Development of EAL Threshold values from NEE-323-CALC-006

The calculated values provided in Calc-006 were rounded to aid in decision maker use during evaluation of the EALs. The resulting value used in the DAEC Fission Product Barrier chart is shown below:

- **Fuel Clad Barrier**:
  - Fuel Clad Barrier LOSS 4.A = Drywell Monitor (9184A/B) reading greater than 200 R/hr.

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		REV. 0
		PAGE NO. 1 of 17

Title:	Correlation of Drywell Radiation Monitors for 300 µCi/gm Dose Equivalent Iodine	Client: NEE
		Project: NEE#DA~00001

Item	Cover Sheet Items	Yes	No
1	Does this calculation contain any open assumptions that require confirmation? (If **YES**, Identify the assumptions) ______	☐	☒
2	Does this calculation serve as an "Alternate Calculation"? (If **YES**, Identify the design verified calculation.) **Design Verified Calculation No.** ______	☐	☒
3	Does this calculation Supersede an existing Calculation? (If **YES**, identify the superseded calculation.) **Superseded Calculation No.** ______	☐	☒

Scope of Revision:

Initial Issue

Revision Impact on Results:

N/A

Study Calculation ☐ **Final Calculation** ☒

Safety-Related ☐ **Non-Safety Related** ☒

(Print Name and Sign)

Originator: Blake Holton *Blake Holton*	**Date:** 12/13/17
Reviewer: Dwayne Blaylock *[signature]*	**Date:** 12/13/17
Approver: Guy Spikes *Guy Spikes*	**Date:** 12/13/17

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CALCULATION REVISION STATUS

REVISION	DATE	DESCRIPTION
0		Initial Issue

PAGE REVISION STATUS

PAGE NO.	REVISION	PAGE NO.	REVISION
1-17	0		

APPENDIX/ATTACHMENT REVISION STATUS

APPENDIX NO.	NO. OF PAGES	REVISION NO.	ATTACHMENT NO.	NO. OF PAGES	REVISION NO.
N/A	N/A		1	11	0

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1. PURPOSE AND SCOPE

The purpose of this calculation is to determine the exposure rates at the Drywell Area Hi-Range Rad Monitors, RE-9184A and RE-9184B, when the dose equivalent iodine concentration in the reactor vessel is equal to the Emergency Action Level (EAL) threshold value of 300 μCi/gm Dose Equivalent Iodine (DEI). With this understanding of the relationship between dose rates and coolant activity, the EAL entry threshold can be refined.

On EPIP Form EAL-01, Table F-1, "Fission Product Barrier Matrix" (Reference 13) the Fuel Clad Barrier Loss column currently contains the following entry condition:

> **"OR**
> Drywell Area Hi Range Rad Monitor, RIM-9184A or B reading GREATER THAN 700 Rem/hr"

For the current drywell case, the radiation monitor reading is representative of conditions **following a line break,** per methodology in NEI 99-01, Rev 4 into the drywell.

This calculation determines the exposure rates at the monitors using MicroShield and provides a method to identify fuel damage resulting in 300 μCi/gm DEI without fission products crossing the RCS barrier per methodology in NEI 99-01, Rev 6. Cases are considered with and without exposure rate contributions from noble gas isotopes.

The MicroShield model in this calculation was previously utilized in NextEra Engineering Calculation CAL-R04-001 (Reference 14). The focus of that calculation was to demonstrate that the Drywell Area Hi-Range Rad Monitors could be used to identify DEI of 2.0 μCi/gm 8 days after the reactor was shut down.

2. SUMMARY OF RESULTS AND CONCLUSION

Given the geometry and the source calculated in Section 7, two MicroShield cases are run. The first includes all isotopes present in the mix. For the second case, the noble gases are removed. The results are given in Table 1.

Table 1
Exposure Rate Results

Dose Point	Monitor	All Isotopes R/hr	Noble Gases Removed R/hr
#1	RE-9184A	266.9	231.0
#2	RE-9184B	157.1	136.0

See Attachment 1 for the output from the MicroShield cases.
While some of the noble gases are likely to be removed from the mix present in reactor coolant (steaming), it is appropriate to use the dose values that were calculated assuming they were present.

The background radiation for each Drywell Area Hi Range Rad Monitor from Assumption 4.8 is then added to determine the EAL threshold value.

RE-9184A-266.9 R/hr+14.76 R/hr=281.66 R/hr

RE-9184B-157.1 R/hr + 11.59=168.69 R/hr

Reading of these levels on computer points B164.V and B.165.V, respectively, will be indicative that fuel damage has occurred. Recommended wording for the EAL entry condition:

OR
Drywell Area Hi Range Rad Monitor reading
GREATER THAN 281.66 R/hour on
RIM 9184A, OR
Drywell Area Hi Range Rad Monitor reading
GREATER THAN 168.69 R/hour on
RIM 9184B

3. REFERENCES

3.1 DAEC Asset Enhancement Program Project Task Report T0802, "Radiation Sources and Fission Products", GE-NE-A22-00100-58-01 Rev 0, May 2000.

3.2 Drawing Number BECH-M338, Rev 21, "Drywell Piping Drawing Section A-A".

3.3 Drawing Number BECH-M339, Rev 16, "Drywell Piping Drawing Section B-B".

3.4 Drawing Number BECH-M340, Rev 19, "Drywell Piping Drawing Section C-C".

3.5 Drawing Number BECH-M341, Rev 14, "Drywell Piping Drawing Section D-D".

3.6 Drawing Number BECH-M405 <02>, Rev 71, "Instrument Points and Lines Diagrams Plan at elevation 757' 6".

3.7 Federal Guidance Report No 11; USEPA-5201/1-88-020, "Limiting Values of Radionuclide intake and Air Concentration & Dose Conversion Factors for Inhalation, Submersion and Ingestion"; USEPA September 1988.

3.8 MicroShield Software Version 10.04 "Gamma Ray Point Kernel Shielding Code", Grove Engineering.

3.9 Regulatory Guide 1.183, "Alternative Radiological Source Terms for Evaluating Design Basis Accidents at Nuclear Power Plants" USNRC, July 2000.

3.10 Technical Information Document No 14844 "Calculation of Distance Factors for Power and Test Reactor Sites", USAEC, March 1962.

3.11 Technical Paper 410, "Flow of Fluids through Valves, Fittings, and Pipe", Crane Co., 2001.

3.12 BECH-M190<DCA>, Rev. 0, "Piping Class DCA".

3.13 EPIP FORM EAL-01, Rev 10, "Duane Arnold Energy Center EAL-01 Emergency Action Level Matrix".

3.14 CAL-R04-001, Rev. 1, "Exposure Rate at RE 9184A and 9184B Resulting From A Dose Equivalent Iodine GAP Release of 0.2 micro-Curies/ml".

3.15 NEE-CALC-006 DIT-001, "Correlation of Drywell Radiation Monitors for 300 µci/gm Dose Equivalent Iodine".

4. ASSUMPTIONS

4.1. The most probable event for a loss of the fuel clad barrier leading to a DEI concentration of 300 µCi/gm without fission products crossing the RCS barrier (Ref. 3.14) is the perforation of fuel rods rather than the melting of the fuel. Consequently, the core inventory source term in Table 3 of Appendix B of the power uprate Task Report T0802 (Reference 1) in conjunction with the Reg. Guide 1.183 (Reference 9) release fractions is an appropriate source term for this calculation.

4.2. The isotopes released into the reactor water are assumed to instantaneously mix.

4.3. Due to the proximity of each detector to its corresponding recirc. pump discharge piping, only the source in the vertical discharge piping needs to be considered. The sources in the vessel, the recirc. system ring header, the

recirculating pump suction, RHR piping and horizontal section of the discharge piping were ignored. An increased contribution from these sources is effectively accounted for by adding in background radiation (Assumption 4.8). While the majority of the background reading is from the discharge line due to the proximity to the detector, its addition is intended as a representative value of the increased contribution from a higher DEI concentration in the RCS. This is appropriate for producing best estimate order of magnitude results to determine EAL thresholds.

4.4. The recirc. pump discharge piping is 22" and is assumed to be schedule-80 stainless steel (Reference 2 and 12). For purposes of determining the shielding effect of the piping, the material is considered to be iron with a nominal density of 7.86 g/cm^3, consistent with the guidance in the MicroShield user's manual (Reference 8).

4.5. Because the threshold of 300 µCi/gm is based on a dose equivalent iodine concentration in the vessel, it is not necessary to determine the actual amount of material released into the water. If the relative amounts released into the water are known, these can be scaled appropriately to provide a water concentration for each isotope of interest. Based on this, the source term values in Ci/MWt do not need to be multiplied by the rated thermal power at DAEC.

4.6. In accordance with TID 14844 (Reference 10), only I-131, I-132, I-133, I-134, and I-135 were considered when determining DEI.

