ATTACHMENT 5

AREVA Inc. Calculation TN40HT-0510, Revision 0
Non-Proprietary

Representative Source Terms
for the Prairie Island ISFSI

28 pages follow

NON-PROPRIETARY VERSION

AREVA	Form 3.2-1 Calculation Cover Sheet TIP 3.2 (Revision 2)	Calculation No.:	TN40HT-0510
		Revision No.:	0
		Page 1 of 28	

DCR NO (if applicable) : NA	PROJECT NAME: High Capacity TN-40HT Storage System
PROJECT NO: TN40HT	CLIENT: NMC
CALCULATION TITLE: Representative Source Terms for the Prairie Island ISFSI	

SUMMARY DESCRIPTION:

1) Calculation Summary

The representative source terms as a function of time are computed for both WE 14x14 STD and GFA fuel to support a site-specific ISFSI calculation.

2) Storage Media Description

1 CD

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

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

NMC is requesting a site-specific ISFSI calculation to support the State of Minnesota Certificate of Need Process to increase the storage at the Prairie Island ISFSI to a total of 65 casks. This activity is not governed by the NRC.

Software Utilized: SCALE	Version: 4.4
Calculation is complete: Originator Name and Signature: RJ Migliore Rick Migliore	Date: 4/13/07
Calculation has been checked for consistency, completeness and correctness: Checker Name and Signature: SR Gardner S R. Gardner	Date: 4/13/07
Calculation is approved for use: Project Engineer Name and Signature: Prakash A. Narayanan A. Prakash	Date: 08/15/2007

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List of Tables

Revision Summary

Rev. 0	Initial Issue

1.0 Purpose

The purpose of this calculation is to determine representative source terms for use in a site-dose calculation at Prairie Island. Both WE STD 14x14 (STD) and WE OFA 14x14 (OFA) fuel is considered.

2.0 References

2.1 SCALE-4.4, "Modular Code System for Performing Standardized Computer Analyses for Licensing Evaluation for Workstations and Personal Computers," CCC-545, ORNL.

2.2 SCALE 4.4 Verification Test Report, Windows XP, TR-VV-07-003, Rev. 0. Packaging Technology, Inc.

2.3 DOE Report DOE/RW-0184-R1, Vol. 1, "Characteristics of Potential Repository Wastes," July 1992.

2.4 Luksic, PNL-6906, Volume 1, "Spent Fuel Assembly Hardware: Characterization and 10 CFR 61 Classification for Waste Disposal," June 1989.

2.5 ORNL/TM-11018, "Standard- and Extended-Burnup PWR and BWR Reactor Models for the ORIGEN2 Computer Code," Oak Ridge National Laboratory, December 1989.

2.6 DOE/ET/47912-3 Vol. III, "Domestic Light Water Reactor Fuel Design Evolution," Prepared for U. S. Department of Energy Savannah River Operations Office, September 1981.

2.7 E-11402, Rev 3, "Design Criteria for the TN-40 Spent Fuel Storage Cask."

2.8 Transnuclear Calculation 1042-8, Rev. 1, "TN-40 – Primary Gamma Shielding."

2.9 Transnuclear Calculation 1042-7, Rev. 0, "Source Terms for TN-40 Cask."

2.10 Transnuclear Calculation 10421-012, Rev. 1, "TN-40 Transport Fuel Qualification and Source Terms."

2.11 DCS E-22497, "Design Criteria for the TN-40HT High Burnup Spent Fuel Storage/Transportation Cask," Rev. 0.

2.12 NMC Letter From S. Leblang to M. Mason, "Weight of SS in Top End fitting of West. STD Fuel," Ref: PINGP: 04FS02-A210-015, Dated 8/2/05.

2.13 "SCALE-4 Analysis of Pressurized Water Reactor Critical Configurations: Volume 5-North Anna Unit 1 Cycle 5," ORNL/TM-12294/V5, 1996.

3.0 Methodology

3.1 Design Inputs

3.1.1 Design Criteria

Important design parameters for this analysis are also provided in the assumptions Section 4 below. The TN-40HT transportation cask design criteria are set forth in the Design Criteria Specification [2.11].

3.1.2 Fuel Data

Fuel data for both the STD and OFA fuel are provided in Table 3-1 and Table 3-2, respectively. References for all values are provided in the tables.

