Serial No. 16-055D
Docket No. 72-16

ATTACHMENT 3

Dominion Calculation, SF-0017, Rev. 0,
"TN-32B HBU Cask ORIGEN Decay Heat Calculation"

(Signatories of this document have been redacted.)

North Anna Power Station ISFSI

Virginia Electric and Power Company

Complete the fields with text or an **X** as required.

Calculation Number: SF-0017	Revision: 0	Addendum: N/A	Sub type: 000	Decommissioning Record? ☐ Yes ☒ No
Vendor (If not Dominion): N/A		Calculation Preparation Risk: ☒ Low ☐ Medium ☐ High		
Vendor Proprietary: ☐ Yes ☒ No				
Calculation Quality Class: ☒ Safety Related ☐ NSQ ☐ Non-Safety Related				
Subject (Calculation Title): TN-32B HBU Cask ORIGEN Decay Heat Calculation				
Addendum Title: N/A				
Station(s) and Unit(s): NA ☐ 1 ☐ 2 ☐ 3 ☒ ISFSI; SU ☐ 1 ☐ 2 ☐ ISFSI; KW ☐ ☐ ISFSI; MP ☐ 1 ☐ 2 ☐ 3 ☐ ISFSI				
Affected System(s), Structure(s), or Component(s): ISFSI				
Purpose (Executive Summary): This calculation is to determine the decay heat of the TN-32B HBU cask at the time of loading using specific powers for each cycle. The decay heat is expected to be 32.934kW total for the TN-32B HBU cask at the time of loading on 7/1/17.				

Originator (Qual. Required): Printed Name (1) (3)		Signature: (1) (3)	Date: (1) (3)
[redacted]		[redacted]	9-2-16
Reviewer (Qual. Required): Printed Name (1) [redacted]	Type of Review: (2) Independent	[redacted]	Date: 9-6-16
Approver: Printed Name [redacted]		[redacted]	Date: 9/6/16

Note: Physical or electronic signatures are acceptable.

Note: (1) Add lines for additional originators or reviewers as necessary. (2) Note if reviews are "Independent," "Peer", "Subject Matter Expert", "Supervisor", or "Owner's". (3) Enter N/A for Owner's Review of Vendor Calculation.

Table of Contents

1. Record of Revisions and Addenda

Original Issue

2. References

1. ETE-NAF-2015-0057, Rev. 0, "Basis for Burn-up Uncertainty used in the Nuclear Spent Fuel Certification Process", 4/28/2015
2. ETE-NAF-2015-0068, Rev. 0, "Fuel Management Scheme 2015", 7/21/2015
3. CALC PM-1737, Rev. 0, "Fuel Management Scheme 2015 and FUTIL 2015 Inputs and Assumptions", 7/9/2015
4. ETE-NAF-2014-0086, Revision 0, "Candidate Fuel Assembly Information for the High Burnup Dry Cask Project", 9/18/2014.
5. ETE-NAF-2016-0111, Revision 0, "TN-32 Cask Decay Heats for AREVA-TN's High Burnup Cask Thermal Analysis", 8/17/16
6. DNES-AA-NAF-NSF-4001, Revision 1, "ISFSI Fuel Certification Requirements and References", 3/22/16
7. NUREG/CR-5625, "Technical Support for a Proposed Decay Heat Guide Using SAS2H/ORIGEN-S Data", September 1994

3. Computer Codes Used

Irradiation and decay of the TN-32B HBU fuel assemblies to be loaded are modeled using ORIGEN-ARP module of the SCALE 6.1.1 production software controlled under IT-AA-SQA-101.

4. *Identification of Computer Inputs and Outputs*

The following files are the input and output files to ORIGEN-ARP. The .arp files are the graphical user interface files that are used to create the .inp files. The .inp and .out files are the respective input and output files to ORIGEN.

File	Checksum	Last Modified
0A4.arp	737695784	8/31/2016 5:09:13 PM
0A4.inp	3426224366	8/31/2016 5:09:13 PM
0A4.out	1319047199	8/31/2016 5:01:33 PM
15B.arp	4104945575	9/1/2016 9:28:22 AM
15B.inp	1133835925	9/1/2016 9:28:22 AM
15B.out	2084172842	9/1/2016 9:28:36 AM
20B.arp	1692976198	9/1/2016 9:32:23 AM
20B.inp	3880106497	9/1/2016 9:32:23 AM
20B.out	2972677958	9/1/2016 9:32:37 AM
22B.arp	2552927646	9/1/2016 9:35:49 AM
22B.inp	620437156	9/1/2016 9:35:49 AM
22B.out	575403017	9/1/2016 9:36:03 AM
28B.arp	154857304	9/1/2016 9:39:29 AM
28B.inp	841874123	9/1/2016 9:39:29 AM
28B.out	765613294	9/1/2016 9:39:43 AM
30A.arp	2223599499	9/1/2016 1:50:16 PM
30A.inp	635404861	9/1/2016 1:52:18 PM
30A.out	503310948	9/1/2016 1:52:33 PM
30B.arp	2462632058	9/1/2016 9:42:20 AM
30B.inp	52745014	9/1/2016 9:42:20 AM
30B.out	1977415112	9/1/2016 9:42:35 AM
3F6.arp	3926861648	8/31/2016 5:31:15 PM
3F6.inp	2941569054	8/31/2016 5:31:15 PM
3F6.out	3894527441	8/31/2016 5:31:29 PM
3K4.arp	2077848844	8/31/2016 6:06:40 PM
3K4.inp	1573642716	8/31/2016 6:06:40 PM