4.7. The density of water is assumed to be 1 g/cm^3. This maximizes the total activity calculated in the discharge piping and maximized the dose rate at the detectors.

4.8 Background Radiation Data from the Drywell Area Hi-Range Rad Monitors is determined from Reference 3.15 between 1/1/2015 to 5/1/2016 which is a time frame where the plant was near full power for the entire period. The average radiation values are shown in Table 2 below:

Table 2
Average Background Radiation Levels from 1/1/2015 to 5/1/2016

Point	Point Description	Average R/hr
B164.V	Drywell Area Hi-Range Rad Monitor (A)	14.76
B165.V	Drywell Area Hi-Range Rad Monitor (B)	11.59

5. INPUT AND DESIGN CRITERIA

5.1 Release Fraction

Tables 3 and 5 of Reg. Guide 1.183 (Reference 9) were used to determine the isotopes of interest (i.e. noble gases, halogens, and alkali metals) and the fraction of the core inventory released into the reactor water, shown in Table 3 below.

Table 3
Non-LOCA Fraction of Fission Products in GAP

Element or Isotope	**Fraction**
I-131	0.08
Kr-85	0.10
Xe and all other Kr isotopes	0.05
Br and all other I isotopes	0.05
Cs and Rb	0.12

5.2 Core Inventory

The core inventory in Table 4 is from Task Report A0802 (Reference 1).

Table 4: Core Inventory

Isotope	Task 802 Core Inventory (Ci/MWT)	Isotope	Task 802 Core Inventory (Ci/MWT)	Isotope	Task 802 Core Inventory (Ci/MWT)
Br-82	2.476E+02	I-128	6.063E+02	Rb-86	9.876E+01
Br-82m	9.537E+01	I-129	1.579E-03	Rb-86m	9.394E+00
Br-83	3.220E+03	I-130	1.512E+03	Rb-88	1.824E+04
Br-84	5.520E+03	I-130m	5.898E+02	Rb-89	2.331E+04
Br-84m	2.087E+02	I-131	2.749E+04	Rb-90	2.252E+04
Br-85	6.609E+03	I-132	3.950E+04	Rb-90m	5.370E+03
Br-86	4.713E+03	I-133	5.496E+04	Rb-91	2.830E+04
Br-86m	4.734E+03	I-133m	1.775E+03	Rb-92	2.487E+04
Br-87	1.074E+04	I-134	6.021E+04	Rb-93	1.899E+04
Br-88	1.135E+04	I-134m	6.296E+03	Rb-94	1.003E+04
Br-89	7.867E+03	I-135	5.150E+04	Rb-95	4.988E+03
Br-90	4.965E+03	I-136	2.434E+04	Rb-96	1.458E+03
Br-91	1.730E+03	I-136m	1.429E+04	Rb-97	2.791E+02
Br-92	1.940E+02	I-137	2.363E+04	Rb-98	6.281E+01
Br-93	3.456E+01	I-138	1.169E+04	Rb-99	6.356E+00
Br-94	2.916E+00	I-139	5.177E+03	Rb-100	5.665E-01
Br-95	2.436E-01	I-140	1.452E+03	Xe-129m	4.257E-01
Cs-132	1.047E+01	I-141	2.409E+02	Xe-131m	3.092E+02
Cs-134	1.065E+04	I-142	3.572E+01	Xe-133	5.279E+04
Cs-134m	2.234E+03	I-143	2.411E+00	Xe-133m	1.735E+03
Cs-135	2.919E-02	I-144	1.984E-01	Xe-134m	4.436E+02
Cs-135m	1.473E+03	Kr-83m	3.230E+03	Xe-135	1.908E+04
Cs-136	2.964E+03	Kr-85	4.501E+02	Xe-135m	1.106E+04
Cs-137	5.233E+03	Kr-85m	6.702E+03	Xe-137	4.792E+04
Cs-138	4.978E+04	Kr-87	1.274E+04	Xe-138	4.477E+04
Cs-138m	2.419E+03	Kr-88	1.792E+04	Xe-139	3.488E+04
Cs-139	4.713E+04	Kr-89	2.171E+04	Xe-140	2.264E+04
Cs-140	4.243E+04	Kr-90	2.142E+04	Xe-141	7.971E+03
Cs-141	3.143E+04	Kr-91	1.595E+04	Xe-142	2.739E+03
Cs-142	1.895E+04	Kr-92	7.941E+03	Xe-143	4.636E+02
Cs-143	9.225E+03	Kr-93	2.939E+03	Xe-144	8.283E+01
Cs-144	2.691E+03	Kr-94	1.035E+03	Xe-145	9.440E+00
Cs-145	6.782E+02	Kr-95	1.428E+02	Xe-146	5.994E-01
Cs-146	1.012E+02	Kr-96	2.179E+01	Xe-147	5.358E-02
Cs-147	1.704E+01	Kr-97	1.347E+00		

5.3 Exposure-to-Dose Conversion Factors for Inhalation.

The inhalation dose correction factors (DCFs) for the thyroid are from Federal Guidance Report (FGR) No. 11, Table 2.1 (Reference 7), shown below.

Table 5
Inhalation Dose Conversion Factors

Isotope	FGR-11 DCF Sv/Bq
I-131	2.92E-07
I-132	1.74E-09
I-133	4.86E-08
I-134	2.88E-10
I-135	8.46E-09

6. METHODOLOGY

The exposure rate at RE 9184A and 9184B is determined using the MicroShield Version 10.04 software. Required inputs into the computer program are:

- Length of the discharge piping,
- radius and thickness of the discharge piping
- composition of the discharge piping
- position of the detector in relationship to the piping, and
- concentration of each isotope in the recirc. pump discharge piping

6.1 Source Scaling

The concentration of each isotope in the discharge piping equivalent to 300 μCi/Gm Dose Equivalent Iodine is determined using the following steps.

Dose Equivalent Iodine

Dose Equivalent Iodine refers to the amount of I-131 which would produce the same dose to an individual as a mixture containing multiple isotopes of iodine. When determining this value, non-Iodine isotopes are disregarded. The relationship can be expressed by the following equation:

$$DEI = \sum \frac{Q_{In} \times DCF_{In}}{DCF_{I131}} \qquad \text{Eq 1}$$

Where:

DEI = Dose Equivalent Iodine 131 (Ci)
Q_{In} = Quantity of Iodine isotope "n"(Ci)
DCF_{In} = Dose Conversion Factor for iodine isotope "n" (Sv/Bq)
DCF_{I-131} = Dose Conversion Factor for I-131 (Sv/Bq).

The inputs for equation 1 are the relative abundances of the various iodines which are taken from Power Uprate Task Report T0802 (Reference 1), Reg. Guide 1.183 (Reference 9) release fractions, and the dose conversion factors are from FGR-11 (Reference 3.7).

Scaling Factor

Once the Dose Equivalent Iodine is determined for the entire inventory the source to be used as an input into the MicroShield can be determined by scaling each isotope from Task T0802 using the following equation:

$$C_T = \frac{Q_{RC} \times DEI_T}{DEI} \qquad \text{Eq 2}$$

Where:

C_T = Concentration of Isotope at the 300 µCi/gm threshold (µCi/gm)
Q_{RC} = Quantity of isotope available to be released (Ci)
DEI_T = Dose Equivalent Iodine Threshold (300 µCi/gm)
DEI = Dose Equivalent Iodine value for the source term (Ci).

7. CALCULATIONS

7.1. MicroShield Geometry

Length of the Discharge Piping.

Per Assumption 3, only the source from the discharge piping is considered in the MicroShield Model. From drawings BECH-M338, M339, M340 and M341 (References 2 through 5), the vertical discharge 22" piping from both 1P-201 "A" and "B" extends from elevation 748' 8" to 773' 11", or about 25' 5".

Radius and Thickness of the Discharge Piping

The vertical discharge piping is schedule 80 stainless steel (Reference 12). Thus, the wall thickness is 1.125" and the inside diameter is 19.75" (Reference 11).

Composition of the Discharge Piping

Per Assumption 4, the material of the discharge piping is considered to be iron with a nominal density of 7.86 g/cm^3. Per Assumption 7, the water within the piping is modeled with a density of 1.0 g/cm^3.

Position of the Detector in Relationship to the Piping

From BECH-M405<02> (Reference 6), RE 9184A is conservatively approximated at a distance of 4' 3" from the center of the vertical section of 1P201A discharge piping and RE 9184B is conservatively approximated at a distance of 7' from the center of the vertical section of 1P201B discharge piping. Figure 1 below shows a portion of Reference 6 with the proximity of the radiation detectors to the vertical discharge piping.