Hardware materials and masses for both the STD and OFA fuel are provided in Table 3-3 and Table 3-4, respectively. The hardware masses for the STD fuel are consistent with those utilized in [2.10], which were primarily obtained from DOE/RW-0184-R1 [2.3].

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The masses for the OFA fuel are obtained from TN calculation 1042-7 [2.9] and were originally obtained from the client. The OFA fuel masses from [2.9] are not consistent with the masses in [2.3], although the masses utilized are considered representative of the actual fuel.

Fuel loading and burnup information to be utilized in this calculation was provided by letter from NMC to TN (this letter is reproduced in Appendix C).

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Isotopic compositions of common LWR fuel assembly hardware materials are taken from Reference [2.5] and listed in Table 3-5.

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Table 3-1. WE STD 14x14 Assembly Design Parameters

Parameter	Value	Reference
Number of Rods	179	2.6
Overall Assembly Length (in)	161.1	2.6
Fuel Rod Length (in)	151.83	2.6
Plenum Length (in)	7.142	2.6
Active Fuel Zone (in)	144	2.6

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Table 3-2. WE OFA 14x14 Assembly Design Parameters

Parameter	Value	Reference
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Fuel Rod Length (in)	151.85	2.3
Plenum Length (in)	7.158	2.3
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Table 3-3. Hardware Materials for WE STD 14x14 Assembly

Part Name	Parts per Assembly	Mass (kg)	Zone	Material	Reference
Bottom Nozzle	1	7.893	Bottom	SS 304	2.3
Guide Tubes[3]	16	7.642	Core/Plenum	SS 304	2.3
Instrument Tube[3]	1	0.478	Core/Plenum	SS 304	2.3
Spacer-Incore	6	5.370	Core	Inconel-718	2.3
Spacer-Plenum[1]	1	0.680	Plenum	Inconel-718	2.3
Plenum Spring	179	5.684	Plenum	SS 302	2.3
Top Nozzle[2]	1	9.380	Top	SS 304	2.3
Hold Down Springs	8	0.508	Top	Inconel-718	2.3

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Table 3-5. Chemical Compositions of LWR Fuel Assembly Materials [2.5]

Element	Atomic Number	Material Composition, grams per kg of material				
		Zircaloy-4	Inconel-718	Inconel X-750	Stainless Steel 304	UO_2 Fuel (per kg U)
H	1	1.30E-02	-	-	-	-
Li	3	-	-	-	-	1.00E-03
B	5	3.30E-04	-	-	-	1.00E-03
C	6	1.20E-01	4.00E-01	3.99E-01	8.00E-01	8.94E-02
N	7	8.00E-02	1.30E+00	1.30E+00	1.30E+00	2.50E-02
O	8	9.50E-01	-	-	-	1.34E+02
F	9	-	-	-	-	1.07E-02
Na	11	-	-	-	-	1.50E-02
Mg	12	-	-	-	-	2.00E-03
Al	13	2.40E-02	5.99E+00	7.98E+00	-	1.67E-02
Si	14	-	2.00E+00	2.99E+00	1.00E+01	1.21E-02
P	15	-	-	-	4.50E-01	3.50E-02
S	16	3.50E-02	7.00E-02	7.00E-02	3.00E-01	-
Cl	17	-	-	-	-	5.30E-03
Ca	20	-	-	-	-	2.00E-03
Ti	22	2.00E-02	7.99E+00	2.49E+01	-	1.00E-03
V	23	2.00E-02	-	-	-	3.00E-03
Cr	24	1.25E+00	1.90E+02	1.50E+02	1.90E+02	4.00E-03
Mn	25	2.00E-02	2.00E+00	6.98E+00	2.00E+01	1.70E-03
Fe	26	2.25E+00	1.80E+02	6.78E+01	6.88E+02	1.80E-02
Co	27	1.00E-02	4.69E+00	6.49E+00	8.00E-01	1.00E-03
Ni	28	2.00E-02	5.20E+02	7.22E+02	8.92E+01	2.40E-02
Cu	29	2.00E-02	9.99E-01	4.99E-01	-	1.00E-03
Zn	30	-	-	-	-	4.03E-02
Zr	40	9.79E+02	-	-	-	-
Nb	41	-	5.55E+01	8.98E+00	-	-
Mo	42	-	3.00E+01	-	-	1.00E-02
Ag	47	-	-	-	-	1.00E-04
Cd	48	2.50E-04	-	-	-	2.50E-02
In	49	-	-	-	-	2.00E-03
Sn	50	1.60E+01	-	-	-	4.00E-03
Gd	64	-	-	-	-	2.50E-03
Hf	72	7.80E-02	-	-	-	-
W	74	2.00E-02	-	-	-	2.00E-03
Pb	82	-	-	-	-	1.00E-03
U	92	2.00E-04	-	-	-	1.00E+03

