


Development of EAL Threshold values from NEE-323-CALC-002


Due to elevated background radiation levels on these monitors during plant operation (10-12 R/hr), the calculated threshold value was rounded to 5 (minimum serviceable threshold value accounting for scale of monitor) for ease of use by the EAL evaluator, and the "in Mode 5 only" caveat is added to the EAL usage.

The resultant EALs are:

- | | |
|---------|---|
| RA2.2 | Reading greater than 5 R/hr on ANY of the following radiation monitors (in Mode 5 only): <ul style="list-style-type: none">• NW Drywell Area Hi Range Rad Monitor, RIM-9184A• South Drywell Area Hi Range Rad Monitor, RIM-9184B |
| CS1/CG1 | Core uncover is indicated by ANY of the following: <ul style="list-style-type: none">• Drywell Monitor (9184A/B) reading greater than 5.0 R/hr |

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Title:	Dose Rate Evaluation of Reactor Vessel Water Levels During Refueling for EAL Thresholds			Client: Duane Arnold Energy Center	
				Project Identifier: NEE-323	
Item	Cover Sheet Items	Yes	No		
1	Does this calculation contain any open assumptions, including preliminary information, that require confirmation? (If YES , identify the assumptions.)	<input type="checkbox"/>	<input checked="" type="checkbox"/>		
2	Does this calculation serve as an "Alternate Calculation"? (If YES , identify the design verified calculation.) Design Verified Calculation No. _____	<input type="checkbox"/>	<input checked="" type="checkbox"/>		
3	Does this calculation supersede an existing Calculation? (If YES , identify the design verified calculation.) Superseded Calculation No. _____	<input type="checkbox"/>	<input checked="" type="checkbox"/>		
Scope of Revision: Initial Issue					
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Study Calculation <input type="checkbox"/> Final Calculation <input checked="" type="checkbox"/>					
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<i>(Print Name and Sign)</i>					
Originator: Jay Bhatt				Date: 12/12/17	
Design Verifier¹ (Reviewer if NSR): Caleb Trainor				Date: 12/12/17	
Approver: Aaron Holloway				Date: 12/12/17	

Note 1: For non-safety-related calculation, design verification can be substituted by review.

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1.0 Purpose and Scope

The purpose of this calculation is to evaluate dose rates with water at the top of active fuel in the reactor vessel during cold shutdown or refueling operations in order to set Emergency Action Level (EAL) thresholds (RA2, CS1, CG1) per NEI 99-01 [Reference 3.5]. The dose rates are calculated at the locations of the drywell monitors 9184A/B so that dose rate measurements by these devices can be correlated to the water level in the core, upon failure of other water level detection systems. This calculation is nonsafety-related as the results of the calculation do not affect the design basis or safety-related systems structures or components. These results are best estimates based on as-built conditions and provide information to operators with respect to classifying an emergency, therefore no acceptance criteria is required.


2.0 Summary of Results and Conclusions

The dose rates just prior to the core being uncovered (i.e. water at the top of the active fuel) are shown in the table below. Note that the results presented below are calculated dose rates and do not account for background radiation or any installed detector check sources.

Table 1 – Dose Rate at Top of Active Fuel


Model Description	Drywell Monitor 9184A Reading (R/hr)	Drywell Monitor 9184B Reading (R/hr)	Drywell Monitor (9184A/B) Range (R/hr)
Head Off	1.81	1.68	1 to 1E+7
Head On	1.11	7.41E-01 ¹	1 to 1E+7

¹ This value is off scale low.

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3.0 References

- 3.1 "Standard Composition Library," ORNL/NUREG/CSD-2/V1/R6, Volume 3, Section M8, March 2000
- 3.2 CGDG-SCALE-6.1.2, Rev 00, Commercial Grade Dedication SCALE Version 6.1.2
- 3.3 CGDG-MCNP6-V1.0, Rev 00, Commercial Grade Dedication MCNP6 Version 1.0
- 3.4 ANSI/ANS 6.1.1-1977, Neutron and Gamma Flux-To-Dose Conversion Factors
- 3.5 NEI 99-01, Rev. 6, "Development of Emergency Action Levels for Non-Passive Reactors"
- 3.6 I.RIM-V115-01, Rev. 10, "Victoreen Model 876A Containment Radiation Monitor Calibration"
- 3.7 NUREG 1940, "RASCAL 4: Descriptions of Models and Methods"
- 3.8 CAL-R00-PUP-008, Rev. 03, "Non-LOCA Radiological Consequence Dose with Alternate Source Term"
- 3.9 RFP 110, Rev. 45, "Refueling Procedure- Reactor Pressure Vessel Disassembly"
- 3.10 Technical Specifications, Section 1.1
- 3.11 Technical Specifications, Section 4.2.1
- 3.12 NUREG 1754, "A New Comparative Analysis of LWR Fuel Designs"
- 3.13 BECH-M009, Rev. 14, "Equipment Locations Reactor Building Section-GG"
- 3.14 BECH-C405, Rev. 14, "Reactor Building Floor Plan @ El. 757'-6"
- 3.15 NG-17-0156, Proprietary Data Transmittal to ENERCON
- 3.16 BECH-M405, Sh 04, Rev. 24, "Instrument Points and Rack Locations Diagram Plans at Elevs 812'-0" & 833'-6"
- 3.17 NG-88-0966, "G.E. Fuel Damage Documentation/Dose Rate Calculations"
- 3.18 C003-029, Rev. 0, "Drywell Cylindrical Shell & Cone"
- 3.19 VS-01-06, Rev. 4, "Top Head Assembly"
- 3.20 BECH-C511, Rev. 5, "Reactor Building RPV Ped Dev. Elev. & Sect's"
- 3.21 BECH-C514, Rev. 1, "Drywell Interior Biological Shield Wall Reinforcing Sections"
- 3.22 BECH-C-516, Rev. 6, "Drywell Interior Biological Shield Wall Plans El. 816'-3 ¼" to El 779'-1 ½"
- 3.23 BECH-M405, Sh 02, Rev. 71, "Instrument Points & Lines Diagrams Plan at Elev 757'-6"
- 3.24 APED-B-31-2816-001, Rev. 5, "Outline Reactor Recirculating Pump"


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3.25 FSAR Section 4.3.2.1, and Section 9.1

3.26 CAL-M98-058, Rev. 1, “ADS Accumulator Size Verification”

4.0 Assumptions

- 4.1 The core is homogenized based on the typical 10x10 fuel assembly dimensions, taking into account the fuel rods and space between. Any small variations in fuel parameters will have a negligible effect on containment dose rates. The cladding is modeled as Zircaloy 4 in lieu of ZIRLO; this is acceptable due to the similarity of the materials.
- 4.2 Any non-fuel hardware, including rod end plugs, is ignored in the active fuel region. This is acceptable since the primary self-shielding occurs in the fuel itself, and there may be some unknown streaming effects through the non-fuel hardware. This homogenization takes into account the presence of water when calculating the isotopic weight fraction and homogenized density. For the case with the reactor vessel head in place, the region between the head and the active fuel region is homogenized based on the actual mass of the upper internals over the entire region. Homogenization of source regions and shields is acceptable due to the insignificant effects on the detector response given the model geometry.
- 4.3 The composition of the containment structure and components are based on the values in the SCALE standard composition library [Reference 3.1]. These material properties are commonly used in shielding applications, and are acceptable for modelling the structures and components used to determine the best estimate response at the detector locations.
- 4.4 The minimum period of decay after reactor shutdown before moving fuel is 60 hours [Reference 3.8, Section 4.3.8]. This calculation assumes a decay time of 50 hours to allow EAL thresholds to be determined for reactor vessel conditions that exist prior to the commencement of fuel movement which is representative of the applicable operating modes (cold shutdown, refueling). This decay time is appropriate to produce best estimate results for both the head on and head off configurations.
- 4.5 The hardware in the upper internals region between the active fuel region, reactor recirculating pumps and reactor vessel head is assumed to be stainless steel type 304. While the actual composition of the hardware may vary slightly, small variations in the material will have a negligible effect on the dose rate response at the detectors.
- 4.6 It is assumed that the water below the active fuel region is liquid at a constant temperature. Using a density of 0.9982 g/cm³ is common in shielding

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applications. Any water above this region would be steam with little shielding value.

- 4.7 The source term is generated shortly after shutdown, therefore, the fuel gamma source term will predominate and the neutron-gamma and hardware activation can be neglected.
- 4.8 The high range detectors read out in roentgen per hour (R/h) which is a measurement of exposure rate, while the MCNP output is provided in mrem/h which is a measurement of the equivalent dose rate that represents the biological effects of ionizing radiation. It is assumed that 1 R is approximately 1000 mrem. This is acceptable as only the gamma source term is considered.
- 4.9 The roof of the Reactor Building is modeled as 0.5 inches of stainless steel. This will account for any scattering interactions that may contribute to the response at the detector. The magnitude of the detector response due to scattering off of the roof will be small due to the geometry and amount of shielding in the model, and is therefore acceptable.
- 4.10 Automatic Depressurization System Accumulators 1R003A/B/C located on the 775'-11 1/2" elevation are not included in the model. The size of the accumulators are 200 gallons [Reference 3.26]. This is relatively small compared to the geometry of the model, and the corresponding scatter interactions will not have a significant impact on the detector response.

5.0 Design Inputs

5.1 Fuel Assembly Parameters

The following fuel assembly parameters are used to homogenize the core in the MCNP model. They are based on typical fuel assembly values for 10x10 fuel.

