

ENCLOSURE 6
RBG-47847

Containment Doses for EALs, Calculation G13.18.9.4-045

<input type="checkbox"/> ANO-1	<input type="checkbox"/> ANO-2	<input type="checkbox"/> GGNS	<input type="checkbox"/> IP-2	<input type="checkbox"/> IP-3	<input type="checkbox"/> PLP
<input type="checkbox"/> JAF	<input type="checkbox"/> PNPS	<input checked="" type="checkbox"/> RBS	<input type="checkbox"/> VY	<input type="checkbox"/> W3	
<input type="checkbox"/> NP-GGNS-3	<input type="checkbox"/> NP-RBS-3				
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I. EC Markups Incorporated (N/A to NP calculations)

G13.18.9.4-045_EC 16369

II. Relationships:	Sht	Rev	Input Doc	Output Doc	Impact Y/N	Tracking No.
1. G13.18.9.5*061	N/A	002	<input checked="" type="checkbox"/>	<input type="checkbox"/>	N	
2. G13.18.9.4-049	N/A	000	<input type="checkbox"/>	<input checked="" type="checkbox"/>	Y	EC 74027
3. G13.18.9.5*065	N/A	001	<input checked="" type="checkbox"/>	<input type="checkbox"/>	N	
4. GE-22A3130AW	N/A	004	<input checked="" type="checkbox"/>	<input type="checkbox"/>	N	
5. PID-25-01B	N/A	007	<input checked="" type="checkbox"/>	<input type="checkbox"/>	N	
6. 0221.110-000-235	N/A	300	<input checked="" type="checkbox"/>	<input type="checkbox"/>	N	
7. 0221.110-000-236	N/A	300	<input checked="" type="checkbox"/>	<input type="checkbox"/>	N	
8. 0221.110-000-232	N/A	300	<input checked="" type="checkbox"/>	<input type="checkbox"/>	N	
9. 0221.120-000-070	N/A	300	<input checked="" type="checkbox"/>	<input type="checkbox"/>	N	
10. 0221.120-000-011	N/A	300	<input checked="" type="checkbox"/>	<input type="checkbox"/>	N	
11. 0221.120-000-021	N/A	300	<input checked="" type="checkbox"/>	<input type="checkbox"/>	N	
12. 0221.180-000-076	N/A	300	<input checked="" type="checkbox"/>	<input type="checkbox"/>	N	
13. 7222.251-000-001A	N/A	300	<input checked="" type="checkbox"/>	<input type="checkbox"/>	N	
14. 6244.400-912-001B	N/A	300	<input checked="" type="checkbox"/>	<input type="checkbox"/>	N	
15. RBS-SA-08-00002	N/A	000	<input checked="" type="checkbox"/>	<input type="checkbox"/>	N	
16. PN-228	N/A	003	<input checked="" type="checkbox"/>	<input type="checkbox"/>	N	
17. PN-330	N/A	001	<input checked="" type="checkbox"/>	<input type="checkbox"/>	N	
18. G13.18.9.4-051	N/A	000	<input type="checkbox"/>	<input checked="" type="checkbox"/>	Y	EC 74027
19. IA-RMS*1	N/A	005	<input checked="" type="checkbox"/>	<input type="checkbox"/>	N	
20. PR-C-358	N/A	001	<input checked="" type="checkbox"/>	<input type="checkbox"/>	N	
21. EV-001A	N/A	010	<input checked="" type="checkbox"/>	<input type="checkbox"/>	N	
22. EK-015A	N/A	003	<input checked="" type="checkbox"/>	<input type="checkbox"/>	N	
23. EK-015V	N/A	004	<input checked="" type="checkbox"/>	<input type="checkbox"/>	N	
24. ES-059A	N/A	006	<input checked="" type="checkbox"/>	<input type="checkbox"/>	N	

III. CROSS REFERENCES:

1. NEI 99-01, Rev. 6, Development of Emergency Action Levels for Non-Passive Reactors, November 2012
2. RBS Technical Specifications
3. Crane Technical Paper 410, 25th Printing, 1991
4. Handbook of Tables for Applied Engineering Science, 2nd Edition
5. Radiation Detection and Measurement, Glenn F. Knoll, 1979
6. Perry's Chemical Engineer's Handbook, 50th Edition, 1984
7. Federal Guidance Report No. 12 (FGR-12), EPA-402-R-93-081, September 1993
8. Radiological Health Handbook
9. Regulatory Guide 1.3 Rev. 2, 1974 Assumptions used for Evaluating the Potential Radiological Consequences of a Loss of Coolant Accident for Boiling Water Reactors

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- 10. Regulatory Guide 1.195, May 2003, Methods and Assumptions for Evaluating Radiological Consequences of Design Basis Accidents at Light-Water Nuclear Power Reactors
- 11. RBC-49932, RBS Issuance of Amendment re: 1.7 Percent Increase in Licensed Power Level (TAC NO. MB5094) / Amendment No. 129 TO NFP-47 / Safety Evaluation / RBF1-03-0022

IV. SOFTWARE USED:

Title: Microsoft Excel Version/Release: 2010 Disk/CD No. N/A
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Title: None Version/Release _____ Disk/CD No. _____

VI. OTHER CHANGES:

Supersede Calculation G13.18.9.4-049 Rev. 000
Supersede Calculation G13.18.9.4-051 Rev. 000

Revision	Record of Revision
0	Initial issue.
1	<p>This calculation is revised to reflect the current EN-DC-126 calculation format, utilize the current requirements of NEI 99-01 Rev. 6 EAL recommendations and basis, include the 24 month cycle source term, and account for the instrument accuracy of the containment and drywell radiation monitors. The extended duration dose rate reading determination portion has been deleted eliminating the need for use of the RADTRAD program.</p> <p>This calculation also incorporates and updates the information previously contained in calculation G13.18.9.4-049, Rev. 0, Drywell Doses for Emergency Action Levels (EALs). As a result, G13.18.9.4-049 will be superseded.</p> <p>This calculation also addresses and revises the information previously contained in calculation G13.18.9.4-051, Rev. 0, Drywell Doses for Emergency Action Levels (EAL-RC4) and no longer utilizes Grand Gulf information. As a result, G13.18.9.4-051 will be superseded.</p>

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Attachments

None

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5.0 PURPOSE

The purpose of this calculation is to determine the dose rate indicated by the DRMS Containment and Drywell Post Accident Monitors (PAMs) in the primary containment (RMS-RE16A, B) and drywell (RMS-RE20A, B) given the following scenarios:

1. An instantaneous release of all reactor coolant mass into primary containment, assuming the reactor coolant activity equals Technical Specification Allowable Limits. This should be determined using the reactor coolant noble gas and iodine inventory with RCS activity at Technical Specification allowable limits released instantaneously into the primary containment atmosphere. This corresponds to NEI 99-01 (Ref. III.1 page 90), RCS Barrier Threshold, Primary Containment Radiation, Loss 4.A.
2. An instantaneous release of all reactor coolant mass into the primary containment assuming that reactor coolant activity equals 300 uCi/gm dose equivalent I-131. Reactor coolant activity above this level is greater than that expected for iodine spikes and corresponds to an approximate range of 2% to 5% fuel clad damage. This corresponds to NEI 99-01 (Ref. III.1, page 86), Clad Barrier Threshold, Primary Containment Radiation, Loss 4.A.
3. An instantaneous release of all reactor coolant mass into the primary containment assuming that 20% of the fuel cladding has failed. This corresponds to NEI 99-01 (Ref. III.1, page 95, 96), Primary Containment Barrier Threshold, Primary Containment Radiation, Loss 4.A.

This is being done to support the revision of the Emergency Plan updating the Emergency Action Levels (EALs) to meet the guidelines of NEI 99-01 Rev. 6 (Ref. III.1).

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6.0 CONCLUSION

The analysis results, including consideration of instrument uncertainty, is provided in Section 10, pages 43 and 44. The analysis and associated discussion provides the basis for the following recommended dose rate threshold values for the Containment and Drywell Post Accident radiation monitors RMS-RE16A, B and RMS-RE20A, B for the three scenarios listed in Section 5.

	Containment RMS-RE16A, B R/hr	Drywell RMS-RE20A, B R/hr
Case 1, 4 uCi/g Dose Equivalent I-131	≥ 59 $(\geq 5.90E+01)$	≥ 38 $(\geq 3.80E+01)$
Case 2, 5% Clad Damage	> 3000 $(\geq 3.00E+03)$	> 2000 $(\geq 2.00E+03)$
Case 3, 20% Clad Damage	$\geq 12,000$ $(\geq 1.20E+04)$	$\geq 8,000$ $(\geq 8.00E+03)$

7.0 INPUT AND DESIGN CRITERIA

Definitions

AST -	Alternative (or Alternate) Source Term (synonymous with "Revised Source Term" or RST)
DBA -	Design Basis Accident
EAL -	Emergency Action Level
EIV -	Early In-Vessel Phase of AST
GAP -	Gap Phase of AST
LOCA -	Loss of Coolant Accident
RCPB -	Reactor Coolant Pressure Boundary
RG -	Regulatory Guide
ST -	Source Term

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General Inputs

Drywell Free Volume = $236,136 \text{ ft}^3 - 11,811 \text{ ft}^3 - 71.6 \text{ ft}^3 - 513 \text{ ft}^3$
= $235,539.589 \text{ ft}^3$ use $235,540 \text{ ft}^3$ (Ref. II.16 and EC Markups
EC 5000047947, EC 108,
EC 23493, EC 25424)

Containment Free Volume = $1,191,590 \text{ ft}^3 - 15.27 \text{ ft}^3 - 0.74 \text{ ft}^3$
 $1,191,573.99 \text{ ft}^3$ use $1,191,574 \text{ ft}^3$ (Ref. II.17 and EC
Markups EC
5000048884, EC
5000050413, EC
23493, EC 62305)

RMS-RE16A Detector Location = RB Floor Elevation 186' 3" (Ref. II.23)
Detector Centerline Elevation 194' 3"
Azimuth 315

RMS-RE16B Detector Location = RB Floor Elevation 186' 3" (Ref. II.23)
Detector Centerline Elevation 194' 3"
Azimuth 45

RMS-RE20A Detector Location = DW Floor Elevation 114' 0" (Ref. II.22)
Detector Centerline Elevation 125' 3"
Azimuth 163

RMS-RE20B Detector Location = DW Floor Elevation 114' 0" (Ref. II.22)
Detector Centerline Elevation 143' 4"
Azimuth $201^\circ 55'$

Containment Inner Diameter = 120' (Ref. II.21)

Containment Monitor Floor Elevation = 186' 3" (Ref. II.23)

Elevation of Containment Dome Bend Line = 226' 3" (Ref. II.21)

Containment Gross Volume Above Dome Bend Line = $226,195 \text{ ft}^3$ (Ref. II.17 pg. 10)

Equipment Volume 186' 3" Elevation = 4984.7 ft^3 (Ref. II.17 pg. 16)

Drywell Inner Diameter = 68' 11.25" (Ref. II.21)

Reactor Shield Wall Outer Radius = 14' 11" (Ref. II.24)

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Rated Thermal Power = 3100 MWt

This is consistent with the rated thermal power of 3091 MWt in the RBS operating license (Reference III.2 Operating License) including a power level uncertainty of 0.3% which was approved by the NRC in the SER for the Thermal Power Optimization project (Reference III.11).

