234E-08	5.145E-08	2.665E-08
64.13	291	1.929E-07	1.278E-07	8.238E-08	5.147E-08	2.666E-08
65.93	292	1.931E-07	1.278E-07	8.242E-08	5.148E-08	2.666E-08
67.73	293	1.933E-07	1.279E-07	8.246E-08	5.150E-08	2.667E-08
69.53	294	1.935E-07	1.280E-07	8.249E-08	5.151E-08	2.666E-08
71.33	295	1.936E-07	1.281E-07	8.253E-08	5.151E-08	2.666E-08
73.13	296	1.938E-07	1.282E-07	8.256E-08	5.152E-08	2.666E-08
74.93	297	1.940E-07	1.283E-07	8.259E-08	5.153E-08	2.665E-08
76.73	298	1.942E-07	1.284E-07	8.262E-08	5.153E-08	2.665E-08
78.53	299	1.944E-07	1.285E-07	8.267E-08	5.156E-08	2.666E-08
80.33	300	1.945E-07	1.286E-07	8.272E-08	5.159E-08	2.667E-08
82.13	301	1.947E-07	1.286E-07	8.276E-08	5.161E-08	2.669E-08
83.93	302	1.949E-07	1.287E-07	8.281E-08	5.164E-08	2.670E-08
85.73	303	1.951E-07	1.288E-07	8.286E-08	5.166E-08	2.671E-08
87.53	304	1.952E-07	1.289E-07	8.291E-08	5.169E-08	2.673E-08
89.33	305	1.954E-07	1.290E-07	8.296E-08	5.172E-08	2.675E-08

Temperature (°F)	Temperature (Kelvin)	Helium Leakage Rate P_{He}-1.0atm	Helium Leakage Rate P_{He}-0.85atm	Helium Leakage Rate P_{He}-0.65atm	Helium Leakage Rate P_{He}-0.45atm	Helium Leakage Rate P_{He}-0.25atm
91.13	306	1.956E-07	1.291E-07	8.301E-08	5.176E-08	2.676E-08
92.93	307	1.958E-07	1.292E-07	8.306E-08	5.179E-08	2.678E-08
94.73	308	1.959E-07	1.293E-07	8.311E-08	5.182E-08	2.680E-08
96.53	309	1.961E-07	1.294E-07	8.317E-08	5.185E-08	2.681E-08
98.33	310	1.963E-07	1.295E-07	8.322E-08	5.188E-08	2.683E-08
100.13	311	1.965E-07	1.296E-07	8.327E-08	5.191E-08	2.685E-08
101.93	312	1.966E-07	1.297E-07	8.332E-08	5.194E-08	2.686E-08
103.73	313	1.968E-07	1.297E-07	8.337E-08	5.197E-08	2.688E-08
105.53	314	1.970E-07	1.298E-07	8.340E-08	5.197E-08	2.687E-08
107.33	315	1.971E-07	1.299E-07	8.342E-08	5.197E-08	2.686E-08
109.13	316	1.973E-07	1.300E-07	8.344E-08	5.196E-08	2.685E-08
110.93	317	1.975E-07	1.300E-07	8.346E-08	5.196E-08	2.684E-08
112.73	318	1.977E-07	1.301E-07	8.348E-08	5.196E-08	2.683E-08
114.53	319	1.978E-07	1.302E-07	8.350E-08	5.195E-08	2.682E-08
116.33	320	1.980E-07	1.303E-07	8.352E-08	5.195E-08	2.681E-08
118.13	321	1.982E-07	1.304E-07	8.354E-08	5.195E-08	2.680E-08
119.93	322	1.984E-07	1.304E-07	8.356E-08	5.195E-08	2.679E-08
121.73	323	1.985E-07	1.305E-07	8.359E-08	5.195E-08	2.678E-08
123.53	324	1.987E-07	1.306E-07	8.363E-08	5.197E-08	2.679E-08
125.33	325	1.989E-07	1.307E-07	8.368E-08	5.199E-08	2.681E-08
127.13	326	1.990E-07	1.308E-07	8.373E-08	5.202E-08	2.682E-08
128.93	327	1.992E-07	1.309E-07	8.377E-08	5.205E-08	2.683E-08
130.73	328	1.994E-07	1.310E-07	8.382E-08	5.207E-08	2.685E-08

Figure 7.2 and Table 7.3 should be used to determine the allowable leak rate, L_{He}, for the maintenance, fabrication, and periodic leak tests of the RT-100 package based on partial pressure of helium used in the test.