Table 2 – Design Input Fuel Assembly Parameters

Parameters	Value	Unit	Reference
Fuel type	10x10		3.25
# of Assemblies in Core	368		3.11
# Fuel rods per assembly	92		3.12
Pitch	0.51	[in]	3.12
Density (% of theoretical)	95		3.12
Fuel pellet OD	0.336	[in]	3.12
Fuel rod OD	0.395	[in]	3.12
Clad thickness	0.026	[in]	3.12
Active length	144	[in]	3.12

5.2 Model Dimensions

The following elevations and dimensions are based on the associated drawings or other reference. Some parameters are estimated using drawing scales when exact dimensions are not provided.

Table 3 – Design Input Dimensions

Dimension	ft	in	cm	Reference
Pedestal inner radius	8		243.84	3.20
Pedestal outer radius	12		365.76	3.20
Reactor vessel inner diameter		185.375	470.85	3.15
Reactor vessel thickness		5	12.70	3.15
Drywell spherical portion radius	31.5		960.12	3.17 Figure 2
Concrete around drywell spherical portion(x and y directions radius)	36	9	1120.14	3.14
Drywell cylindrical portion radius	17		518.16	3.16
Drywell liner thickness		0.75	1.91	3.18
Concrete around drywell cylindrical portion (x and y directions)	22	9	693.42	3.16
Reactor Building (x and y directions)	140		4267.20	3.14
Reactor Building Roof Thickness		0.5	1.27	Assumption 4.9
Height of active fuel		144	365.76	3.12
Vessel Height		704.5	1789.43	3.15

Dimension	ft	in	cm	Reference
Reactor vessel head thickness		3.9375	10.00	3.19
Distance from vessel 0 to bottom of active fuel		200.94	510.39	3.15, 3.12
Bio shield inner radius	9	6.25	290.20	3.21
Bio shield outer radius	11	8.25	356.24	3.21
Reactor recirculating pump height	17	2	523.24	3.24
Reactor recirculating pump radius	2	9	83.82	3.24
Detector RE-9184A distance from origin (x plane)	-4		-121.92	3.23 [Scaled]
Detector RE-9184A distance from origin (y plane)	13.33		406.29	3.23 [Scaled]
Detector RE-9184B distance from origin (x plane)	6		182.88	3.23 [Scaled]
Detector RE-9184B distance from origin (y plane)	-12		-365.76	3.23 [Scaled]
Reactor Recirculating Pump IP-201A distance from origin (x plane)	12		365.76	3.23 [Scaled]
Reactor Recirculating Pump IP-201A distance from origin (y plane)	12		365.76	3.23 [Scaled]
Reactor Recirculating Pump IP-201B distance from origin (x plane)	-12		-365.76	3.23 [Scaled]
Reactor Recirculating Pump IP-201B distance from origin (y plane)	-12		-365.76	3.23 [Scaled]

 Table 4 – Design Input Elevations²

Dimension:	ft.	in	cm	Reference
Drywell Equator	766	0.5	0.00	3.13
Vessel 0	772	5.5	195.58	3.15
Bottom of pedestal elevation	742	9	-709.93	3.13
Top of cylindrical portion of drywell concrete	855		2711.45	3.13
Top of Reactor Building	897	6	4006.85	3.13
Detector elevation	760		-184.15	3.17
Top of pedestal/ bottom of bio shield	770	10.5	147.32	3.20
Top of bio shield	816	3.25	1530.99	3.22
Reactor recirculating pump bottom	748	8.5	-528.32	3.13

² All elevations listed in centimeters are relative to the equator of the drywell elevation of 766' 0.5" [Reference 3.13].

5.3 Core Isotopic Inventory

Core isotopic activities in Ci/MWt are taken from Reference 3.7 Table 1-1. A table of the input values is shown in Table 5, below. The activities in Ci are determined by multiplying by the rated thermal power of 1912 MWt taken from Reference 3.10.

Table 5 – Core Source Term

Isotope	Ci/MWt	Ci	Isotope	Ci/MWt	Ci
Ba-139	4.74E+04	9.06E+07	Rh-105	2.81E+04	5.37E+07
Ba-140	4.76E+04	9.10E+07	Ru-103	4.34E+04	8.30E+07
Ce-141	4.39E+04	8.39E+07	Ru-105	3.06E+04	5.85E+07
Ce-143	4.00E+04	7.65E+07	Ru-106	1.55E+04	2.96E+07
Ce-144	3.54E+04	6.77E+07	Sb-127	2.39E+03	4.57E+06
Cm-242	1.12E+03	2.14E+06	Sb-129	8.68E+03	1.66E+07
Cs-134	4.70E+03	8.99E+06	Sr-89	2.41E+04	4.61E+07
Cs-136	1.49E+03	2.85E+06	Sr-90	2.39E+03	4.57E+06
Cs-137	3.25E+03	6.21E+06	Sr-91	3.01E+04	5.76E+07
I-131	2.67E+04	5.11E+07	Sr-92	3.24E+04	6.19E+07
I-132	3.88E+04	7.42E+07	Tc-99m	4.37E+04	8.36E+07
I-133	5.42E+04	1.04E+08	Te-127	2.36E+03	4.51E+06
I-134	5.98E+04	1.14E+08	Te-127m	3.97E+02	7.59E+05
I-135	5.18E+04	9.90E+07	Te-129	8.26E+03	1.58E+07
Kr-83m	3.05E+03	5.83E+06	Te-129m	1.68E+03	3.21E+06
Kr-85	2.78E+02	5.32E+05	Te-131m	5.41E+03	1.03E+07
Kr-85m	6.17E+03	1.18E+07	Te-132	3.81E+04	7.28E+07
Kr-87	1.23E+04	2.35E+07	Xe-131m	3.65E+02	6.98E+05
Kr-88	1.70E+04	3.25E+07	Xe-133	5.43E+04	1.04E+08
La-140	4.91E+04	9.39E+07	Xe-133m	1.72E+03	3.29E+06
La-141	4.33E+04	8.28E+07	Xe-135	1.42E+04	2.72E+07
La-142	4.21E+04	8.05E+07	Xe-135m	1.15E+04	2.20E+07
Mo-99	5.30E+04	1.01E+08	Xe-138	4.56E+04	8.72E+07
Nb-95	4.50E+04	8.60E+07	Y-90	2.45E+03	4.68E+06
Nd-147	1.75E+04	3.35E+07	Y-91	3.17E+04	6.06E+07
Np-239	5.69E+05	1.09E+09	Y-92	3.26E+04	6.23E+07
Pr-143	3.96E+04	7.57E+07	Y-93	2.52E+04	4.82E+07
Pu-241	4.26E+03	8.15E+06	Zr-95	4.44E+04	8.49E+07
Rb-86	5.29E+01	1.01E+05	Zr-97	4.23E+04	8.09E+07

5.4 Material Compositions

The following compositions used in the MCNP model are taken or developed from the SCALE standard composition library [Reference 3.1] and are shown in Table 6.

Table 6 – Scale Standard Compositions used in MCNP Model

Material	Isotope	Weight Fraction
Zry- 4 (6.56 g/cm ³)	Zr	0.9823
	Sn	0.0145
	Cr	0.0010
	Fe	0.0021
	Hf	0.0001
UO₂ (10.412 g/cm ³)	U-235	0.0348
	U-238	0.8466
	O	0.1186
Air (1.21E-03 g/cm ³)	C	0.0001
	N	0.7651
	O	0.2348
Water (0.9982 g/cm ³)	H	0.1111
	O	0.8889
SS-304 (7.94 g/cm ³)	Fe	0.6838
	Cr	0.1900
	Ni	0.0950
	Mn	0.0200
	Si	0.0100
	C	0.0008
	P	0.0004
Concrete (2.30 g/cm ³) [KENO Regular Concrete Standard Mix]	O	0.5320
	Si	0.3370
	Ca	0.0440
	Al	0.0340
	Na	0.0290
	Fe	0.0140
	H	0.0100
Carbon Steel (7.82 g/cm ³)	C	0.0100
	Fe	0.9900

5.5 Upper Internals

The following weights are used in the MCNP model for the region between the active fuel and the reactor vessel head [Reference 3.9, Appendix 8.9]:

- The weight of stainless steel for the moisture separator is 83,000 lbs.
- The weight of stainless steel for the steam dryer is 50,000 lbs.

5.6 The drywell (9184 A/B) and torus (9185 A/B) radiation monitor ranges (1 to 10^7 R/hr) are taken from Reference 3.6.

5.7 ANSI/ANS-1977 Flux to Dose Factors

Flux to dose conversion factors are taken from ANSI/ANS-6.1.1-1977 [Reference 3.4] and are shown in Table 7.

Table 7 – ANSI/ANS-6.1.1-1977 Flux to Dose Factors

MeV	mrem/hr/($\gamma/\text{cm}^2/\text{s}$)	MeV	mrem/hr/($\gamma/\text{cm}^2/\text{s}$)
0.01	3.96E-03	0.8	1.68E-03
0.03	5.82E-04	1	1.98E-03
0.05	2.90E-04	2.2	3.42E-03
0.07	2.58E-04	2.6	3.82E-03

6.0 Methodology

The reactor source terms are decayed to 50 hours with ORIGEN-S of the SCALE 6.1 code package, Reference 3.2. The results are used to bin design input isotope specific activities into energy dependent photon bins. These energy specific photon emission bins are used as input for the energy distribution described by the MCNP source definitions.

The MCNP6, Reference 3.3, Monte Carlo transport code is used to determine the dose rates via the flux to dose conversion factors in Table 7, while accounting for shielding and particle transport.