File	Checksum	Last Modified
3K4.out	3331402286	8/31/2016 6:06:56 PM
3K7.arp	2239405087	8/31/2016 6:09:50 PM
3K7.inp	3910237490	8/31/2016 6:09:50 PM
3K7.out	3454308297	8/31/2016 6:10:05 PM
3T2.arp	3572450520	9/1/2016 1:54:31 PM
3T2.inp	702720416	9/1/2016 1:54:31 PM
3T2.out	4200718125	9/1/2016 1:54:46 PM
3T6.arp	3132723507	8/31/2016 5:43:55 PM
3T6.inp	3360101489	8/31/2016 5:43:55 PM
3T6.out	2357977735	8/31/2016 5:44:10 PM
3U4.arp	3646219094	8/31/2016 5:53:51 PM
3U4.inp	2770545297	8/31/2016 5:53:51 PM
3U4.out	756191393	8/31/2016 5:54:06 PM
3U6.arp	2476769860	8/31/2016 5:56:24 PM
3U6.inp	1052841014	8/31/2016 5:56:24 PM
3U6.out	934150543	8/31/2016 5:56:39 PM
3U9.arp	3833808095	8/31/2016 5:58:45 PM
3U9.inp	2398409386	8/31/2016 5:58:45 PM
3U9.out	2086210671	8/31/2016 5:59:00 PM
4F1.arp	3876884526	8/31/2016 5:35:08 PM
4F1.inp	3750310798	8/31/2016 5:35:08 PM
4F1.out	1091831077	8/31/2016 5:35:23 PM
4V4.arp	1980958855	8/31/2016 6:03:20 PM
4V4.inp	994182930	8/31/2016 6:03:20 PM
4V4.out	1114104212	8/31/2016 6:03:34 PM
50B.arp	4172710841	9/1/2016 9:45:29 AM
50B.inp	2970446603	9/1/2016 9:45:29 AM
50B.out	1149574592	9/1/2016 9:45:43 AM
54B.arp	3756363686	9/1/2016 9:48:39 AM

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54B.inp	1157241502	9/1/2016 9:48:39 AM
54B.out	3817923297	9/1/2016 9:48:53 AM
56B.arp	2912680663	9/1/2016 9:52:18 AM
56B.inp	2024536050	9/1/2016 9:52:18 AM
56B.out	1381257009	9/1/2016 9:52:32 AM
57A.arp	1312265519	9/1/2016 9:10:01 AM
57A.inp	1484673667	9/1/2016 9:10:01 AM
57A.out	750753369	9/1/2016 9:10:15 AM
5D5.arp	2782495744	8/31/2016 5:16:19 PM
5D5.inp	1024534561	8/31/2016 5:16:19 PM
5D5.out	2316648696	8/31/2016 5:16:34 PM
5D9.arp	3482042939	8/31/2016 5:22:54 PM
5D9.inp	450527108	8/31/2016 5:22:54 PM
5D9.out	258667185	8/31/2016 5:23:09 PM
5K1.arp	1348870905	9/1/2016 8:50:48 AM
5K1.inp	518322446	9/1/2016 8:50:48 AM
5K1.out	1952764564	9/1/2016 8:51:04 AM
5K6.arp	2896981555	9/1/2016 8:53:39 AM
5K6.inp	250135385	9/1/2016 8:53:39 AM
5K6.out	2850199093	9/1/2016 8:53:53 AM
5K7.arp	2382031559	9/1/2016 8:56:22 AM
5K7.inp	730538810	9/1/2016 8:56:22 AM
5K7.out	3414757864	9/1/2016 8:56:37 AM
5T9.arp	1076755324	8/31/2016 5:48:15 PM
5T9.inp	2978906078	8/31/2016 5:48:15 PM
5T9.out	1049322807	8/31/2016 5:48:30 PM
6F2.arp	1773162589	8/31/2016 5:37:38 PM
6F2.inp	146992873	8/31/2016 5:37:38 PM
6F2.out	2335905680	8/31/2016 5:37:54 PM

File	Checksum	Last Modified
6K4.arp	442628132	9/1/2016 9:00:50 AM
6K4.inp	2671236001	9/1/2016 9:00:50 AM
6K4.out	56750740	9/1/2016 9:01:04 AM
6T0.arp	3724433736	8/31/2016 5:50:56 PM
6T0.inp	3437975836	8/31/2016 5:50:56 PM
6T0.out	1773929179	8/31/2016 5:51:11 PM
6V0.arp	2227980259	9/1/2016 9:03:41 AM
6V0.inp	3721261010	9/1/2016 9:03:41 AM
6V0.out	1073423416	9/1/2016 9:03:56 AM
F40.arp	465432068	8/31/2016 5:11:35 PM
F40.inp	473860975	8/31/2016 5:11:35 PM
F40.out	1651923212	8/31/2016 5:11:50 PM

5. *Design Inputs*

Attachment 1 contains the design inputs required for ORIGEN-ARP. Attachment 1 lists fuel assembly specific inputs which have been extracted from FUTIL 2015, Cycle end dates, and fuel assembly design information to convert the ORIGEN output to a decay heat that is relevant to the specific assemblies to be loaded into the TN-32B HBU cask.