Case 1 Coolant Mass (Steam and Water) Determination Inputs

Maximum reactor coolant weight at normal water level (includes vessel and recirculation loops) @ 75 deg. F = 685,000 lb	(Ref. II.4, pg. 3)
Normal water level (nominal instrument zero) = 520.62" above vessel "0"	(Ref. II.5)
Head Flange level = 842" above vessel "0"	(Ref. II.5)
Nominal Vessel Radius = 109"	(Ref. II.6 and II.7)
Vessel Head height above flange surface = 109"	(Ref. II.8)
Weight of Shroud Head and Separators = 88,000 lbs	(Ref. II.9)
Shroud Head and Separator Material = Austenitic Stainless Steel	(Ref. II.9)
Weight of Steam Dryer = 64,000 lbs	(Ref. II.10)
Steam Dryer Material = 304 Series Stainless Steel	(Ref. II.11)
ρ Water at 70°F = 62.305 lb/ft ³	(Ref. III.3 pg. A6)
Nominal Specific Gravity (s.g.) 304 Stainless Steel = 8.02	(Ref. III.4, pg. 118)
Main Steam Line Volume to Outboard MSIV including RCIC = 1221 ft ³	(Ref. II.12)
Reactor Operating Pressure = 1070 psia	(Ref. II.13)
Specific Volume of Steam at 1050 psia = 0.42224 ft ³ /lb	(Ref. III.3 pg. A-15)
Specific Volume of Steam at 1100 psia = 0.40058 ft ³ /lb	(Ref. III.3 pg. A-15)

Case 1 Source Term Inputs

Steady State Dose Equivalent I-131 Limit = ≤ 0.2 uCi/gm (Ref. III.2, TS 3.4.8)

Action Level Limit Dose Equivalent I-131 = ≤ 4 uCi/gm (Ref. III.2, TS 3.4.8)

Steady State Noble Gas Gross Gamma Activity Limit
 ≤ 290 mCi/s after decay of 30 minutes (Ref. III.2, TS 3.7.4)

Reactor Coolant System Isotopic Concentrations (Ref. II.20 Image pg. 11, 12)

Table 7.1

AST Group	Isotope	Reactor Coolant Concentration uCi/gm	Reactor Steam Concentration uCi/gm (release rate 303.9 mCi/s)
1	Kr-85		3.00E-05
1	Kr-85m		9.70E-03
1	Kr-87		3.30E-02
1	Kr-88		3.30E-02
1	Xe-133		1.30E-02
1	Xe-135		3.60E-02
2	I-131	2.10E-02	3.40E-04
2	I-132	3.10E-01	4.70E-03
2	I-133	2.80E-01	4.40E-03
2	I-134	4.90E-01	9.70E-03
2	I-135	2.70E-01	4.30E-03
3	Cs-134	1.70E-04	1.70E-07
3	Cs-136	1.10E-04	1.10E-07
3	Cs-137	4.40E-04	4.40E-07

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1 Bq = 2.703E-11 Ci

(Ref. III.5 pg. 4)

1 Sv = 100 Rem

(Ref. III.5 pg. 78)

Iodine dose conversion factor, Sv/Bq from NUREG/CR-6604, Table 1.4.3.3-2 contained in Ref. II.14, image page 384 and 385, Thyroid line, Inhaled Chronic column for each isotope below.

Table 7.2

Isotope	Dose Conversion Factor, 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
Cs-134	1.11E-08
Cs-136	1.73E-09
Cs-137	7.93E-09

Case 2 and 3 Source Term

Release Fractions

Table 7.3

AST Radionuclide Groups and BWR Gap Release Fractions

Group*	Title	Elements	Gap Release
1	Noble Gases	Xe, Kr	0.05
2	Halogens	I, Br	0.05
3	Alkali Metals	Cs, Rb	0.05
4	Tellurium Group	Te, Sb, Se	0
5	Barium, Strontium	Ba, Sr	0
7	Noble Metals	Ru, Rh, Pd, Mo, Tc, Co	0
8	Cerium Group	Ce, Pu, Np	0
9	Lanthanides	La, Zr, Nd, Eu, Nb, Pm, Pr, Sm, Y, Cm, Am	0

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Nuclide Inventory

**Table 7.4
BWR Core Inventories**

AST Group	Isotope	Half-life (sec) (Ref. II.14, pg. 81-82)	Gamma Energy, MeV (Ref. III.7, Table A.1, pg. 200-211)	24 Month Cycle Concentration, Ci/MWt (Ref. II.15)
1	Kr-85	3.38E+08	2.00E-03	3.66E+02
1	Kr-85m	1.61E+04	1.58E-01	7.02E+03
1	Kr-87	4.58E+03	7.93E-01	1.35E+04
1	Kr-88	1.02E+04	1.96E+00	1.89E+04
1	Xe-133	4.53E+05	4.60E-02	5.26E+04
1	Xe-135	3.27E+04	2.49E-01	1.99E+04
2	I-131	6.95E+05	3.82E-01	2.70E+04
2	I-132	8.21E+03	2.28E+00	3.92E+04
2	I-133	7.49E+04	6.07E-01	5.52E+04
2	I-134	3.16E+03	2.63E+00	6.06E+04
2	I-135	2.38E+04	1.58E+00	5.17E+04
3	Rb-86	1.61E+06	9.50E-02	6.31E+01
3	Cs-134	6.51E+07	1.55E+00	6.11E+03
3	Cs-136	1.13E+06	2.17E+00	2.00E+03
3	Cs-137	9.51E+08	6.62E-01	3.95E+03

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8.0 ASSUMPTIONS

Case 1

8.1 Case 1 requires that all reactor coolant mass be released into the primary containment. For this analysis, reactor coolant volume is assumed to be composed of the volume of water in the reactor vessel and recirculation loops and the volume of steam out to the outboard MSIV's including the RCIC steam supply line to the outer isolation valve. For simplicity, vessel instrument zero (520.62 inches Above Vessel 0 or AV0) is assumed to be the dividing line between the vessel water and steam volumes. The steam separator and steam dryer are assumed to completely reside in the steam volume portion of the reactor.

It should be noted that the mass of water and steam used in this analysis are significantly greater than that used for design basis events, such as the Main Steam Line Break analyzed in G13.18.9.5*065. In design basis events, the core shroud maintains a floodable volume to the level of the top of the jet pumps and only one of two recirculation loops (in a recirculation line double ended rupture) would lose volume. This analysis interprets "all" to imply 100% of the water and steam in the reactor coolant boundary as opposed to "all postulated water and steam released".

8.2 The steam volume is assumed to contain saturated steam at a normal reactor operating pressure of 1070 psia. Assuming normal operating pressure and saturated conditions maximizes the mass per cubic foot of steam and corresponding source term.

8.3 The vessel steam volume will be determined by treating the reactor vessel as a right circular cylinder with a height from vessel instrument zero level to the top head flange level. The volume of the separator and dryer will be subtracted from this volume.

8.4 The reactor vessel top head is treated as a hemisphere with a radius equal to the vessel radius and height equal to the vessel radius.

8.5 Case 1 requires the coolant iodine concentration and noble gas concentration to be at the Technical Specification limit. The coolant iodine concentration will have two cases, one at the TS Steady State Limit of 0.2 uCi/g dose equivalent I-131 and the second at 0.4 uCi/g dose equivalent I-131. The design basis liquid source term isotopes from Ref. II.20 will be normalized to the dose equivalent concentration. For both dose equivalent iodine cases, the design basis noble gas source term will be used. The design basis noble gas concentration is based upon a release rate of approximately 304 mCi/sec with 30 minutes decay which exceeds the TS limit of a release rate of ≤ 290 mCi/sec after 30 minutes decay.

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8.6 The activity concentrations for the reactor coolant and main steam are based upon Normal Water Chemistry concentrations rather than Hydrogen Water Chemistry concentrations. This is due to the implementation of Noble Metals chemistry and the substantial reduction in hydrogen injection rates from the historical full power HWC application rate of 77 scfm hydrogen to the current application rate of approximately 10.5 scfm hydrogen. The current addition rate more closely reflects Normal Water Chemistry conditions than HWC conditions. Other conservatisms present in the calculation more than accommodate any non-conservatisms resulting from the slight changes in steam line iodine concentration due to HWC.

Case 2 and 3

8.7 As Case 2 and 3 scenarios involve release of gap activity, the source term will be calculated based upon 3100 MWt consistent with the LOCA and Main Steam Line Break analysis. Refer to input item for rated thermal power on page 9.

All Cases

8.8 The radiation monitors can only detect the portion of the release that is within their "line of sight". Therefore the containment volume used in the geometry factor will be limited to the containment volume above the floor elevation where the detectors are located (elevation 186' 3"). The containment 186' 3" floor elevation is the refueling floor and has thick concrete floors surrounding the upper pool area. The shielding provided by the pools and the surrounding concrete pool support structure and area concrete floors reduce the dose contribution from the elevations below to insignificant levels. Similarly, geometry factor volume for the drywell will reduce the drywell volume to account for the area shielded by the reactor vessel and primary shield wall (bioshield).

8.9 The release is instantaneous and uniformly mixed in the containment and drywell. A flashing fraction of 100% is assumed for the isotopes in the liquid phase (i.e. 100% of the halogen and cesium activity present in the coolant is released).

