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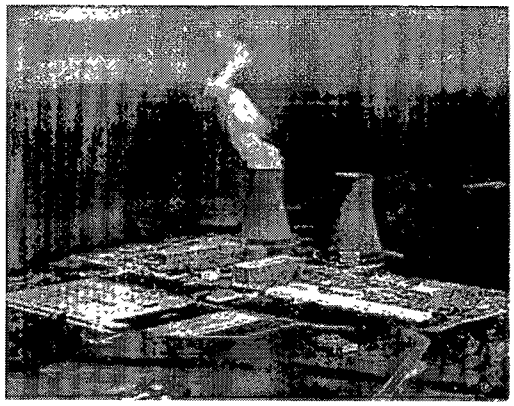

Perry Nuclear Power Plant (PNPP)

Containment Radiation EAL Values

EP-EALCALC-PNPP-1402
Revision 0

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1. PURPOSE

The PNPP Emergency Action Level (EAL) Technical Bases Manual contains background information, event declaration thresholds, bases and references for the site specific EAL and Fission Product Barrier (FPB) values used to implement the Nuclear Energy Institute (NEI) 99-01 Rev. 6 EAL guidance methodology. This calculation document provides additional technical detail specific to the derivation of the FPB containment high range radiation monitor (CHRRM) readings developed in accordance with the guidance in NEI 99-01 Rev. 6.

Documentation of the assumptions, calculations and results are provided for the PNPP site specific FPB CHRRM values associated the NEI 99-01 Rev 6 EALs listed below.

- NEI Fuel Clad Loss 4.A
- NEI Reactor Coolant Loss 4.A
- NEI Containment Potential Loss 4.A

2. DEVELOPMENT METHODOLOGY AND BASES

Note – PNPP site specific terminology for the CHRRMs equate to the guidance terminology for the containment radiation monitors as follows:

- NUREG drywell containment monitor is the PNPP drywell monitor
- NUREG wetwell containment monitor is the PNPP containment monitor

2.1. Fuel Clad Loss 4.A

Guidance Criteria

Per NEI 99-01 Rev 6, this radiation monitor reading should be calculated assuming the instantaneous release and dispersal of the reactor coolant noble gas and iodine inventory associated with a concentration of 300 µCi/gm dose equivalent I-131. This level of reactor coolant activity is well above that expected for iodine spikes and corresponds to an approximate range of 2% to 5% fuel clad damage.

PNPP Bases

The Fuel Clad FPB threshold value is based on an instantaneous release of all reactor coolant mass into the drywell and containment air spaces at a reactor coolant activity equivalent to 300 µCi/gm DEI-131.

NUREG-1228 Fission Product Inventory values were used to develop the PNPP site specific source term that correlates 300 µCi/gm DEI-131 to a % fuel clad damage value. NUREG-1228 is a guidance document used for source term determination in EAL development, core damage estimation and offsite does assessment functions by the industry. Other source bases are available for site specific source term values, but provide no greater precision due to the uncertainty and variability of other factors such as damage type mix, damage progression, power history, reduction mechanisms, etc.

2.2. RCS Loss 4.A

Guidance Criteria

Per NEI 99-01 Rev 6, this radiation monitor reading should be calculated assuming the instantaneous release and dispersal of the reactor coolant noble gas and iodine inventory associated with normal operating concentrations (i.e., maximum allowed by T/S) into the drywell atmosphere. Using RCS activity at Technical Specification allowable limits aligns this threshold with IC SU4. Also, RCS activity at his level will typically result in containment radiation levels that can be more readily detected by containment radiation monitors, and more readily differentiated from those caused by piping or component "shine" sources.

In some cases, the site-specific physical location and sensitivity of the containment radiation monitor(s) may be such that radiation from a cloud of released RCS gases cannot be distinguished from radiation emanating from piping and components containing elevated reactor coolant activity. If so, refer to the Developer Guidance for Loss/Potential Loss 5.A and determine if an alternate indication is available.

