ENCLOSURE 2

Calculation Number 13922-0402, Revision 0,
Helium Leak Rate Evaluation for 24PHB DSC

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AREVA	Form 3.2-1 Calculation Cover Sheet TIP 3.2 (Revision 6)	Calculation No.	13922-0402
		Revision No.	0
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DCR NO (if applicable): NA	PROJECT NAME:	NUHOMS® 24PHB / Oconee Nuclear Station	
PROJECT NO: 13922	CLIENT:	Duke Energy	

CALCULATION TITLE:
Helium Leak Rate Evaluation for 24PHB DSC

SUMMARY DESCRIPTION:

1) Calculation Summary

This calculation determines the reference leak rate in air based on the bounding leak rate for helium provided by Oconee Nuclear Station (OCS). Using the bounding helium leak rate from OCS, the amount of helium remaining within the DSC cavity after 100 years of storage in HSM is also evaluated.

2) Storage Media Description

Secure network initially, then redundant tape backup.

If original issue, is licensing review per TIP 3.5 required?
Yes ☐ **No** ☒ **(explain below)** **Licensing Review No.:**

This calculation is performed to support an exemption request by Oconee Nuclear Station from the requirements of helium leak rate for 24PHB DSC as specified in Section 1.2.4a of Technical Specification for Amendment 9 to CoC 1004. Therefore, a licensing review per TIP 3.5 is not applicable.

Software utilized (subject to test requirements of TIP 3.3): None	**Version:** N/A
Calculation is complete Originator Name and Signature: [signature] Slava Guzeyev	**Date:** 8/13/2014
Calculation has been checked for consistency, completeness, and correctness Checker Name and Signature: [signature] Venkata Venigalla	**Date:** 8/13/14
Calculation is approved for use Project Engineer Name and Signature: T. M. Edwards Tom Edwards	**Date:** 8/13/14

REVISION SUMMARY

Rev.	Date	Description	Affected Pages	Affected Disks
0	8/13/14	Initial issue	All	All

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1.0 PURPOSE

Oconee Nuclear Station (OCS) ISFSI utilizes 24PHB DSCs to store spent nuclear fuel. Each of the DSCs loaded at OCS undergoes a helium leak test to ensure that the leakage rate limit of $1x10^{-7}$ ref cc/s specified in Section 1.2.4a of Technical Specification for 24PHB DSC [6.2] is satisfied. Since the leak rate specified in [6.2] is based on air, OCS uses an equivalent helium leak rate of $3.4x10^{-8}$ atm cc/s during the leak test [6.1, 6.5].

Further, for each leak test a correction factor depending on the ambient temperature is applied to the measured leakage rate from the Helium Leak Detector to ensure that it remains below the equivalent helium leak rate of $3.4x10^{-8}$ atm cc/s. However, for five DSCs noted in [6.4], the ambient temperature records at the time of leak test could not be retrieved. Therefore, to bound the temperature in the operating bay OCS is utilizing a conservative ambient temperature of 105°F. Using correction factor based on an ambient temperature of 105°F the helium leak rate was determined to be 3.79×10^{-8} atm cc/s [6.4], which is higher than the equivalent helium leak rate of $3.4x10^{-8}$ atm cc/s.

Since the measured leak rate exceeds the leak rate specified in the Technical Specification for 24PHB DSC in Section 1.2.4a of [6.2], this calculation is performed to:

a) Determine the reference leak rate in air using the bounding helium leak rate of $3.79x10^{-8}$ atm cc/s, so that it can be compared directly to the leakage rate of $1x10^{-7}$ ref. cc/s specified in Section 1.2.4a of the Technical Specification for 24PHB DSC [6.2].

b) Using the helium leak rate of $3.79x10^{-8}$atm cc/s, determine the leakage from the DSC and amount of helium remaining within the 24PHB DSC after 100 years of storage in HSM.

2.0 CONSERVATISM

The following conservatisms are considered in this evaluation:

1. The leak rate from DSC is higher at the beginning of storage due to the higher DSC internal pressure. As the heat load drops with time, the DSC internal pressure is reduced and this in turn lowers the leak rate. However, the bounding leak rate measured at the beginning of the storage is used to determine the leakage over a period of 100 years storage.

2. Currently the 24PHB DSCs are licensed for 20 years with a possibility for 40 years extension bringing the total storage time to 60 years. However a storage time of 100 years is considered to conservatively bound leakage.

3. The maximum heat load of 24 kW allowed for storage in the 24PHB DSC [6.2] is considered to determine the amount of helium within the DSC cavity at the time of backfill. Using the maximum heat load provides the maximum average helium temperature in DSC cavity. This is conservative since a higher temperature will results in lower amount of helium within the DSC as the backfill pressure is constant at 2.5 psig.

In determining the reference leak rate in air this calculation considers the same conservatisms as noted in Section 1 of [6.5].