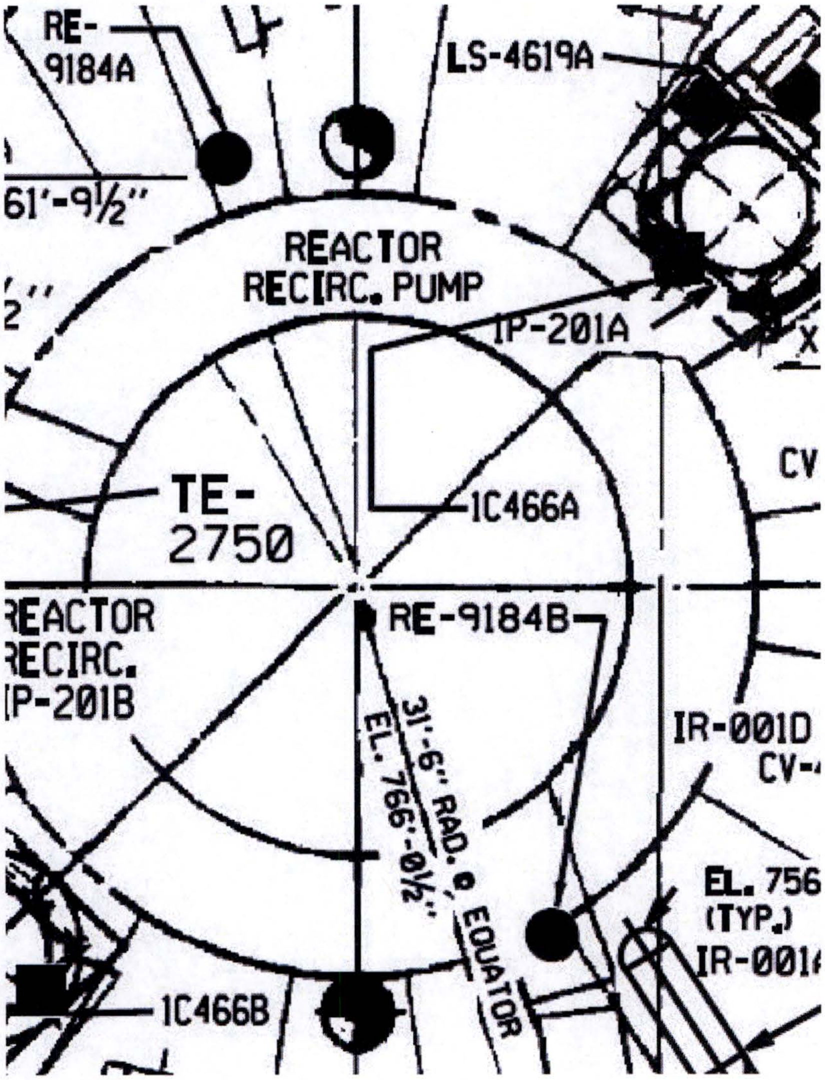

Figure 1: Location of RE9184A/9184B

Based on Reference 14, RE-9184 A/B are located at elevation 761' which is approximately the midpoint of the vertical discharge piping, therefore the detectors are modeled at the midpoint of the source.

Thus, based on discussion above the MicroShield geometry inputs pertaining to RE-9184A and B are set to:
A cylindrical volume with:

- A height of 25' 5"A radius of 9.875", and
- Filled with water with a density of 1.0 g/cm^3
- An iron side shield 1.125" thick with a density of 7.86 g/cm^3
- The dose receptors are located at:X = 4' 3"; Y = 12.7'; and Z = 0 for RE-9184A; and X = 7'; Y = 12.7'; and Z = 0 for RE-9184B.

7.2. Source Term

A spreadsheet is used to determine the isotopic mix present when reactor coolant has a DEI concentration of 300 µCi/gm. For clarification, formulas are displayed in rows 2 and 9.

For rows 2-7 of the spreadsheet, the concentration of each isotope contributing to the DEI of the mix is determined by multiplying the iodine value in the column B by the DCF fraction from Input 5.3 in column D. For I-131 the ratio is one. The sum of these DEI values is shown in Cell C7. By using this value, the mix can be normalized to the desired DEI value.

The relative quantity of each isotope present in the coolant mix is determined by multiplying the Reg. Guide 1.183 (Reference 9) release fraction from Input 5.1 by the given Curies per MWt value from Input 5.2 for each isotope. Cell D9 is an example for Br-82.

To determine total activity present in the pipe, concentration, µCi/gm is multiplied by internal volume. That value is divided by 1E+06 to obtain units of curies. Curies = µCi/gm * (774.7 cm*pi*[25.083 cm]^2)/1E+06.

Table 6
MicroShield Source Term

	A	B	C	D	E	F
		Relative Quantity	Unitless DEI	DEI Fraction	FGR-11 DCF (Sv/Bq)	
2	I-131	=D52	=B2*$D2	=E2/E$2	2.92E-07	
2	I-131	2.20E+03	2.20E+03	1.000	2.92E-07	
3	I-132	1.98E+03	1.18E+01	0.006	1.74E-09	Target DEI:
4	I-133	2.75E+03	4.57E+02	0.166	4.86E-08	300
5	I-134	3.01E+03	2.97E+00	0.001	2.88E-10	
6	I-135	2.58E+03	7.46E+01	0.029	8.46E-09	
7			2.75E+03			

	Isotope	Task 802 Core Inventory (Ci/MWT)	Reg Guide 1.183 Gap Release Fraction	Relative Isotopic composition for GAP Release (Ci)	Isotope	Concentration Assuming 300 µCi/gm DEI	Curies
9	Br-82	2.476E+02	0.05	=B9*$C9	Br-82	=D9*$F$4/$C$7	
9	Br-82	2.476E+02	0.05	1.24E+01	Br-82	1.35E+00	2.0711E+00
	Br-82m	9.537E+01	0.05	4.77E+00	Br-82m	5.21E-01	7.9773E-01
	Br-83	3.220E+03	0.05	1.61E+02	Br-83	1.76E+01	2.6934E+01
	Br-84	5.520E+03	0.05	2.76E+02	Br-84	3.02E+01	4.6173E+01
	Br-84m	2.087E+02	0.05	1.04E+01	Br-84m	1.14E+00	1.7457E+00
	Br-85	6.609E+03	0.05	3.30E+02	Br-85	3.61E+01	5.5282E+01

Isotope	Task 802 Core Inventory (Ci/MWT)	Reg Guide 1.183 Gap Release Fraction	Relative Isotopic composition for GAP Release (Ci)	Isotope	Concentration Assuming 300 µCi/gm DEI	Curies
Br-86	4.713E+03	0.05	2.36E+02	Br-86	2.57E+01	3.9422E+01
Br-86m	4.734E+03	0.05	2.37E+02	Br-86m	2.59E+01	3.9598E+01
Br-87	1.074E+04	0.05	5.37E+02	Br-87	5.87E+01	8.9836E+01
Br-88	1.135E+04	0.05	5.68E+02	Br-88	6.20E+01	9.4939E+01
Br-89	7.867E+03	0.05	3.93E+02	Br-89	4.30E+01	6.5805E+01
Br-90	4.965E+03	0.05	2.48E+02	Br-90	2.71E+01	4.1530E+01
Br-91	1.730E+03	0.05	8.65E+01	Br-91	9.45E+00	1.4471E+01
Br-92	1.940E+02	0.05	9.70E+00	Br-92	1.06E+00	1.6227E+00
Br-93	3.456E+01	0.05	1.73E+00	Br-93	1.89E-01	2.8908E-01
Br-94	2.916E+00	0.05	1.46E-01	Br-94	1.59E-02	2.4391E-02
Br-95	2.436E-01	0.05	1.22E-02	Br-95	1.33E-03	2.0376E-03
Cs-132	1.047E+01	0.12	1.26E+00	Cs-132	1.37E-01	2.1019E-01
Cs-134	1.065E+04	0.12	1.28E+03	Cs-134	1.40E+02	2.1380E+02
Cs-134m	2.234E+03	0.12	2.68E+02	Cs-134m	2.93E+01	4.4848E+01
Cs-135	2.919E-02	0.12	3.50E-03	Cs-135	3.83E-04	5.8599E-04
Cs-135m	1.473E+03	0.12	1.77E+02	Cs-135m	1.93E+01	2.9571E+01
Cs-136	2.964E+03	0.12	3.56E+02	Cs-136	3.89E+01	5.9503E+01
Cs-137	5.233E+03	0.12	6.28E+02	Cs-137	6.86E+01	1.0505E+02
Cs-138	4.978E+04	0.12	5.97E+03	Cs-138	6.53E+02	9.9934E+02
Cs-138m	2.419E+03	0.12	2.90E+02	Cs-138m	3.17E+01	4.8562E+01
Cs-139	4.713E+04	0.12	5.66E+03	Cs-139	6.18E+02	9.4614E+02
Cs-140	4.243E+04	0.12	5.09E+03	Cs-140	5.56E+02	8.5179E+02
Cs-141	3.143E+04	0.12	3.77E+03	Cs-141	4.12E+02	6.3096E+02
Cs-142	1.895E+04	0.12	2.27E+03	Cs-142	2.48E+02	3.8042E+02
Cs-143	9.225E+03	0.12	1.11E+03	Cs-143	1.21E+02	1.8519E+02
Cs-144	2.691E+03	0.12	3.23E+02	Cs-144	3.53E+01	5.4022E+01
Cs-145	6.782E+02	0.12	8.14E+01	Cs-145	8.89E+00	1.3615E+01
Cs-146	1.012E+02	0.12	1.21E+01	Cs-146	1.33E+00	2.0316E+00
Cs-147	1.704E+01	0.12	2.04E+00	Cs-147	2.23E-01	3.4208E-01
Cs-148	1.119E+00	0.12	1.34E-01	Cs-148	1.47E-02	2.2464E-02
I-128	6.063E+02	0.05	3.03E+01	I-128	3.31E+00	5.0715E+00
I-129	1.579E-03	0.05	7.90E-05	I-129	8.63E-06	1.3208E-05
I-130	1.512E+03	0.05	7.56E+01	I-130	8.26E+00	1.2647E+01
I-130m	5.898E+02	0.05	2.95E+01	I-130m	3.22E+00	4.9335E+00
52 I-131	2.749E+04	0.08	2.20E+03	I-131	2.40E+02	3.6791E+02
I-132	3.950E+04	0.05	1.98E+03	I-132	2.16E+02	3.3040E+02
I-133	5.496E+04	0.05	2.75E+03	I-133	3.00E+02	4.5972E+02
I-133m	1.775E+03	0.05	8.88E+01	I-133m	9.70E+00	1.4847E+01
I-134	6.021E+04	0.05	3.01E+03	I-134	3.29E+02	5.0363E+02
I-134m	6.296E+03	0.05	3.15E+02	I-134m	3.44E+01	5.2664E+01
I-135	5.150E+04	0.05	2.58E+03	I-135	2.81E+02	4.3078E+02
I-136	2.434E+04	0.05	1.22E+03	I-136	1.33E+02	2.0359E+02
I-136m	1.429E+04	0.05	7.15E+02	I-136m	7.81E+01	1.1953E+02
I-137	2.363E+04	0.05	1.18E+03	I-137	1.29E+02	1.9766E+02