8.10 There is no dilution, plate out or scrubbing of the release.

8.11 Only the AST fuel gap inventory isotopes are considered.

8.12 The chemical form of the release is 95% cesium iodine (CsI) (which is a particulate or aerosol), 4.85% elemental iodine, and 0.15% organic iodine

8.13 Containment leakage is 0 scfm

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9.0 METHOD OF ANALYSIS

Case 1

An instantaneous release of all reactor coolant mass into primary containment, assuming the reactor coolant activity equals Technical Specification Allowable Limits. This should be determined using the reactor coolant noble gas and iodine inventory with RCS activity at Technical Specification allowable limits released instantaneously into the primary containment atmosphere. This corresponds to NEI 99-01 (Ref. III.1 page 90), RCS Barrier Threshold, Primary Containment Radiation, Loss 4.A.

The reactor coolant mass is defined in Assumption 8.1.

The mass of water is obtained from Reference II.4.

The total volume of steam, V_{st} is calculated with the following formula:

$$V_{st} \text{ ft}^3 = V_{rs} \text{ ft}^3 - V_{sd} \text{ ft}^3 + V_h \text{ ft}^3 + V_{ms} \text{ ft}^3$$

Where:

V_{rs} = Volume of the vessel between instrument zero and the head flange, ft^3

$$V_{rs}, \text{ ft}^3 = \pi * (\text{vessel radius, in})^2 * (\text{Head flange level, in AVO} - \text{Normal water level, in AVO}) / 1728 \text{ in}^3/\text{ft}^3$$

V_{sd} = Volume displaced by the steam separator and steam dryer, ft^3

$$V_{sd} \text{ ft}^3 = (\text{Separator Weight, lb} + \text{Dryer Weight, lb}) / (\rho \text{ water lb/ft}^3 * \text{s.g. 304SS})$$

V_h = Volume of the vessel head, ft^3

$$V_h \text{ ft}^3 = 2/3 * \pi * r^2 * h * 1728 \text{ in}^3/\text{ft}^3 \quad (\text{Ref. III.6 pg. 2-12})$$

Where: r = head radius = vessel radius, in
 h = head height, in

V_{ms} = Volume of the main steam lines to the outboard MSIV's, ft^3 , from Reference II.12.

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The mass of steam, Ms, is determined based on the total volume and steam specific volume at the conditions of Assumption 8.2.

$$M_s, \text{ lb} = V_{st} \text{ ft}^3 / SV_{1070}, \text{ ft}^3/\text{lb}$$

Mw, lb = Maximum reactor coolant weight at normal water level

The source term is based upon the source term for normal operating conditions from PR-C-358 (Ref. II.20). The dose equivalent I-131 concentration is calculated based upon the activity concentration in the reactor coolant (water) only. The coolant activity released will be determined for both the normal equilibrium Dose Equivalent I-131 concentration of 0.2 uCi/gm and maximum transient limit of 4 uCi/gm. As the cesium is released primarily in the form of CsI, the cesium species present in the reactor coolant will also be included in the normalization process.

The activity released in the steam phase, including iodine and cesium isotopes will be determined in the same manner as the noble gases, i.e. concentration of each isotope multiplied by the mass of steam released. The activity in the steam phase is equal to the activity of each isotope in the vessel meeting or exceeding the value corresponding to the TS release rate of $\leq 290 \text{ mCi/sec}$ or

The detector reading will be based upon the sum of the coolant and steam activity releases of each isotope.

The equations used are generally the same as those in Ref. II.3, however some are in a slightly different format with differing variable names for clarity purposes.

Dose Equivalent RCS Iodine Activity Concentration

$$C_i = CD_i (L * DCF_{I-131}) / \sum^i (CD_i * DCF_i) \quad (\text{Ref. II.3 pg. 17})$$

Where: C_i = reactor coolant activity concentration for isotope I for Technical Specification reactor coolant dose equivalent I-131 activity limit L, uCi/gm.

L = Technical Specification dose equivalent I-131 reactor coolant activity limit
= 0.2 uCi/gm dose equivalent I-131 steady state limit
= 4.0 uCi/gm dose equivalent I-131 action level limit

CD_i = design basis reactor coolant activity concentration for isotope i from Table 7.1, uCi/gm

DCF_{I-131} = thyroid inhalation dose conversion factor for I-131, from Table 7.2, converted from units of Sv/Bq to Rem/Ci

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DCF_i = thyroid inhalation dose conversion factor for isotope i , from Table 7.2, converted from units of Sv/Bq to Rem/Ci

Equivalent Iodine Activity Released in Water

$$C_i * CF = F_{Ci}$$

Where: C_i = reactor coolant activity concentration for iodine isotope i for Technical Specification reactor coolant dose equivalent I-131 activity limit L , uCi/gm.

CF = Conversion Factor, $453.6 \text{ g/lb} * 1\text{E-}6 \text{ Ci/uCi} = 4.54\text{E-}4 \text{ g}\cdot\text{Ci} / \text{lbm}\cdot\text{uCi}$

F_{Ci} = Reactor Coolant Iodine Concentration, Ci/lb

Iodine Activity Released in Water

$$A_{wi} = F_{Ci} * M_w$$

Where: A_{wi} = reactor coolant water activity released for isotope i , Ci

F_{Ci} = Reactor Coolant Iodine Concentration, Ci/lb

M_w = Mass of Reactor Water released, lbm

Activity Released in Steam

$$C_i * CF = F_{Ci}$$

Where: C_i = reactor steam activity concentration for isotope i \geq the TS limit of 290 uCi/sec with 30 minutes decay, uCi/gm.

CF = Conversion Factor, $453.6 \text{ g/lb} * 1\text{E-}6 \text{ Ci/uCi} = 4.54\text{E-}4 \text{ g}\cdot\text{Ci} / \text{lbm}\cdot\text{uCi}$

F_{Ci} = Reactor Steam isotope i Concentration, Ci/lb

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$$A_{si} = F_{Ci} * M_s$$

Where: A_{si} = reactor coolant steam activity released for Iodine isotope i, Ci

F_{Ci} = Reactor Steam Iodine Concentration, Ci/lb

M_s = Mass of Steam released, lbm

Total Iodine Activity Released

$$A_i = A_{wi} + A_{si}$$

Where: A_i = total activity released for Iodine isotope i, Ci

A_{wi} = reactor coolant water activity released for Iodine isotope i, Ci

A_{si} = reactor coolant steam activity released for Iodine isotope i, Ci

The total isotopic activity determined for 0.2 uCi/gm Dose Equivalent I131 and 4 uCi/gm Dose Equivalent I131 is assumed to be released instantaneously into the combined containment and drywell free volume. The combined containment and drywell volume will be used to determine the concentration of each isotope present in each area.

The formula used to manually convert the curies of each isotope released to the combined containment and drywell volume is from Reg. Guide 1.3:

$$\text{Dose, } \gamma, \text{ Rads/sec} = \sum_i (0.25 * E_{avei} * X_i) \quad (\text{Ref. III.9 pg. 1.3-2})$$

Where: $\text{Dose, } \gamma,$ = gamma dose, Rads/sec
 E_{ave} = average gamma energy for isotope i, MeV
 X_i = concentration in Ci/m³ for isotope i

$$X_i = C_i / V_{tot}$$

Where: C_i = isotopic concentration for isotope i, Curies
 V_{tot} = Containment/Drywell volume m³

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Because the radioactive material released is assumed to be distributed throughout the combined containment and drywell volume, an adjustment factor is required to distribute the dose rate for each isotope to the individual containment and drywell area volumes. In addition, only a portion of the containment and drywell volumes in the vicinity of each detector will contribute to the detector reading. To adjust the total volume to the volume of the individual containment and drywell spaces and account for the detector location, a Geometry Factor is used. This converts the infinite cloud dose to a volume specific cloud dose.

$$GF = 352 / V^{0.338} \quad (\text{III.10, pg. 11})$$

Where: GF is Geometry Factor, unitless
V is the volume of the source cloud, m³

The containment volume used in this factor will be the volume only in the vicinity of RMS-RE16A and B, which is the free volume of containment above the 186'3" floor elevation. This includes the cylindrical volume between the elevation 186'3" floor and the elevation of the dome bend line at 226' 3", and the volume of the dome area above the bend line at elevation 226' 3". The free air portion is determined by subtracting the volume of equipment on or above 186'3" from the total volume above the 186'3" floor. Equipment volume is obtained from Ref. II.17.

Volume of Containment above 186'3", ft³ = Cylindrical Volume between 186'3" and dome bend line elevation, ft³ + containment dome volume, ft³

Cylindrical Volume between 186'3" and dome bend line elevation = $\pi * r^2 * h$

Where: r = inner radius of containment, ft (= inner diameter / 2, ft)
h = height between 186'3" and dome bend line elevation, ft

Vc, Geometry Factor Volume of Containment above 186'3, ft³ =
Volume of Containment above 186'3", ft³ - Equipment Volume above 186'3, ft³

Vc, m³ = Geometry Factor Volume of Containment above 186'3, ft³ * 2.832E-2 m³/ft³

The drywell geometry factor volume will be determined to only include the volume in the line of sight for RMS-RE20A, B. The detectors in the drywell cannot "see" the portion shielded by the reactor shield wall area. As the reactor and reactor shield wall is a vertical cylinder within the cylindrical drywell, the volume of the drywell hidden can be calculated by determining the hidden and visible detector areas. The hidden drywell volume is determined by multiplying the full drywell open volume by the ratio of hidden area to seen area.