PNPP Bases

Per SVI-D19-T5353 Section 5.1.4 Note 3, the minimum reading of 1D19-K100 and 1D19-K200 is 1.21E+00 R/hr due to instrument limitations.

RCS Loss FPB threshold values based on the TS High Limit of 4 µCi/gm DEI-131 are very close to the minimum reading of the radiation monitors (5.5 R/hr Drywell and 8 R/hr Containment – See section 4.3). An RCS Loss FPB threshold at this level would be susceptible to radiation emanating from piping and components containing elevated reactor coolant activity. Historical PNPP operations with minor pin leakage has resulted in such elevated readings.

An alternate method to the use of the TS High Limit as a basis is to establish the RCS Loss threshold at $1/10^{th}$ the Fuel Clad Loss threshold, which will to provide sufficient margin from potential erroneous indication due to shine and provide an escalation progression that meets the intent of NEI 99-01 generic guidance (see Section 4.3.2). This new threshold is approximately half that of the prior NRC approved RCS Loss threshold of 135 R/hr, which was based upon NUMARC methodology prior to the endorsement of the current NEI 99-01 methodology.

2.3. Containment Potential Loss 4.A

Guidance Criteria

Per NEI 99-01 Rev 6, this radiation monitor reading corresponds to an instantaneous release of all reactor coolant mass into the primary containment, assuming that 20% of the fuel cladding has failed.

NUREG-1228 provides the basis for using the 20% fuel cladding failure value and indicates that it must be greater than approximately 20% in order for there to be a major release of radioactivity requiring offsite protective actions. For this condition to exist, there must already have been a loss of the RCS Barrier and the Fuel Clad Barrier. It is therefore prudent to treat this condition as a potential loss of containment which would then escalate the emergency classification level to a General Emergency

PNPP Bases

The Containment FPB threshold value is based on an instantaneous release of all reactor coolant mass into the drywell and containment air spaces at an equivalent of 20% clad damage.

2.4. Decay Considerations

Guidance Criteria

Per NEI 99-01, the event for FPB CHRRM reading corresponds to an instantaneous release of all reactor coolant mass into the primary containment.

Fission product barrier thresholds and their associated EALs are applicable only when the plant is in Hot Shutdown, Startup, or Power Operation mode (known as the hot operating modes).

PNPP Bases

NUREG/BR-0150 Figures A-11 and A-12 containment radiation tables used as the basis for the FPB threshold values begin at time = 1 hour after shutdown and provide core damage assessment correlation out to time = 24 hours. The 1 hour after shutdown values are used to develop the PNPP site specific FPB threshold values.

2.5. Reduction Mechanisms

Guidance Criteria

NEI 99-01 does not contain specific criteria for the consideration of reduction mechanisms for the development of the FPB threshold values. It does state that Containment FPB threshold values are to be based on an instantaneous release of all reactor coolant mass into the drywell and containment air spaces.

NUREG/BR-0150 Figures A-11 and A-12 includes BWR Mark III drywell containment monitor response figures for sprays on and sprays off.

PNPP Bases

Reduction mechanisms such as containment sprays and suppression pool are not included in the source term determination to comply with the NEI 99-01 criteria for the instantaneous release of all reactor coolant mass into the drywell and containment air spaces.