3.2 Analysis

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These analyses were carried out using the SAS2H depletion module from the SCALE4.4 computer software [2.1] . All cases were run on PacTec machine ADANC491TC (Windows XP). SCALE4.4 is authorized for use on Windows XP machines [2.2]. For more detailed information on SAS2H and SCALE refer to the user manual. For all SAS2H calculations the latest SCALE 44 group ENDF/B-V (44groupndf5) library was used.

Several formulas were used to develop the SAS2H inputs. First, the weight fractions of the uranium isotopes were calculated using Equations 1 through 3 below [2.13]. Second, the active fuel length for the UO_2 was calculated using Equation 4 assuming 96% dense UO_2. A proper active fuel length ensures the correct MTU is input to SAS2H. Third, the irradiation time was calculated using Equation 5.

$$W_{234} = 0.007731\ (W_{235})^{1.0837} \qquad \text{Equation 1}$$

$$W_{236} = 0.0046 * W_{235} \qquad \text{Equation 2}$$

$$W_{238} = (1 - W_{235} - W_{236} - W_{238}) \qquad \text{Equation 3}$$

$$FUELENGTH = M_U * 1000/[\pi/4 * OD^2 * 0.96 * 10.96 * 0.8814 * 179] \qquad \text{Equation 4}$$

where, M_U is the initial uranium loading in kilograms, 0.8814 is the weight fraction of U in UO_2, 10.96 g/cm^3 is the theoretical density of UO_2, OD is the outer diameter of the pellet in centimeters, and 179 is the number of fuel rods in one assembly. For the OFA fuel, FUELENGTH = 360.80 cm, while for STD fuel, FUELENGTH = 355.16 cm.

$$T = BU * M_U / P \qquad \text{Equation 5}$$

where, T is the lifetime irradiation time in days, M_U is the initial uranium loading in metric tons, BU is the assembly burnup in MWD/MTU, and P is the power in MW/assy.

4.0 Assumptions

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4.3 Chemical impurities as defined in ORNL/TM-11018 [2.5] are assumed for the hardware and fuel materials. Flux scaling factors from PNL-6906 [2.4] are assumed for the top nozzle, bottom nozzle and plenum regions. These factors are: 0.2 – bottom nozzle, 1.0 – core, 0.2 – plenum, and 0.1 – top end fitting.

4.4 The SS302 plenum springs are assumed to have a composition similar to SS304.

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5.0 Computation

Prior to development of the SAS2H models, the mass of light elements in each fuel zone must be determined. The fuel cladding, guide tubes, and instrument tube span both the core and plenum regions, so the mass of these items must be split appropriately.

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For the OFA fuel, this split has been performed in the reference document [2.9] (see Table 3-4) and no additional computations are required. Note that slightly different masses would be determined if these values were computed explicitly rather than taken from [2.9]. These differences are small and may be neglected. Details of the masses utilized are provided in spreadsheet *Materials – OFA.XLS*

Given the masses of each constituent listed in Table 5-1, the light element masses (including impurities) may be computed using the compositions listed in Table 3-5 and the scaling factors for each zone noted in Assumption 4.3. These light elements also include impurities in the UO_2. The final light elements to be input to SAS2H are provided in Table 5-2 and Table 5-3 for STD and OFA fuel, respectively.

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Separate input files are developed for each of the four fuel zones. A listing of the input and output files is included in Appendix A. Input files are named with the following convention:

Type_zone#.in

where:

Type = OFA or STD
Zone = BN for bottom nozzle
CORE for in-core
P for plenum
TN for top nozzle

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Sample input files are included in Appendix B. The only differences between input files of the same fuel type are the light element composition and the output switch on the 84$$ card. (For the top, bottom, and plenum models, the 84$$ card is set so that only light elements are output.)

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