Non - PROPRIETARY Version

TRANSNUCLEAR AN AREVA COMPANY	Form 3.2-1 Calculation Cover Sheet TIP 3.2 (Revision 2)	Calculation No.:	13302.0404
		Revision No.:	0
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DCR NO:	N/A	PROJECT NAME:	SMUD General Services
PROJECT NO:	13302	CLIENT:	SMUD, Sacramento Municipal Utility District

CALCULATION TITLE:

Thermal Evaluation of FC DSC loaded with Damaged Fuel Assemblies.

SUMMARY DESCRIPTION:

1) Calculation Summary

This study evaluates the effects of loading damaged fuel assemblies on thermal performance of FC DSCs. FC DSCs are designed to store intact fuel assemblies only. This study also determines the maximum fuel cladding temperature based on actual decay heat load.

2) Storage Media Description

N/A

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

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

This study is performed to support an exemption request to NRC for loading of damaged fuel assemblies in FC canisters and hence no licensing review is needed.

Software Utilized:	Version:
HEATING	7.2b

Calculation is complete: Originator Name and Signature: Venkata Venigalla *[signature]*	Date: 03/13/2008
Calculation has been checked for consistency, completeness and correctness: Checker Name and Signature: Slava Guzeyev *[signature]*	Date: 3/13/2008
Calculation is approved for use: Project Engineer Name and Signature: Ian McInnes *[signature]*	Date: 3/20/08

REVISION SUMMARY

REV.	DATE	DESCRIPTION	AFFECTED PAGES	AFFECTED DISKS
0	3/20/08	Initial Issue	All	All

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1.0 PURPOSE

FC DSC is designed to store intact/undamaged fuel assemblies (FA) only. Fuel assemblies with cladding breaches less than 0.34 inches across the cladding and less than 0.7 inches high along the cladding were initially classified as Class C assemblies [6] and were loaded into FC DSCs. However, due to the difference in definition of damaged fuel from the time the loading was completed to the current definition, these FC DSCs are considered now as loaded with damaged FAs with cladding defects exceeding pinholes and hairline cracks.

This calculation determines maximum fuel cladding temperature for FC DSCs loaded with damaged FAs and also evaluates the oxidation of damaged FAs during vacuum drying operations.

2.0 REFERENCES

1. *"FO/FC DSC Thermal Analysis for Storage Conditions"*, Transnuclear, Inc., Calculation No. NUH005.0451, Rev.4.

2. USNRC, SFPO, "Cladding considerations for the Transportation and Storage of Spent Fuel", Interim Staff Guidance ISG-11, Rev. 3.

3. *"Transient Thermal Analysis of FO/FC Canister during Vacuum Drying"*, Transnuclear, Inc, Calculation No. 13302.0403, Rev.0.

4. 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, Rev. 12.

5. USNRC, SFPO, "Classifying the Condition of Spent Nuclear Fuel for Interim Storage and Transportation Based on Function", Interim Staff Guidance ISG-1, Rev. 2.

6. Sacramento Municipal Utility District, Rancho Seco ISFSI, "Interim Disposition", PDQ 05-0003.

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

8. Computer Code, HEATING7, Version 7.2b, "A Multidimensional Heat Conduction Analysis with the Finite Difference Formulation," NUREG/CR-200, Volume 2, Revision 4, Section F10, ORNL/NUREG/CSD-2/V2, 1993.

3.0 ASSUMPTIONS AND CONSERVATISM

Assumptions noted in [1] are valid for this study.

It is assumed that no additional damage, significant to alter the thermal performance of the FAs will occur due to DSC drop accident.

All FAs in DSC are assumed to be having the effective thermal conductivity equal to that of the damaged FAs.

4.0 DESIGN INPUT

Due to the difference in definition of damaged fuel from the time the DSC's at Rancho Seco were loaded to the current applicable definitions, a study was performed which determined that damaged fuel assemblies with cladding defects exceeding pinholes and hairline cracks were loaded into FC DSCs [6]. This study concluded that six damaged fuel assemblies were loaded into five casks. The cladding breaches on the damaged fuel assemblies were less than 0.34 inches across the cladding and less than 0.7 inches high along the cladding [6]. Table 4-1 presents details of the damaged fuel assemblies with cladding breaches.

Table 4-1 Details of Damaged Fuel Assemblies [6].

Fuel Assembly	Estimated Flaw Size	Canister Number
2G6	0.25" X 0.04"	FC24P-P16
OEL	0.75" long with 0.2" hole	FC24P-P10
ODY	0.2" hole	FC24P-P10
17G	Unknown	FC24P-P17
1C34	1" X 0.1"	FC24P-P18
1C04	0.3" holes (two)	FC24P-P03

Since each of the cladding breach is greater than pinhole/hairline crack, it can be concluded that the fuel Cladding is grossly breached for the fuel assemblies mentioned in Table 4-1 [5].

The DSC component materials properties are from [1] except for the effective thermal conductivity (ETC) of damaged FAs and poison plates. The poison plate material properties are obtained from [3]. Section 5-2 presents the ETC values used for damaged FAs.

The maximum time for onset of fuel oxidation is 100 hrs [3].

5.0 METHODOLOGY

5.1 Thermal Model

The HEATING7.2 [8] computer program is used to perform the thermal analysis of DSC. The HEATING7.2 DSC model from section 3.4 of [1] is used in the current analysis. The HEATING7.2 model of the DSC is a two-dimensional model of a cross-section of the DSC

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5.3 Effect on Fuel Oxidation during Vacuum Drying

The currently damaged fuel assemblies were initially classified as "Class C" fuel and therefore were handled normally during loading operations. During pre-vacuum drying operations, the fuel assemblies were exposed to air, an oxidizing atmosphere. Oxidation of fuel pellets from UO_2 to U_3O_8 can propagate preexisting cracks and holes on the fuel cladding [4]. This necessitates the need wherein the vacuum drying process must be completed before the incubation time limit of 100 hrs [3], needed for onset of oxidation within the fuel assemblies. The maximum vacuum drying time for DSCs with damaged fuel is 56.2 hrs [7]. This is within the time limit determined for the onset of oxidation.

6.0 CONCLUSIONS

The maximum fuel cladding temperature for DSCs loaded with damaged FAs and placed in HSM is 544°F. This shows that the fuel cladding temperature remains much below the current allowable limit of 752°F [2] for normal conditions. Hence there is no effect of loading damaged FAs on the maximum fuel cladding temperature of 701°F reported in [1].

A review of the vacuum drying times for canisters with damaged assemblies reveals that maximum duration was 56.2 hrs for FC24P-P10 [7]. This is below the oxidation time limit of 100 hrs calculated in [3]. This shows us that no further propagation of fuel cladding cracks during vacuum drying process occurred.

7.0 LISTING OF COMPUTER FILES

The HEATING run summary, associated files and macros are listed in Table 7-1 and Table 7-2 below. The input, output, database and results files are contained in an optical disc, which accompanies this calculation.

Table 7-1 HEATING7.2 Run Summary

Run Name	Description	Date and Time	OP / CPU
FCHSM70-DAM	Steady-State Analysis of DSC with Damaged Fuel	03/11/08 15:58	MSDOS/ AMD-K6(tm)-2/450 MHz

Table 7-2 Associated Files and Macros

File/Macro	Description
FCHSM70-DAM.OUT	Run Summary
FCHSM70-DAM-PLOT	Unprocessed Output File
FCHSM70-DAM-MAP.TXT	Processed Nodal Temperature File.