The detailed engineering drawings are converted into MCNP surface and cell cards in the dimensions shown in Table 3 and Table 4. The radiation monitors of interest are modeled as point detectors to determine the expected dose rate for those detectors. The dose rates are calculated for two reactor refueling conditions:

1. With Head – the reactor is modeled with a 3.9375 inch carbon steel plate as indicated in Table 3, which is additional attenuation between the source and detector. The mass of the moisture separator and steam dryer is homogenized between the active fuel region and the vessel head.
2. Without head – the reactor is modeled with air between the active fuel zone and containment.
3. A sensitivity case is run with a mirror surface at the top of the drywell to ensure the modeling of the drywell cap would not significantly affect the response at the detector locations due to scattering.

Variance reduction is accomplished with a geometric importance map that is imposed on the homogenized core. In addition, cell based importance weighting and source biasing (see Section 7.5) are utilized to improve the variance reduction of the simple geometric scheme. A superimposed weight window mesh is utilized where necessary to improve variance. The weight windows are iteratively generated using the MCNP weight windows generator card. All final dose rates presented in this calculation include weight windows variance reduction.

7.0 Calculation

7.1 Source Terms

The ORIGEN-S input deck, *DAECEAL.inp*, is provided in Appendix C. This input produces a simple case where the isotopic composition from Table 5 is decayed. The isotope is specified in the 73\$\$ card using the special identifier described in Section F7.6.2 of the ORIGEN-S manual, and the activity in curies is specified in the 74** card. The time steps for the decay are given on the 60** card in hours. Although multiple time steps are calculated, the source term with 50 hours decay time is used in this calculation to model the core shortly after shutdown. The output of the decay is given in terms of photons/s/Energy-Group, which is automatically normalized in the MCNP input. The results of this calculation are summarized below in Table 8. These values are used in the MCNP input source definition.

Table 8 – Binned Total Core Source Term

Energy Group	Energy Boundaries (MeV)	Photons/sec
1	0.01-0.05	2.028E+19
2	0.05-0.1	6.572E+18
3	0.1-0.2	1.557E+19
4	0.2-0.3	9.672E+18
5	0.3-0.4	3.582E+18
6	0.4-0.6	7.837E+18
7	0.6-0.8	1.373E+19
8	0.8-1	2.132E+18
9	1-1.33	4.942E+17
10	1.33-1.66	3.579E+18
11	1.66-2	6.576E+16
12	2-2.5	7.518E+16
13	2.5-3	1.110E+17
14	3-4	8.689E+14
15	4-5	1.553E+10
16	5-6.5	2.568E+08
17	6.5-8	3.792E+07
18	8-10	8.041E+06
19	10-11	4.352E+05
totals		8.37E+19

7.2 MCNP Model Core Homogenization

The source term is given for the entire core, therefore, the self-shielding from the assemblies is an important part of the dose rate response. For simplicity, the core is modeled as a three dimensional cylinder with a uniformly distributed spatial particle distribution. The calculations for determining the mass of fuel, cladding and water for the core and the resulting density are shown below. The inputs are based on the dimensions in Table 2.

$$\begin{aligned} \text{Assembly Width} &= (\text{Array Size} - 1) \times \text{pitch} + \text{Rod OD} = (10 - 1)(0.51 \text{ in}) + 0.395 \text{ in} \\ &= 4.985 \text{ in} \end{aligned}$$

$$\begin{aligned} \text{Active Fuel Region Area} &= (\text{Assembly Width})^2 \times \text{Number of Assemblies in Core} \\ &= (4.985 \text{ in})^2 \times 368 = 9144.883 \text{ in}^2 \end{aligned}$$

$$\begin{aligned} \text{Active Fuel Equivalent Radius} &= \sqrt{\text{Active Fuel Region Area} / \pi} = \sqrt{9144.883 \text{ in}^2 / \pi} \\ &= 53.953 \text{ in} \end{aligned}$$

$$\begin{aligned} \text{Rod Volume}_{\text{UO}_2} &= \pi (\text{Pellet Radius})^2 \times \text{Active Length} = \pi (0.168 \text{ in})^2 (144 \text{ in}) \\ &= 12.768 \text{ in}^3 \end{aligned}$$

$$\text{Rod Mass}_{\text{UO}_2} = \rho \times V = \left(10.412 \frac{\text{g}}{\text{cc}}\right) (12.7682 \text{ in}^3) \left(2.54 \frac{\text{cm}}{\text{in}}\right)^3 = 2178.54 \text{ g}$$

$$\begin{aligned} \text{Assembly Mass}_{\text{UO}_2} &= \text{Rod Mass} \times \frac{\text{Number of Fuel Rods}}{\text{Assembly}} = (2178.54 \text{ g})(92) \\ &= 200.43 \text{ kg} \end{aligned}$$

$$\begin{aligned} \text{Clad Volume} &= \pi \left(\frac{\text{OD}^2}{4} - \frac{\text{ID}^2}{4} \right) \times \text{Active Length} \\ &= (\pi) \left[\frac{(0.395 \text{ in})^2}{4} - \frac{(0.343 \text{ in})^2}{4} \right] (144 \text{ in}) = 4.34 \text{ in}^3 \end{aligned}$$

$$\text{Rod Mass}_{\text{Zry-4}} = \rho \times V = \left(6.56 \frac{\text{g}}{\text{cc}}\right) (4.34 \text{ in}^3) \left(2.54 \frac{\text{cm}}{\text{in}}\right)^3 = 466.5 \text{ g}$$

$$\text{Assembly Mass}_{\text{Zry-4}} = \text{Rod Mass} \times \frac{\text{Number of Fuel Rods}}{\text{Assembly}} = (466.5g)(92) = 42.92 \text{ kg}$$

Assembly H₂O Volume

$$\begin{aligned} &= [(\text{Assembly Width})^2 \\ &\quad - \pi(\text{Rod Radius})^2 \times \text{Number of Fuel Rods}] \times \text{Active Length} \\ &= [(4.985 \text{ in})^2 - (\pi)(0.1975 \text{ in})^2(92)](144 \text{ in}) = 1955 \text{ in}^3 \end{aligned}$$

$$\text{Assembly Mass}_{\text{H}_2\text{O}} = \rho \times V = \left(0.9982 \frac{\text{g}}{\text{cc}}\right) \left(\frac{1955}{\text{in}^3}\right) \left(2.54 \frac{\text{cm}}{\text{in}}\right)^3 = 31.98 \text{ kg}$$

$$\begin{aligned} \text{Assembly Volume} &= \text{Active Length} \times (\text{Assembly Width})^2 = (144 \text{ in})(4.985 \text{ in})^2 \\ &= 3578.4 \text{ in}^3 \end{aligned}$$

$$\text{Density} = \frac{\text{Total Mass}}{\text{Volume}} = \frac{1000g/kg(200.43 + 42.92 + 31.98) \text{ kg}}{3578.4 \text{ in}^3 \left(2.54 \frac{\text{cm}}{\text{in}}\right)^3} = 4.70 \text{ g/cc}$$

The corresponding isotopic composition for the homogenized active fuel region is calculated based on the compositions in Table 6. An example calculation for the mass fraction of U-235 is included below.

$$\begin{aligned} \text{Mass Fraction U235} &= \frac{\text{Assembly Mass}_{\text{UO}_2}}{\text{Total Mass}} \times \text{weight fraction U235} \\ &= \frac{200.43 \text{ kg}}{(200.43 + 42.92 + 31.98) \text{ kg}} \times 0.0348 = 0.0253 \end{aligned}$$

The remaining calculations for the homogenization are done in the worksheet Compositions of the EXCEL workbook DAEAL.xlsx and are shown in Appendix B. The isotopic compositions are calculated with the water level above the top of the fuel. Note that the EXCEL workbook uses additional significant figures.


	Dose Rate Evaluation of Reactor Vessel Water Levels During Refueling for EAL Thresholds	CALC NO. NEE-323-CALC-002
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Table 9 – Homogenization of Active Fuel Region

ZAID Number	Atom	Mass Fraction Active Fuel Region Homogenized
92235	U-235	0.0253
92238	U-238	0.6163
8016	O	0.1896
40000	Zr	0.1531
50000	Sn	0.0023
24000	Cr	0.0002
26000	Fe	0.0003
72000	Hf	0.0000
1001	H	0.0129

7.3 MCNP Model Upper Internals Homogenization

For the case with the reactor vessel head in place, the steam dryer and moisture separator region are modeled as a discrete cylinder with a uniformly distributed homogenized material to account for the mass of stainless steel between the active fuel height and reactor vessel head. The homogenization accounts for the mass of metal from Section 5.5 (assumed stainless steel type 304 per Assumption 4.5) distributed evenly across the volume between the active fuel height ($Z=1071.73$ cm) and the head ($Z=1985.01$ cm).

$$\text{Mass Upper Internals} = (83000 \text{ lb} + 50000 \text{ lb}) \left(453.59 \frac{\text{g}}{\text{lb}} \right) = 6.033 \times 10^7 \text{ g}$$

The mass is divided by the volume of the region between the active fuel height and the reactor vessel head to determine the density.

$$\begin{aligned} \text{Density Upper Internals} &= \text{Mass Upper Internals} \div V \\ &= 6.033 \times 10^7 \text{ g} \div (913.28 \text{ cm} \times (\pi(235.43 \text{ cm})^2)) = 0.379 \frac{\text{g}}{\text{cc}} \end{aligned}$$

7.4 MCNP Model Geometry

The following MCNP model geometry is based on the containment dimensions summarized in Table 3 and Table 4. The model only focuses on the primary systems and components that provide shielding or reflection from the core to the radiation monitors. These components include the reactor vessel, recirculation pumps, pedestal, biological shield and drywell. VISED plots of the model geometry are provided in Figures 1-3. The MCNP surface cards with the model dimensions (cm) are shown in Figure 4, and the cell cards are shown in Figure 5 for the cases with no reactor vessel head. A VISED plot of the model with the reactor vessel head is shown in Figure 6. Areas that are not of interest

are given an importance of zero (white areas) so MCNP will not track particles in locations that will not contribute to the detector response.