3. INPUTS

3.1. Constants and Conversion Factors

3.1.1. Net Electrical Output (USAR 1.1)..... 1277 MWe

3.1.2. Halogen Gap Release Fraction (NUREG-1228 Table 4.4)..... 0.02 (2%)

3.1.3. RCS Mass (USAR Table 11.3-8a)..... 5.28E+05 lbm

3.1.4. DEI-131 Upper Limit (TS 3.4.8)..... 4.0 µCi/gm

3.1.5. Mass Unit Conversion Factor..... 453.6 gm per lbm

3.2. Core Fission Product Inventory (FPI) and Decay Constants

Core FPI values for Noble Gas and Halogen isotopes were taken from NUREG-1228 Table 2.2

	Core FPI (Ci/MWe)
Kr-85	5.6E+02
Kr-85m	2.4E+04
Kr-87	4.7E+04
Kr-88	6.8E+04
Xe-131m	1.0E+03
Xe-133	1.7E+05
Xe-133m	6.0E+03
Xe-135	3 4E+04
Xe-138	1 7E+05
I-131	8.5E+04
I-132	1.2E+05
I-133	1.7E+05
I-134	1 9E+05
I-135	1.5E+05

3.3. DEI Isotopic Conversion Factors

Isotopic Conversion Factors were derived from TID-14844 Table III as referenced in ODCM Appendix C Section 1.

	TID-14844 (R/Ci)	DEI Factor (unitless)
I-131	1 48E+06	1 00E+00
I-132	5.35E+04	3.62E-02
I-133	4 00E+05	2.70E-01
I-134	2.50E+04	1.69E-02
I-135	1.24E+05	8.38E-02

3.4. Containment Radiation Monitor (CRM) Readings

Note – PNPP site specific terminology for the CHRRMs equate to the guidance terminology for the containment radiation monitors as follows:

- NUREG drywell containment monitor is the PNPP drywell monitor
- NUREG wetwell containment monitor is the PNPP containment monitor

Radiation monitor readings in R/hr corresponding to 100% and 1% clad (gap) damage were derived from NUREG/BR-0150 Figures A-11 and A-12 (see Attachment 1) as follows:

	High (100%)	Low (1%)
Drywell Containment (Figure A-11)		
TAS = 1hr	2E+04	2E+02
TAS = 24hr	8E+02	8E+00
Wetwell Containment (Figure A-12)		
TAS = 1hr	3E+04	3E+02
TAS = 24hr	3E+03	3E+01

TAS = Time After Shutdown

4. CALCULATIONS

4.1. Fuel Clad Damage Estimate Based on 300 µCi/gm DEI-131

See Attachment 2 for the iterative results to the below calculation steps used to determine the fuel clad source term activity and the % clad damage.

4.1.1. Reactor Coolant System (RCS) Mass (mRCS)

mRCS (gm) = mRCS (lbm) x 453.6 gm/lbm

2.40E+08	=	5.28E+05	x	453.6 gm/lbm

4.1.2. 100% Core Activity Equivalent Halogen Coolant Concentrations

NUREG-1228 provides a total core activity, in Curies/MWe, for each iodine isotope. Those values are converted to an equivalent coolant concentration representing 100% core activity, in µCi/gm, as follows:

$$\textbf{Activity}_i\ \textbf{(µCi/gm)} = \frac{\textbf{Activity}_i\ \textbf{(Ci/MWe)} \times \textbf{PNPP MWe} \times \textbf{1E+06 (µCi/Ci)}}{\textbf{mRCS (gm)}}$$

	I-131	I-132	I-133	I-134	I-135
RCS Activity (µCi/gm - 100% Core)	4.53E+05	6.40E+05	9.06E+05	1.01E+06	8 00E+05

4.1.3. 100% Fuel Clad Gap Activity Equivalent Halogen RCS Concentrations

The 100% core coolant activity is reduced by the release fraction (RF) to represent 100% fuel clad gap activity by multiplying as follows:

$Activity_{gap\text{-}i}$ (µCi/gm) = $Activity_{core\text{-}i}$ (µCi/gm) x RF

	I-131	I-132	I-133	I-134	I-135
RCS Activity (µCi/gm - 100% Gap)	9 06E+03	1 28E+04	1 81E+04	2 03E+04	1 60E+04

4.1.4. 100% Fuel Clad Gap Activity Equivalent DEI-131 RCS Concentrations

The total RCS DEI-131 activity associated with 100% fuel clad is calculated from the DEI conversion factors (DEI CFs) as follows