Isotope	Task 802 Core Inventory (Ci/MWT)	Reg Guide 1.183 Gap Release Fraction	Relative Isotopic composition for GAP Release (Ci)	Isotope	Concentration Assuming 300 µCi/gm DEI	Curies
I-138	1.169E+04	0.05	5.85E+02	I-138	6.39E+01	9.7782E+01
I-139	5.177E+03	0.05	2.59E+02	I-139	2.83E+01	4.3304E+01
I-140	1.452E+03	0.05	7.26E+01	I-140	7.93E+00	1.2145E+01
I-141	2.409E+02	0.05	1.20E+01	I-141	1.32E+00	2.0150E+00
I-142	3.572E+01	0.05	1.79E+00	I-142	1.95E-01	2.9878E-01
I-143	2.411E+00	0.05	1.21E-01	I-143	1.32E-02	2.0167E-02
I-144	1.984E-01	0.05	9.92E-03	I-144	1.08E-03	1.6595E-03
Kr-83m	3.230E+03	0.05	1.62E+02	Kr-83m	1.76E+01	2.7018E+01
Kr-85	4.501E+02	0.1	4.50E+01	Kr-85	4.92E+00	7.5298E+00
Kr-85m	6.702E+03	0.05	3.35E+02	Kr-85m	3.66E+01	5.6060E+01
Kr-87	1.274E+04	0.05	6.37E+02	Kr-87	6.96E+01	1.0657E+02
Kr-88	1.792E+04	0.05	8.96E+02	Kr-88	9.79E+01	1.4989E+02
Kr-89	2.171E+04	0.05	1.09E+03	Kr-89	1.19E+02	1.8160E+02
Kr-90	2.142E+04	0.05	1.07E+03	Kr-90	1.17E+02	1.7917E+02
Kr-91	1.595E+04	0.05	7.98E+02	Kr-91	8.71E+01	1.3342E+02
Kr-92	7.941E+03	0.05	3.97E+02	Kr-92	4.34E+01	6.6423E+01
Kr-93	2.939E+03	0.05	1.47E+02	Kr-93	1.61E+01	2.4584E+01
Kr-94	1.035E+03	0.05	5.18E+01	Kr-94	5.65E+00	8.6574E+00
Kr-95	1.428E+02	0.05	7.14E+00	Kr-95	7.80E-01	1.1945E+00
Kr-96	2.179E+01	0.05	1.09E+00	Kr-96	1.19E-01	1.8227E-01
Kr-97	1.347E+00	0.05	6.74E-02	Kr-97	7.36E-03	1.1267E-02
Kr-98	1.553E-01	0.05	7.77E-03	Kr-98	8.48E-04	1.2990E-03
Rb-86	9.876E+01	0.12	1.19E+01	Rb-86	1.29E+00	1.9826E+00
Rb-86m	9.394E+00	0.12	1.13E+00	Rb-86m	1.23E-01	1.8859E-01
Rb-88	1.824E+04	0.12	2.19E+03	Rb-88	2.39E+02	3.6617E+02
Rb-89	2.331E+04	0.12	2.80E+03	Rb-89	3.06E+02	4.6795E+02
Rb-90	2.252E+04	0.12	2.70E+03	Rb-90	2.95E+02	4.5209E+02
Rb-90m	5.370E+03	0.12	6.44E+02	Rb-90m	7.04E+01	1.0780E+02
Rb-91	2.830E+04	0.12	3.40E+03	Rb-91	3.71E+02	5.6813E+02
Rb-92	2.487E+04	0.12	2.98E+03	Rb-92	3.26E+02	4.9927E+02
Rb-93	1.899E+04	0.12	2.28E+03	Rb-93	2.49E+02	3.8123E+02
Rb-94	1.003E+04	0.12	1.20E+03	Rb-94	1.31E+02	2.0135E+02
Rb-95	4.988E+03	0.12	5.99E+02	Rb-95	6.54E+01	1.0013E+02
Rb-96	1.458E+03	0.12	1.75E+02	Rb-96	1.91E+01	2.9269E+01
Rb-97	2.791E+02	0.12	3.35E+01	Rb-97	3.66E+00	5.6030E+00
Rb-98	6.281E+01	0.12	7.54E+00	Rb-98	8.23E-01	1.2609E+00
Rb-99	6.356E+00	0.12	7.63E-01	Rb-99	8.33E-02	1.2760E-01
RB100	5.665E-01	0.12	6.80E-02	RB100	7.43E-03	1.1373E-02
Xe-129m	4.257E-01	0.05	2.13E-02	Xe-129m	2.33E-03	3.5608E-03
Xe-131m	3.092E+02	0.05	1.55E+01	Xe-131m	1.69E+00	2.5863E+00
Xe-133	5.279E+04	0.05	2.64E+03	Xe-133	2.88E+02	4.4157E+02
Xe-133m	1.735E+03	0.05	8.68E+01	Xe-133m	9.48E+00	1.4513E+01
Xe-134m	4.436E+02	0.05	2.22E+01	Xe-134m	2.42E+00	3.7105E+00

Isotope	Task 802 Core Inventory (Ci/MWT)	Reg Guide 1.183 Gap Release Fraction	Relative Isotopic composition for GAP Release (Ci)	Isotope	Concentration Assuming 300 µCi/gm DEI	Curies
Xe-135	1.908E+04	0.05	9.54E+02	Xe-135	1.04E+02	1.5960E+02
Xe-135m	1.106E+04	0.05	5.53E+02	Xe-135m	6.04E+01	9.2513E+01
Xe-137	4.792E+04	0.05	2.40E+03	Xe-137	2.62E+02	4.0083E+02
Xe-138	4.477E+04	0.05	2.24E+03	Xe-138	2.45E+02	3.7448E+02
Xe-139	3.488E+04	0.05	1.74E+03	Xe-139	1.91E+02	2.9176E+02
Xe-140	2.264E+04	0.05	1.13E+03	Xe-140	1.24E+02	1.8938E+02
Xe-141	7.971E+03	0.05	3.99E+02	Xe-141	4.35E+01	6.6674E+01
Xe-142	2.739E+03	0.05	1.37E+02	Xe-142	1.50E+01	2.2911E+01
Xe-143	4.636E+02	0.05	2.32E+01	Xe-143	2.53E+00	3.8778E+00
Xe-144	8.283E+01	0.05	4.14E+00	Xe-144	4.52E-01	6.9284E-01
Xe-145	9.440E+00	0.05	4.72E-01	Xe-145	5.16E-02	7.8962E-02
Xe-146	5.994E-01	0.05	3.00E-02	Xe-146	3.27E-03	5.0138E-03
Xe-147	5.358E-02	0.05	2.68E-03	Xe-147	2.93E-04	4.4818E-04

8 COMPUTER SOFTWARE

All cases were evaluated using the MicroShield Version 10.04 software (Reference 8). MicroShield is used to analyze shielding and estimate exposure from gamma ray radiation as well as assessing radiation exposure to people and materials (Reference 8). A review of MicroShield error notifications ("Bug List") for Version 10.04 was performed. The notices are either not applicable or dispositioned as having a minor impact on the model results. MicroShield is maintained under the ENERCON software quality assurance program and is suitable for applications such as this.