Figure 1 X-Z VISED Plot of Reactor Vessel (No Head)

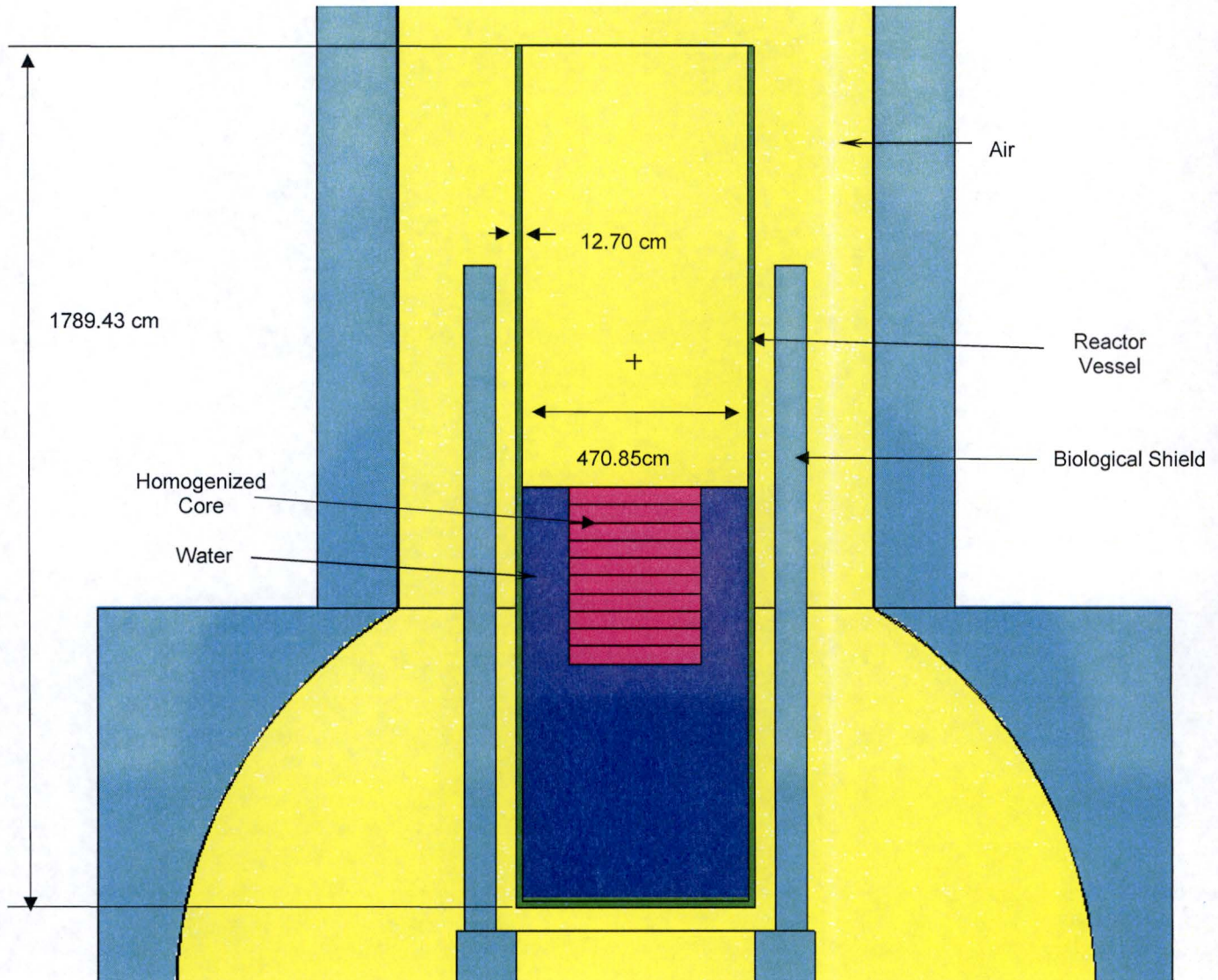
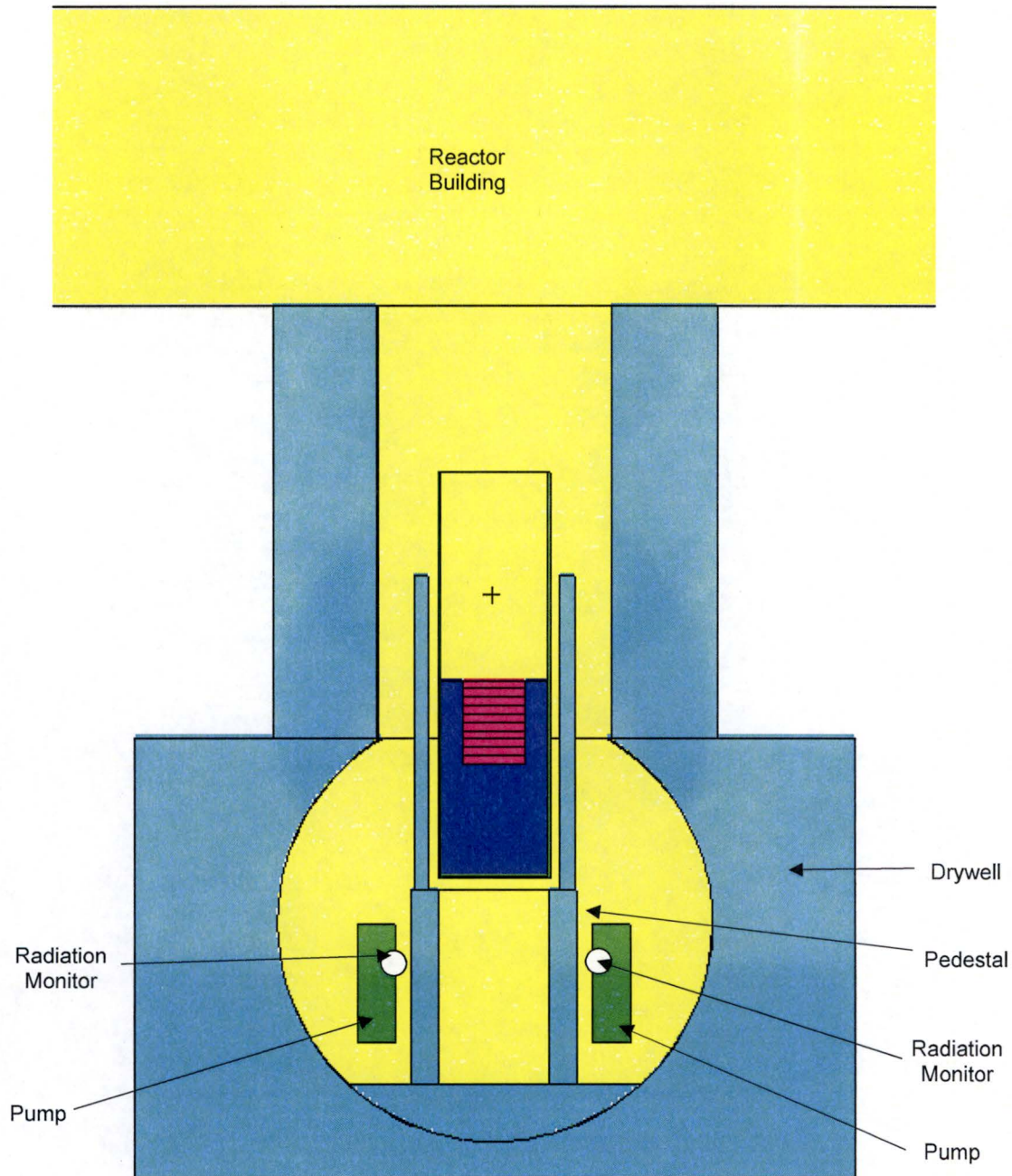
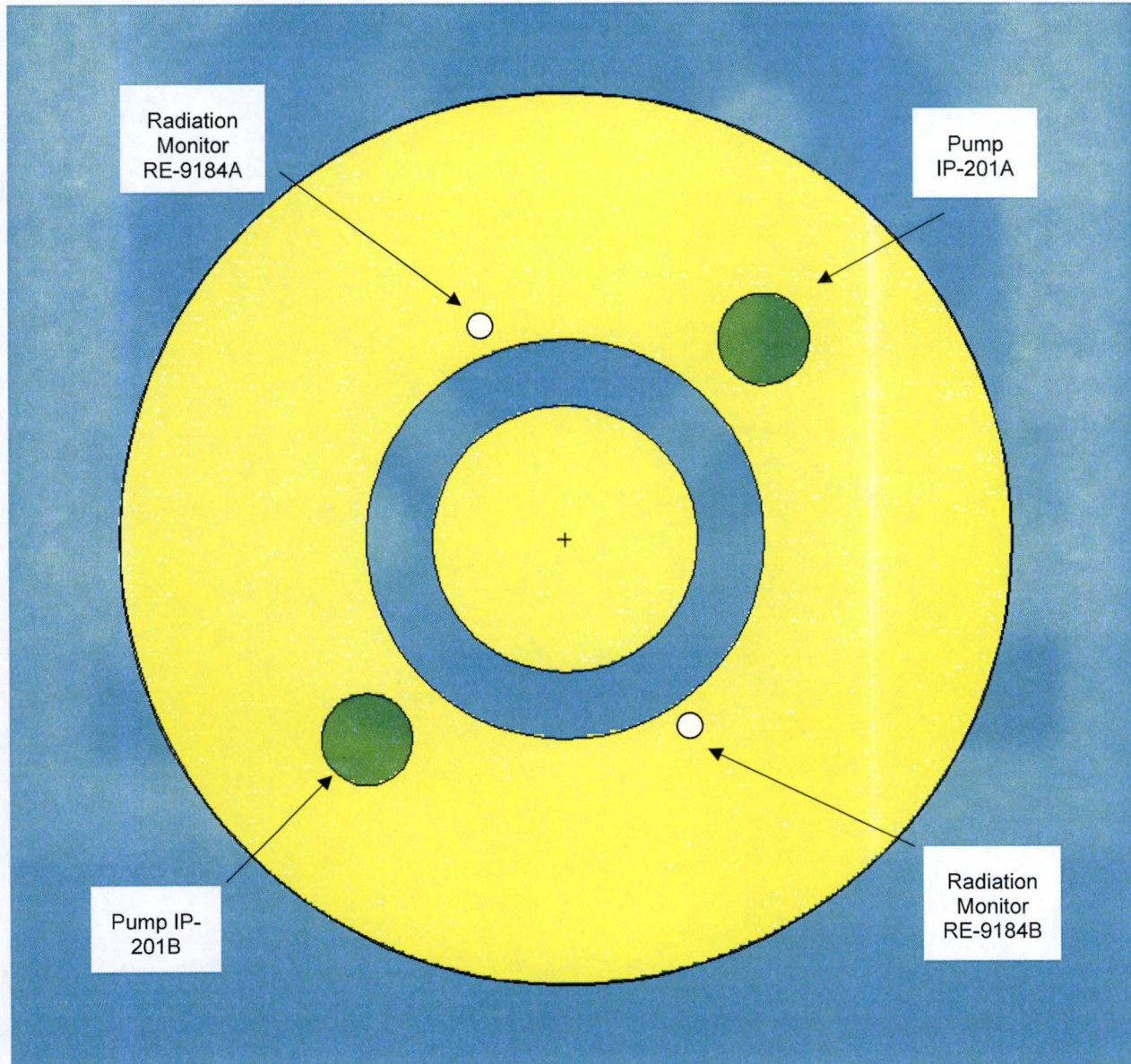