6. *Assumptions*

1. ORIGEN-ARP has an express form for Westinghouse 17x17 fuel types, which is a general model of Westinghouse 17x17 fuel. For the purpose of this calculation it is assumed that the generic Westinghouse 17x17 model in ORIGEN-ARP is representative of the fuel designs to be loaded into the TN-32B HBU cask.
2. The final TN-32B HBU cask payload will be the payload documented in Reference 5.

7. *Methodology*

Each of the fuel assemblies to be stored in the TN-32B HBU cask will be modeled with ORIGEN-ARP. Values for uranium loading (MTU) are based on nominal values for each fuel assembly design. Enrichments are batch average values. The enrichment is adjusted by -0.05 wt% to account for uncertainties in the batch enrichment provided in FUTIL 2015 [Reference 1]. Burnup is the calculated individual fuel assembly burnup for a given cycle. The cycle-average power for each fuel assembly has been determined using burnup for a specific cycle and dividing by the effective full power days (EFPD) for the cycle. To account for burnup uncertainty, Reference 1 has 2.5% added to the final burnup value. To account for burnup uncertainty in this calculation the +2.5% adjustment will be applied to the calculated cycle-average power for each cycle.

The fuel assemblies have been modeled at a constant power level for each individual cycle. There is assumed to be no cooling time between cycles, which provides a conservative value for the final decay heat values. The fuel assembly skeleton components must be accounted for separately and included as separate composition in the ORIGEN-ARP input. The material composition for non-fuel components is not included in the ORIGEN-ARP Westinghouse 17x17 model. The material values have been obtained from NUREG/CR-5625 [Reference 7].

The resulting decay heats for the modeled fuel assemblies are based on a one metric ton of uranium loading (MTU). To obtain the actual fuel assembly decay heat, the ORIGEN output decay heat must be multiplied by the fuel assembly design MTU.

8. *Calculations*

The ORIGEN-ARP input was determined from cycle specific average powers as provided in Table-1, Table-2, and Table-3. Each provides the burnup and EFPD for the respective fuel assembly cycle. The average power has been calculated by dividing the burnup by the EFPD. The average power has then been increased by 2.5% in the last column of the table to accommodate the burnup uncertainty as described in Reference 1. The Average Power (+2.5%) column provides the corresponding cycle power input in ORIGEN-ARP. The design input data is provided in Attachment 1.

Table-1: Cycle 1 Inputs

	Cycle 1			
Fuel Assembly ID	Burnup (MWD/MTU)	EFPD	Average Power (MW/MTU)	Average Power (+2.5%) (MW/MTU)
F40	17105	350	48.8714	50.0932
0A4	27244	503	54.1630	55.5171
5D5	17859	419	42.6229	43.6885
5D9	17664	419	42.1575	43.2115
3F6	21100	509	41.4538	42.4902
4F1	21220	509	41.6896	42.7318
6F2	21112	509	41.4774	42.5143
3T2	23486	462	50.8355	52.1064
3T6	23049	462	49.8896	51.1369
5T9	23098	462	49.9957	51.2456
6T0	22638	462	49.0000	50.2250
3U4	21525	451	47.7273	48.9205
3U6	21790	451	48.3149	49.5227
3U9	21738	451	48.1996	49.4045
4V4	23917	485	49.3134	50.5462
3K4	21631	510	42.4137	43.4741
3K7	24242	510	47.5333	48.7217
5K1	24331	510	47.7078	48.9005
5K6	24134	510	47.3216	48.5046
5K7	24350	510	47.7451	48.9387
6K4	21565	510	42.2843	43.3414
6V0	23453	485	48.3567	49.5656
30A	24076	508	47.3937	48.5785
57A	24154	508	47.5472	48.7359
15B	20513	507	40.4596	41.4711
20B	19982	507	39.4122	40.3975
22B	20254	507	39.9487	40.9474
28B	20676	507	40.7811	41.8006
30B	20291	507	40.0217	41.0222
50B	20414	507	40.2643	41.2709
54B	24029	507	47.3945	48.5793
56B	20343	507	40.1243	41.1274

