Non - PROPRIETARY Version

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DCR NO (if applicable) : N/A	PROJECT NAME: SMUD General Services
PROJECT NO: 13302	CLIENT: SMUD, Sacramento Municipal Utility District

CALCULATION TITLE:

Transient Thermal Analysis of FO/FC Canister during Vacuum Drying.

SUMMARY DESCRIPTION:

1) Calculation Summary

This calculation determines time limit at which fuel can be exposed to oxidizing atmosphere during vacuum drying of FO/FC DSCs based on methodologies developed in [1] and utilizes the computational model from [2].

2) Storage Media Description

1 CD

If original issue, is licensing review per TIP 3.5 required?

Yes ☐ No ☒ (explain below) Licensing Review No.:

This calculation is performed to support the evaluation of ISG-22 [8] compliance during DSC vacuum drying at Rancho Seco ISFSI.

Software Utilized:	Version:
HEATING	7.2
Calculation is complete: Originator Name and Signature: Venkata Venigalla Venkat	Date: 01/02/08
Calculation has been checked for consistency, completeness and correctness: Checker Name and Signature: Slava Guzeyev	Date: 01/02/2008
Calculation is approved for use: Project Engineer Name and Signature: Ian McInnes	Date: 1/15/08

REVISION SUMMARY

REV.	DATE	DESCRIPTION	AFFECTED PAGES	AFFECTED DISKS
0	1/15/08	Initial Issue	ALL	N/A

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1.0 PURPOSE

During DSC drain down and vacuum drying operations, the fuel assemblies (FAs) are exposed to air which may lead to fuel oxidation. Oxidation of fuel pellets from UO_2 to U_3O_8 can propagate the preexisting cracks and holes on the fuel cladding [8].

The purpose of this calculation is to determine a time limit at which fuel can be exposed to oxidizing atmosphere during the vacuum drying of FO/FC (FAs without Control Components / FAs with Control Components) canisters loaded with 24 Pressurized Water Reactor (PWR) fuel assemblies.

2.0 REFERENCES

1. "Methodology to determine time limit for fuel oxidation during Vacuum Drying", Transnuclear, Inc, Calculation No. 13302-0401, Rev.0.

2. "Steady State Thermal Analysis of FO/FC Canister during Vacuum Drying", Transnuclear, Inc, Calculation No. 13302-0402, Rev.0.

3. "FO/FC DSC Thermal Analysis for Storage Conditions", Transnuclear, Inc, Calculation NUH005.0451, Rev.4.

4. Sacramento Municipal Utility District, Rancho Seco ISFSI, "Vacuum Drying Durations and DSC Loading Data", July 26, 2007.

5. Computer Code, HEATING7, Version 7.2c, "A Multidimensional Heat Conduction Analysis with the Finite Difference Formulation," NUREG/CR-200, Volume 2, Revision 6, Section F10, ORNL/NUREG/CSD-2/R6.

6. Safety Analysis Report for the NUHOMS-MP187 MULTI-PURPOSE CASK, NUH005.0151, Rev.17, Transnuclear, Inc.

7. Sacramento Municipal Utility District, Rancho Seco ISFSI, "DSC Loading Plans", November 8th, 2007.

8. USNRC, SFPO, "Potential Rod Splitting due to Exposure to an Oxidizing Atmosphere during Short-Term Cask Loading Operations in LWR or Other Uranium Oxide Based Fuel", Interim Staff Guidance ISG-22.

9. Electric Power Research institute, "Oxidation of Spent Fuel at Between 250 and 360°C", EPRI NP-4524, April 1986.

10. Bechtel SAIC Company, LLC, "Commercial Spent Nuclear Fuel Handling in Air Study", DT-44482, 000-30R-MGR0-00700-000-00, March 2005.

11. Safety Analysis Report for the STANDARDIZED NUHOMS® HORIZONTAL MODULAR STORAGE SYSTEM FOR IRRADIATED NUCLEAR FUEL, NUH003.0103, Rev.9, Transnuclear, Inc.

12. AAR Brooks & Perkins, Advanced Structural Division, "BORAL® The Neutron Absorber", Product Performance Report 624.

13. Rancho Seco Independent Spent Fuel Storage Installation Final Safety Analysis Report (IFSAR), REVISION 0, November 2000, Volume I.