Figure 2 Vised Plot of Drywell and Reactor Building³



³ Radiation monitors are not on the same plane shown above. They are included for visualization purposes only. The VISED Plot was rotated around the Z axis until the Recirculating Pumps were visible.

Figure 3 X-Y Vised Plot of Detectors and Reactor Recirculating Pumps at Elevation 760'-0" ⁴



⁴ Detectors are included for visualization purposes only.

Figure 4 MCNP Model Surface Cards⁵

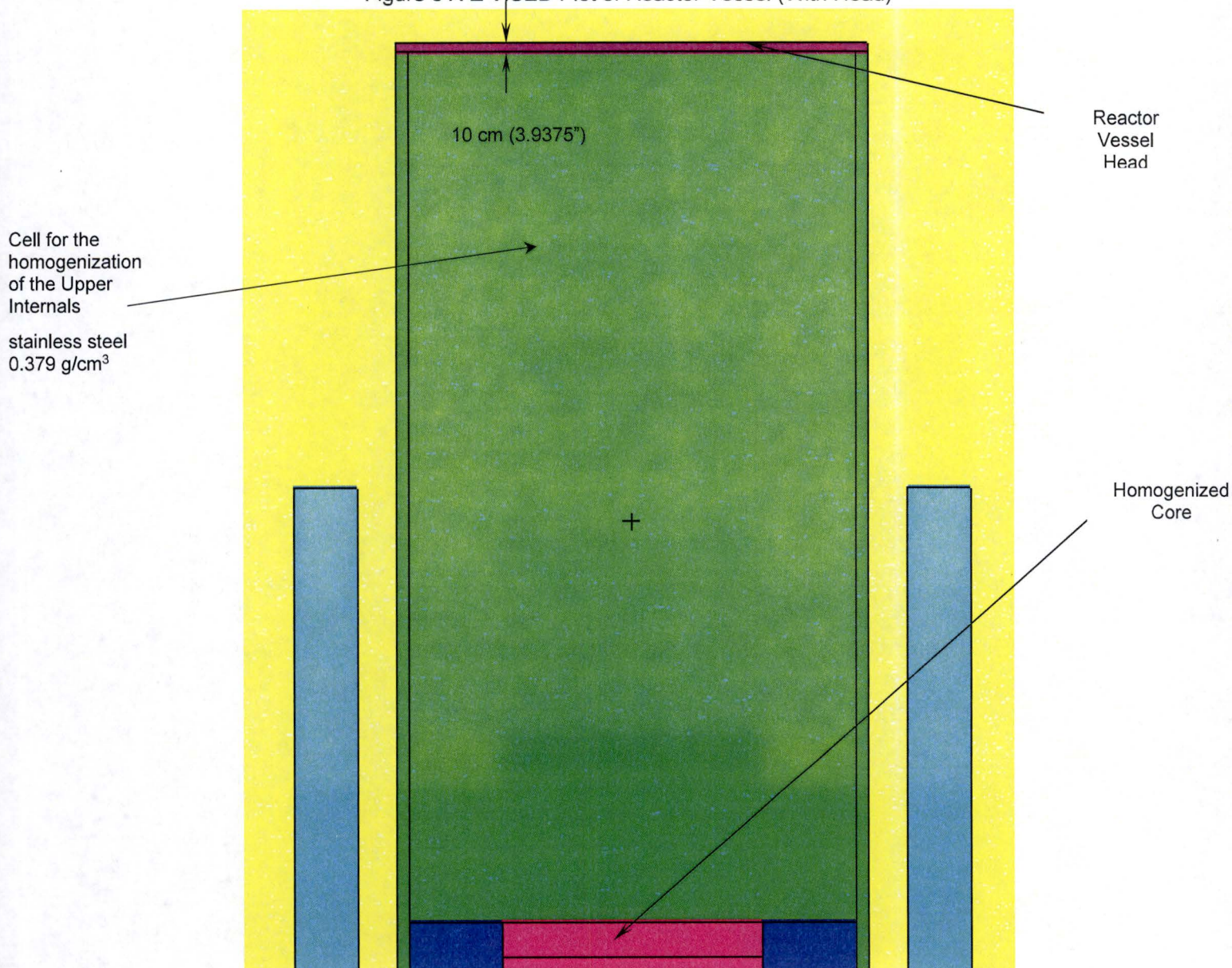
<p>c surfaces</p> <p>1 rcc 0 0 705.97 0 0 365.76 137.045</p> <p>2 rcc 0 0 208.28 0 0 1776.73 235.43</p> <p>3 rcc 0 0 195.58 0 0 1789.43 248.13</p> <p>4 rpp -1120.14 1120.14 -1120.14 1120.14 -1120.14 821.86</p> <p>5 so 960.12</p> <p>6 so 958.21</p> <p>7 pz -709.93</p> <p>8 rcc 0 0 -709.93 0 0 857.25 243.84</p> <p>9 rcc 0 0 -709.93 0 0 857.25 365.76</p> <p>81 rcc 0 0 147.32 0 0 1383.67 290.20</p> <p>91 rcc 0 0 147.32 0 0 1383.67 356.24</p> <p>82 rcc 365.76 365.76 -528.32 0 0 523.24 83.82</p> <p>92 rcc -365.76 -365.76 -528.32 0 0 523.24 83.82</p> <p>10 pz 195.58</p> <p>11 pz 821.86</p> <p>12 rcc 0 0 821.86 0 0 1889.59 518.16</p> <p>13 rcc 0 0 821.86 0 0 1889.59 516.25</p> <p>14 rpp -693.42 693.42 -693.42 693.42 821.86 2711.45</p> <p>15 pz 1071.73</p> <p>16 pz 1985.01</p> <p>17 rpp -4267.2 4267.2 -4267.2 4267.2 2711.45 4006.85</p> <p>18 rpp -4267.2 4267.2 -4267.2 4267.2 4006.85 4008.12</p> <p>19 pz 147.32</p> <p>20 pz 1530.99</p> <p>28 rcc 0 0 1985.01 0 0 10.00 248.13</p> <p>101 pz 742.546</p> <p>102 pz 779.122</p> <p>103 pz 815.698</p> <p>104 pz 852.274</p> <p>105 pz 888.85</p> <p>106 pz 925.246</p> <p>107 pz 962.002</p> <p>108 pz 998.578</p> <p>109 pz 1035.154</p> <p>110 pz 1071.73</p>	<p>\$ Active Fuel Region</p> <p>\$ Reactor Pressure Vessel Inner Surface</p> <p>\$ Reactor Pressure Vessel Outer Surface</p> <p>\$ Concrete Spher port drywell outer</p> <p>\$ Spher portion of drywell outer surface</p> <p>\$ Spher portion of drywell liner surface</p> <p>\$ Bottom of Pedestal Elevation</p> <p>\$ Pedestal Inner Surface</p> <p>\$ Pedestal Outer Surface</p> <p>\$ Bio Shield Inner Surface</p> <p>\$ Bio Shield Outer Surface</p> <p>\$ Recirc Pump IP-201A</p> <p>\$ Recirc Pump IP-201B</p> <p>\$ Vessel 0</p> <p>\$ Transition Spherical to Cylindrical</p> <p>\$ cylin port drywell concrete surface</p> <p>\$ cylin port drywell liner surface</p> <p>\$ Concrete cylin port drywell outer</p> <p>\$ Water Elevation Surface</p> <p>\$ Top of RPV (head level)</p> <p>\$ Reactor building above drywell</p> <p>\$ Reactor building roof</p> <p>\$ Top of Ped Elevation/Bottom Bio Shield</p> <p>\$ Top of Ped Elevation/Bottom Bio Shield</p> <p>\$ Reactor Head</p>
--	---

⁵ The surface card for the MCNP model without the reactor vessel head does not have surface 28.