3.0 ASSUMPTIONS

In determining the reference leak rate in air, this calculation considers the same assumptions as noted in [6.5]. Since the bounding helium leak rate of 3.79×10^{-8} atm cc/s from OCS is based on a 105°F ambient temperature [6.4], it is assumed in this evaluation that the helium temperature is 105°F. This is acceptable since the helium temperature is in general above that of the ambient temperature.

The following assumptions are also considered in calculating the helium leakage from 24PHB DSC:

1. The 24PTH DSC is assumed to be backfilled with helium at a nominal pressure of 2.5 psig after vacuum drying, as shown in Section 1.2.3a from [6.2] and [6.4].

4.0 DESIGN INPUT/DATA

4.1 Design Input

The following input is obtained from OCS [6.4].

a. The bounding helium leak rate is 3.79×10^{-8} atm cc/s.

b. The bounding ambient temperature at the time of helium leak test is 105°F.

c. A nominal internal pressure of 2.5 psig is considered for the 24PHB DSCs at the time of backfilling.

In addition to determine the amount of helium at the time of backfilling the following inputs are obtained from [6.6]:

a. The free volume of the 24PHB DSC = 384,463 in^3,

b. The average temperature of the backfill = 449°F.

The dynamic viscosity for air and helium is calculated using polynomial gas equations from [6.7].

Maximum gas temperature after welding is 350°F [6.5].

Mixture of 50% air and 50% helium is considered beneath the port covers in this calculation based on the methodology from [6.5].

5.0 METHODOLOGY

5.1 Air Leak Rate

To determine the reference air leak rate, i.e. the equivalent leak rate in air using the bounding helium leak rate of 3.79×10^{-8} atm cc/s this evaluation uses the methodology specified in Section 5 of [6.5]. However this evaluation reverses the sequence of steps as listed below:

1) The helium temperature of 105°F is used to evaluate the equivalent leakage hole diameter for bounding helium leak rate.

2) Using the equivalent leakage hole diameter calculated in Step "1", the leak rate in air is calculated using the equations listed in Section B.3 of ANSI N14.5 [6.3].

5.2 Amount of Helium within the 24PHB DSC

The following steps are used to determine the amount of helium remaining in the DSC cavity after the 100 years storage based on the bounding helium leak rate of 3.79×10^{-8} atm cc/s from OCS [6.4] and also using the equivalent helium leak rate of 3.4×10^{-8} atm cc/s corresponding to the Technical Specifications air leak rate limit of 1×10^{-7} ref cc/s:

1) Calculate the mass of helium at the beginning of the DSC storage for 2.5 psig backfill pressure.

2) Calculate the mass of the helium lost from DSC cavity after 100 years of storage using the bounding helium leak rate of 3.79×10^{-8} atm cc/s from OCS [6.4].

3) Calculate the mass of the helium lost from DSC cavity at 100 years of storage using the equivalent helium leak rate of 3.4×10^{-8} atm cc/s corresponding to the acceptance limit of 1×10^{-7} ref cc/s specified in Section 1.2.4a of the Technical Specification for 24PHB DSC [6.2].

4) Calculate and compare total mass of helium in DSC cavity for the leakage determined in Step 2 and 3.

6.0 REFERENCES

6.1. TN Document, "Acceptance Criteria for Leak Testing at Canister Closure," No. E-31157, July 1st, 2011.

6.2. TN Technical Specification, "Standardized NUHOMS® Horizontal Modular Storage System. Certificate of Compliance No. 1004, Amendment 9," Docket 72-1004.

6.3. ANSI N14.5, "American National Standard for Radioactive Materials – Leakage Tests on Packages for Shipment," Revision of ANSI N14.5-1997, February, 1998.

6.4. Letter from Oconee Nuclear Station. See Appendix A.

6.5. TN Calculation, "Helium Leak Testing Vent & Siphon Ports for Leak Tight NUHOMS® DSC's," 1098-8 Rev.3.

6.6. TN Calculation, "24P Internal Pressure Calculation with B&W 15x15 55 GWD/MTU Burn-Up," NUH-HBU.0402 Rev.0.

6.7. Roshenow, W. M., J. P. Hartnett, and Y. I. Cho, *Handbook of Heat Transfer*, 3rd Edition, 1998.

7.0 NOMENCLATURE

DSC – Dry Shielded Canister

HSM – Horizontal Storage Module

Other nomenclatures used in the equations are specifically listed with the equations.

8.0 COMPUTATIONS

8.1 Reference Air Leak Rate

The steps described in Section 5.1 are used to determine the reference air leak rate i.e. the equivalent leak rate in air using the bounding helium leak rate of 3.79×10^{-8} atm cc/s. Based on the step 1 of Section 5.1 the equivalent hole size is determined as 1.342×10^{-4} cm. Using this equivalent hole size, the reference leak rate is calculated as noted in step 2 of Section 5.1. The reference air leak rate is 1.02×10^{-7} ref cc/s. The computations for the reference leak rate are captured in excel spreadsheet "24PHB_Leakage.xls".

