NON-PROPRIETARY VERSION

AREVA	Form 3.2-1 Calculation Cover Sheet TIP 3.2 (Revision 2)	Calculation No.: TN40HT-0511 Revision No.: 0 Page: 1 of 24

DCR NO (if applicable) :

PROJECT NAME: High Capacity TN40HT Storage System

PROJECT NO: TN40HT

CLIENT: NMC

CALCULATION TITLE: Dose Rates Estimate for Prairie Island ISFSI Comprised with TN40HT Casks Loaded with WE 14x14 OFA and WE 14x14 STD Fuel Assemblies.

SUMMARY DESCRIPTION:

1) Calculation Summary

Calculate Prairie Island (PI) ISFSI dose rates due to 65 TN40HT casks arranged in two arrays at specified locations. It is assumed that 56 casks are loaded with WE 14x14 OFA Fuel Assemblies (FA) type, the rest of the casks contain WE 14x14 STD. Credit is taken for radiological source terms variation in the casks due to scheduled ISFSI loading. No control components (BPRAs) and associated with them radiological source terms are considered.

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 to provide support for off-site dose evaluation performed by the client, NMC. 10CFR72.48 review is not required.

Software Utilized: MCNP 5 v. 1.40

Version: C00730MNYCP00

Calculation is complete:

Originator Name and Signature: Yevgeniy Terekhin Yevgeniy Terekhin — Date: 06/25/07

Calculation has been checked for consistency, completeness and correctness:

Checker Name and Signature: Rick Migliore Rick Migliore — Date: 06/25 /07

Calculation is approved for use:

Project Engineer Name and Signature: A. Prakash Prakash Narayanan ~~Steve Streutker~~ — Date: 08 /16 /07

TRANSNUCLEAR

REVISION SUMMARY

REV.	DATE	DESCRIPTION	AFFECTED PAGES	AFFECTED DISKS
0	08/16/2007	Initial Issue	1 - 24	1

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PROJECT NO:	TN40HT	REVISION:	0
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LIST OF FIGURES

1 Purpose

The purpose of this calculation package is to estimate the far field neutron and gamma dose rates in the vicinity of a customer, Prairie Island (PI), designed ISFSI. When fully loaded, the ISFSI admits 65 TN40HT Dry Storage casks arranged in two arrays. Each cask contains 40 fuel assemblies. The shielding calculation provides the dose rates as a function of distance (from the north-west corner of the array) at 600, 700 and 800 meters. Dose rates account for radiological source terms decrease due to scheduled loading at a pace of two casks per year until the ISFSI contains in total 65 casks.

2 References

1. TN Document, “Prairie Island ISFSI Safety Analysis Report”, Revision 9.

2. TN Calculation “TN-40HT Near Field Shielding Calculation.” TN40HT-0501 Revision 0.

3. NMC Letter, “Request for Proposal for More realistic PI ISFSI Offsite Dose Calculation”, Letter Ref.# PINGP: 04FS03-A210-059

4. TN Calculation “TN-40HT Far Field Shielding Calculations.” TN40HT-0502 Revision 0.

5. TN Calculation “Representative Source terms for the Prairie Island ISFSI.” TN40HT-0510, Revision 0.

6. “MCNP/MCNPX – Monte Carlo N-Particle Transport Code System Including MCNP5 1.40 and MCNPX 2.5.0 and Data Libraries,” CCC-730, Oak Ridge National Laboratory, RSICC Computer Code Collection, January 2006.

7. “MCNP5 v1.40 Verification Test Report on the 64-Bit Opteron Running Linux.” TN File No. E-23526, Revision 0,

8. Title 10, “Energy,” Code of Federal Regulations, Part 20, “Standards for Protection Against Radiation.”

9. Title 10, “Energy,” Code of Federal Regulations, Part 72, “Licensing Requirements for the Independent Storage of Spent Nuclear Fuel and High-Level Radioactive Waste.”

10. Title 40, “Protection of Environment,” Part 190, “Environmental Radiation Protection Standards for Nuclear Power Operations.”

11. "American National Standard for Calculation and Measurement of Direct and Scattered Gamma Radiation from LWR Nuclear Power Plants," ANSI/ANS-6.6.1-1977, American Nuclear Society, Illinois, 1977.

12. TN Calculation "Standardized NUHOMS® System HSM Surface Dose Rates for High Burnup Fuel." NUH-HBU.0501, Revision 0.

13. Oak Ridge National Laboratory, RSIC Computer Code Collection, "SCALE: A Modular Code System for Performing Standardized Computer Analyses for Licensing Evaluation," NUREG/CR-0200, Rev. 6 (ORNL/NUREG/CSD-2/R6), Vols. I, II, and III

14. "CASK-81 - 22 Neutron, 18 Gamma-Ray Group, P3, Cross Sections for Shipping Cask Analysis." ORNL DLC-23 Updated (June 16, 1981)

15. R.W. Roussin and J.B. Wright, "Contents, Energy Group Structure, and Weighting Function Used for DLC-23/Cask". Informal Notes (1972). DLC-0023/03

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

3 Assumptions

The shielding calculation is performed based on the following assumptions regarding ISFSI layout, casks arrangement and MCNP models. The assumptions are itemized under various sub-sections. Other assumptions are documented, wherever used in the calculation. The assumptions are based on data from reference [1] (Figure 1.3-1, Figure 2.5-6 and Figure 2.5-7 in particular from [1]) and [3].

3.1 ISFSI Layout.

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4 Methodology

The three-dimensional Monte Carlo particle transport computer code, MCNP, reference [6] has been utilized to calculate the dose rates. The MCNP computer code has been utilized by Transnuclear for shielding evaluations in NRC approved applications as shown in reference [1].

4.1 Source Determination

Source information required by MCNP includes neutron and gamma spectra, total neutron and gamma activities for each fuel assembly axial exposure zone and total neutron and gamma activities for the entire ISFSI. The neutron and gamma radiation source terms strength per fuel assembly and spectra are determined in reference [5].

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5 MCNP Analysis - Input and Outputs

The 3-D Monte Carlo code MCNP [6] is utilized to calculate the dose rates at the points of interest specified in item 4, Section 3.3.

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5.1 Geometry

Assumptions specified in Section 3 provide a “skeleton” for building ISFSI geometry in MCNP models. Casks in arrays are represented as lattice cells in MCNP input decks. Indices of the lattice cells can be mapped onto casks depicted on Figure 1 using Figure 2.

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5.2 Flux-to-Dose Rate Factors

Flux-to-dose rate factors for both neutrons and gammas are taken from reference [11]. MCNP logarithmically interpolates the flux-to-dose factor for each scoring particle from the tabulated values input in the DE and DF variables.

5.3 MCNP Input Files

Three MCNP runs are used to calculate the dose rates around the ISFSI.

- ***GD.mi*** and ***NGD.mi*** determines gamma radiation dose rate
- ***ND.mi*** and ***ND_4.mi*** determine the neutron radiation dose rate

The MCNP input and all associated output files(namely, ***.mo**, ***_tl**, ***_tpe**,) are listed in Section 8. They are also included on the attached compact disk. **Note** that information provided in the comment cards, either after $ or “c” character (when “c” is the first character in a line) is optional and **may not correspond to the actual parameter(s) used**.

5.4 Calculations

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

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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
Proprietary Information Withheld Pursuant to 10 CFR 2.390		
Fuel Rod Length (in)	151.85	2.3
Plenum Length (in)	7.158	2.3
Proprietary Information Withheld Pursuant to 10 CFR 2.390		

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.

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

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

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

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

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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