7.2.1 Fabrication Leakage Test Description

The Fabrication leakage tests are performed on the lid inner O-ring and the vent port inner O-ring. They are generally performed as follows:

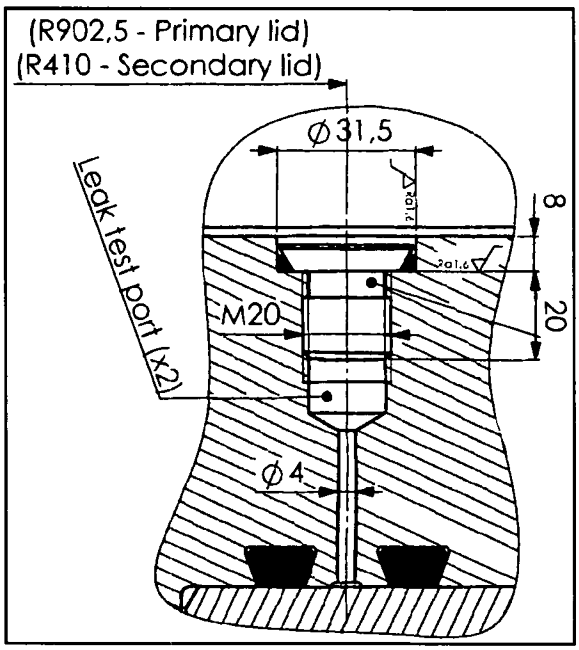
The cask body is assembled with a substitute sealed plate used in place of the cask lid. The entire vessel is placed within a bag taped on the outer surface of the upper flange. A vacuum in the cask cavity of 0.01 atm or less is established. The bag is filled with helium to a partial pressure of at least 25% of the total gas pressure. The helium flow signal detected in the cavity is measured. The test duration will be calculated

by test personnel based on the response time of the test detection device. Any condition which results in leakage in excess of the maximum allowable leak rate must be corrected and re-tested.

7.2.2 Maintenance and Periodic Leakage Test Description

The Maintenance and Periodic leakage tests are performed on the lid inner O-ring and the vent port inner O-ring. They are generally performed as follows:

Figure 7.3 Leak Test Port [6, Section F-F]



After the cask has been assembled, the vent port cover plate is removed. The leak test port plug on either the primary or secondary lid (depending on which containment boundary is being tested) is removed. Figure 7.3 provides an illustration of a leak test port. A vacuum pump and leak detection equipment are attached and a pressure in the O-ring interspace of 0.01 atm or less is established. The void space in the cavity is pressurized with a helium test gas through the vent port in the lid as shown in Figure 7.4. The minimum helium partial pressure utilized in the test is set at 25% of the total pressure. The helium flow signal detected in the interspace is measured. The test duration will be calculated by test personnel based on the response time of the test detection device. Any condition which results in leakage in excess of the maximum allowable leak rate must be corrected and re-tested.

Proprietary Information Content Withheld Under 10 CFR 2.390

7.2.3 Pre-shipment Leakage Test Description

A pre-shipment leakage test is required before each shipment of Type B material quantities to verify proper O-ring integrity. A pre-shipment test is generally performed as follows:

After the cask is assembled, the applicable leak test port plug is removed. A vacuum pump is attached to the appropriate test port of the primary lid, secondary lid, or vent port cover plate. A vacuum of 10^{-3} atm is generated in the annulus between the O-rings. Once the appropriate pressure has been achieved and the pump is isolated from the system, the pressure in the isolated cavity is measured over a minimum period of 10 minutes. The measurement of the pressure rise shall take into account the sensitivity required during the test (humidity vaporization can lead to longer pumping in the interspace). Any condition which results in a detectable leakage is corrected and re-tested.