Table-2: Cycle 2 Inputs

	Cycle 2			
Fuel Assembly ID	**Burnup (MWD/MTU)**	**EFPD**	**Average Power (MW/MTU)**	**Average Power (+2.5%) (MW/MTU)**
F40	34388	349	49.5215	50.7595
0A4	50047	494	46.1599	47.3139
5D5	34608	452	37.0553	37.9817
5D9	34104	452	36.3717	37.2810
3F6	45148	497	48.3863	49.5960
4F1	45356	497	48.5634	49.7775
6F2	45019	497	48.1026	49.3052
3T2	35099	451	25.7494	26.3932
3T6	34606	451	25.6253	26.2659
5T9	34986	451	26.3592	27.0182
6T0	34177	451	25.5854	26.2250
3U4	39062	485	36.1588	37.0627
3U6	39188	485	35.8722	36.7690
3U9	39274	485	36.1567	37.0606
4V4	46169	499	44.5932	45.7080
3K4	44993	508	45.9882	47.1379
3K7	47915	508	46.6004	47.7654
5K1	47643	508	45.8898	47.0370
5K6	47685	508	46.3602	47.5192
5K7	47772	508	46.1063	47.2590
6K4	45030	508	46.1909	47.3457
6V0	46849	499	46.8858	48.0579
30A	45766	507	42.7811	43.8506
57A	45863	507	42.8185	43.8890
15B	45548	514	48.7062	49.9239
20B	45026	514	48.7237	49.9418
22B	45707	514	49.5195	50.7574
28B	45580	514	48.4514	49.6626
30B	45230	514	48.5195	49.7324
50B	45430	514	48.6693	49.8860
54B	46756	514	44.2160	45.3214
56B	45642	514	49.2198	50.4503

Table-3: Cycle 3 Inputs

	Cycle 3			
Fuel Assembly ID	**Burnup (MWD/MTU)**	**EFPD**	**Average Power (MW/MTU)**	**Average Power (+2.5%) (MW/MTU)**
F40	50646	401	40.5436	41.5572
0A4	N/A	N/A	N/A	N/A
5D5	55496	509	41.0373	42.0633
5D9	54579	509	40.2259	41.2316
3F6	52138	451	15.4989	15.8864
4F1	52285	451	15.3636	15.7477
6F2	51904	451	15.2661	15.6477
3T2	55087	485	41.2124	42.2427
3T6	54298	485	40.6021	41.6171
5T9	54890	485	41.0392	42.0652
6T0	54223	485	41.3320	42.3653
3U4	52850	499	27.6313	28.3220
3U6	52968	499	27.6152	28.3056
3U9	53074	499	27.6553	28.3467
4V4	51183	482	10.4025	10.6626
3K4	51841	507	13.5069	13.8446
3K7	53414	507	10.8462	11.1173
5K1	53012	507	10.5897	10.8545
5K6	53268	507	11.0118	11.2871
5K7	53335	507	10.9724	11.2467
6K4	51868	507	13.4872	13.8244
6V0	53506	507	13.1302	13.4584
30A	52020	514	12.1673	12.4715
57A	52154	514	12.2393	12.5453
15B	50972	409	13.2616	13.5932
20B	50477	409	13.3276	13.6608
22B	51155	409	13.3203	13.6533
28B	50966	409	13.1687	13.4979
30B	50623	409	13.1858	13.5155
50B	50870	409	13.3007	13.6333
54B	51340	409	11.2078	11.4880
56B	50952	409	12.9829	13.3075

The cooling time has been provided in Table-4. The cooling time has been calculated from the last irradiation date of the fuel assembly's last at power cycle shutdown date to the conservative loading date of July 1st, 2017 for the loading date of the TN-32B HBU cask. The cooling time has been used as the time for the decay cycle of the fuel assembly in ORIGEN-ARP.

Table-4: Cooling Time

Fuel Assembly ID	Last Irradiation Date	Loading Date	Cooling Time (Years)
F40	4/19/1987	7/1/2017	30.20
0A4	9/9/1994	7/1/2017	22.81
5D5	5/12/2000	7/1/2017	17.14
5D9	5/12/2000	7/1/2017	17.14
3F6	5/2/2004	7/1/2017	13.16
4F1	5/2/2004	7/1/2017	13.16
6F2	5/2/2004	7/1/2017	13.16
3T2	10/2/2005	7/1/2017	11.75
3T6	10/2/2005	7/1/2017	11.75
5T9	10/2/2005	7/1/2017	11.75
6T0	10/2/2005	7/1/2017	11.75
3U4	3/18/2007	7/1/2017	10.29
3U6	3/18/2007	7/1/2017	10.29
3U9	3/18/2007	7/1/2017	10.29
4V4	9/14/2008	7/1/2017	8.79
3K4	3/8/2009	7/1/2017	8.31
3K7	3/8/2009	7/1/2017	8.31
5K1	3/8/2009	7/1/2017	8.31
5K6	3/8/2009	7/1/2017	8.31
5K7	3/8/2009	7/1/2017	8.31
6K4	3/8/2009	7/1/2017	8.31
6V0	3/8/2009	7/1/2017	8.31
30A	9/12/2010	7/1/2017	6.80
57A	9/12/2010	7/1/2017	6.80
15B	3/11/2012	7/1/2017	5.31
20B	3/11/2012	7/1/2017	5.31
22B	3/11/2012	7/1/2017	5.31
28B	3/11/2012	7/1/2017	5.31
30B	3/11/2012	7/1/2017	5.31
50B	3/11/2012	7/1/2017	5.31
54B	3/11/2012	7/1/2017	5.31
56B	3/11/2012	7/1/2017	5.31