Total $RCS_{Gap\ DEI}$ (µCi/gm) = $\sum$ $Activity_{gap\text{-}i}$ (µCi/gm) x $DEI\ CF_i$

	I-131	I-132	I-133	I-134	I-135
RCS Activity (µCi/gm - 100% Gap DEI)	9 06E+03	1.28E+04	1 81E+04	2.03E+04	1 60E+04
Total:	1.61E+04				

4.1.5. % Clad Damage for 300 µCi/gm DEI-131

$$\%\ Clad\ Damage = \frac{Target\ RCS_{Gap\ DEI}\ (\mu Ci/gm)}{Total\ RCS_{Gap\ DEI}\ (\mu Ci/gm)}$$

$$1.9\% = \frac{3.00E+02\ (\mu Ci/gm)}{1.61E+04\ (\mu Ci/gm)}$$

4.2. Fuel Clad and Containment FPB Threshold Values

4.2.1. Derivation of 20% and 2% Values

PNPP radiation monitor readings in R/hr corresponding to the 20% clad damage (Containment potential loss) and 2% clad damage (Fuel Clad loss) thresholds are ratioed from the Section 3.4 1 table as follows:

	High (20%)	Low (2%)
Drywell Radiation Monitors (R/hr)		
TAS = 1hr	4 0E+03	4.0E+02
TAS = 24hr	1.6E+02	1.6E+01
Containment Radiation Monitors (R/hr)		
TAS = 1hr	6.0E+03	6.0E+02
TAS = 24hr	6.0E+02	6 0E+01

4.2.2. Relative Half Life

The relative half-life values for the radiation monitor readings were determined as follows:

$$\textbf{\textit{Relative Half Life (RHL)}} = -0.693 \times \frac{\textbf{\textit{Decay Time}}}{\ln(\frac{DR_f}{DR_i})}$$

Where:	
0.693:	ln(2)
Decay Time:	23 hours
DR:	Monitor Dose Rate (R/hr)

See Attachment 3 for the spreadsheet calculation that develops the relative half-life values used to determine the CHRRM values between 1 and 24 hours.

- Drywell Relative Half-Life ..... 4.95 hrs
- Containment Relative Half-Life ..... 6.92 hrs

4.2.3. Decay Adjusted Fuel Clad and Containment CHRRM FPB Threshold Values

The decay adjusted Fuel Clad and Containment CHRRM FPB threshold values were determined as follows:

$$CHRRM_{t=x} = CHRRM_{t=1} \times e^{\frac{-.693}{RHL} \times t=x-1}$$

Where:	
0.693:	ln(2)
RHL:	Relative Half-Life Values
t:	Time After Shutdown (hr)

See Attachment 4 for the spreadsheet calculation that develops the Fuel Clad and Containment CHRRM FPB threshold values between 1 and 24 hours.

	Fuel Clad: 2% Clad Damage		Containment: 20% Clad Damage	
hrs	**Drywell**	**Containment**	**Drywell**	**Containment**
0	4 0E+02	6 0E+02	4 0E+03	6 0E+03
1	4 0E+02	6 0E+02	4 0E+03	6 0E+03
2	3 5E+02	5 4E+02	3 5E+03	5.4E+03
3	3 0E+02	4 9E+02	3.0E+03	4.9E+03
4	2.6E+02	4.4E+02	2 6E+03	4.4E+03
5	2 3E+02	4 0E+02	2 3E+03	4 0E+03
6	2.0E+02	3.6E+02	2 0E+03	3 6E+03
7	1 7E+02	3 3E+02	1 7E+03	3 3E+03
8	1 5E+02	3.0E+02	1.5E+03	3.0E+03
9	1 3E+02	2 7E+02	1 3E+03	2.7E+03
10	1 1E+02	2 4E+02	1 1E+03	2.4E+03