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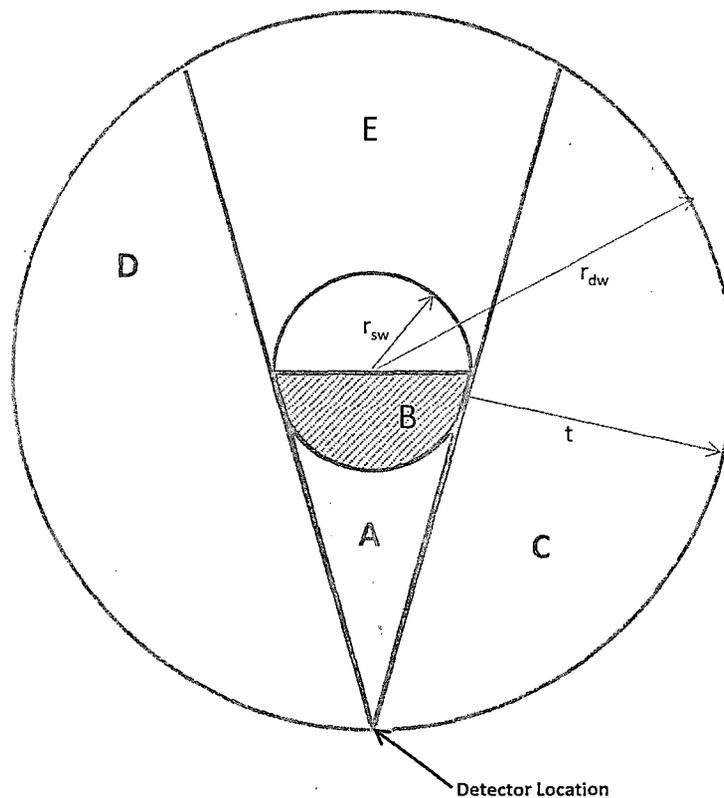
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In order to determine the area the drywell detectors can see, lines (chords) are drawn from the detector location tangent to the reactor shield wall on each side. (Refer to the figure below.) The tangent points are on either side of the reactor shield wall diameter. These chords enclose areas on either side of the reactor shield wall that can be seen by the detector (Areas C and D). The height of the chord, h , is equal to the drywell radius minus the reactor shield wall radius. Area C is equal to Area D.

Area A and B enclose the triangular area directly in front of the detector extending to the centerline of the reactor shield wall. Triangle AB has a height equal to the drywell radius and a base equal to the reactor shield wall diameter. Area B is half of the area encircled by the reactor shield wall. Area A is determined by subtracting area B from the area of Triangle AB.

The total area that can be seen by the detector = Area A + Area C + Area D



r_{sw} , ft = Reactor shield wall outer radius, ft

A_{sw} , ft² = Reactor Shield Wall Area = $\pi * r_{sw}^2$

d_{dw} , ft = Drywell Inner Diameter, ft

r_{dw} , ft = Drywell Radius, ft = Drywell Inner Diameter, ft / 2

Adw = Drywell Area = $\pi * r_{dw}^2$

t , ft = r_{dw} , ft - r_{sw} , ft

Area of Triangle AB, ft² = $\frac{1}{2} * b * h$

Where b = reactor shield wall inner diameter, ft

h = radius of the drywell, ft

Area of B, ft² = $\frac{1}{2} * \pi * r_{sw}^2$

Area of A, ft² = Area of Triangle AB - Area of B

θ , radians = $2 \cos^{-1}(r_{sw} / r_{dw})$ (Ref. III.6 pg. 2-11)

Area of Sector C or D, ft² = $\frac{1}{2} * r_{dw}^2 * \theta$, radians (Ref. III.6 pg. 2-11)

A_s , ft², area seen by the detector = Area A + Area C + Area D

D_{CF} , Drywell Volume Correction Factor = A_s / Adw

V_D , Geometry Factor Drywell Volume, m³ = Drywell Free Volume, m³ * D_{CF}

For Containment $GF_C = 352 / V_C^{0.338}$

Where: V_C is the Geometry Factor volume of containment, m³

For Drywell $GF_D = 352 / V_D^{0.338}$

Where: V_D is the Geometry Factor volume of the drywell, m³

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The units of dose used are R/hr rather than R/sec. Incorporating these factors into the previous Gamma Dose formula provides the following formula for the gamma dose in containment:

$$\text{Dose, } \gamma, \text{ Containment, R/hr} = \sum_i (0.25 * E_{avei} * C_i / V_{tot}) * 3600 \text{ sec/hr} / (352 / V_c^{0.338})$$

Where: Dose, γ , Containment = Containment gamma dose, R/hr
 E_{ave} = average gamma energy for isotope i, MeV
 C_i = isotopic concentration for isotope i, Curies
 V_{tot} = Containment/Drywell volume m^3
 V_c is the Geometry Factor volume of containment, m^3

The total gamma dose in the drywell is similar:

$$\text{Dose, } \gamma, \text{ Drywell, R/hr} = \sum_i (0.25 * E_{avei} * C_i / V_{tot}) * 3600 \text{ sec/hr} / (352 / V_D^{0.338})$$

Where: Dose, γ , Containment = Containment gamma dose, R/hr
 E_{ave} = average gamma energy for isotope i, MeV
 C_i = isotopic concentration for isotope i, Curies
 V_{tot} = Containment/Drywell volume m^3
 V_D is the Geometry Factor volume of the drywell, m^3

The total gamma dose for both containment and drywell is determined for both 0.2 uCi/gm and 4 uCi/gm Dose Equivalent I131.

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Case 2

An instantaneous release of all reactor coolant mass into the primary containment assuming that reactor coolant activity equals 300 uCi/gm dose equivalent I-131. Reactor coolant activity above this level is greater than that expected for iodine spikes and corresponds to an approximate range of 2% to 5% fuel clad damage. This corresponds to NEI 99-01 (Ref. III.1, page 86), Clad Barrier Threshold, Primary Containment Radiation, Loss 4.A.

River Bend is currently an AST plant, therefore, the AST source term will be used in this calculation. The EAL requires doses for 5% clad damage (i.e., no fuel melt assumed). The AST gap activity will be used in this evaluation. This phase begins when the fuel cladding begins to fail. During this phase the fission gases contained in the plenum and between the fuel pellet and cladding are released. Typically, these gases include the noble gases, the halogens, and the alkali metals. The bulk of the fission products are retained in the fuel pellets. Table 7.3 contains the NUREG 1465 release groups and the gap release fractions for these groups.

GE provided a generic core source term as part of the transition to 24 Month Cycles (Ref. II.15). The source term for nuclides in the AST groups 1, 2, and 3 are listed in Table 7.4

The curies of each isotope for a complete gap release of the noble gases, the halogens, and the alkali metals is determined as follows:

$$\text{Gap Release}_i, C_i = C_i / \text{MWt}_i * \text{MWt} * \text{Gap Release Fraction}_i$$

The damage fraction (DF_5) associated with 5% clad damage is 5% of the complete gap release.

$$\text{Damage Release}_i, C_i = \text{Gap Release}_i * DF_5$$

$$\text{By definition } DF_5 = 0.05$$

As with Case 1, 100% of the activity is assumed to be instantaneously released to the combined containment and drywell volume. The containment and drywell dose associated with each isotope will be calculated using the RG 1.3 methodology including conversions and geometry adjustment factors from Case 1. The formulas for the dose in containment and drywell are reproduced below.

$$\text{Dose, } \gamma, \text{ Containment, R/hr} = \sum_i (0.25 * E_{avei} * C_i / V_{tot}) * 3600 \text{ sec/hr} / (352 / V_c^{0.338})$$

Where:

- Dose, γ , Containment = Containment gamma dose, R/hr
- E_{ave} = average gamma energy for isotope i , MeV
- C_i = isotopic concentration for isotope i , Curies
- V_{tot} = Containment/Drywell volume m^3
- V_c is the volume of containment, m^3

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$$\text{Dose, } \gamma, \text{ Drywell, R/hr} = \sum_i (0.25 * E_{avei} * C_i / V_{tot}) * 3600 \text{ sec/hr} / (352 / V_D)^{0.338}$$

Where: Dose, γ , Containment = Containment gamma dose, R/hr
 E_{ave} = average gamma energy for isotope i, MeV
 C_i = isotopic concentration for isotope i, Curies
 V_{tot} = Containment/Drywell volume m^3
 V_D is the volume of the drywell, m^3

Case 3

An instantaneous release of all reactor coolant mass into the primary containment assuming that 20% of the fuel cladding has failed. This corresponds to NEI 99-01 (Ref. III.1, page 95, 96), Primary Containment Barrier Threshold, Primary Containment Radiation, Loss 4.A.

As with case 2, this case involves the release of gap activity associated with clad damage. The formulas for analysis of this case are identical to case 2 with the exception of the damage fraction and damage release.

The damage fraction (DF_{20}) associated with 20% clad damage is 20% of the complete gap release.

$$\text{Damage Release}_i, C_i = \text{Gap Release}_i * DF_{20}$$

$$\text{By definition } DF_{20} = 0.20$$

Instrument Accuracy

Per Ref. II.19 pg. 28 and 42, the overall accuracy of RMS-RE16A, B and RMS-RE20A, B is +100%, - 50% of reading. All other allowances are included in the overall accuracy.

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10.0 CALCULATIONS

The total volume of steam, Vst is calculated with the following formula:

$$V_{st} \text{ ft}^3 = V_{rs} \text{ ft}^3 - V_{sd} \text{ ft}^3 + V_h \text{ ft}^3 + V_{ms} \text{ ft}^3$$

Where:

Vrs = Volume of the vessel between instrument zero and the head flange, ft³

$$V_{rs}, \text{ ft}^3 = \pi * (\text{vessel radius, in})^2 * (\text{Head flange level, in AVO} - \text{Normal water level, in AVO}) / 1728 \text{ in}^3/\text{ft}^3$$

Nominal Vessel Radius = 109" (Ref. II.6 and II.7)

Head Flange level = 842" above vessel "0" (Ref. II.5)

Normal water level (nominal instrument zero) = 520.62" above vessel "0" (Ref. II.5)

$$V_{rs}, \text{ ft}^3 = (\pi * (109")^2 * (842" - 520.62")) / 1728 \text{ in}^3/\text{ft}^3 = 6941.9 \text{ ft}^3$$

Vsd = Volume displaced by the steam separator and steam dryer, ft³

$$V_{sd} \text{ ft}^3 = (\text{Separator Weight, lb} + \text{Dryer Weight, lb}) / (\rho \text{ water lb}/\text{ft}^3 * \text{s.g. 304SS})$$

Weight of Shroud Head and Separators = 88,000 lbs (Ref. II.9)

Weight of Steam Dryer = 64,000 lbs (Ref. II.10)

ρ Water at 70°F = 62.305 lb/ft³ (Ref. III.3 pg. A6)

Nominal Specific Gravity (s.g.) 304 Stainless Steel = 8.02 (Ref. III.4, pg. 118)

$$V_{sd} \text{ ft}^3 = (88,000 \text{ lb} + 64,000 \text{ lb}) / (62.305 \text{ lb}/\text{ft}^3 * 8.02) = 304.2 \text{ ft}^3$$

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Vh = Volume of the vessel head, ft³

$$Vh \text{ ft}^3 = 2/3 * \pi * r^2 * h * 1728 \text{ in}^3/\text{ft}^3 \quad (\text{Ref. III.6 pg. 2-12})$$

Where: r = head radius = vessel radius, in
h = head height, in

Nominal Vessel Radius = 109" (Ref. II.6 and II.7)

Vessel Head height above flange surface = 109" (Ref. II.8)

$$Vh \text{ ft}^3 = (2/3 * \pi * (109")^2 * 109") / 1728 \text{ in}^3/\text{ft}^3 = \mathbf{1569.6 \text{ ft}^3}$$

Vms = Volume of the main steam lines to the outboard MSIV's, ft³, from Reference II.12.