The enrichment values used for this calculation are batch enrichments for the fuel assemblies. Batch enrichments are acceptable for use; however batch enrichments may be +/- 0.05 wt% of the provided value. To account for the uncertainty, the enrichment has been decreased by 0.05 wt% of U-235, which will provide a conservative decay heat value. Table-5 provides the adjusted enrichment values as well as fuel type design and design MTU. The adjusted enrichment is input into ORIGEN-ARP, and the MTU value is used to calculate the specific fuel assembly decay heat from the ORIGEN output file, which is based on one (1) MTU.

Table-5: Enrichment and MTU

Fuel Assembly ID	Enrichment (wt% U235)	Enrichment (-0.05) (wt% U235)	Fuel Assembly Design	Fuel Assembly Design MTU
F40	3.59	3.54	LOPAR	0.460
0A4	4	3.95	NAIF	0.464
5D5	4.2	4.15	NAIF/P+Z	0.465
5D9	4.2	4.15	NAIF/P+Z	0.465
3F6	4.25	4.20	NAIF/P+Z	0.465
4F1	4.25	4.20	NAIF/P+Z	0.465
6F2	4.25	4.20	NAIF/P+Z	0.465
3T2	4.25	4.20	NAIF/P+Z	0.465
3T6	4.25	4.20	NAIF/P+Z	0.465
5T9	4.25	4.20	NAIF/P+Z	0.465
6T0	4.25	4.20	NAIF/P+Z	0.465
3U4	4.45	4.40	NAIF/P+Z	0.465
3U6	4.45	4.40	NAIF/P+Z	0.465
3U9	4.45	4.40	NAIF/P+Z	0.465
4V4	4.4	4.35	AMBW	0.466
3K4	4.55	4.50	AMBW	0.466
3K7	4.55	4.50	AMBW	0.466
5K1	4.55	4.50	AMBW	0.466
5K6	4.55	4.50	AMBW	0.466
5K7	4.55	4.50	AMBW	0.466
6K4	4.55	4.50	AMBW	0.466
6V0	4.4	4.35	AMBW	0.466
30A	4.55	4.50	AMBW	0.466
57A	4.55	4.50	AMBW	0.466
15B	4.55	4.50	AMBW	0.466
20B	4.55	4.50	AMBW	0.466
22B	4.55	4.50	AMBW	0.466
28B	4.55	4.50	AMBW	0.466
30B	4.55	4.50	AMBW	0.466
50B	4.55	4.50	AMBW	0.466
54B	4.55	4.50	AMBW	0.466
56B	4.55	4.50	AMBW	0.466

The decay heats have been extracted from the ORIGEN output files and listed in Table-6. The decay heats calculated are on a per MTU basis. To provide the decay heat on the fuel assembly basis, the decay heat from ORIGEN is multiplied by the fuel assembly MTU.

Table-6: Decay Heat

Fuel Assembly ID	Decay Heat (Watts/MTU)	Fuel Assembly Design MTU	Decay Heat (Watts)
F40	1264	0.460	581
0A4	1432	0.464	664
5D5	1835	0.465	853
5D9	1794	0.465	834
3F6	1845	0.465	858
4F1	1852	0.465	861
6F2	1834	0.465	853
3T2	2111	0.465	982
3T6	2069	0.465	962
5T9	2101	0.465	977
6T0	2065	0.465	960
3U4	2070	0.465	963
3U6	2076	0.465	965
3U9	2082	0.465	968
4V4	2082	0.466	970
3K4	2165	0.466	1009
3K7	2247	0.466	1047
5K1	2222	0.466	1035
5K6	2239	0.466	1043
5K7	2242	0.466	1045
6K4	2167	0.466	1010
6V0	2276	0.466	1061
30A	2384	0.466	1111
57A	2393	0.466	1115
15B	2746	0.466	1280
20B	2710	0.466	1263
22B	2762	0.466	1287
28B	2744	0.466	1279
30B	2719	0.466	1267
50B	2738	0.466	1276
54B	2741	0.466	1277
56B	2743	0.466	1278
	Total Decay Heat (Watts):		**32,934**

9. *Results and/or Conclusions*

The TN-32B HBU cask has a calculated decay heat of 32,934 Watts utilizing the ORIGEN-ARP module of Scale 6.1.1. The resulting decay heat of this calculation is a conservative estimate that takes into account uncertainties for enrichment, burnup, and minimal cooling time between cycles.

10. *Precautions and Limitations*

None

Dominion®

Complete Calculation

Calculation # SF-0017 Rev. 0 Add. N/A

If "Yes" is not answered, an explanation may be provided below. Reference may be made to explanations contained in the calculation or addendum.