hrs	Fuel Clad: 2% Clad Damage Drywell	Containment	Containment: 20% Clad Damage Drywell	Containment
11	9 9E+01	2 2E+02	9.9E+02	2.2E+03
12	8 6E+01	2.0E+02	8.6E+02	2 0E+03
13	7.5E+01	1 8E+02	7.5E+02	1 8E+03
14	6.5E+01	1 6E+02	6.5E+02	1.6E+03
15	5.6E+01	1 5E+02	5.6E+02	1.5E+03
16	4 9E+01	1 3E+02	4.9E+02	1 3E+03
17	4 3E+01	1 2E+02	4 3E+02	1.2E+03
18	3 7E+01	1 1E+02	3.7E+02	1 1E+03
19	3.2E+01	9.9E+01	3 2E+02	9.9E+02
20	2 8E+01	9 0E+01	2 8E+02	9 0E+02
21	2 4E+01	8 1E+01	2 4E+02	8.1E+02
22	2 1E+01	7 3E+01	2 1E+02	7.3E+02
23	1 8E+01	6 6E+01	1 8E+02	6.6E+02
24	1 6E+01	6 0E+01	1 6E+02	6 0E+02

4.3. RCS FPB Threshold Values

4.3.1. The RCS Loss threshold determined by ratio to the Fuel Clad Loss threshold, based on 300 µCi/gm DEI-131, to the TS upper limit of 4 µCi/gm as follows:

$$RCS\ Loss = FC\ Loss \times \frac{4(\frac{\mathbf{uCi}}{\mathbf{gm}})}{300\ (\frac{\mathbf{uCi}}{\mathbf{gm}})}$$

Drywell	Containment
5.3 R/hr = 400 R/hr x $\frac{4\ \mu Ci/gm}{300\ \mu Ci/gm}$	**8 R/hr** = 600 R/hr x $\frac{4\ \mu Ci/gm}{300\ \mu Ci/gm}$

4.3.2. The RCS Loss threshold based on 1/10th the Fuel Clad Loss threshold (0.2% clad damage) is as follows:

$$RCS\ Loss = \frac{FC\ Loss}{10}$$

Drywell	Containment
40 R/hr = $\frac{400\ R/hr}{10}$	**60 R/hr** = $\frac{600\ R/hr}{10}$

5. CONCLUSIONS

5.1. 300 µCi/gm DEI-131 is equivalent to 1.9% fuel clad (gap) damage.

5.2. FPB threshold values correspond to the following radiation monitor readings:

	Fuel Clad Loss	RCS Loss	Cont Potential Loss
Drywell	4 0E+02 R/hr	4.0E+01 R/hr	4 0E+03 R/hr
Containment	6.0E+02 R/hr	6 0E+01 R/hr	6.0E+03 R/hr

6. REFERENCES

7.1. NEI 99-01, Methodology for Development of Emergency Action Levels, Revision 6

7.2 NUREG/BR-0150 Vol 1 R4, Response Technical Manual (RTM-96), March 1996

7 3. NUREG-1228, Source Term Estimation During Incident Response to Severe Nuclear Power Plant Accidents, October 1988

7.4. DOE/TIC-11206, D.C. Kocher: Radioactive Decay Tables - A Handbook of Decay Data for Application to Dosimetry and Radiological Assessments, 1981

7.5. TID-14844, Calculation of Distance Factors for Power and Test Reactor Sites, 03/23/62

7.6. PNPP Updated Safety Analysis Report (USAR), Revision 16

- Table 1.3-4, Comparison of Containment Design Characteristics
- Table 11.3-8, Input Parameters Used For Calculating Gaseous Releases

7 7 PNPP ODCM, Revision 20

7.8. Technical Specifications Section 3.4.8, RCS Specific Activity

7.9. SVI-D-19-T5353, Post accident Monitoring Channel Check for 1D19-K100 and 1D19-K200, Revision 6

7.10. PSI-0019, Emergency Action Level (EAL) Bases Document, Revision 19

7.11. PY-NUS/CEI-705, Drywell Radiation Plots and Technical Bases

7 12. Field Clarification Request (FRC) 016986, NUMARC EAL Methodology Requires, 12/09/92

Fig. A-11
BWR Mark III drywell containment monitor response (sprays off).