Main Steam Line Volume to Outboard MSIV including RCIC = 1221 ft³ (Ref. II.12)

$$Vms = \mathbf{1221 \text{ ft}^3}$$

$$Vst \text{ ft}^3 = Vrs \text{ ft}^3 - Vsd \text{ ft}^3 + Vh \text{ ft}^3 + Vms \text{ ft}^3$$

$$Vst \text{ ft}^3 = 6941.9 \text{ ft}^3 - 304.2 \text{ ft}^3 + 1569.6 \text{ ft}^3 + 1221 \text{ ft}^3 = \mathbf{9428.3 \text{ ft}^3}$$

Interpolate specific volume of steam at 1050 psia and 1100 psia to obtain specific volume of steam at 1170 psia.

Specific Volume of Steam at 1050 psia = 0.42224 ft³/lb (Ref. III.3 pg. A-15)

Specific Volume of Steam at 1100 psia = 0.40058 ft³/lb (Ref. III.3 pg. A-15)

Specific Volume of Steam at 1070 (by interpolation) = 0.41358 ft³/lb

$$Ms, \text{ lb} = Vst \text{ ft}^3 / SV_{1070}, \text{ ft}^3/\text{lb}$$

$$Ms, \text{ lb} = 9428.3 \text{ ft}^3 / 0.41358 \text{ ft}^3/\text{lb} = 22,796.8 \text{ lb use } 22797 \text{ lb}$$

Mw, lb = Maximum reactor coolant weight at normal water level from Ref. II.4

$$Mw = 685,000 \text{ lb} \quad (\text{Ref. II.4, pg. 3})$$

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Case 1

Dose Equivalent RCS Iodine Activity Concentration

The following equations are placed into an Excel spread sheet.

Dose Equivalent RCS Iodine Activity Concentration

$$C_i = CD_i (L * DCF_{I-131}) / \sum^i (CD_i * DCF_i) \quad (\text{Ref. II.3 pg. 17})$$

Where: C_i = reactor coolant activity concentration for isotope I for Technical Specification reactor coolant dose equivalent I-131 activity limit L, uCi/gm.

L = Technical Specification dose equivalent I-131 reactor coolant activity limit
= 0.2 uCi/gm dose equivalent I-131 steady state limit
= 4.0 uCi/gm dose equivalent I-131 action level limit

CD_i = design basis reactor coolant activity concentration for isotope i from Table 7.1, uCi/gm

DCF_{I-131} = thyroid inhalation dose conversion factor for I-131, from Table 7.2, converted from units of Sv/Bq to Rem/Ci

DCF_i = thyroid inhalation dose conversion factor for isotope i , from Table 7.2, converted from units of Sv/Bq to Rem/Ci

Equivalent Iodine Activity Released in Water

$$C_i * CF = FC_i$$

Where: C_i = reactor coolant activity concentration for Iodine isotope I for Technical Specification reactor coolant dose equivalent I-131 activity limit L, uCi/gm.

CF = Conversion Factor, $453.6 \text{ g/lb} * 1\text{E-6 Ci/uCi} = 4.54\text{E-4 g}\cdot\text{Ci} / \text{lbm}\cdot\text{uCi}$

FC_i = Reactor Coolant Iodine Concentration, Ci/lb

Iodine Activity Released in Water

$$A_{wi} = FC_i * M_w$$

Where: A_{wi} = reactor coolant water activity released for isotope i , Ci

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FCi = Reactor Coolant Iodine Concentration, Ci/lb

Mw = Mass of Reactor Water released, lbm

Activity Released in Steam

$$Ci * CF = FCi$$

Where: Ci = reactor steam activity concentration for isotope $i \geq$ the TS limit of 290 uCi/sec with 30 minutes decay, uCi/gm.

CF = Conversion Factor, $453.6 \text{ g/lb} * 1E-6 \text{ Ci/uCi} = 4.54E-4 \text{ g}\cdot\text{Ci} / \text{lbm}\cdot\text{uCi}$

FCi = Reactor Steam isotope i Concentration, Ci/lb

$$Asi = FCi * Ms$$

Where: Asi = reactor coolant steam activity released for Iodine isotope i , Ci

FCi = Reactor Steam Iodine Concentration, Ci/lb

Ms = Mass of Steam released, lbm

Total Iodine Activity Released

$$Ai = Awi + Asi$$

Where: Ai = total activity released for Iodine isotope i , Ci

Awi = reactor coolant water activity released for Iodine isotope i , Ci

Asi = reactor coolant steam activity released for Iodine isotope i , Ci

The following pages include the results of the above equations performed in an Excel spreadsheet for both 0.2 uCi/g I-131 dose equivalent and 4 uCi/g dose equivalent.

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0.2 uci/gm I-131 Dose Equivalent

RCS Isotope	Design Basis RCS Concentration, CDi (uCi/gm)	Thyroid Dose Conversion Factor, DCFi (Rem/Ci)	CDi *DCFi	L, uCi/gm	DCF _{I-131}	S CDi*DCFi	Ci, uCi/gm
I-131	2.10E-02	1.08E+06	2.27E+04	0.2	1.08E+06	8.40E+04	5.40E-02
I-132	3.10E-01	6.44E+03	2.00E+03	0.2	1.08E+06	8.40E+04	7.97E-01
I-133	2.80E-01	1.80E+05	5.03E+04	0.2	1.08E+06	8.40E+04	7.20E-01
I-134	4.90E-01	1.07E+03	5.22E+02	0.2	1.08E+06	8.40E+04	1.26E+00
I-135	2.70E-01	3.13E+04	8.45E+03	0.2	1.08E+06	8.40E+04	6.94E-01
Cs-134	1.70E-04	4.11E+04	6.98E+00	0.2	1.08E+06	8.40E+04	4.37E-04
Cs-136	1.10E-04	6.40E+03	7.04E-01	0.2	1.08E+06	8.40E+04	2.83E-04
Cs-137	4.40E-04	2.93E+04	1.29E+01	0.2	1.08E+06	8.40E+04	1.13E-03
TOTAL			8.40E+04				

RCS Isotope	Equivalent RCS Concentration, Ci, uCi/gm	Conversion Factor g-Ci / lbm-uCi	Reactor water concentration Fci (Ci/lbm)	Mass Water Released, Mw, lbm	Activity Released Water, Awi, Curies
I-131	5.40E-02	4.54E-04	2.45E-05	6.85E+05	1.68E+01
I-132	7.97E-01	4.54E-04	3.62E-04	6.85E+05	2.48E+02
I-133	7.20E-01	4.54E-04	3.27E-04	6.85E+05	2.24E+02
I-134	1.26E+00	4.54E-04	5.72E-04	6.85E+05	3.92E+02
I-135	6.94E-01	4.54E-04	3.15E-04	6.85E+05	2.16E+02
Cs-134	4.37E-04	4.54E-04	1.99E-07	6.85E+05	1.36E-01
Cs-136	2.83E-04	4.54E-04	1.28E-07	6.85E+05	8.80E-02
Cs-137	1.13E-03	4.54E-04	5.14E-07	6.85E+05	3.52E-01

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Reactor Steam Isotope	Design Basis Reactor Steam Concentration, CDi (uCi/gm)	Conversion Factor g-Ci / lbm-uCi	Reactor Steam concentration Fci (Ci/lbm)	Mass Steam Released, Ms, lbm	Activity Released Steam, Aws, Curies
Kr-85	3.00E-05	4.54E-04	1.36E-08	2.28E+04	3.10E-04
Kr-85m	9.70E-03	4.54E-04	4.40E-06	2.28E+04	1.00E-01
Kr-87	3.30E-02	4.54E-04	1.50E-05	2.28E+04	3.42E-01
Kr-88	3.30E-02	4.54E-04	1.50E-05	2.28E+04	3.42E-01
Xe-133	1.30E-02	4.54E-04	5.90E-06	2.28E+04	1.35E-01
Xe-135	3.60E-02	4.54E-04	1.63E-05	2.28E+04	3.73E-01
I-131	3.40E-04	4.54E-04	1.54E-07	2.28E+04	3.52E-03
I-132	4.70E-03	4.54E-04	2.13E-06	2.28E+04	4.86E-02
I-133	4.40E-03	4.54E-04	2.00E-06	2.28E+04	4.55E-02
I-134	9.70E-03	4.54E-04	4.40E-06	2.28E+04	1.00E-01
I-135	4.30E-03	4.54E-04	1.95E-06	2.28E+04	4.45E-02
Cs-134	1.70E-07	4.54E-04	7.72E-11	2.28E+04	1.76E-06
Cs-136	1.10E-07	4.54E-04	4.99E-11	2.28E+04	1.14E-06
Cs-137	4.40E-07	4.54E-04	2.00E-10	2.28E+04	4.55E-06

Isotope	Activity Released Water, Awi, Curies	Activity Released Steam, Aws, Curies	0.2 uCi/gm I-131 Equivalent, Curies
Kr-85		3.10E-04	3.10E-04
Kr-85m		1.00E-01	1.00E-01
Kr-87		3.42E-01	3.42E-01
Kr-88		3.42E-01	3.42E-01
Xe-133		1.35E-01	1.35E-01
Xe-135		3.73E-01	3.73E-01
I-131	1.68E+01	3.52E-03	1.68E+01
I-132	2.48E+02	4.86E-02	2.48E+02
I-133	2.24E+02	4.55E-02	2.24E+02
I-134	3.92E+02	1.00E-01	3.92E+02
I-135	2.16E+02	4.45E-02	2.16E+02
Cs-134	1.36E-01	1.76E-06	1.36E-01
Cs-136	8.80E-02	1.14E-06	8.80E-02
Cs-137	3.52E-01	4.55E-06	3.52E-01