Questions:	Yes	N/A
Have the sources of design inputs been correctly selected and referenced in the calculation?	[x]	[ ]
Are the sources of design inputs up-to-date and retrievable/attached to the calculation?	[x]	[ ]
Where appropriate, have the other disciplines reviewed or provided the design inputs for which they are responsible?	[x]	[ ]
Have design inputs been confirmed by analysis, test, measurement, field walkdown, or other pertinent means as appropriate for the configuration analyzed?	[x]	[ ]
Have the bases for assumptions been adequately and clearly presented and are they bounded by the Station Design Basis?	[x]	[ ]
Were appropriate calculation/analytic methods used and are outputs reasonable when compared to inputs?	[x]	[ ]
Are computations technically accurate?	[x]	[ ]
Has the calculation made appropriate allowances for instrument errors and calibration equipment errors?	[x]	[ ]
Have those computer codes used in the analysis been referenced in the calculation?	[x]	[ ]
Have all exceptions to station design basis criteria and regulatory requirements been identified and justified in accordance with NQA-1-1994?	[x]	[ ]
Has the design authority/original preparer for this calculation been informed of its revision or addendum, if required?	[x]	[ ]
Was the pre-job brief completed without any identified HU error precursors/compensating actions? (If HU error precursors/compensating actions were identified, then mark N/A and provide explanation/summary below or attach pre-job brief form to calculation.)	[x]	[ ]

Comments: (Attach additional pages if needed)

[redacted] Date: 9-2-16
(Preparer)

: [redacted] Date: 9-6-16
(Reviewer)

: ______________________ Date: __________
(Owner's Review, if applicable)

Note: Physical or electronic signatures are acceptable.

Design Inputs Extracted from FUTIL 2015 [Reference 2, 3]

Fuel Assembly ID*	Batch	Enrichment	Unit	Status	Status 2	No. of Cycles	Burnup C1	Burnup C2	Burnup C3	Burnup C4	Burnup Final	Cycle 1	Cycle 2	Cycle 3	Cycle 4
F40	N1/_6A3	3.59	N1	R	D	3	17105	34388	50646	0	50646	N1C4	N1C5	N1C6	0
0A4	N1/11A1	4	N1	R	D	2	27244	50047	0	0	50047	N1C9	N1C10	0	0
5D5	N1/14B2	4.2	N1	R	D	3	17859	34608	55496	0	55496	N1C12	N1C13	N1C14	0
5D9	N1/14B2	4.2	N1	R	D	3	17664	34104	54579	0	54579	N1C12	N1C13	N1C14	0
3F6	N1/16B2	4.25	N1	0	D	3	21100	45148	52138	0	52138	N1C14	N1C15	N2C16	0
4F1	N1/16B2	4.25	N1	0	D	3	21220	45356	52285	0	52285	N1C14	N1C15	N2C16	0
6F2	N1/16B2	4.25	N1	0	D	3	21112	45019	51904	0	51904	N1C14	N1C15	N2C16	0
3T2	N2/17B2	4.25	N2	0	D	3	23486	35099	55087	0	55087	N2C15	N2C16	N2C17	0
3T6	N2/17B2	4.25	N2	0	D	3	23049	34606	54298	0	54298	N2C15	N2C16	N2C17	0
5T9	N2/17B2	4.25	N2	0	D	3	23098	34986	54890	0	54890	N2C15	N2C16	N2C17	0
6T0	N2/17B2	4.25	N2	0	D	3	22638	34177	54223	0	54223	N2C15	N2C16	N2C17	0
3U4	N2/18B2	4.45	N2	0	D	3	21525	39062	52850	0	52850	N2C16	N2C17	N2C18	0
3U6	N2/18B2	4.45	N2	0	D	3	21790	39188	52968	0	52968	N2C16	N2C17	N2C18	0
3U9	N2/18B2	4.45	N2	0	D	3	21738	39274	53074	0	53074	N2C16	N2C17	N2C18	0
4V4	N2/19B2	4.4	N2	0	D	3	23917	46169	51183	0	51183	N2C17	N2C18	N2C19	0
3K4	N1/20B2	4.55	N1	0	D	3	21631	44993	51841	0	51841	N1C18	N1C19	N1C20	0
3K7	N1/20B2	4.55	N1	0	D	3	24242	47915	53414	0	53414	N1C18	N1C19	N1C20	0
5K1	N1/20B2	4.55	N1	0	D	3	24331	47643	53012	0	53012	N1C18	N1C19	N1C20	0
5K6	N1/20B2	4.55	N1	0	D	3	24134	47685	53268	0	53268	N1C18	N1C19	N1C20	0
5K7	N1/20B2	4.55	N1	0	D	3	24350	47772	53335	0	53335	N1C18	N1C19	N1C20	0
6K4	N1/20B2	4.55	N1	0	D	3	21565	45030	51868	0	51868	N1C18	N1C19	N1C20	0
6V0	N2/19B3	4.4	N2	0	D	3	23453	46849	53506	0	53506	N2C17	N2C18	N1C20	0
30A	N1/21B2	4.55	N1	0	D	3	24076	45766	52020	0	52020	N1C19	N1C20	N1C21	0
57A	N1/21B2	4.55	N1	0	D	3	24154	45863	52154	0	52154	N1C19	N1C20	N1C21	0
15B	N1/22B2	4.55	N1	0	D	3	20513	45548	50972	0	50972	N1C20	N1C21	N1C22	0
20B	N1/22B2	4.55	N1	0	D	3	19982	45026	50477	0	50477	N1C20	N1C21	N1C22	0
22B	N1/22B2	4.55	N1	0	D	3	20254	45707	51155	0	51155	N1C20	N1C21	N1C22	0
28B	N1/22B2	4.55	N1	0	D	3	20676	45580	50966	0	50966	N1C20	N1C21	N1C22	0
30B	N1/22B2	4.55	N1	0	D	3	20291	45230	50623	0	50623	N1C20	N1C21	N1C22	0
50B	N1/22B2	4.55	N1	0	D	3	20414	45430	50870	0	50870	N1C20	N1C21	N1C22	0
54B	N1/22B2	4.55	N1	0	D	3	24029	46756	51340	0	51340	N1C20	N1C21	N1C22	0
56B	N1/22B2	4.55	N1	0	D	3	20343	45642	50952	0	50952	N1C20	N1C21	N1C22	0