Figure 5 MCNP Model Cell Cards (No Head)

c cells		
101 1 -4.49 -1 -101	imp:p=256	\$ Active Fuel Region
102 1 -4.49 -1 101 -102	imp:p=128	\$ Active Fuel Region
103 1 -4.49 -1 102 -103	imp:p=64	\$ Active Fuel Region
104 1 -4.49 -1 103 -104	imp:p=32	\$ Active Fuel Region
105 1 -4.49 -1 104 -105	imp:p=16	\$ Active Fuel Region
106 1 -4.49 -1 105 -106	imp:p=8	\$ Active Fuel Region
107 1 -4.49 -1 106 -107	imp:p=4	\$ Active Fuel Region
108 1 -4.49 -1 107 -108	imp:p=3	\$ Active Fuel Region
109 1 -4.49 -1 108 -109	imp:p=2	\$ Active Fuel Region
110 1 -4.49 -1 109 -110	imp:p=1	\$ Active Fuel Region
2 2 -0.9982 1 -2 -15	imp:p=256	\$ Water Region
3 3 -1.21E-03 15 -2	imp:p=256	\$ Air Region inside vessel
4 4 -7.94 2 -3 -16	imp:p=256	\$ RPV Shell
7 5 -2.3 5 -4	imp:p=256	\$ Concrete Surrounding RPV spherical
8 5 -2.3 -14 12	imp:p=256	\$ Concrete Surrounding RPV cylindrical
9 5 -2.3 -9 8 7 -19	imp:p=256	\$ Pedestal
91 5 -2.3 -91 81 19 -20	imp:p=256	\$ Bio Shield
10 5 -2.3 -6 -7	imp:p=256	\$ Concrete at bottom of pedestal
11 3 -1.21E-03 -8	imp:p=256	\$ Inside Pedestal Air
12 3 -1.21E-03 -6 7 -11 9 3		
#18 #19 #91	imp:p=256	\$ Inside Spherical portion Air
13 3 -1.21E-03 -13 3 #91	imp:p=256	\$ Inside Cylindrical portion Air
14 3 -1.21E-03 -17	imp:p=256	\$ Reactor Building above drywell Air
15 4 -7.94 2 -18	imp:p=256	\$ Reactor Build Roof Stainless Steel
16 4 -7.94 6 -5 -11	imp:p=256	\$ Containment Liner Spherical portion
17 4 -7.94 13 -12	imp:p=256	\$ Containment Liner Cylin portion
18 4 -7.94 -82	imp:p=256	\$ Recirc Pump IP-201A
19 4 -7.94 -92	imp:p=256	\$ Recirc Pump IP-201B
999 0 1 #2 #3 #4 #7 #8 #9 #10 #11 #12 #13 #14		
#15 #16 #17 #18 #19 #91	imp:p=0	\$ Problem Boundary

Figure 6 X-Z VISED Plot of Reactor Vessel (With Head)



7.5 MCNP Source Definition

The core source term is modeled as uniformly distributed throughout the homogenized core, and has an energy spectra based on the decayed core inventory (Section 7.1). Only the gamma source term is taken into account for this evaluation. The source term is generated shortly after shutdown, therefore, the fuel gamma source term will predominate, and the neutron-gamma and hardware activation source terms can be neglected (Assumption 4.7). The source is defined on the MCNP sdef card using

distributions to define the particle location and energy. The radius of the core is defined with the rad parameter, which automatically creates a uniform distribution based on a cylindrical geometry. The ext and axs parameters define the direction and distance of the cylinder axis. These parameters combined define the core where the particles can be born. The erg parameter defines the energy spectrum of source particles, and is based on the results of the ORIGEN-S calculation discussed previously. This distribution is a histogram of energies represented by activities. These are automatically normalized by MCNP to create a probability distribution. The total activity is preserved in the tally multiplier. The MCNP source definition cards are shown below in Figure 7. The sb card is a source biasing card, which in this case biases the particle generation to the lower end of the core. This is a variance reduction technique to improve the statistical certainty in the results.

Figure 7 MCNP Source Definition Cards

```

sdef rad=d1 ext=d2 axs=0 0 1 erg=d8
                                     ←Source Definition Card
                                     -Radius = d1
                                     -Extent = d2
                                     -Axis = +Z
                                     -Energy = d8

si1 137.045
si2 h 0 742.546 779.122 815.698 852.274 888.85 925.246 962.002
    998.578 1035.154 1071.73
                                     ←Core Radius Distribution
                                     ←Core Axial Distribution

sp2 0 1 1 1 1 1 1 1 1 1
                                     ←Actual Uniform Distribution
sb2 0 1 1 0.1 0.1 0.1 0.01 0.01 0.01 0.001 0.001
                                     ←Biased to Bot Distribution

c Fuel Gamma Spectra
si8 h 1.000e-002 5.000e-002 1.000e-001 2.000e-001 3.000e-001 4.000e-001
    6.000e-001 8.000e-001 1.000e+000 1.330e+000 1.660e+000 2.000e+000
    2.500e+000 3.000e+000 4.000e+000 5.000e+000 6.500e+000 8.000e+000
    1.000e+001 1.100e+001
                                     ←Source Energy Groups

sp8 0.00E+00 2.028E+19 6.572E+18 1.557E+19 9.672E+18 3.582E+18 7.837E+18
    1.373E+19 2.132E+18 4.942E+17 3.579E+18 6.576E+16 7.518E+16 1.110E+17
    8.689E+14 1.553E+10 2.568E+08 3.792E+07 8.041E+06 4.352E+05
                                     ←Source Emission on
                                     Energy Basis
  
```

7.6 MCNP Tally Specification

The tallies used in this evaluation are point detectors placed at approximate locations of radiation monitors RE-9184A, and RE-9184B. Point detectors are chosen because they use quasi-deterministic dose calculations that will provide better results than surface or cell based tallies that require the particles to enter those regions. The inputs to this card are the coordinates of the dose points followed by an exclusion zone to reduce variance, as well as a multiplier card, which represents the total core activity in photons/sec. The tally cards are shown in Figure 8.

Figure 8 MCNP Tally Cards

```
f5c RE-9184A, and 9184B
f5:p -121.92 406.29 -184.15 20
182.88 -365.76 -184.15 20
fm5 8.370E+19
```

←Tally Comment Card
 ←Tally 5 (point detector)
 x y z exclusion
 ← Tally Multiplier
 (Total Activity)


In addition, the flux is multiplied by ANSI/ANS flux-dose conversion factors [Reference 3.4]. This is specified in MCNP using the de/df cards. These are shown in Figure 9.

Figure 9 ANSI/ANS-6.1.1-1977 Gamma Flux to Dose Conversion Factors

```
c -----
c ANSI/ANS-6.1.1-1977
c Gamma Flux to Dose Conversion Factors
c (mrem/hr) / (photons/cm2-s)
c -----
de0 .01 .03 .05 .07 .10 .15 .20 .25 .30 .35 .40
    .45 .50 .55 .60 .65 .70 .80 1. 1.4 1.8 2.2
    2.6 2.8 3.25 3.75 4.25 4.75 5. 5.25 5.75 6.25
    6.75 7.5 9. 11.
df0 3.96E-03 5.82E-04 2.90E-04 2.58E-04 2.83E-04 3.79E-04
    5.01E-04 6.31E-04 7.59E-04 8.78E-04 9.85E-04 1.08E-03
    1.17E-03 1.27E-03 1.36E-03 1.44E-03 1.52E-03 1.68E-03
    1.98E-03 2.51E-03 2.99E-03 3.42E-03 3.82E-03 4.01E-03
    4.41E-03 4.83E-03 5.23E-03 5.60E-03 5.80E-03 6.01E-03
    6.37E-03 6.74E-03 7.11E-03 7.66E-03 8.77E-03 1.03E-02
```

←Energy Bins for Flux
 to Dose Conversion

←Energy Dependent
 Flux Multipliers

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7.7 MCNP Material Cards

The MCNP material cards are provided in Figure 9. These are based on the compositions described in Table 6 or calculated in Section 7.2.

Figure 10 MCNP Material Cards

m1	92235 -0.0253	\$ Homogenized Active Fuel Region
	92238 -0.6163	
	8016 -0.1896	
	40000 -0.1531	
	50000 -0.0023	
	24000 -0.0002	
	26000 -0.0003	
	1001 -0.0129	
m2	1001 2 8016 1	\$ Water
m3	6012 -0.000126	\$ Air
	7014 -0.76508	
	8016 -0.234793	
m4	6000 -0.0008	\$ SS 304
	14000 -0.01	
	15031 -0.00045	
	24000 -0.19	
	25055 -0.02	
	26000 -0.68375	
	28000 -0.095	
m5	26000 -0.014	\$ Reg-Concrete
	1001 -0.01	
	13027 -0.034	
	20000 -0.044	
	8016 -0.532	
	14000 -0.337	
	11023 -0.029	
m6	6012 -0.01	\$ Carbon Steel
	26056 -0.99	

7.8 Results

The dose rates are provided in Table 10 for the water level at the top of the fuel assemblies. The dose rate is slightly above the detectable response of 1 R/h (1E+03 mrem/h) for the no head configuration, and below the detectable response for the configuration with the reactor vessel head in place for one of the detectors. The sensitivity case shows that there is no significant impact due to reflection from the drywell cap.


Table 10 – Dose Rate Response (mrem/h)

Configuration	Dose Rate 1 RE-9184A	fsd ⁶	Dose Rate 2 RE-9184B	fsd	Tally File
No Head	1.81E+03	10.81%	1.68E+03	7.31%	d0ndm
With Head	1.11E+03	10.16%	7.41E+02	8.24%	d0hgm
With Head (Sensitivity Case)	1.07E+03	15.27%	7.67E+02	15.51%	d0rdm

8.0 Computer Software

This calculation uses ORIGEN-S of the SCALE Version 6.1.2 code package [Reference 3.2] and MCNP Version 6.1.0 [Reference 3.3] in accordance with CSP 3.09.