Attachment 1: MicroShield Output Files

Figure 2 below shows the geometry of the MicroShield model as described in Section 7.1. The recirc. Discharge piping is the red cylindrical structure along the Y-axis. The two orange dots are representative of RE-9184A and RE-9184B (RE-9184A is the orange dot closer to the source) at the midpoint of the source.

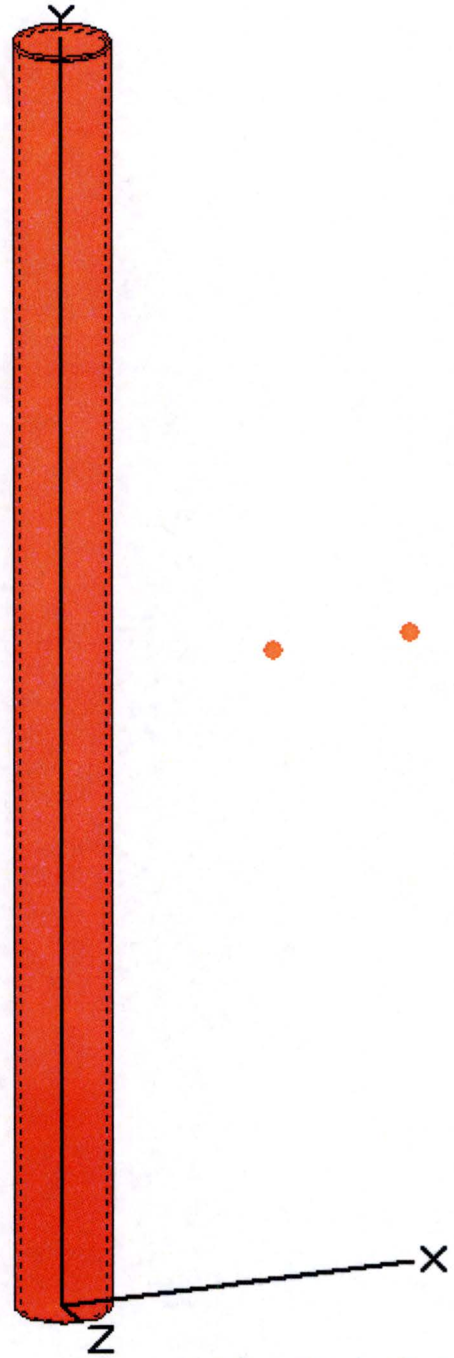

Figure 2: MicroShield Model

MicroShield 10.04
Enercon Services

Date	By	Checked

File Name	Run Date	Run Time	Duration
17-004-C.msd	October 14, 2017	8:56:21 AM	00:00:00

Project Info	
Case Title	Case 1
Description	Case 1
Geometry	7 - Cylinder Volume - Side Shields

Source Dimensions	
Height	774.802 cm (25 ft 5.0 in)
Radius	25.083 cm (9.9 in)

Dose Points

A	X	Y	Z
#1	129.54 cm (4 ft 3.0 in)	387.096 cm (12 ft 8.4 in)	0.0 cm (1 in)
#2	213.36 cm (7 ft .0 in)	387.096 cm (12 ft 8.4 in)	0.0 cm (1 in)

Shield

Shield N	Dimension	Material	Density (g/cm³)
Source	54.08 ft³	Water	1
Transition		Air	0.00122
Air Gap		Air	0.00122
Wall Clad	.094 ft	Iron	7.86
Top Clad	.094 ft	Iron	7.86

Source Input: Grouping Method - Standard Indices
Number of Groups: 25
Lower Energy Cutoff: 0.015
Photons< 0.015: Included
Library: Grove

Nuclide	Ci	Bq	μCi/cm³	Bq/cm³
Ba-137m	9.9330e+001	3.6752e+012	6.4863e+001	2.3999e+006
Br-82	2.0700e+000	7.6590e+010	1.3517e+000	5.0014e+004
Br-83	2.6900e+001	9.9530e+011	1.7566e+001	6.4994e+005
Br-84	4.6200e+001	1.7094e+012	3.0169e+001	1.1163e+006

Br-85	5.5300e+001	2.0461e+012	3.6111e+001	1.3361e+006
Cs-132	2.1000e-001	7.7700e+009	1.3713e-001	5.0739e+003
Cs-134	2.1400e+002	7.9180e+012	1.3974e+002	5.1705e+006
Cs-134m	4.4800e+001	1.6576e+012	2.9255e+001	1.0824e+006
Cs-135	5.8600e-004	2.1682e+007	3.8266e-004	1.4159e+001
Cs-136	5.9500e+001	2.2015e+012	3.8854e+001	1.4376e+006
Cs-137	1.0500e+002	3.8850e+012	6.8566e+001	2.5369e+006
Cs-138	9.9900e+002	3.6963e+013	6.5235e+002	2.4137e+007
Cs-139	9.4600e+002	3.5002e+013	6.1774e+002	2.2857e+007
I-128	5.0700e+000	1.8759e+011	3.3107e+000	1.2250e+005
I-129	1.3200e-005	4.8840e+005	8.6197e-006	3.1893e-001
I-130	1.2600e+001	4.6620e+011	8.2279e+000	3.0443e+005
I-131	3.6800e+002	1.3616e+013	2.4031e+002	8.8913e+006
I-132	3.3000e+002	1.2210e+013	2.1549e+002	7.9732e+006
I-133	4.6000e+002	1.7020e+013	3.0038e+002	1.1114e+007
I-134	5.0400e+002	1.8648e+013	3.2912e+002	1.2177e+007
I-135	4.3100e+002	1.5947e+013	2.8145e+002	1.0414e+007
I-136	2.0400e+002	7.5480e+012	1.3321e+002	4.9289e+006
Kr-83m	2.7000e+001	9.9900e+011	1.7631e+001	6.5235e+005
Kr-85	7.5300e+000	2.7861e+011	4.9171e+000	1.8193e+005
Kr-85m	5.6100e+001	2.0757e+012	3.6634e+001	1.3554e+006
Kr-87	1.0700e+002	3.9590e+012	6.9872e+001	2.5853e+006
Kr-88	1.5000e+002	5.5500e+012	9.7951e+001	3.6242e+006
Kr-89	1.8200e+002	6.7340e+012	1.1885e+002	4.3974e+006
Kr-90	1.7900e+002	6.6230e+012	1.1689e+002	4.3249e+006
Rb-86	1.9800e+000	7.3260e+010	1.2930e+000	4.7839e+004
Rb-88	3.6600e+002	1.3542e+013	2.3900e+002	8.8430e+006
Rb-89	4.6800e+002	1.7316e+013	3.0561e+002	1.1307e+007
Rb-90	4.5200e+002	1.6724e+013	2.9516e+002	1.0921e+007
Rb-90m	1.0800e+002	3.9960e+012	7.0525e+001	2.6094e+006
Xe-129m	3.5600e-003	1.3172e+008	2.3247e-003	8.6014e+001
Xe-131m	2.5900e+000	9.5830e+010	1.6913e+000	6.2578e+004
Xe-133	4.4200e+002	1.6354e+013	2.8863e+002	1.0679e+007
Xe-133m	1.4500e+001	5.3650e+011	9.4686e+000	3.5034e+005
Xe-135	1.6000e+002	5.9200e+012	1.0448e+002	3.8658e+006

Xe-135m	9.2500e+001	3.4225e+012	6.0403e+001	2.2349e+006
Xe-137	4.0100e+002	1.4837e+013	2.6186e+002	9.6887e+006
Xe-138	3.7400e+002	1.3838e+013	2.4422e+002	9.0363e+006