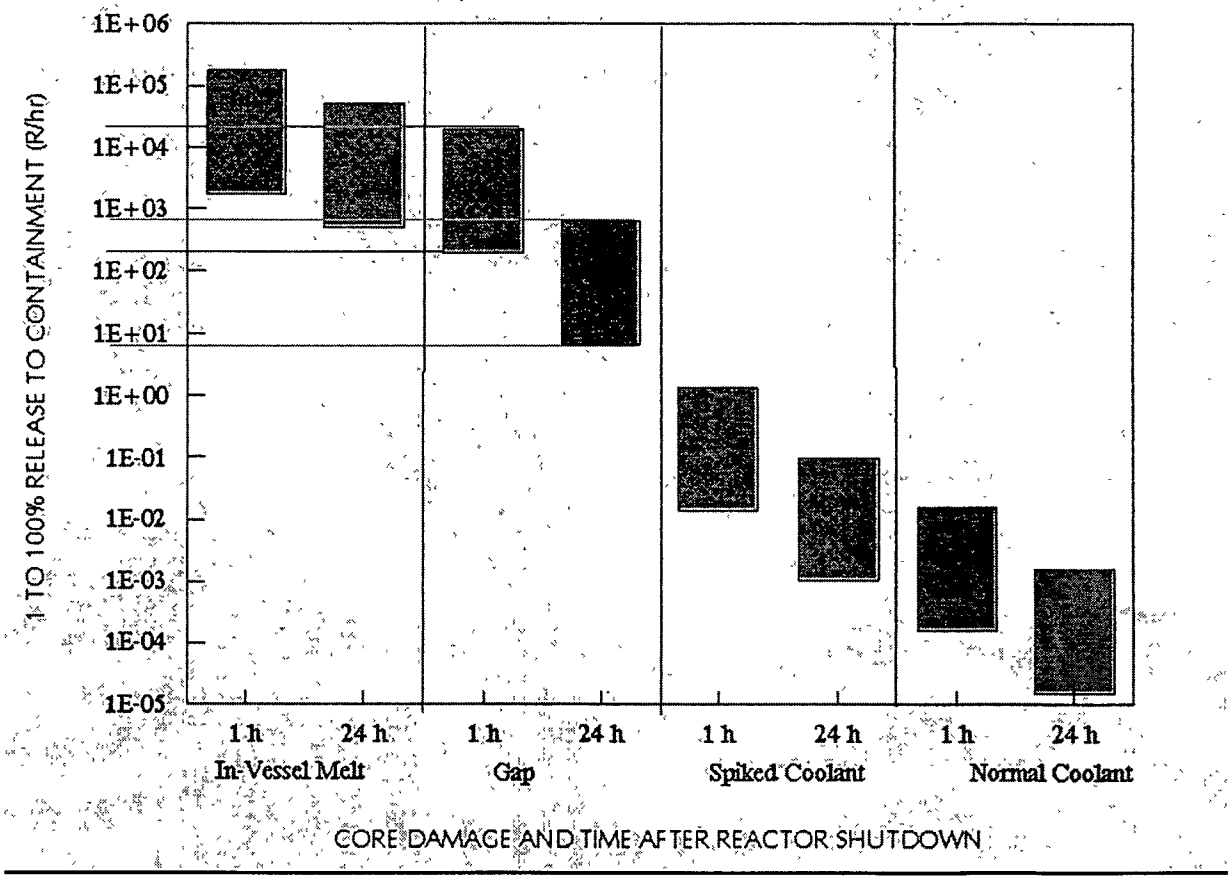