⁶ Fraction standard deviation.

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9.0 Impact Assessment

This calculation is based on “realistic” assumptions for the purpose of declaring EALs, rather than typical conservative “bounding” type design basis analyses. The calculation results are intended to provide order of magnitude dose rates to assist Operations and Emergency Response personnel in determination of core uncover in accordance with NEI 99-01 Rev. 6.

Origen output:
07/26/2017 04:19 PM

82,114 DAECEAL.OUT

MCNP output:

Directory of \No head\
08/16/2017 09:13 AM

327,680 d0nao

Directory of \With Head\
08/16/2017 10:01 AM

1,269,760 d0hgo


Directory of \sensitivity\
08/16/2017 03:54 AM


286,720 d0rdo


	A	B	C	D	E	F	G	H	I	J	K	L
1												
2		Material	Isotope	Weight Fraction	Reference	Material	Mas s (KG)			ZAID Number	Atom	Mass Fraction Active Fuel Region Homogenized
3		Zry- 4	Zr	0.9823	[1]	UO₂	200.4			92235	U-235	0.0253
4		(6.56 g/cm ³)	Sn	0.0145		Zry- 4	42.92			92238	U-238	0.6163
5			Cr	0.001		Water	31.98			8016	O	0.1896
6			Fe	0.0021						40000	Zr	0.1531
7			Hf	0.0001						50000	Sn	0.0023
8		UO₂	U-235	0.0348	[1]					24000	Cr	0.0002
9			U-238	0.8466						26000	Fe	0.0003
10			O	0.1186						72000	Hf	0.0000
11		Air	C	0.0001	[1]					1001	H	0.0129
12		(1.21E-03 g/cm ³)	N	0.7651								1.0000
13			O	0.2348								
14		Water	H	0.1111	[1]							
15		(0.9982 g/cm ³)	O	0.8889								
16		SS-304	Fe	0.6838	[1]							
17		(7.94 g/cm ³)	Cr	0.19								
18			Ni	0.095								
19			Mn	0.02								
20			Si	0.01								
21			C	0.0008								
22			P	0.0004								
23		Concrete	O	0.532	[1]							
24		(2.30 g/cm ³)	Si	0.337								
25			Ca	0.044								
26			Al	0.034								
27			Na	0.029								
28			Fe	0.014								
29			H	0.01								
30		Carbon Steel	C	0.01	[1]							
31		(7.82 g/cm ³)	Fe	0.99								