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4 uci/gm I-131 Dose Equivalent

RCS Isotope	Design Basis RCS Concentration, CDi (uCi/gm)	Thyroid Dose Conversion Factor, DCFi (Rem/Ci)	CDi *DCFi	L, uCi/gm	DCF _{I-131}	□ CDi*DCFi	Ci, uCi/gm
I-131	2.10E-02	1.08E+06	2.27E+04	4	1.08E+06	8.40E+04	1.08E+00
I-132	3.10E-01	6.44E+03	2.00E+03	4	1.08E+06	8.40E+04	1.59E+01
I-133	2.80E-01	1.80E+05	5.03E+04	4	1.08E+06	8.40E+04	1.44E+01
I-134	4.90E-01	1.07E+03	5.22E+02	4	1.08E+06	8.40E+04	2.52E+01
I-135	2.70E-01	3.13E+04	8.45E+03	4	1.08E+06	8.40E+04	1.39E+01
Cs-134	1.70E-04	4.11E+04	6.98E+00	4	1.08E+06	8.40E+04	8.75E-03
Cs-136	1.10E-04	6.40E+03	7.04E-01	4	1.08E+06	8.40E+04	5.66E-03
Cs-137	4.40E-04	2.93E+04	1.29E+01	4	1.08E+06	8.40E+04	2.26E-02
TOTAL			8.40E+04				

RCS Isotope	Equivalent RCS Concentration, Ci, uCi/gm	Conversion Factor g-Ci / lbm-uCi	Reactor water concentration Fci (Ci/lbm)	Mass Water Released, Mw, lbm	Activity Released Water, Awi, Curies
I-131	1.08E+00	4.54E-04	4.90E-04	6.85E+05	3.36E+02
I-132	1.59E+01	4.54E-04	7.24E-03	6.85E+05	4.96E+03
I-133	1.44E+01	4.54E-04	6.54E-03	6.85E+05	4.48E+03
I-134	2.52E+01	4.54E-04	1.14E-02	6.85E+05	7.84E+03
I-135	1.39E+01	4.54E-04	6.31E-03	6.85E+05	4.32E+03
Cs-134	8.75E-03	4.54E-04	3.97E-06	6.85E+05	2.72E+00
Cs-136	5.66E-03	4.54E-04	2.57E-06	6.85E+05	1.76E+00
Cs-137	2.26E-02	4.54E-04	1.03E-05	6.85E+05	7.04E+00

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Reactor Steam Isotope	Design Basis Reactor Steam Concentration, CDi (uCi/gm)	Conversion Factor g-Ci / lbm-uCi	Reactor Steam concentration Fci (Ci/lbm)	Mass Steam Released, Ms, lbm	Activity Released Steam, Aws, Curies
Kr-85	3.00E-05	4.54E-04	1.36E-08	2.28E+04	3.10E-04
Kr-85m	9.70E-03	4.54E-04	4.40E-06	2.28E+04	1.00E-01
Kr-87	3.30E-02	4.54E-04	1.50E-05	2.28E+04	3.42E-01
Kr-88	3.30E-02	4.54E-04	1.50E-05	2.28E+04	3.42E-01
Xe-133	1.30E-02	4.54E-04	5.90E-06	2.28E+04	1.35E-01
Xe-135	3.60E-02	4.54E-04	1.63E-05	2.28E+04	3.73E-01
I-131	3.40E-04	4.54E-04	1.54E-07	2.28E+04	3.52E-03
I-132	4.70E-03	4.54E-04	2.13E-06	2.28E+04	4.86E-02
I-133	4.40E-03	4.54E-04	2.00E-06	2.28E+04	4.55E-02
I-134	9.70E-03	4.54E-04	4.40E-06	2.28E+04	1.00E-01
I-135	4.30E-03	4.54E-04	1.95E-06	2.28E+04	4.45E-02
Cs-134	1.70E-07	4.54E-04	7.72E-11	2.28E+04	1.76E-06
Cs-136	1.10E-07	4.54E-04	4.99E-11	2.28E+04	1.14E-06
Cs-137	4.40E-07	4.54E-04	2.00E-10	2.28E+04	4.55E-06

Isotope	Activity Released Water, Awi, Curies	Activity Released Steam, Aws, Curies	4 uCi/gm I-131 Equivalent, Curies
Kr-85		3.10E-04	3.10E-04
Kr-85m		1.00E-01	1.00E-01
Kr-87		3.42E-01	3.42E-01
Kr-88		3.42E-01	3.42E-01
Xe-133		1.35E-01	1.35E-01
Xe-135		3.73E-01	3.73E-01
I-131	3.36E+02	3.52E-03	3.36E+02
I-132	4.96E+03	4.86E-02	4.96E+03
I-133	4.48E+03	4.55E-02	4.48E+03
I-134	7.84E+03	1.00E-01	7.84E+03
I-135	4.32E+03	4.45E-02	4.32E+03
Cs-134	2.72E+00	1.76E-06	2.72E+00
Cs-136	1.76E+00	1.14E-06	1.76E+00
Cs-137	7.04E+00	4.55E-06	7.04E+00

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A summary of the Case 1 0.2 uCi/g and 4 uCi/g source terms is provided in the following table.

Isotope	0.2 uCi/gm I-131 Equivalent, Curies	4 uCi/gm I-131 Equivalent, Curies
Kr-85	3.10E-04	3.10E-04
Kr-85m	1.00E-01	1.00E-01
Kr-87	3.42E-01	3.42E-01
Kr-88	3.42E-01	3.42E-01
Xe-133	1.35E-01	1.35E-01
Xe-135	3.73E-01	3.73E-01
I-131	1.68E+01	3.36E+02
I-132	2.48E+02	4.96E+03
I-133	2.24E+02	4.48E+03
I-134	3.92E+02	7.84E+03
I-135	2.16E+02	4.32E+03
Cs-134	1.36E-01	2.72E+00
Cs-136	8.80E-02	1.76E+00
Cs-137	3.52E-01	7.04E+00

Determine the Containment and Drywell Dose Rate Readings

Containment/Drywell Volume, ft³ = Containment Volume, ft³ + Drywell Volume, ft³

Drywell Volume = 236,136 ft³ - 11.811 ft³ - 71.6 ft³ - 513 ft³
= 235,539.589 ft³ use 235,540 ft³

(Ref. II.16 and EC Markups
EC 5000047947, EC 108,
EC 23493, EC 25424)

Containment Free Volume = 1,191,590 ft³ - 15.27 ft³ - 0.74 ft³
1,191,573.99 ft³ use 1,191,574 ft³

(Ref. II.17 and EC
Markups EC
5000048884, EC
5000050413, EC
23493, EC 62305)

Containment/Drywell Volume, ft³ = 1,191,574 ft³ + 235,540 ft³
= 1,427,114 ft³ OR 1.427E6 ft³

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$$\text{ft}^3 * 2.832\text{E-}2 = \text{m}^3 \quad (\text{Ref. III.8 pg. 25})$$

$$\text{Containment Free Volume, m}^3 = 1,191,573.99 \text{ ft}^3 * 2.832\text{E-}2 = 33,745.38 \text{ m}^3$$

$$\text{Drywell Free Volume, m}^3 = 235,539.589 \text{ ft}^3 * 2.832\text{E-}2 = 6,670.48 \text{ m}^3$$

$$\text{Containment/Drywell Free Volume, m}^3 = 1,427,114 \text{ ft}^3 * 2.832\text{E-}2 = 40,416 \text{ m}^3$$

Containment and Drywell Volumes for Geometry Factor

$$\text{Elevation of Containment Dome Bend Line} = 226' 3'' \quad (\text{Ref. II.21})$$

$$\text{Containment Inner Diameter} = 120' \quad (\text{Ref. II.21})$$

$$\text{Containment Gross Volume Above Dome Bend Line} = 226,195 \text{ ft}^3 \quad (\text{Ref. II.17 pg. 10})$$

$$\text{Equipment Volume 186' 3" Elevation} = 4984.7 \text{ ft}^3 \quad (\text{Ref. II.17 pg. 16})$$

$$\text{Drywell Inner Diameter} = 68' 11.25'' \quad (\text{Ref. II.21})$$

$$\text{Reactor Shield Wall Outer Radius} = 14' 11'' \quad (\text{Ref. II.24})$$

$$\text{Volume of Containment above 186'3", ft}^3 =$$

$$\begin{aligned} &\text{Cylindrical Volume between 186'3" and dome bend line elevation, ft}^3 \\ &+ \text{containment dome volume, ft}^3 \end{aligned}$$

$$\text{Cylindrical Volume between 186'3" and dome bend line elevation, ft}^3 = \pi * r^2 * h$$

$$\begin{aligned} \text{Where: } &r = \text{inner radius of containment, ft (= inner diameter / 2, ft)} \\ &h = \text{height between 186'3" and dome bend line elevation, ft} \end{aligned}$$

$$r = \text{inner radius of containment, ft (= inner diameter / 2, ft)} = 120' / 2 = 60'$$

$$h = 226' 3'' - 186' 3'' = 40'$$

$$\begin{aligned} &\text{Cylindrical Volume between 186'3" and dome bend line elevation} \\ &= \pi * 60'^2 * 40' = 452,389.342 \text{ ft}^3 \end{aligned}$$