*Fuel Assemblies to be loaded into the TN-32B HBU cask are provided in Reference 5

Fuel Assembly design and last irradiation date [Reference 4]

Assy ID	Fuel Design	Initial ^{235}U Enrichment (wt %)	Cycles Resident	Assembly Burnup by Cycle (MWD/MTU)	Final Burnup (MWD/MTU)	Last Irradiation Date	Cooling Time as of 1/1/2017 (years)	Cladding Type	Decay Heat (watts) as of:		
									1/1/2017	7/1/2017	1/1/2027
6T0	NAIF/P+Z	4.25	N2C15, N2C16, N2C17	22638, 34177, 54223	54223	10/2/2005	11.25	ZIRLO™	1033	1013	818
3K7	AMBW	4.55	N1C18, N1C19, N1C20	24242, 47915, 53414	53414	3/8/2009	7.82	M5™	1210	1167	837
3T6	NAIF/P+Z	4.25	N2C15, N2C16, N2C17	23049, 34606, 54298	54298	10/2/2005	11.25	ZIRLO™	1035	1015	820
6F2	NAIF/P+Z	4.25	N1C14, N1C15, N2C16	21112, 45019, 51904	51904	5/2/2004	12.67	ZIRLO™	923	909	756
3F6	NAIF/P+Z	4.25	N1C14, N1C15, N2C16	21100, 45148, 52138	52138	5/2/2004	12.67	ZIRLO™	929	914	761
30A	AMBW	4.55	N1C19, N1C20, N1C21	24076, 45766, 52020	52020	9/12/2010	6.31	M5™	1346	1276	832
22B	AMBW	4.55	N1C20, N1C21, N1C22	20254, 45707, 51155	51155	3/11/2012	4.81	M5™	1637	1503	841
20B	AMBW	4.55	N1C20, N1C21, N1C22	19982, 45026, 50477	50477	3/11/2012	4.81	M5™	1608	1477	827
5K6	AMBW	4.55	N1C18, N1C19, N1C20	24134, 47685, 53268	53268	3/8/2009	7.82	M5™	1206	1163	834
5D5	NAIF/P+Z	4.20	N1C12, N1C13, N1C14	17859, 34608, 55496	55496	3/12/2000	16.81	ZIRLO™	912	903	795
5D9	NAIF/P+Z	4.20	N1C12, N1C13, N1C14	17664, 34104, 54579	54579	3/12/2000	16.81	ZIRLO™	891	882	777
28B	AMBW	4.55	N1C20, N1C21, N1C22	20676, 45580, 50966	50966	3/11/2012	4.81	M5™	1629	1496	837
F52	LOPAR	3.59	N1C4, N1C5, N1C6, N1C7	16762, 25392, 42703, 58093	58093	2/25/1989	27.85	Zircaloy-4	862	858	803
57A	AMBW	4.55	N1C19, N1C20, N1C21	24154, 45863, 52154	52154	9/12/2010	6.31	M5™	1350	1281	834
30B	AMBW	4.55	N1C20, N1C21, N1C22	20291, 45230, 50623	50623	3/11/2012	4.81	M5™	1614	1482	830
3K4	AMBW	4.55	N1C18, N1C19, N1C20	21631, 44993, 51841	51841	3/8/2009	7.82	M5™	1162	1120	803
5K7	AMBW	4.55	N1C18, N1C19, N1C20	24350, 47772, 53335	53335	3/8/2009	7.82	M5™	1208	1165	835
50B	AMBW	4.55	N1C20, N1C21, N1C22	20414, 45430, 50870	50870	3/11/2012	4.81	M5™	1625	1492	835
3U9	NAIF/P+Z	4.45	N2C16, N2C17, N2C18	21738, 39274, 53074	53074	3/18/2007	9.79	ZIRLO™	1063	1037	805
0A4	NAIF	4.00	N1C9, N1C10	27244, 50047	50047	9/9/1994	22.31	Zircaloy-4 (low tin)	729	725	664
15B	AMBW	4.55	N1C20, N1C21, N1C22	20513, 45548, 50972	50972	3/11/2012	4.81	M5™	1629	1496	837
6K4	AMBW	4.55	N1C18, N1C19, N1C20	21565, 45030, 51868	51868	3/8/2009	7.82	M5™	1162	1121	804
3T2	NAIF/P+Z	4.25	N2C15, N2C16, N2C17	23486, 35099, 55087	55087	10/2/2005	11.25	ZIRLO™	1056	1036	837
3U4	NAIF/P+Z	4.45	N2C16, N2C17, N2C18	21525, 39062, 52850	52850	3/18/2007	9.79	ZIRLO™	1057	1031	801
56B	AMBW	4.55	N1C20, N1C21, N1C22	20343, 45642, 50952	50952	3/11/2012	4.81	M5™	1628	1495	837
54B	AMBW	4.55	N1C20, N1C21, N1C22	24029, 46756, 51340	51340	3/11/2012	4.81	M5™	1645	1511	846
6V0	AMBW	4.40	N2C17, N2C18, N1C20	23453, 46849, 53506	53506	3/8/2009	7.82	M5™	1221	1178	843
3U6	NAIF/P+Z	4.45	N2C16, N2C17, N2C18	21790, 39188, 52968	52968	3/18/2007	9.79	ZIRLO™	1060	1035	803
4V4	AMBW	4.40	N2C17, N2C18, N2C19	23917, 46169, 51183	51183	9/14/2008	8.30	M5™	1109	1073	787
5K1	AMBW	4.55	N1C18, N1C19, N1C20	24331, 47643, 53012	53012	3/8/2009	7.82	M5™	1198	1155	828
5T9	NAIF/P+Z	4.25	N2C15, N2C16, N2C17	23098, 34986, 54890	54890	10/2/2005	11.25	ZIRLO™	1051	1031	832
4F1	NAIF/P+Z	4.25	N1C14, N1C15, N2C16	21220, 45356, 52285	52285	5/2/2004	12.67	ZIRLO™	933	918	764

