ATTACHMENT (8)

NONPROPRIETARY TRANSNUCLEAR, INC. CALCULATION, "NUHOMS® 32P CE 14X14 FUEL CLADDING STRENGTH UNDER ACCIDENT SIDE DROP CONDITIONS," DOCUMENT NO. NUH32P+.0201, REVISION NO. 1

Non-proprietary Version

AREVA TRANSNUCLEAR INC.	Form 3.2-1 Calculation Cover Sheet TIP 3.2 (Revision 3)	Calculation No.:	NUH32P+.0201
		Revision No.:	1
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DCR NO (if applicable) NUH32P+002	PROJECT NAME: NUH32P+ Dry Fuel Storage Project
PROJECT NO: 50953 - NUH32P+	CLIENT: CCNPP

CALCULATION TITLE:

NUHOMS® 32P CE14X14 Fuel Cladding Strength Under Accident Side Drop Conditions

SUMMARY DESCRIPTION:

1) Calculation Summary

The purpose of this calculation is to verify the structural adequacy of the CE 14x14 fuel assembly with Zircaloy clad fuel rods loaded in a NUHOMS® 32P DSC when subjected to a transfer cask side drop accident at 750° F.

2) Storage Media Description 1 CD

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

Yes ☐ **No** ☐ **(explain below)** **Licensing Review No.:** ____________

Software Utilized:	Version:
ANSYS	10.0

Calculation is complete: Paul D. Manhardt Originator Name and Signature: [signature]	10/21/08 Date:
Calculation has been checked for consistency, completeness and correctness: Raheel Haroon Checker Name and Signature: [signature]	10/21/08 Date:
Calculation is approved for use: PETER SHIH Project Engineer Name and Signature: [signature]	12/8/08 Date:

REVISION SUMMARY

REV.	DATE	DESCRIPTION	AFFECTED PAGES	AFFECTED DISCS
0	08/03/07	Initial Issue	ALL	1 CD
1	12/8/08	Change the cladding oxidation from 120 micron to 125 micron	2, 4-11	1 new CD

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1.0 Purpose

The purpose of this calculation is to verify the structural adequacy of the CE 14x14 fuel assembly with Zircaloy clad fuel rods loaded in a NUHOMS® 32P DSC when subjected to a transfer cask side drop accident at 750° F.

2.0 References

1. NUHOMS® 32P Dry Shielded Canister Design Specification, SP-0564C-R4.
2. UCID – 21246, "Dynamic Impact Effects on Spent Fuel Assemblies," Lawrence Livermore National Laboratory, October 20, 1987.
3. Not Used
4. Transnuclear Calculation No. 972-179, Rev. 0, "TN-68 High Burnup Cladding Mechanical Properties."
5. Transnuclear Calculation No. NUH32P+ .0402, Rev 0, "Effect of Updated Fuel Performance Data on NUHOMS® 32P+ DSC Internal Pressure."
6. Transnuclear Calculation No. 1095-20, Rev 1, "Maximum Operating Pressures, Storage and Transfer."
7. ANSYS User's Manual, Rev 10.0.
8. ANSYS database and results files:

   Analysis is performed on the TN, Columbia offices Linux cluster system.

   Side drop analysis files :

   Proprietary Information Withheld
   Pursuant to 10 CFR 2.390

9. Not Used
10. Not Used

3.0 Methodology

The cladding tube is computer analyzed [7] as a continuous beam by using the actual span lengths and spacer widths. The beam model is subjected to lateral loads due to cladding tube and fuel pellets mass inertia. However, no credit is taken for fuel pellet strength and loads are entirely supported by the cladding tube.

Intact fuel rod internal pressure due to Helium fill gas and fuel fission gas is calculated from the perfect gas law, applying the total number of moles calculated in [5]

The maximum calculated bending plus pressure loaded axial stress is compared with the dynamic yield stress of fuel cladding material Zircaloy-4 at 750° F.

4.0 Assumptions

1. After irradiation, the fuel pellets are not assumed to be fused with each other and with the cladding tube and do not contribute to axial or bending stiffness. The fuel pellet weight, however, is carried by the cladding tube over the active fuel region for side drop calculations.

[redacted]

3. The yield stress of high burnup fuel Zircaloy-4 cladding is taken from [4] at 750° F and includes a strain rate correction effect of $0.5s^{-1}$.
4. The fuel cladding thickness is reduced by .00281 in. (125 microns thickness oxidation of the outer surface. See Appendix A.
5. The continuous beam model span lengths are from Appendix A. Some minor missing dimensions are approximated.
6. Poisson ratio of .404 is used throughout
7. The assembly end fittings are supported by the guide tubes. Therefore, the end fittings do not load the cladding.
8. The spacer grid leaf springs are assumed to have collapsed at high loads, and are not considered in the analysis.