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Volume of Containment above 186'3", ft³ =

$$452,389.342 \text{ ft}^3 + 226,195 \text{ ft}^3 = 678,584.342 \text{ ft}^3$$

Free Air Volume of Containment above 186'3, ft³ =

$$\text{Volume of Containment above 186'3", ft}^3 - \text{Equipment Volume above 186'3, ft}^3$$

$$\begin{aligned} V_c, \text{ Geometry Factor Free Air Volume of Containment above 186'3, ft}^3 \\ = 678,584.342 \text{ ft}^3 - 4984.7 \text{ ft}^3 = \mathbf{673,599.642 \text{ ft}^3 *} \end{aligned}$$

$$\begin{aligned} V_c, \text{ Geometry Factor Free Air Volume of Containment above 186'3, m}^3 \\ = 673,599.642 \text{ ft}^3 * 2.832\text{E-}2 = \mathbf{19,076.342 \text{ m}^3} \end{aligned}$$

r_{sw} , ft = Reactor shield wall outer radius, ft = 14' 11" or 14.917'

$$A_{sw}, \text{ ft}^2 = \text{Reactor Shield Wall Area} = \pi * r_{sw}^2$$

$$A_{sw}, \text{ ft}^2 = \text{Reactor Shield Wall Area} = \pi * 14.917^2 = 699.057 \text{ ft}^2$$

d_{dw} , ft = Drywell Inner Diameter, ft = 68' 11.25" or 68.938'

r_{dw} , ft = Drywell Radius, ft = Drywell Inner Diameter, ft / 2 = 68.938 / 2 = 34.469 ft

$$A_{dw} = \text{Drywell Area} = \pi * r_{dw}^2$$

$$A_{dw} = \pi * 34.469^2 = 3732.564 \text{ ft}^2$$

t , ft = r_{dw} , ft - r_{sw} , ft

$$t, \text{ ft} = 34.469 \text{ ft} - 14.917 \text{ ft} = 19.552 \text{ ft}$$

Area of Triangle AB, ft² = 1/2 * b * h

Where b = reactor shield wall inner diameter, ft

h = radius of the drywell, ft

$$\text{Area of Triangle AB, ft}^2 = 14.917' * 34.469 = 514.174 \text{ ft}^2$$

$$\text{Area of B, ft}^2 = \frac{1}{2} * \pi * r_{sw}^2$$

$$\text{Area of B, ft}^2 = \frac{1}{2} * \pi * 14.917^2 = 349.529 \text{ ft}^2$$

$$\text{Area of A, ft}^2 = \text{Area of Triangle AB} - \text{Area of B}$$

$$\text{Area of A, ft}^2 = 514.174 \text{ ft}^2 - 349.529 \text{ ft}^2 = 164.645 \text{ ft}^2$$

$$\theta, \text{ radians} = 2 \cos^{-1}(r_{sw} / r_{dw})$$

$$\begin{aligned} \theta, \text{ radians} &= 2 \cos^{-1}(14.917 / 34.469) \\ &= 2 \cos^{-1}(0.433) = 2.246 \text{ radians (128.714 deg)} \end{aligned}$$

$$\begin{aligned} \text{Area of Sector C or D, ft}^2 &= \frac{1}{2} * r_{dw}^2 * \theta, \text{ radians} \\ &= \frac{1}{2} * 34.469^2 * 2.246 \text{ radians} = 1334.25 \text{ ft}^2 \end{aligned}$$

$$A_s, \text{ ft}^2, \text{ area seen by the drywell detector} = \text{Area A} + \text{Area C} + \text{Area D}$$

$$A_s, \text{ ft}^2 = 164.645 \text{ ft}^2 + 1334.25 \text{ ft}^2 + 1334.25 \text{ ft}^2 = 2833.145 \text{ ft}^2$$

$$\begin{aligned} D_{CF}, \text{ Drywell Volume Correction Factor} &= A_s / A_{dw} \\ &= 2833.145 \text{ ft}^2 / 3732.564 \text{ ft}^2 = 0.759 \end{aligned}$$

$$V_D, \text{ Geometry Factor Drywell Volume, m}^3 = \text{Drywell Free Volume, m}^3 * D_{CF}$$

$$V_D, \text{ m}^3 = 6,670.48 \text{ m}^3 * 0.759 = 5062.894 \text{ m}^3$$

$$\text{For Containment} \quad GF_C = 352 / V_C^{0.338}$$

Where: V_C is the Geometry Factor volume of containment, m^3

$$GF_C = 352 / 19,076.342^{0.338} = 12.58$$

$$\text{For Drywell} \quad GF_D = 352 / V_D^{0.338}$$

Where: V_D is the Geometry Factor volume of the drywell, m^3

$$GF_D = 352 / 5062.894^{0.338} = 19.7$$

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The units used are R/hr rather than Rads/sec. Incorporating these factors into the previous Gamma Dose formula provides the following formula for the gamma dose in containment:

$$\text{Dose, } \gamma, \text{ Containment, R/hr} = \sum_i (0.25 * E_{avei} * C_i / V_{tot}) * 3600 \text{ sec/hr} / (352 / V_c^{0.338})$$

Where:

- Dose, γ , Containment = Containment gamma dose, R/hr
- E_{ave} = average gamma energy for isotope i, MeV
- C_i = isotopic concentration for isotope i, Curies
- V_{tot} = Containment/Drywell volume m^3
- V_c is the Geometry Factor volume of containment, m^3

$$\text{Dose, } \gamma, \text{ Drywell, R/hr} = \sum_i (0.25 * E_{avei} * C_i / V_{tot}) * 3600 \text{ sec/hr} / (352 / V_D^{0.338})$$

Where:

- Dose, γ , Containment = Containment gamma dose, R/hr
- E_{ave} = average gamma energy for isotope i, MeV
- C_i = isotopic concentration for isotope i, Curies
- V_{tot} = Containment/Drywell volume m^3
- V_D is the Geometry Factor volume of the drywell, m^3

An Excel spread sheet is used to calculate the total containment dose rate and total drywell dose rate for 0.2 uCi/gm and 4 uCi/g dose equivalent I-131. The results are shown on the following tables:

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0.2 uCi/gm I-131 Equivalent Containment and Drywell Dose Rate

Isotope	0.2 uCi/gm I-131 Equivalent, Curies	Gamma Energy, MeV	GF _C	Containment Dose Rate, R/hr	GF _D	Drywell Dose Rate, R/hr
Kr-85	3.10E-04	2.00E-03	12.58	1.10E-09	19.70	7.02E-10
Kr-85m	1.00E-01	1.58E-01	12.58	2.81E-05	19.70	1.79E-05
Kr-87	3.42E-01	7.93E-01	12.58	4.79E-04	19.70	3.06E-04
Kr-88	3.42E-01	1.96E+00	12.58	1.18E-03	19.70	7.57E-04
Xe-133	1.35E-01	4.60E-02	12.58	1.10E-05	19.70	6.99E-06
Xe-135	3.73E-01	2.49E-01	12.58	1.64E-04	19.70	1.05E-04
I-131	1.68E+01	3.82E-01	12.58	1.14E-02	19.70	7.25E-03
I-132	2.48E+02	2.28E+00	12.58	1.00E+00	19.70	6.39E-01
I-133	2.24E+02	6.07E-01	12.58	2.41E-01	19.70	1.54E-01
I-134	3.92E+02	2.63E+00	12.58	1.82E+00	19.70	1.17E+00
I-135	2.16E+02	1.58E+00	12.58	6.04E-01	19.70	3.86E-01
Cs-134	1.36E-01	1.55E+00	12.58	3.73E-04	19.70	2.38E-04
Cs-136	8.80E-02	2.17E+00	12.58	3.38E-04	19.70	2.16E-04
Cs-137	3.52E-01	6.62E-01	12.58	4.12E-04	19.70	2.63E-04
TOTAL				3.68E+00		2.35E+00

4 uCi/gm I-131 Equivalent Containment and Drywell Dose Rate

Isotope	4 uCi/gm I-131 Equivalent, Curies	Gamma Energy, MeV	GF _C	Containment Dose Rate, R/hr	GF _D	Drywell Dose Rate, R/hr
Kr-85	3.10E-04	2.00E-03	12.58	1.10E-09	19.70	7.02E-10
Kr-85m	1.00E-01	1.58E-01	12.58	2.81E-05	19.70	1.79E-05
Kr-87	3.42E-01	7.93E-01	12.58	4.79E-04	19.70	3.06E-04
Kr-88	3.42E-01	1.96E+00	12.58	1.18E-03	19.70	7.57E-04
Xe-133	1.35E-01	4.60E-02	12.58	1.10E-05	19.70	6.99E-06
Xe-135	3.73E-01	2.49E-01	12.58	1.64E-04	19.70	1.05E-04
I-131	3.36E+02	3.82E-01	12.58	2.27E-01	19.70	1.45E-01
I-132	4.96E+03	2.28E+00	12.58	2.00E+01	19.70	1.28E+01
I-133	4.48E+03	6.07E-01	12.58	4.81E+00	19.70	3.07E+00
I-134	7.84E+03	2.63E+00	12.58	3.65E+01	19.70	2.33E+01
I-135	4.32E+03	1.58E+00	12.58	1.21E+01	19.70	7.71E+00
Cs-134	2.72E+00	1.55E+00	12.58	7.46E-03	19.70	4.76E-03
Cs-136	1.76E+00	2.17E+00	12.58	6.76E-03	19.70	4.32E-03
Cs-137	7.04E+00	6.62E-01	12.58	8.25E-03	19.70	5.27E-03
TOTAL				7.36E+01		4.70E+01

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Case 2

An Excel spread sheet with the isotopes from Table 7.4 is used with the following formulas to calculate the containment and drywell doses for this case. The tabular results are provided on the following page.

$$\text{Gap Release}_i, C_i = C_i / \text{MWt}_i * \text{MWt} * \text{Gap Release Fraction}_i$$

$$\text{MWt} = 3100$$

$$\text{Gap Release Fraction} = 0.05$$

Table 7.3

$$\text{Gap Release}_i, C_i = C_i / \text{MWt}_i * 3100 \text{ MWt} * 0.05$$

$$\text{Damage Release}_i, C_i = \text{Gap Release}_i * \text{DF}_5$$

$$\text{Damage Release}_i, C_i = \text{Gap Release}_i * 0.05$$

$$\text{Dose, } \gamma, \text{ Containment, Rem/hr} = \sum_i (0.25 * E_{\text{ave}i} * C_i / V_{\text{tot}}) * 3600 \text{ sec/hr} / (352 / V_c^{0.338})$$

Where: Dose, γ , Containment = Containment gamma dose, R/hr
 E_{ave} = average gamma energy for isotope i, MeV
 C_i = isotopic concentration for isotope i, Curies
 V_{tot} = Containment/Drywell volume m^3
 V_c is the volume of containment, m^3

$$V_{\text{tot}} = 40,426 \text{ m}^3$$

$$V_c = 19,076.342 \text{ m}^3$$

$$\text{Dose, } \gamma, \text{ Drywell, Rem/hr} = \sum_i (0.25 * E_{\text{ave}i} * C_i / V_{\text{tot}}) * 3600 \text{ sec/hr} / (352 / V_D^{0.338})$$