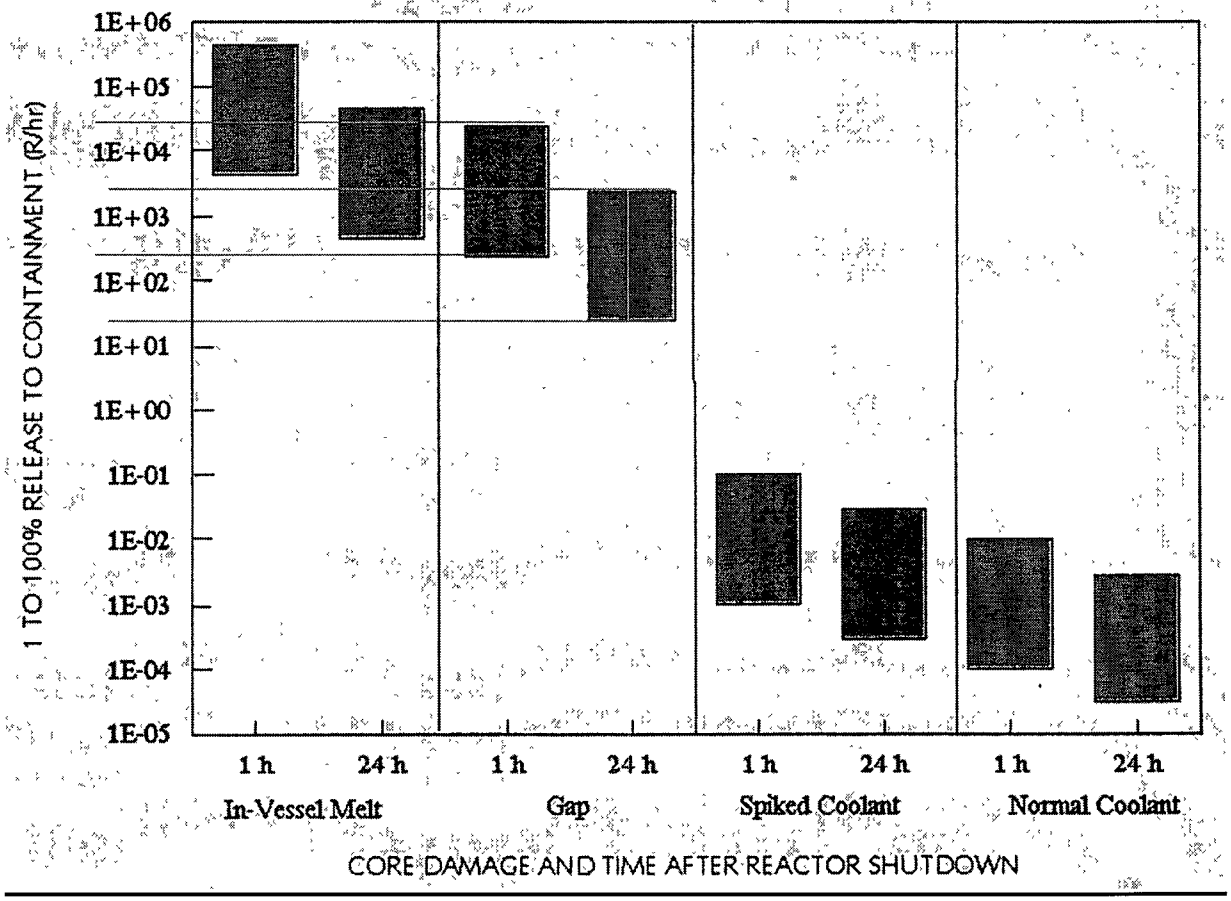