Buildup: The material reference is Source.
Integration Parameters

Radial	10
Circumferential	10
Y Direction (axial)	20

Results - Dose Point # 1 - (4.25,12.7,0) ft

Energy (MeV)	Activity (Photons/sec)	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup	Absorbed Dose Rate mrad/hr No Buildup	Absorbed Dose Rate mrad/hr With Buildup	Absorbed Dose Rate mGy/hr No Buildup	Absorbed Dose Rate mGy/hr With Buildup
0.015	3.986e+12	0.000e+00	2.036e-21	0.000e+00	1.746e-22	0.000e+00	1.524e-22	0.000e+00	1.524e-24
0.03	1.218e+13	2.134e-75	4.080e-19	2.115e-77	4.044e-21	1.846e-77	3.530e-21	1.846e-79	3.530e-23
0.04	2.073e+11	3.464e-33	7.048e-20	1.532e-35	3.117e-22	1.338e-35	2.721e-22	1.338e-37	2.721e-24
0.06	2.744e+11	1.775e-09	2.950e-06	3.526e-12	5.859e-09	3.078e-12	5.114e-09	3.078e-14	5.114e-11
0.08	6.497e+12	5.427e-02	3.720e+01	8.588e-05	5.887e-02	7.497e-05	5.139e-02	7.497e-07	5.139e-04
0.1	2.409e+12	4.327e+00	1.270e+03	6.620e-03	1.944e+00	5.779e-03	1.697e+00	5.779e-05	1.697e-02
0.15	4.553e+12	7.841e+02	6.255e+04	1.291e+00	1.030e+02	1.127e+00	8.992e+01	1.127e-02	8.992e-01
0.2	1.197e+13	9.811e+03	4.046e+05	1.732e+01	7.142e+02	1.512e+01	6.235e+02	1.512e-01	6.235e+00
0.3	8.965e+12	3.033e+04	6.220e+05	5.753e+01	1.180e+03	5.022e+01	1.030e+03	5.022e-01	1.030e+01
0.4	2.409e+13	1.816e+05	2.485e+06	3.538e+02	4.842e+03	3.089e+02	4.227e+03	3.089e+00	4.227e+01
0.5	4.810e+13	6.433e+05	6.646e+06	1.263e+03	1.305e+04	1.102e+03	1.139e+04	1.102e+01	1.139e+02
0.6	4.185e+13	8.783e+05	7.354e+06	1.714e+03	1.435e+04	1.497e+03	1.253e+04	1.497e+01	1.253e+02
0.8	7.476e+13	3.134e+06	1.932e+07	5.961e+03	3.676e+04	5.204e+03	3.209e+04	5.204e+01	3.209e+02

1.0	5.982e+13	4.235e+06	2.107e+07	7.806e+03	3.884e+04	6.814e+03	3.391e+04	6.814e+01	3.391e+02
1.5	6.326e+13	1.117e+07	3.970e+07	1.880e+04	6.679e+04	1.641e+04	5.831e+04	1.641e+02	5.831e+02
2.0	3.131e+13	1.007e+07	2.952e+07	1.557e+04	4.564e+04	1.359e+04	3.985e+04	1.359e+02	3.985e+02
3.0	1.202e+13	8.318e+06	1.949e+07	1.129e+04	2.645e+04	9.852e+03	2.309e+04	9.852e+01	2.309e+02
4.0	5.230e+12	5.897e+06	1.212e+07	7.296e+03	1.500e+04	6.369e+03	1.309e+04	6.369e+01	1.309e+02
5.0	8.984e+11	1.433e+06	2.686e+06	1.642e+03	3.079e+03	1.434e+03	2.688e+03	1.434e+01	2.688e+01
6.0	3.195e+10	6.626e+04	1.167e+05	7.195e+01	1.267e+02	6.281e+01	1.106e+02	6.281e-01	1.106e+00
Total	**4.124e+14**	**4.607e+07**	**1.616e+08**	**7.183e+04**	**2.669e+05**	**6.271e+04**	**2.330e+05**	**6.271e+02**	**2.330e+03**

Results - Dose Point # 2 - (7,12.7,0) ft

Energy (MeV)	Activity (Photons/sec)	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup	Absorbed Dose Rate mrad/hr No Buildup	Absorbed Dose Rate mrad/hr With Buildup	Absorbed Dose Rate mGy/hr No Buildup	Absorbed Dose Rate mGy/hr With Buildup
0.015	3.986e+12	0.000e+00	1.054e-21	0.000e+00	9.037e-23	0.000e+00	7.889e-23	0.000e+00	7.889e-25
0.03	1.218e+13	1.169e-75	2.111e-19	1.158e-77	2.093e-21	1.011e-77	1.827e-21	1.011e-79	1.827e-23
0.04	2.073e+11	2.069e-33	3.647e-20	9.151e-36	1.613e-22	7.989e-36	1.408e-22	7.989e-38	1.408e-24
0.06	2.744e+11	1.054e-09	1.761e-06	2.094e-12	3.497e-09	1.828e-12	3.053e-09	1.828e-14	3.053e-11
0.08	6.497e+12	3.257e-02	2.232e+01	5.154e-05	3.533e-02	4.499e-05	3.084e-02	4.499e-07	3.084e-04
0.1	2.409e+12	2.582e+00	7.590e+02	3.951e-03	1.161e+00	3.449e-03	1.014e+00	3.449e-05	1.014e-02
0.15	4.553e+12	4.671e+02	3.752e+04	7.691e-01	6.178e+01	6.714e-01	5.394e+01	6.714e-03	5.394e-01
0.2	1.197e+13	5.855e+03	2.428e+05	1.033e+01	4.285e+02	9.021e+00	3.741e+02	9.021e-02	3.741e+00
0.3	8.965e+12	1.813e+04	3.724e+05	3.439e+01	7.064e+02	3.002e+01	6.167e+02	3.002e-01	6.167e+00
0.4	2.409e+13	1.086e+05	1.485e+06	2.116e+02	2.893e+03	1.847e+02	2.526e+03	1.847e+00	2.526e+01

0.5	4.810e+13	3.848e+05	3.964e+06	7.553e+02	7.780e+03	6.594e+02	6.792e+03	6.594e+00	6.792e+01
0.6	4.185e+13	5.252e+05	4.378e+06	1.025e+03	8.545e+03	8.949e+02	7.460e+03	8.949e+00	7.460e+01
0.8	7.476e+13	1.872e+06	1.147e+07	3.560e+03	2.182e+04	3.108e+03	1.905e+04	3.108e+01	1.905e+02
1.0	5.982e+13	2.526e+06	1.247e+07	4.655e+03	2.299e+04	4.064e+03	2.007e+04	4.064e+01	2.007e+02
1.5	6.326e+13	6.636e+06	2.335e+07	1.117e+04	3.928e+04	9.747e+03	3.429e+04	9.747e+01	3.429e+02
2.0	3.131e+13	5.958e+06	1.727e+07	9.214e+03	2.671e+04	8.043e+03	2.332e+04	8.043e+01	2.332e+02
3.0	1.202e+13	4.895e+06	1.133e+07	6.641e+03	1.537e+04	5.798e+03	1.342e+04	5.798e+01	1.342e+02
4.0	5.230e+12	3.457e+06	7.018e+06	4.276e+03	8.682e+03	3.733e+03	7.580e+03	3.733e+01	7.580e+01
5.0	8.984e+11	8.373e+05	1.552e+06	9.599e+02	1.779e+03	8.380e+02	1.553e+03	8.380e+00	1.553e+01
6.0	3.195e+10	3.865e+04	6.728e+04	4.197e+01	7.306e+01	3.664e+01	6.378e+01	3.664e-01	6.378e-01
Total	**4.124e+14**	**2.726e+07**	**9.501e+07**	**4.255e+04**	**1.571e+05**	**3.715e+04**	**1.372e+05**	**3.715e+02**	**1.372e+03**

MicroShield 10.04
Enercon Services

Date	By	Checked

File Name	Run Date	Run Time	Duration
17-004-C_nobles.msd	October 14, 2017	9:01:08 AM	00:00:00

Project Info	
Case Title	Case 1
Description	Case 1
Geometry	7 - Cylinder Volume - Side Shields

Source Dimensions	
Height	774.497 cm (25 ft 4.9 in)
Radius	25.083 cm (9.9 in)

Dose Points

A	X	Y	Z
#1	129.54 cm (4 ft 3.0 in)	387.096 cm (12 ft 8.4 in)	0.0 cm (1 in)
#2	213.36 cm (7 ft .0 in)	387.096 cm (12 ft 8.4 in)	0.0 cm (1 in)

Shield

Shield N	Dimension	Material	Density (g/cm^3)
Source	1.53e+06 cm^3	Water	1
Transition		Air	0.00122
Air Gap		Air	0.00122
Wall Clad	2.858 cm	Iron	7.86
Top Clad	2.858 cm	Iron	7.86

Source Input: Grouping Method - Standard Indices
Number of Groups: 25
Lower Energy Cutoff: 0.015
Photons< 0.015: Included
Library: Grove