8.2 Amount of Helium in the 24PHB DSC Cavity

The initial mass of helium in the DSC cavity for nominal internal pressure of 2.5 psig at the beginning of storage is:

$$m_{init} = P_{init} \cdot V_{DSC\ cavity} \cdot M / (R \cdot T_{backfill})$$

where

m_{init} - is mass of helium at the time of backfill, lb_m,
P_{init} = 2.5 psig =17.2 psia - is initial backfill pressure,
$V_{DSC\ cavity}$ = 384,463 in^3 = 222.49 ft^3 - is free volume in 24PHB DSC cavity from Section 3.1.2 of [6.6],
$T_{backfill}$ = 449^{0}F = 909^{0}R - is average backfill helium temperature for 24PHB DSC from Section 3.1.2 of [6.6].

The volume of helium lost due to leakage is

$$V_{he} = L_{u\ he} \cdot t\ ,\ ft^3,$$

where
V_{he} - volume of helium lost, ft^3,
t - time for leakage, *seconds*,
$L_{u\ he}$ - helium leakage rate, cm^3/s.

Mass of helium lost from DSC cavity due to leakage is

$$m_{leakage\ 100yrs} = P_{std} \cdot V_{u\ he} \cdot M / (R \cdot T_{std})$$

where
$m_{leakage\ 100yrs}$ - is mass of helium lost due to leakage, lb_m,
P_{std} =14.7 psia - is atmospheric pressure,
R = 1545 ft·lb$_f$/(lb$_m$·^{0}R) - is gas constant.

Total mass of helium in DSC cavity after 100 year of storage is

$$m_{He\_100} = m_{init} - m_{leakage\ 100yrs}.$$

The spreadsheet "24PHB_Leakage.xls" includes calculation to determine the helium in the 24PHB DSC cavity. presents the amount of helium lost due to the standard and bounding leak rates specified in Section 5.2.

9.0 RESULTS, CONCLUSIONS, AND RECOMMENDATIONS

As seen from Table 1, the amount of helium leakage from 24PHB DSC cavity in 100 years is insignificant for the bounding helium leak rate of 3.79×10^{-8} atm cc/s listed in OCS letter [6.4]. Further, a comparison of this conservative bounding leak rate to the helium leak rate from the Technical Specification [6.2] shows the difference in leakage is negligible. Therefore, there is no impact on maintaining an inert helium atmosphere within the 24PHB DSCs.

Table 1: Leakage from 24PHB DSC at 100 Years of Storage

Leak Rate	Tech Spec Leak Rate	Bounding Leak Rate
Leak rate in air, cm^3/s	1.0e-07	1.02e-07
Leak rate in helium, cm^3/s	3.40e-08	3.79e-08
Leaking hole diameter, cm	1.334e-04	1.342e-04
Backfill helium in DSC cavity, lb_m	1.57	1.57
Helium mass lost from DSC cavity after 100 years, lb_m	3.87e-05	4.31e-05
Helium mass in DSC cavity after 100 years, lb_m	1.57[1]	1.57[1]

Note 1: The difference in the mass using the two different leak rates is not within the significant digits.

10.0 LISTING OF COMPUTER FILES

Table 2 presents the spreadsheet used to compute the leakage from 24PHB DSC in this calculation.

Table 2: List of Spreadsheets

File Name	Date & Time	Description
24PHB_Leakage.xls	08/8/2014 5:51 PM EST	Spreadsheet to calculate leak rate for standard and bounding conditions, calculate mass of helium in DSC cavity after backfill, volume and mass of helium leakage from 24PHB DSC cavity after 100 years storage.

11.0 APPENDIX A

August 6, 2014

To: Tom Edwards

Subject: He Leak Rate
Dry Shielded Canisters 93,94,100,105,106

Oconee performed leak rate verification in accordance with CoC 1004 for 24PHB canisters. The leak standard was verified at 23°C. A correction must be applied for any measurement made not at that temperature. The correction made was 3%/°C and should have been 4%/°C. Since the paper work cannot be found documenting the ambient temperature at which the He leak rate verification was performed, a bounding leak rate limit is desired. If the ambient temperature of the measurement was assumed to be 40.55°C (105°F) for what is realistically the worst case temperature it could have been, a new leak rate limit may be calculated.

That would be (40.55 – 23) = 17.55°C correction required.

17.55 * 0.03 = 0.5265

So back out the 3%/°C correction 3.4E-8/1.5265 = 2.23E-8

Determine the 4%/°C correction

17.55 * 0.04 = 0.702

And put in 4%/°C correction 2.23E-8*1.702 = 3.79E-8

Then, to determine a revised leak rate limit, the ratio of these values is determined as follows:

3.78E-8/2.23E-8 x 1.0E-7 = 1.7E-7

Can this ratio be applied to the corresponding value stated in the Technical Specifications (1.0E-7 ref cc/s) creating a new limit of 1.7E-7 re cc/s?

If this is the allowed new Technical Specification limit and an initial He pressure of 2.5 psig is assumed, would the leakage analysis demonstrate that an inert atmosphere will be maintained within the cask during the storage lifetime?

Steve Perrero
Reactor Engineering
864 873 3278