Fig. A-12
BWR Mark III wetwell containment monitor response.



	Core Activity (Curies/MWe)	RCS Activity (uCi/gm - 100% Core)	RCS Activity (uCi/gm - 100% Gap)	DEI Conversion Factor	RCS Activity (uCi/gm - 100% Gap DEI)
I-131	8.50E+04	4.53E+05	9.06E+03	1.00E+00	9.06E+03
I-132	1.20E+05	6.40E+05	1.28E+04	3.61E-02	4.63E+02
I-133	1.70E+05	9.06E+05	1.81E+04	2.70E-01	4 90E+03
I-134	1.90E+05	1.01E+06	2 03E+04	1.69E-02	3.42E+02
I-135	1.50E+05	8.00E+05	1 60E+04	8.38E-02	1 34E+03
Total	7 15E+05	3.81E+06	7 62E+04		1.61E+04

Power (MWe):	1277
Halogen Release Fraction (RF):	2%
Activity Conversion Factor (uCi/Ci):	1.00E+06
RCS Mass (lbm):	5.28E+05
Conversion Factor (gm/lbm):	453.6
RCS Mass (gm):	2.40E+08
Target DEI-131 (uCi/gm):	3.00E+02
% Clad Damage:	**1.9%**

	100%	20%	2%
Drywell Monitor (Sprays Off)			
1 hour	2.00E+04	4 00E+03	4.00E+02
24 hours	8.00E+02	1 60E+02	1.60E+01
Containment Monitor			
1 hour	3.00E+04	6.00E+03	6.00E+02
24 hours	3.00E+03	6 00E+02	6.00E+01

-ln(2).	-0.693
Decay Time (hrs)	23

Drywell Relative Half-Life (hrs):	**4.95E+00**
Containment Relative Half-Life (hrs):	**6.92E+00**

	Fuel Clad: 2% Clad Damage		Containment: 20% Clad Damage	
hrs	Drywell	Containment	Drywell	Containment
1	4.0E+02	6.0E+02	4.0E+03	6.0E+03
2	3.5E+02	5.4E+02	3.5E+03	5 4E+03
3	3.0E+02	4.9E+02	3.0E+03	4.9E+03
4	2.6E+02	4.4E+02	2.6E+03	4.4E+03
5	2.3E+02	4.0E+02	2.3E+03	4.0E+03
6	2.0E+02	3 6E+02	2.0E+03	3.6E+03
7	1.7E+02	3 3E+02	1.7E+03	3.3E+03
8	1.5E+02	3 0E+02	1.5E+03	3.0E+03
9	1.3E+02	2.7E+02	1.3E+03	2.7E+03
10	1 1E+02	2 4E+02	1.1E+03	2.4E+03
11	9.9E+01	2 2E+02	9.9E+02	2.2E+03
12	8.6E+01	2.0E+02	8.6E+02	2.0E+03
13	7.5E+01	1.8E+02	7.5E+02	1.8E+03
14	6 5E+01	1.6E+02	6 5E+02	1.6E+03
15	5.6E+01	1 5E+02	5.6E+02	1 5E+03
16	4.9E+01	1.3E+02	4.9E+02	1.3E+03
17	4.3E+01	1 2E+02	4 3E+02	1.2E+03
18	3.7E+01	1.1E+02	3 7E+02	1.1E+03
19	3.2E+01	9.9E+01	3.2E+02	9.9E+02
20	2.8E+01	9.0E+01	2.8E+02	9.0E+02
21	2.4E+01	8.1E+01	2.4E+02	8.1E+02
22	2.1E+01	7.3E+01	2.1E+02	7 3E+02
23	1.8E+01	6 6E+01	1.8E+02	6.6E+02
24	1.6E+01	6.0E+01	1.6E+02	6 0E+02

Drywell Relative Half-Life (hrs):	4.95E+00
Containment Relative Half-Life (hrs):	6.92E+00

TS DEI I-131 (uCi/cc)	4.00E+00
EAL DEI I-131 (uCi/cc).	3.00E+02