Nuclide	Ci	Bq	μCi/cm^3	Bq/cm^3
Ba-137m	9.9376e+001	3.6769e+012	6.4919e+001	2.4020e+006
Br-82	2.0710e+000	7.6627e+010	1.3529e+000	5.0058e+004
Br-83	2.6933e+001	9.9652e+011	1.7594e+001	6.5099e+005
Br-84	4.6171e+001	1.7083e+012	3.0162e+001	1.1160e+006
Br-85	5.5280e+001	2.0454e+012	3.6112e+001	1.3362e+006

Cs-132	2.1018e-001	7.7766e+009	1.3730e-001	5.0802e+003
Cs-134	2.1379e+002	7.9103e+012	1.3966e+002	5.1675e+006
Cs-134m	4.4846e+001	1.6593e+012	2.9296e+001	1.0840e+006
Cs-135	5.8597e-004	2.1681e+007	3.8279e-004	1.4163e+001
Cs-136	5.9500e+001	2.2015e+012	3.8869e+001	1.4382e+006
Cs-137	1.0505e+002	3.8868e+012	6.8625e+001	2.5391e+006
Cs-138	9.9930e+002	3.6974e+013	6.5281e+002	2.4154e+007
Cs-139	9.4610e+002	3.5006e+013	6.1806e+002	2.2868e+007
I-128	5.0713e+000	1.8764e+011	3.3129e+000	1.2258e+005
I-129	1.3207e-005	4.8867e+005	8.6278e-006	3.1923e-001
I-130	1.2647e+001	4.6793e+011	8.2617e+000	3.0568e+005
I-131	3.6790e+002	1.3612e+013	2.4033e+002	8.8923e+006
I-132	3.3039e+002	1.2224e+013	2.1583e+002	7.9858e+006
I-133	4.5970e+002	1.7009e+013	3.0031e+002	1.1111e+007
I-134	5.0362e+002	1.8634e+013	3.2899e+002	1.2173e+007
I-135	4.3076e+002	1.5938e+013	2.8140e+002	1.0412e+007
I-136	2.0359e+002	7.5327e+012	1.3300e+002	4.9209e+006
Rb-86	1.9825e+000	7.3354e+010	1.2951e+000	4.7920e+004
Rb-88	3.6616e+002	1.3548e+013	2.3920e+002	8.8503e+006
Rb-89	4.6793e+002	1.7314e+013	3.0568e+002	1.1310e+007
Rb-90	4.5207e+002	1.6727e+013	2.9532e+002	1.0927e+007
Rb-90m	1.0780e+002	3.9886e+012	7.0421e+001	2.6056e+006

Buildup: The material reference is Source.
Integration Parameters

Radial	10
Circumferential	10
Y Direction (axial)	20

Results - Dose Point # 1 - (129.54,387.096,0) cm

Energy (MeV)	Activity (Photons/sec)	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup	Absorbed Dose Rate mrad/hr No Buildup	Absorbed Dose Rate mrad/hr With Buildup	Absorbed Dose Rate mGy/hr No Buildup	Absorbed Dose Rate mGy/hr With Buildup
0.015	6.216e+11	0.000e+00	3.176e-22	0.000e+00	2.724e-23	0.000e+00	2.378e-23	0.000e+00	2.378e-25
0.03	2.551e+12	4.471e-76	8.551e-20	4.432e-78	8.475e-22	3.869e-78	7.398e-22	3.869e-80	7.398e-24

0.04	2.074e+11	3.466e-33	7.050e-20	1.533e-35	3.118e-22	1.338e-35	2.722e-22	1.338e-37	2.722e-24
0.06	2.744e+11	1.776e-09	2.951e-06	3.528e-12	5.861e-09	3.080e-12	5.117e-09	3.080e-14	5.117e-11
0.08	4.947e+11	4.134e-03	2.834e+00	6.541e-06	4.484e-03	5.711e-06	3.915e-03	5.711e-08	3.915e-05
0.1	6.545e+10	1.176e-01	3.453e+01	1.799e-04	5.282e-02	1.571e-04	4.611e-02	1.571e-06	4.611e-04
0.15	1.969e+12	3.392e+02	2.706e+04	5.586e-01	4.456e+01	4.876e-01	3.890e+01	4.876e-03	3.890e-01
0.2	2.257e+12	1.850e+03	7.632e+04	3.266e+00	1.347e+02	2.851e+00	1.176e+02	2.851e-02	1.176e+00
0.3	4.054e+12	1.372e+04	2.814e+05	2.602e+01	5.337e+02	2.272e+01	4.659e+02	2.272e-01	4.659e+00
0.4	1.704e+13	1.284e+05	1.758e+06	2.502e+02	3.425e+03	2.185e+02	2.990e+03	2.185e+00	2.990e+01
0.5	3.797e+13	5.080e+05	5.248e+06	9.971e+02	1.030e+04	8.705e+02	8.993e+03	8.705e+00	8.993e+01
0.6	3.923e+13	8.235e+05	6.895e+06	1.607e+03	1.346e+04	1.403e+03	1.175e+04	1.403e+01	1.175e+02
0.8	7.215e+13	3.026e+06	1.866e+07	5.756e+03	3.549e+04	5.025e+03	3.098e+04	5.025e+01	3.098e+02
1.0	5.430e+13	3.845e+06	1.913e+07	7.087e+03	3.526e+04	6.187e+03	3.079e+04	6.187e+01	3.079e+02
1.5	5.858e+13	1.035e+07	3.677e+07	1.741e+04	6.187e+04	1.520e+04	5.401e+04	1.520e+02	5.401e+02
2.0	2.029e+13	6.528e+06	1.914e+07	1.009e+04	2.960e+04	8.813e+03	2.584e+04	8.813e+01	2.584e+02
3.0	1.071e+13	7.420e+06	1.739e+07	1.007e+04	2.359e+04	8.788e+03	2.060e+04	8.788e+01	2.060e+02
4.0	4.920e+12	5.550e+06	1.141e+07	6.866e+03	1.411e+04	5.994e+03	1.232e+04	5.994e+01	1.232e+02
5.0	8.984e+11	1.433e+06	2.688e+06	1.643e+03	3.081e+03	1.434e+03	2.690e+03	1.434e+01	2.690e+01
6.0	3.189e+10	6.615e+04	1.165e+05	7.183e+01	1.265e+02	6.271e+01	1.104e+02	6.271e-01	1.104e+00
Total	**3.286e+14**	**3.969e+07**	**1.396e+08**	**6.188e+04**	**2.310e+05**	**5.402e+04**	**2.017e+05**	**5.402e+02**	**2.017e+03**
Results - Dose Point # 2 - (213.36,387.096,0) cm									
Energy	**Activity (Photons/sec)**	**Fluence Rate MeV/cm²/s**	**Fluence Rate MeV/cm²/s**	**Exposure Rate mR/hr**	**Exposure Rate mR/hr**	**Absorbed Dose Rate**	**Absorbed Dose Rate**	**Absorbed Dose Rate**	**Absorbed Dose Rate**

(MeV)		ec No Buildup	ec With Buildup	No Buildup	With Buildup	mrad/hr No Buildup	mrad/hr With Buildup	mGy/hr No Buildup	mGy/hr With Buildup
0.015	6.216e+11	0.000e+00	1.643e-22	0.000e+00	1.409e-23	0.000e+00	1.230e-23	0.000e+00	1.230e-25
0.03	2.551e+12	2.450e-76	4.425e-20	2.428e-78	4.385e-22	2.120e-78	3.828e-22	2.120e-80	3.828e-24
0.04	2.074e+11	2.070e-33	3.648e-20	9.156e-36	1.614e-22	7.993e-36	1.409e-22	7.993e-38	1.409e-24
0.06	2.744e+11	1.055e-09	1.762e-06	2.095e-12	3.499e-09	1.829e-12	3.054e-09	1.829e-14	3.054e-11
0.08	4.947e+11	2.481e-03	1.700e+00	3.926e-06	2.691e-03	3.427e-06	2.349e-03	3.427e-08	2.349e-05
0.1	6.545e+10	7.018e-02	2.063e+01	1.074e-04	3.156e-02	9.373e-05	2.755e-02	9.373e-07	2.755e-04
0.15	1.969e+12	2.021e+02	1.623e+04	3.327e-01	2.673e+01	2.905e-01	2.333e+01	2.905e-03	2.333e-01
0.2	2.257e+12	1.104e+03	4.579e+04	1.949e+00	8.082e+01	1.701e+00	7.055e+01	1.701e-02	7.055e-01
0.3	4.054e+12	8.202e+03	1.685e+05	1.556e+01	3.196e+02	1.358e+01	2.790e+02	1.358e-01	2.790e+00
0.4	1.704e+13	7.682e+04	1.050e+06	1.497e+02	2.046e+03	1.307e+02	1.786e+03	1.307e+00	1.786e+01
0.5	3.797e+13	3.038e+05	3.130e+06	5.964e+02	6.143e+03	5.207e+02	5.363e+03	5.207e+00	5.363e+01
0.6	3.923e+13	4.924e+05	4.105e+06	9.611e+02	8.012e+03	8.391e+02	6.995e+03	8.391e+00	6.995e+01
0.8	7.215e+13	1.807e+06	1.107e+07	3.438e+03	2.106e+04	3.001e+03	1.839e+04	3.001e+01	1.839e+02
1.0	5.430e+13	2.293e+06	1.132e+07	4.227e+03	2.087e+04	3.690e+03	1.822e+04	3.690e+01	1.822e+02
1.5	5.858e+13	6.147e+06	2.162e+07	1.034e+04	3.638e+04	9.029e+03	3.176e+04	9.029e+01	3.176e+02
2.0	2.029e+13	3.863e+06	1.120e+07	5.974e+03	1.732e+04	5.216e+03	1.512e+04	5.216e+01	1.512e+02
3.0	1.071e+13	4.366e+06	1.011e+07	5.924e+03	1.371e+04	5.171e+03	1.197e+04	5.171e+01	1.197e+02
4.0	4.920e+12	3.253e+06	6.604e+06	4.024e+03	8.171e+03	3.513e+03	7.133e+03	3.513e+01	7.133e+01
5.0	8.984e+11	8.377e+05	1.552e+06	9.603e+02	1.779e+03	8.384e+02	1.553e+03	8.384e+00	1.553e+01