	A	B	C	D	E	F	G	H	I	J	K	L
1												
2		Material	Isotope	Weight Fraction	Reference		Material	Mass (KG)		ZAID Number	Atom	Mass Fraction Active Fuel Region Homogenized
3		Zry- 4	Zr	0.9823	[1]		UO ₂	200.42		92235	U-235	=(H3/SUM(H3:H5))*D8
4		(6.56 g/cm ³)	Sn	0.0145			Zry- 4	42.92		92238	U-238	=(H3/SUM(H3:H5))*D9
5			Cr	0.001			Water	31.98		8016	O	=(H3/(SUM(H3:H5)))*D10+((H5/(SUM(H3:H5))))*D15
6			Fe	0.0021						40000	Zr	=(H\$4/SUM(H\$3:H\$5))*D3
7			Hf	0.0001						50000	Sn	=(H\$4/SUM(H\$3:H\$5))*D4
8		UO ₂	U-235	0.0348	[1]					24000	Cr	=(H\$4/SUM(H\$3:H\$5))*D5
9			U-238	0.8466						26000	Fe	=(H\$4/SUM(H\$3:H\$5))*D6
10			O	0.1186						72000	Hf	=(H\$4/SUM(H\$3:H\$5))*D7
11		Air	C	0.0001	[1]					1001	H	=(H5/SUM(H3:H5))*D14
12		(1.21E-03 g/cm ³)	N	0.7651								=SUM(L3:L11)
13			O	0.2348								
14		Water	H	0.1111	[1]							
15		(0.9982 g/cm ³)	O	0.8889								
16		SS-304	Fe	0.6838	[1]							
17		(7.94 g/cm ³)	Cr	0.19								
18			Ni	0.095								
19			Mn	0.02								
20			Si	0.01								
21			C	0.0008								
22			P	0.0004								
23		Concrete	O	0.532	[1]							
24		(2.30 g/cm ³)	Si	0.337								
25			Ca	0.044								
26			Al	0.034								
27			Na	0.029								
28			Fe	0.014								
29			H	0.01								
30		Carbon Steel	C	0.01	[1]							
31		(7.82 g/cm ³)	Fe	0.99								



```
=origens
0$$$ all 71 e t
BWR Source Term DAEC EAL Analysis
3$$$ 21 1 1 a4 27 a16 4 a33 19 e t
35$$$ 0 t
54$$$ a8 0 all 2 e
56$$$ 0 6 a6 1 a10 0 a13 63 3 3 0 2 0 e
57** 0 a3 1-16 e
95$$$ 0 t
DAECEAL
Ci Source Terms
60** 0 24 40 50 60 70
61** 5r1-8 1+6 1+4
65$$$
'GRAM-ATOMS   GRAMS   CURIES   WATTS-ALL   WATTS-GAMMA
      3Z      0 1 0      1 0 0      1 0 0      3Z      6Z
      3Z      1 1 1      1 0 1      1 1 1      3Z      6Z
      3Z      1 1 1      1 1 1      1 1 1      3Z      6Z
81$$$ 2 0 26 1 e
82$$$ f2
83** 1.10E+07 1.00E+07 8.00E+06 6.50E+06 5.00E+06 4.00E+06 3.00E+06
      2.50E+06 2.00E+06 1.66E+06 1.33E+06 1.00E+06 8.00E+05 6.00E+05
      4.00E+05 3.00E+05 2.00E+05 1.00E+05 5.00E+04 1.00E+04 e
84** 2.00E+07 6.43E+06 3.00E+06 1.85E+06 1.40E+06 9.00E+05 4.00E+05
      1.00E+05 1.70E+04 3.00E+03 5.50E+02 1.00E+02 3.00E+01 1.00E+01
      3.05E+00 1.77E+00 1.30E+00 1.13E+00 1.00E+00 8.00E-01 4.00E-01
      3.25E-01 2.25E-01 1.00E-01 5.00E-02 3.00E-02 1.00E-02 1.00E-05 e
73$$$ 561390 561400 581410 581430 581440 962420 551340 551360
      551370 531310 531320 531330 531340 531350 360831 360850
      360851 360870 360880 571400 571410 571420 420990 410950
      601470 932390 591430 942410 370860 451050 441030 441050
      441060 511270 511290 380890 380900 380910 380920 430991
      521270 521271 521290 521291 521311 521320 541311 541330
      541331 541350 541351 541380 390900 390910 390920 390930
      400950 400970
74** 9.06E+07 9.10E+07 8.39E+07 7.65E+07 6.77E+07 2.14E+06 8.99E+06
      2.85E+06 6.21E+06 5.11E+07 7.42E+07 1.04E+08 1.14E+08 9.90E+07
      5.83E+06 5.32E+05 1.18E+07 2.35E+07 3.25E+07 9.39E+07 8.28E+07
      8.05E+07 1.01E+08 8.60E+07 3.35E+07 1.09E+09 7.57E+07 8.15E+06
      1.01E+05 5.37E+07 8.30E+07 5.85E+07 2.96E+07 4.57E+07 1.66E+07
      4.61E+07 4.57E+06 5.76E+07 6.19E+07 8.36E+07 4.51E+06 7.59E+05
      1.58E+07 3.21E+06 1.03E+07 7.28E+07 6.98E+05 1.04E+08 3.29E+06
      2.72E+07 2.20E+07 8.72E+07 4.68E+07 6.06E+07 6.23E+07 4.82E+07
      8.49E+07 8.09E+07
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56$$$ f0 t
end
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 ENERCON <i>Excellence—Every project. Every day.</i>	Attachment 1 CALCULATION PREPARATION CHECKLIST	CALC NO. NEE-323-CALC-002		
		REV. 0		
CHECKLIST ITEMS¹		YES	NO	N/A
GENERAL REQUIREMENTS				
1. If the calculation is being performed to a client procedure, is the procedure being used the latest revision?		<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
The Calculation is performed in accordance with ENERCON procedures.				
2. Are the proper forms being used and are they the latest revision?		<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
The Calculation is performed in accordance with ENERCON procedures.				
3. Have the appropriate client review forms/checklists been completed?		<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
OAR will be performed after calculation submittal				
4. Are all pages properly identified with a calculation number, calculation revision and page number consistent with the requirements of the client's procedure?		<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
5. Is all information legible and reproducible?		<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
6. Is the calculation presented in a logical and orderly manner?		<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
7. Is there an existing calculation that should be revised or voided?		<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
There is no existing calculation that should be revised or voided.				
8. Is it possible to alter an existing calculation instead of preparing a new calculation for this situation?		<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
No existing calculation would be applicable.				
9. If an existing calculation is being used for design inputs, are the key design inputs, assumptions and engineering judgments used in that calculation valid and do they apply to the calculation revision being performed.		<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
No existing calculation is used for design inputs				
10. Is the format of the calculation consistent with applicable procedures and expectations?		<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
11. Were design input/output documents properly updated to reference this calculation?		<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
There are no design output documents.				
12. Can the calculation logic, methodology and presentation be properly understood without referring back to the originator for clarification?		<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
OBJECTIVE AND SCOPE				
13. Does the calculation provide a clear concise statement of the problem and objective of the calculation?		<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
14. Does the calculation provide a clear statement of quality classification?		<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
15. Is the reason for performing and the end use of the calculation understood?		<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
16. Does the calculation provide the basis for information found in the plant's license basis?		<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
This does not provide basis for license basis				
17. If so, is this documented in the calculation?		<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>

	<p align="center">Attachment 1 CALCULATION PREPARATION CHECKLIST</p>	<p>CALC NO. NEE-323-CALC-002</p>		
<p>REV. 0</p>				
<p align="center">CHECKLIST ITEMS¹</p>		<p align="center">YES</p>	<p align="center">NO</p>	<p align="center">N/A</p>
<p>See above</p>				
<p>18. Does the calculation provide the basis for information found in the plant's design basis documentation?</p>	<p align="center"><input type="checkbox"/></p>	<p align="center"><input type="checkbox"/></p>	<p align="center"><input checked="" type="checkbox"/></p>	
<p>This does not provide basis for design basis</p>				
<p>19. If so, is this documented in the calculation?</p>	<p align="center"><input type="checkbox"/></p>	<p align="center"><input type="checkbox"/></p>	<p align="center"><input checked="" type="checkbox"/></p>	
<p>See above</p>				
<p>20. Does the calculation otherwise support information found in the plant's design basis documentation?</p>	<p align="center"><input type="checkbox"/></p>	<p align="center"><input checked="" type="checkbox"/></p>	<p align="center"><input type="checkbox"/></p>	
<p>This does not provide support for information found in design basis documentation</p>				
<p>21. If so, is this documented in the calculation?</p>	<p align="center"><input type="checkbox"/></p>	<p align="center"><input type="checkbox"/></p>	<p align="center"><input checked="" type="checkbox"/></p>	
<p>See above</p>				
<p>22. Has the appropriate design or license basis documentation been revised, or has the change notice or change request documents being prepared for submittal?</p>	<p align="center"><input type="checkbox"/></p>	<p align="center"><input type="checkbox"/></p>	<p align="center"><input checked="" type="checkbox"/></p>	
<p>See above</p>				
<p>DESIGN INPUTS</p>				
<p>23. Are design inputs clearly identified?</p>	<p align="center"><input checked="" type="checkbox"/></p>	<p align="center"><input type="checkbox"/></p>	<p align="center"><input type="checkbox"/></p>	
<p>24. Are design inputs retrievable or have they been added as attachments?</p>	<p align="center"><input checked="" type="checkbox"/></p>	<p align="center"><input type="checkbox"/></p>	<p align="center"><input type="checkbox"/></p>	
<p>25. If Attachments are used as design inputs or assumptions are the Attachments traceable and verifiable?</p>	<p align="center"><input checked="" type="checkbox"/></p>	<p align="center"><input type="checkbox"/></p>	<p align="center"><input type="checkbox"/></p>	
<p>26. Are design inputs clearly distinguished from assumptions?</p>	<p align="center"><input checked="" type="checkbox"/></p>	<p align="center"><input type="checkbox"/></p>	<p align="center"><input type="checkbox"/></p>	
<p>27. Does the calculation rely on Attachments for design inputs or assumptions? If yes, are the attachments properly referenced in the calculation?</p>	<p align="center"><input checked="" type="checkbox"/></p>	<p align="center"><input type="checkbox"/></p>	<p align="center"><input type="checkbox"/></p>	
<p>The Design Information Transmittal is included as an Attachment is properly referenced in the calculation</p>				
<p>28. Are input sources (including industry codes and standards) appropriately selected and are they consistent with the quality classification and objective of the calculation?</p>	<p align="center"><input checked="" type="checkbox"/></p>	<p align="center"><input type="checkbox"/></p>	<p align="center"><input type="checkbox"/></p>	
<p>29. Are input sources (including industry codes and standards) consistent with the plant's design and license basis?</p>	<p align="center"><input checked="" type="checkbox"/></p>	<p align="center"><input type="checkbox"/></p>	<p align="center"><input type="checkbox"/></p>	
<p>30. If applicable, do design inputs adequately address actual plant conditions?</p>	<p align="center"><input checked="" type="checkbox"/></p>	<p align="center"><input type="checkbox"/></p>	<p align="center"><input type="checkbox"/></p>	
<p>31. Are input values reasonable and correctly applied?</p>	<p align="center"><input checked="" type="checkbox"/></p>	<p align="center"><input type="checkbox"/></p>	<p align="center"><input type="checkbox"/></p>	
<p>32. Are design input sources approved?</p>	<p align="center"><input checked="" type="checkbox"/></p>	<p align="center"><input type="checkbox"/></p>	<p align="center"><input type="checkbox"/></p>	
<p>The Design Information Transmittal contains information from a superseded calculation.</p>				
<p>33. Does the calculation reference the latest revision of the design input source?</p>	<p align="center"><input checked="" type="checkbox"/></p>	<p align="center"><input type="checkbox"/></p>	<p align="center"><input type="checkbox"/></p>	
<p>The calculation uses information from a superseded calculation. This information is provided in a Design Information Transmittal.</p>				
<p>34. Were all applicable plant operating modes considered?</p>	<p align="center"><input checked="" type="checkbox"/></p>	<p align="center"><input type="checkbox"/></p>	<p align="center"><input type="checkbox"/></p>	
<p>ASSUMPTIONS</p>				

 <i>Excellence—Every project. Every day.</i>	Attachment 1 CALCULATION PREPARATION CHECKLIST	CALC NO. NEE-323-CALC-002		
		REV. 0		
CHECKLIST ITEMS¹		YES	NO	N/A
35. Are assumptions reasonable/appropriate to the objective?		<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
36. Is adequate justification/basis for all assumptions provided?		<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
37. Are any engineering judgments used?		<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
Engineering judgement not used as design input.				
38. Are engineering judgments clearly identified as such?		<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
Engineering Judgement is not used as a design input.				
39. If engineering judgments are utilized as design inputs, are they reasonable and can they be quantified or substantiated by reference to site or industry standards, engineering principles, physical laws or other appropriate criteria?		<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
Engineering Judgement is not used as a design input.				
METHODOLOGY				
40. Is the methodology used in the calculation described or implied in the plant's licensing basis?		<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
The scope of calculation is outside of plant licensing basis				
41. If the methodology used differs from that described in the plant's licensing basis, has the appropriate license document change notice been initiated?		<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
see above.				
42. Is the methodology used consistent with the stated objective?		<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
43. Is the methodology used appropriate when considering the quality classification of the calculation and intended use of the results?		<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
BODY OF CALCULATION				
44. Are equations used in the calculation consistent with recognized engineering practice and the plant's design and license basis?		<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
45. Is there reasonable justification provided for the use of equations not in common use?		<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
There are no uncommon equations used in the calculation.				
46. Are the mathematical operations performed properly and documented in a logical fashion?		<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
47. Is the math performed correctly?		<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
48. Have adjustment factors, uncertainties and empirical correlations used in the analysis been correctly applied?		<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
49. Has proper consideration been given to results that may be overly sensitive to very small changes in input?		<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
SOFTWARE/COMPUTER CODES				
50. Are computer codes or software languages used in the preparation of the calculation?		<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
MCNP and Scale are used				

	<p align="center">Attachment 1 CALCULATION PREPARATION CHECKLIST</p>	CALC NO. NEE-323-CALC-002		
		REV. 0		
CHECKLIST ITEMS¹		YES	NO	N/A
51. Have the requirements of CSP 3.09 for use of computer codes or software languages, including verification of accuracy and applicability been met?	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
52. Are the codes properly identified along with source vendor, organization, and revision level?	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
53. Is the computer code applicable for the analysis being performed?	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
54. If applicable, does the computer model adequately consider actual plant conditions?	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
55. Are the inputs to the computer code clearly identified and consistent with the inputs and assumptions documented in the calculation?	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
56. Is the computer output clearly identified?	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
57. Does the computer output clearly identify the appropriate units?	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
58. Are the computer outputs reasonable when compared to the inputs and what was expected?	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
59. Was the computer output reviewed for ERROR or WARNING messages that could invalidate the results?	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
RESULTS AND CONCLUSIONS				
60. Is adequate acceptance criteria specified? There is no acceptance criteria as discussed in calc.	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	
61. Are the stated acceptance criteria consistent with the purpose of the calculation, and intended use? See above	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	
62. Are the stated acceptance criteria consistent with the plant's design basis, applicable licensing commitments and industry codes, and standards? See above	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	
63. Do the calculation results and conclusions meet the stated acceptance criteria? See above.	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	
64. Are the results represented in the proper units with an appropriate tolerance, if applicable?	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
65. Are the calculation results and conclusions reasonable when considered against the stated inputs and objectives?	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
66. Is sufficient conservatism applied to the outputs and conclusions?	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	

	Attachment 1 CALCULATION PREPARATION CHECKLIST	CALC NO. NEE-323-CALC-002		
		REV. 0		
CHECKLIST ITEMS¹		YES	NO	N/A
67. Do the calculation results and conclusions affect any other calculations?		<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
No other calculations are affected by this calculation.				
68. If so, have the affected calculations been revised?		<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
No other calculations are affected by this calculation.				
69. Does the calculation contain any conceptual, unconfirmed or open assumptions requiring later confirmation?		<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
There are no open assumptions requiring confirmation later.				
70. If so, are they properly identified?		<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
There are no open assumptions requiring confirmation later.				
DESIGN REVIEW				
71. Have alternate calculation methods been used to verify calculation results?		<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
No a Design Review was performed.				

Note:

- Where required, provide clarification/justification for answers to the questions in the space provided below each question. An explanation is required for any questions answered as "No" or "N/A".

Originator: Jay Bhatt

Print Name and Sign

Date