3.0 ASSUMPTIONS AND CONSERVATISM

All assumptions and conservatism pertinent to the vacuum drying analysis in [2, 3] are applicable to this calculation.

The material property for Neutron Absorber plates in thermal models [2, 3] was conservatively assumed to be Type 304 Stainless Steel. However, since the neutron absorber is composed of boron carbide and 1100 alloy aluminum [13], the effective thermal conductivity of neutron absorber plates is used in this calculation and presented in Appendix A.

Rancho Seco ISFSI has one DSC (DSC # FF13P-R21) loaded with 13 failed fuel PWR assemblies. The decay heat from fuel assemblies loaded in this cask is 4.642 kW [4]. Since the FO/FC DSCs are analyzed with a heat load of 9 kW which is approximately double the decay heat load of loaded FF DSC, the time limits determined for fuel oxidation in FO/FC DSCs are conservatively applied to the FF DSC.

After starting of vacuum drying, the oxygen level in the DSC cavity is too low to create any significant oxidation. However, the time from start of blow down to finish of vacuum drying was conservatively considered in the current analysis.

4.0 DESIGN INPUT

The bounding heat load of 9 kW used in this transient thermal analysis is based on the DSCs currently loaded in HSMs at Rancho Seco ISFSI [4, 7] (See Table 6-3). The maximum vacuum drying duration for DSCs at Rancho Seco ISFSI reported in [4] is 95.2 hrs (For DSC # FC24P-013).

Material properties used in this analysis are from [2, 3] except for neutron absorber plates and fuel regions. Effective density and effective specific heat properties of fuel regions for use in transient analysis are calculated and presented in Appendix B.

The following material properties are used in determining the effective thermal properties,

Table 4-1 1100 Alloy Aluminum Thermal Properties [11]

Temperature (°F)	k (Btu/min-in-°F)	ρ (lbm/in^3)	Cp (Btu/lbm-°F)
70	0.1850	0.0980	0.2140
100	0.1830		0.2160
150	0.1810		0.2190
200	0.1780		0.2220
250	0.1770		0.2240
300	0.1750		0.2270
350	0.1740		0.2290
400	0.1730		0.2320

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Table 6-3 Rancho Seco ISFSI DSC Loading Data

DSC Serial Number[1]	Decay Heat[1] [kW]	Blow down Duration[1, 3] [hr]	Vacuum Drying Duration[1] [hr]	Total Time for Exposure to Air[2] [hr]	Time Limit [hr]
FO24P-P01	9.005	10.4	49.5	59.9	100
FO24P-P02	8.774	4.4	43.5	47.9	100
FC24P-P03	8.145	10.9	41.0	51.9	100
FC24P-P04	8.268	11.4	44.2	55.6	100
FC24P-P05	8.149	6.1	50.0	56.1	100
FC24P-P06	8.152	2.6	48.2	50.8	100
FC24P-P07	8.161	2.4	60.7	63.1	100
FC24P-P08	8.151	4.6	52.3	56.9	100
FC24P-P09	8.146	4.6	95.2	99.8	100
FC24P-P10	8.137	5.7	56.2	61.9	100
FC24P-P11	8.139	4.1	47.3	51.4	100
FC24P-P12	8.162	4.6	41.8	46.4	100
FC24P-P13	8.157	3.9	47.5 (Estimated)	51.4	100
FC24P-P14	8.139	No record	47.7 (Estimated)	59.1	100
FC24P-P15	8.147	3.7	47.5	51.2	100
FC24P-P16	8.156	No record	45.4	56.8	100
FC24P-P17	8.132	No record	41.5	52.9	100
FC24P-P18	8.141	3.7	44.7	48.4	100
FC24P-P19	8.144	No record	44.4	55.8	100
FC24P-P20	8.127	No record	50.8	62.2	100
FF13P-R21	4.642	No record	35.5	46.9	100

1 Loading Data from SMUD [5].

2 Total Time for Exposure to Air = Blow down Duration + Vacuum Drying Duration

3 Maximum blow down duration of 11.4 hours is used for DSCs with no record.

As seen from Table 6-3, the maximum total time of fuel exposure to air is less than the calculated time limit of 100 hours. The maximum exposure total time of 99.8 hours (DSC # FC24P-P09) is close to the calculated time limit. However, it includes additional conservatism for this DSC due to ~10% lower decay heat load of DSC # FC24P-P09 when compared to the bounding heat load of 9 kW used in this analysis.

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