6.0	3.189e+10	3.859e+04	6.716e+04	4.190e+01	7.294e+01	3.658e+01	6.367e+01	3.658e-01	6.367e-01
Total	**3.286e+14**	**2.349e+07**	**8.207e+07**	**3.666e+04**	**1.360e+05**	**3.200e+04**	**1.187e+05**	**3.200e+02**	**1.187e+03**

ENERCON Excellence—Every project. Every day.	CALCULATION PREPARATION CHECKLIST	CALC NO.	NEE-323-CALC-006
		REV.	0

	CHECKLIST ITEMS[1]	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?	☐	☐	☒
2.	Are the proper forms being used and are they the latest revision?	☒	☐	☐
3.	Have the appropriate client review forms/checklists been completed?	☐	☐	☒
4.	Are all pages properly identified with a calculation number, calculation revision and page number consistent with the requirements of the client's procedure?	☒	☐	☐
5.	Is all information legible and reproducible?	☒	☐	☐
6.	Is the calculation presented in a logical and orderly manner?	☒	☐	☐
7.	Is there an 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?	☐	☒	☐
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.	☒	☐	☐
10.	Is the format of the calculation consistent with applicable procedures and expectations?	☒	☐	☐
11.	Were design input/output documents properly updated to reference this calculation?	☐	☐	☒
12.	Can the calculation logic, methodology and presentation be properly understood without referring back to the originator for clarification?	☒	☐	☐
OBJECTIVE AND SCOPE				
13.	Does the calculation provide a clear concise statement of the problem and objective of the calculation?	☒	☐	☐
14.	Does the calculation provide a clear statement of quality classification?	☒	☐	☐
15.	Is the reason for performing and the end use of the calculation understood?	☒	☐	☐
16.	Does the calculation provide the basis for information found in the plant's license basis?	☐	☐	☒
17.	If so, is this documented in the calculation?	☐	☐	☒
18.	Does the calculation provide the basis for information found in the plant's design basis documentation?	☐	☐	☒
19.	If so, is this documented in the calculation?	☐	☐	☒
20.	Does the calculation otherwise support information found in the plant's design basis documentation?	☐	☐	☒

CHECKLIST ITEMS[1]		YES	NO	N/A
21.	If so, is this documented in the calculation?	☐	☐	☒
22.	Has the appropriate design or license basis documentation been revised, or has the change notice or change request documents being prepared for submittal?	☐	☐	☒
DESIGN INPUTS				
23.	Are design inputs clearly identified?	☒	☐	☐
24.	Are design inputs retrievable or have they been added as attachments?	☒	☐	☐
25.	If Attachments are used as design inputs or assumptions are the Attachments traceable and verifiable?	☒	☐	☐
26.	Are design inputs clearly distinguished from assumptions?	☒	☐	☐
27.	Does the calculation rely on Attachments for design inputs or assumptions? If yes, are the attachments properly referenced in the calculation?	☐	☒	☐
28.	Are input sources (including industry codes and standards) appropriately selected and are they consistent with the quality classification and objective of the calculation?	☒	☐	☐
29.	Are input sources (including industry codes and standards) consistent with the plant's design and license basis?	☒	☐	☐
30.	If applicable, do design inputs adequately address actual plant conditions?	☒	☐	☐
31.	Are input values reasonable and correctly applied?	☒	☐	☐
32.	Are design input sources approved?	☒	☐	☐
33.	Does the calculation reference the latest revision of the design input source?	☒	☐	☐
34.	Were all applicable plant operating modes considered?	☒	☐	☐
ASSUMPTIONS				
35.	Are assumptions reasonable/appropriate to the objective?	☒	☐	☐
36.	Is adequate justification/basis for all assumptions provided?	☒	☐	☐
37.	Are any engineering judgments used?	☐	☒	☐
38.	Are engineering judgments clearly identified as such?	☒	☐	☐
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?	☒	☐	☐
METHODOLOGY				
40.	Is the methodology used in the calculation described or implied in the plant's licensing basis?	☐	☒	☐

CHECKLIST ITEMS[1]		YES	NO	N/A
41.	If the methodology used differs from that described in the plant's licensing basis, has the appropriate license document change notice been initiated?	☐	☐	☒
42.	Is the methodology used consistent with the stated objective?	☒	☐	☐
43.	Is the methodology used appropriate when considering the quality classification of the calculation and intended use of the results?	☒	☐	☐
BODY OF CALCULATION				
44.	Are equations used in the calculation consistent with recognized engineering practice and the plant's design and license basis?	☒	☐	☐
45.	Is there reasonable justification provided for the use of equations not in common use?	☐	☐	☒
46.	Are the mathematical operations performed properly and documented in a logical fashion?	☒	☐	☐
47.	Is the math performed correctly?	☒	☐	☐
48.	Have adjustment factors, uncertainties and empirical correlations used in the analysis been correctly applied?	☒	☐	☐
49.	Has proper consideration been given to results that may be overly sensitive to very small changes in input?	☒	☐	☐
SOFTWARE/COMPUTER CODES				
50.	Are computer codes or software languages used in the preparation of the calculation?	☒	☐	☐
51.	Have the requirements of CSP 3.09 for use of computer codes or software languages, including verification of accuracy and applicability been met?	☒	☐	☐
52.	Are the codes properly identified along with source vendor, organization, and revision level?	☒	☐	☐
53.	Is the computer code applicable for the analysis being performed?	☒	☐	☐
54.	If applicable, does the computer model adequately consider actual plant conditions?	☒	☐	☐
55.	Are the inputs to the computer code clearly identified and consistent with the inputs and assumptions documented in the calculation?	☒	☐	☐
56.	Is the computer output clearly identified?	☒	☐	☐
57.	Does the computer output clearly identify the appropriate units?	☒	☐	☐
58.	Are the computer outputs reasonable when compared to the inputs and what was expected?	☒	☐	☐
59.	Was the computer output reviewed for ERROR or WARNING messages that could invalidate the results?	☒	☐	☐

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		REV.	0

CHECKLIST ITEMS[1]	YES	NO	N/A
RESULTS AND CONCLUSIONS			
60. Is adequate acceptance criteria specified?	☐	☐	☒
61. Are the stated acceptance criteria consistent with the purpose of the calculation, and intended use?	☐	☐	☒
62. Are the stated acceptance criteria consistent with the plant's design basis, applicable licensing commitments and industry codes, and standards?	☐	☐	☒
63. Do the calculation results and conclusions meet the stated acceptance criteria?	☐	☐	☒
64. Are the results represented in the proper units with an appropriate tolerance, if applicable?	☒	☐	☐
65. Are the calculation results and conclusions reasonable when considered against the stated inputs and objectives?	☒	☐	☐
66. Is sufficient conservatism applied to the outputs and conclusions?	☒	☐	☐
67. Do the calculation results and conclusions affect any other calculations?	☐	☒	☐
68. If so, have the affected calculations been revised?	☐	☐	☒
69. Does the calculation contain any conceptual, unconfirmed or open assumptions requiring later confirmation?	☐	☒	☐
70. If so, are they properly identified?	☐	☐	☒
DESIGN REVIEW			
71. Have alternate calculation methods been used to verify calculation results?	☐	☒	☐

Note:

1. 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: Blake Holton *Blake Holton* 12/13/17

Print Name and Sign Date