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5.0 Calculations

[redacted] The weight of the fuel pellets, is incorporated in the cladding tube model by using an equivalent density. The dimensions of the fuel rod beam model are from Appendix A. The finite element model input details and equivalent densities are computed in Table A-1. The Zircaloy-4 cladding tube material properties (at 750° F) used in this analysis are:

Young's Modulus,	E = 9.93E06 psi	[4]
Poisson Ratio,	υ = 0.404	(assumed)
Yield Strength,	92,000 psi	[4]

Loads:

A 75 g side drop load is applied as body force acceleration and bending stress is calculated. Also, a combined Helium and fuel gas internal pressure load at 818 °F is applied in Table 1 and is calculated as follows:

$$PV = n R T = 0.08897 \text{ gmole[5,p7]} * 0.0016094 \text{ atm-ft}^3\text{/gmole-°R} * 1{,}277.7 \text{ °R} = 0.182954 \text{ atm ft}^3$$

$$P = 14.7 * 0.182954 \text{ atm ft}^3 / .001152 \text{ ft}^3 = 2{,}335 \text{ psi} \quad \text{(V is from [6, p4])}$$

Boundary Conditions:

[redacted]

Ansys Files:

[redacted]

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6.0 Discussion of Results

[redacted] it is clear that stress levels are maximized at the edges of the spacers and are related to each span length. The stress pattern is quite uniform along the rod where the span lengths are constant but are noticeably lower at the rod ends where shorter spans reduce the stress levels.

Maximum stress levels are presented in Table 1. [redacted]

[redacted]

7.0 Conclusions

A representative CE 14x14 fuel rod is computationally subjected to design limit accident condition side drop loading while inside the transfer cask. The fuel rod experiences stress levels resulting in satisfactory factor of safety. It is concluded, therefore, that CE 14x14 fuel assemblies are structurally adequate to perform as designed in the event of an accidental side drop.

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Table A-1 PWR Fuel Assembly Data - Concluded

Notes:

(1) Includes 0.00281 in. reduction in cladding thickness to account for oxidation. Ref. 1, below

(2) Source: Ref. 2, below

(3) $\rho = [(OD^2_{orig} - ID^2) / (OD^2 - ID^2)] \times \rho_{orig}$ --- $\rho_{orig} = 0.234$, Ref. 3, below

(4) $\rho = \rho_{cladding} + \rho_{fuel} * [OD^2_{fuel\ pellet} / (OD^2 - ID^2)]$ --- $\rho_{fuel} = 0.382$, Ref. 4, below

Ref. 1 Van Swam, L.F., Strasser, A.A., Cook, J.D. and Burger, J.M., 1997, "Behavior of Zircalloy-4 and Zirconium Liner Zircalloy-4 Cladding at High Burnup," pp 421-431, Proceedings of the 1997 International Topical Meeting on LWR Fuel Performance, Portland, Oregon, ANS, LaGrange Park, Illinois.

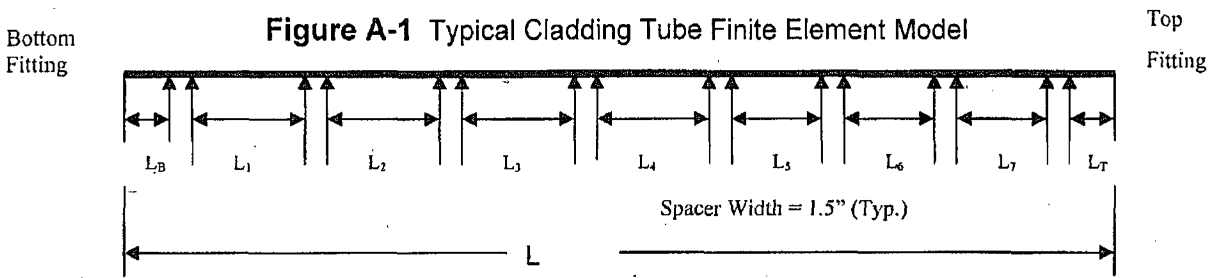
The fuel cladding thickness is reduced by 125 microns at the outer surface. The Pilling-Bedworth factor of 1.75, for Zircaloy cladding, is applied and the maximum reduction in cladding thickness is calculated, as: (125/1.75) µm x 39.37e-6 in/µm = 0.00281 in

Ref. 2 DOE/RW-0184, Vol 3 of 6, "Characteristics of Spent Fuel, High Level Lste and other Radioactive Lstes which require Long Term Isolation – Physical Descriptions of LWR Fuel Assemblies, U.S. DOE, December, 1987.

Ref. 3 UCID – 21246, "Dynamic Input Effects on Spent Fuel Assemblies," Lawrence Livermore National Laboratory, October 20, 1987.

Ref. 4 SCALE NUREG/CR-0200, Vol 3, Rev. 5 (Table M8.2)

Figure A-1 Typical Cladding Tube Finite Element Model



(Not to Scale)

See Table A-1 for continuous beam span lengths