Where: Dose, γ , Containment = Containment gamma dose, R/hr
 E_{ave} = average gamma energy for isotope i, MeV
 C_i = isotopic concentration for isotope i, Curies
 V_{tot} = Containment/Drywell volume m^3
 V_D is the volume of the drywell, m^3

$$V_{\text{tot}} = 40,426 \text{ m}^3$$

$$V_D, \text{ m}^3 = 5062.894 \text{ m}^3$$

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Containment and Drywell Dose Rates with 5% Clad Damage

Isotope	Half-life, (sec)	Gamma Energy, MeV	24 Month Cycle Conc., Ci/MWt	Total Conc., Ci	Gap Release, Ci	5% Clad Damage Release, Ci	GF _C	Containment Dose Rate, R/hr	GF _D	Drywell Dose Rate, R/hr
Kr-85	3.38E+08	2.00E-03	3.66E+02	1.13E+06	5.67E+04	2.84E+03	12.58	1.00E-02	19.70	6.41E-03
Kr-85m	1.61E+04	1.58E-01	7.02E+03	2.18E+07	1.09E+06	5.44E+04	12.58	1.52E+01	19.70	9.71E+00
Kr-87	4.58E+03	7.93E-01	1.35E+04	4.19E+07	2.09E+06	1.05E+05	12.58	1.47E+02	19.70	9.38E+01
Kr-88	1.02E+04	1.96E+00	1.89E+04	5.86E+07	2.93E+06	1.46E+05	12.58	5.08E+02	19.70	3.24E+02
Xe-133	4.53E+05	4.60E-02	5.26E+04	1.63E+08	8.15E+06	4.08E+05	12.58	3.32E+01	19.70	2.12E+01
Xe-135	3.27E+04	2.49E-01	1.99E+04	6.17E+07	3.08E+06	1.54E+05	12.58	6.80E+01	19.70	4.34E+01
I-131	6.95E+05	3.82E-01	2.70E+04	8.37E+07	4.19E+06	2.09E+05	12.58	1.41E+02	19.70	9.03E+01
I-132	8.21E+03	2.28E+00	3.92E+04	1.22E+08	6.08E+06	3.04E+05	12.58	1.23E+03	19.70	7.83E+02
I-133	7.49E+04	6.07E-01	5.52E+04	1.71E+08	8.56E+06	4.28E+05	12.58	4.59E+02	19.70	2.93E+02
I-134	3.16E+03	2.63E+00	6.06E+04	1.88E+08	9.39E+06	4.70E+05	12.58	2.19E+03	19.70	1.40E+03
I-135	2.38E+04	1.58E+00	5.17E+04	1.60E+08	8.01E+06	4.01E+05	12.58	1.12E+03	19.70	7.15E+02
Rb-86	1.61E+06	9.50E-02	6.31E+01	1.96E+05	9.78E+03	4.89E+02	12.58	8.22E-02	19.70	5.25E-02
Cs-134	6.51E+07	1.55E+00	6.11E+03	1.89E+07	9.47E+05	4.74E+04	12.58	1.30E+02	19.70	8.29E+01
Cs-136	1.13E+06	2.17E+00	2.00E+03	6.20E+06	3.10E+05	1.55E+04	12.58	5.95E+01	19.70	3.80E+01
Cs-137	9.51E+08	6.62E-01	3.95E+03	1.22E+07	6.12E+05	3.06E+04	12.58	3.59E+01	19.70	2.29E+01
TOTAL								6.13E+03		3.91E+03

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Case 3

An instantaneous release of all reactor coolant mass into the primary containment assuming that 20% of the fuel cladding has failed. This corresponds to NEI 99-01 (Ref. III.1, page 95, 96), Primary Containment Barrier Threshold, Primary Containment Radiation, Loss 4.A.

As with case 2, this case involves the release of gap activity associated with clad damage. The formulas for analysis of this case are identical to case 2 with the exception of the damage fraction and damage release.

The damage fraction (DF_{20}) associated with 20% clad damage is 20% of the complete gap release.

$$\text{Damage Release}_i, Ci = \text{Gap Release}_i * DF_{20}$$

By definition $DF_{20} = 0.20$

An Excel spread sheet with the isotopes from Table 7.4 is used with the formulas listed in Case 2 and the formula above to calculate the containment and drywell doses for this case. The tabular results are provided on the following page.

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Containment and Drywell Dose Rates with 20% Clad Damage

Isotope	Half-life, (sec)	Gamma Energy, MeV	24 Month Cycle Conc., Ci/MWt	Total Conc. Ci	Gap Release, Ci	20% Clad Damage Release, Ci	GF _C	Containment Dose Rate, R/hr	GF _D	Drywell Dose Rate, R/hr
Kr-85	3.38E+08	2.00E-03	3.66E+02	1.13E+06	5.67E+04	1.13E+04	12.58	4.02E-02	19.70	2.56E-02
Kr-85m	1.61E+04	1.58E-01	7.02E+03	2.18E+07	1.09E+06	2.18E+05	12.58	6.08E+01	19.70	3.89E+01
Kr-87	4.58E+03	7.93E-01	1.35E+04	4.19E+07	2.09E+06	4.19E+05	12.58	5.87E+02	19.70	3.75E+02
Kr-88	1.02E+04	1.96E+00	1.89E+04	5.86E+07	2.93E+06	5.86E+05	12.58	2.03E+03	19.70	1.30E+03
Xe-133	4.53E+05	4.60E-02	5.26E+04	1.63E+08	8.15E+06	1.63E+06	12.58	1.33E+02	19.70	8.48E+01
Xe-135	3.27E+04	2.49E-01	1.99E+04	6.17E+07	3.08E+06	6.17E+05	12.58	2.72E+02	19.70	1.74E+02
I-131	6.95E+05	3.82E-01	2.70E+04	8.37E+07	4.19E+06	8.37E+05	12.58	5.66E+02	19.70	3.61E+02
I-132	8.21E+03	2.28E+00	3.92E+04	1.22E+08	6.08E+06	1.22E+06	12.58	4.90E+03	19.70	3.13E+03
I-133	7.49E+04	6.07E-01	5.52E+04	1.71E+08	8.56E+06	1.71E+06	12.58	1.84E+03	19.70	1.17E+03
I-134	3.16E+03	2.63E+00	6.06E+04	1.88E+08	9.39E+06	1.88E+06	12.58	8.74E+03	19.70	5.58E+03
I-135	2.38E+04	1.58E+00	5.17E+04	1.60E+08	8.01E+06	1.60E+06	12.58	4.48E+03	19.70	2.86E+03
Rb-86	1.61E+06	9.50E-02	6.31E+01	1.96E+05	9.78E+03	1.96E+03	12.58	3.29E-01	19.70	2.10E-01
Cs-134	6.51E+07	1.55E+00	6.11E+03	1.89E+07	9.47E+05	1.89E+05	12.58	5.19E+02	19.70	3.32E+02
Cs-136	1.13E+06	2.17E+00	2.00E+03	6.20E+06	3.10E+05	6.20E+04	12.58	2.38E+02	19.70	1.52E+02
Cs-137	9.51E+08	6.62E-01	3.95E+03	1.22E+07	6.12E+05	1.22E+05	12.58	1.43E+02	19.70	9.16E+01
TOTAL								2.45E+04		1.57E+04

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Dose Rate Summary with Accident Instrument Uncertainty Range

	Containment RMS-RE16A, B Calculated Reading, R/hr	Maximum Reading (+100%), R/hr	Minimum Reading (-50%), R/hr
Case 1, 0.2 uCi/g Dose Equivalent I-131	3.68E+00	7.36E+00	1.84E+00
Case 1, 4 uCi/g Dose Equivalent I-131	7.36E+01	1.47E+02	3.68E+01
Case 2, 5% Clad Damage	6.13E+03	1.23E+04	3.06E+03
Case 3, 20% Clad Damage	2.45E+04	4.90E+04	1.23E+04

	Drywell RMS-RE20A, B Calculated Reading, R/hr	Maximum Reading (+100%)	Minimum Reading (-50%)
Case 1, 0.2 uCi/g Dose Equivalent I-131	2.35E+00	4.70E+00	1.18E+00
Case 1, 4 uCi/g Dose Equivalent I-131	4.70E+01	9.40E+01	2.35E+01
Case 2, 5% Clad Damage	3.91E+03	7.83E+03	1.96E+03
Case 3, 20% Clad Damage	1.57E+04	3.13E+04	7.83E+03

The above table provides the ranges of indications for the containment and drywell radiation monitors including the accident environment instrument uncertainty. It should be noted under normal conditions that the radiation monitors are required to perform to a $\pm 20\%$ of reading uncertainty per STP-511-4249, 4250, 4289, and 4290.

Case 1 – using the 4 uCi/g Dose Equivalent I-131 value gives a Drywell Post Accident Monitor reading range from 23.5 R/hr to 94 R/hr and a Containment Post Accident Monitor reading range of 36.8 to 147 R/hr considering accident instrument uncertainty. Under normal uncertainty conditions the range would be 37.6 R/hr to 56.4 R/hr for the Drywell Post Accident Monitor reading and 58.9 R/hr to 88.3 R/hr for the Containment Post Accident Monitor reading.

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In order to ensure abnormal conditions exist, it is recommended that the readings used for Case 1 entry use the lower value of the normal uncertainty band, rather than the accident uncertainty band, with values greater than or equal to 38 R/hr for the Drywell and 59 R/hr for Containment.

Case 2 – The case 2 reading range for the Drywell monitors is $1.96E+03$ R/hr to $7.83E+03$ R/hr. The reading range for Containment Monitors are $3.06E+03$ R/hr to $1.23E+04$ R/hr. Using the lowest reading of the band and rounding to the nearest decade gives greater than or equal to 2000 R/hr for the Drywell and 3000 R/hr for Containment.

Case 3 - The case 3 reading range for the Drywell monitors is $7.83E+03$ R/hr to $3.13E+04$ R/hr. The reading range for Containment Monitors are $1.23E+04$ R/hr to $4.90E+04$ R/hr. Using the lowest reading of the band and rounding to the nearest decade gives greater than or equal to 8,000 R/hr for the Drywell and 12,000 R/hr for Containment.