Note: Decay heats calculated as per Table 2-2B, NUHOMS HD System UFSAR. Decay heat calculations use conservatively adjusted enrichments and burnups as per Dominion Fuel Certification Procedure (enrichment decreased by 0.05 wt% U^{235}; burnup increased by 2.5%), however the unadjusted, best estimate values are provided above for assembly burnups and enrichments.

Note: F52 was replaced by F40 in the fuel assembly payload for the TN-32B HBU cask. The design inputs from Reference 4 are to provide fuel assembly design and the last irradiation date. F40 is a LOPAR assembly with a final irradiation date of 4/19/87 [Reference 2].

Fuel Assembly design MTU loading [Reference 4]

Fuel Assembly type	MTU
LOPAR	.460
NAIF	.464
NAIF/P+Z	.465
AMBW	.466

Burnup Uncertainty

A Burnup Uncertainty of 2.5% has been included in this calculation as described in Reference 1.

EFPD

Cycle	EFPD	Cycle	EFPD	Cycle	EFPD
N1C4	350	N1C15	497	N2C17	485
N1C5	349	N1C18	510	N2C18	499
N1C6	401	N1C19	508	N2C19	482
N1C9	503	N1C20	507		
N1C10	494	N1C21	514		
N1C12	419	N1C22	409		
N1C13	452	N2C15	462		
N1C14	509	N2C16	451		

Fuel Assembly Structure Elements from Reference 7

Table 3.11 Element contents[a] from clad, structure, and water (for BWR)

Element[b]	BWR g/kgU	PWR g/kgU	Cooper Station kg/assembly	Point Beach kg/assembly	Turkey Point kg/assembly
H	16.4		3.1		
B	0.068		0.013		
O	265.0	135.0	50.5	52.0	62.0
Cr	2.4	5.9	0.45	2.3	2.7
Mn	0.15	0.33	0.029	0.13	0.15
Fe	6.6	12.9	1.2	5.0	5.9
Co	0.024	0.075	0.0046	0.029	0.034
Ni	2.4	9.9	0.45	3.8	4.5
Zr	516.0	221.0	98.2	85.0	101.0
Nb	0	0.71	0	0.27	0.32
Sn	8.7	3.6	1.6	1.4	1.6
Gd	c		0.544		

[a]Calculated from data and factors in Ref. 21, except for spectral correction factors in Ref. 22 for PWRs.
[b]Included only elements with contents exceeding 0.5 g/kgU plus Mn, Co, and B (for BWR only).
[c]The Gd in BWR standard cases varied with wt % Gd in pins.