NINE MILE POINT NUCLEAR STATION

EMERGENCY PROCEDURES

PROCEDURE NO. EPP-9

DETERMINATION OF CORE DAMAGE UNDER ACCIDENT CONDITIONS

APPROVALS	SIGNATURES	DATE AND INITIALS REVISION 0	REVISION 1	REVISION 2
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Summary of Pages

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NIAGARA MOHAWK POWER CORPORATION

THIS PROCEDURE NOT TO BE
USED AFTER
SUBJECT TO PERIODIC REVIEW.

DETERMINATION OF CORE DAMAGE UNDER ACCIDENT CONDITIONS

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DETERMINATION OF CORE DAMAGE UNDER ACCIDENT CONDITIONS

1.0 PURPOSE

The purpose of this procedure is to determine the degree of reactor core damage from the measured fission product concentrations in either the reactor water or containment gas samples taken under accident conditions. The procedure involves calculations of fission product inventories in the core and the release of inventories into the reactor water and containment atmosphere under postulated design basis loss-of-coolant accident conditions. The fuel gap fission products are assumed to be released upon the rupture of fuel cladding; the majority of fission product inventories in the fuel rods would be released when the fuel is melted at higher temperatures.

After the initial core damage estimate is made, confirmation and refinement of the analysis can be achieved using the approach outlined in Flow Chart 1 and Section 6.0 of this procedure. This includes assessment of core damage using (a) Containment hydrogen analysis (b) Containment High Radiation monitors (c) Water level indications and (d) Ba, Sr, La, Ru analyses.

2.0 PROCEDURE BASIS

2.1 Reference Plant

The estimation of core damage will be calculated by comparing the measured concentrations of major fission products in gas and/or liquid samples, after appropriate normalization, with reference plant data from a BWR-6/238 with Mark III containment. Fission product inventories in the primary system were calculated based on postulated design basis loss-of-coolant accident conditions after three years (1095 days) of continuous operation at 3651 MWt or 102% of rated power by using a computer code developed at Los Alamos and adopted to the GE computer system. The inventories of major fission products in the core at the time of reactor shutdown are given in Table 1.

2.2 Parameters for Reference Plant and NMP-1

The pertinent plant parameters for the reference plant and the Nine Mile Point - Unit 1 plant are given below:

	Reference Plant	NMP-1
Rated reactor thermal power	3579 MWt	1850 MWt
Number of fuel bundles	748 bundles	532 bundles

2.2 (Cont.)

	Reference Plant	NMP-1
Reactor water mass	2.46×10^8g	2.17×10^8g
Suppression pool water mass	3.67×10^9g	2.16×10^9g*
Total primary coolant mass (Reactor water plus suppression pool water)	3.92×10^9g	2.38×10^9g*
Drywell gas volume	7.77×10^9 cc	5.10×10^9cc
Torus/Containment gas volume	32.5×10^9cc	3.70×10^9cc*
Total containment and drywell gas spare volume	4.0×10^{10}cc	8.80×10^9cc*

*assumes torus downcomer submergence of 3 ft. (570,000 gal total). Adjust if necessary to account for HPCI or Containment Spray Raw Water Additions.

3.0 EQUIPMENT REQUIRED

3.1 Apparatus

3.1.1 GeLi - 1 and GeLi - 2 Gamma Spectroscopy System

3.1.2 Appropriate dilution equipment as specified in S-CAP-60 and N1-PSP-13

3.2 Reagents

None

4.0 RESPONSIBILITIES

4.1 The Chemistry and Radiation Management Department is responsible for performing sampling and analysis of reactor water and containment atmosphere as necessary to support the calculations of Sections 5.0 and 6.0 (See Sections 5.2.1 through 5.2.3, 6.1 and 6.4).

4.2 The Reactor Analysis Department is responsible for performing fission product inventory correction factor calculations (See Section 5.6).

4.3 The Technical Support Department is responsible for calculating % core damage in accordance with the methodology of Section 5.3, and of Sections 5.4, 5.5, 5.7, 5.8 and 5.2.8, or the methods of Section 6.1, 6.3 or 6.4, based on the isotopic data and inventory correction factors supplied.

5.0 PROCEDURES FOR DETERMINATION OF CORE DAMAGE

5.1 Description

Gas/water samples taken from the Post Accident Sampling system are analyzed for major fission product concentrations with the GeLi-1 or GeLi-2 gamma spectrometers. After incorporation of appropriate decay and normalization correction factors to the isotopic analysis results for I-131, Cs-137, Xe-133 and Kr-85, the extent of fuel or cladding damage can be determined by reference to Figures 1 through 4. Measurements of Cs-137 and Kr-85 activities are not very likely until the reactor has been shut down for longer than a few weeks and most of the shorter-lived isotopes have decayed.

If the concentration falls into a range where the release of the fission product from the fuel gap or from molten fuel cannot be definitely determined, additional data may be needed to determine the source of fission product release. For example, in addition to longer-lived isotopes, some shorter-lived isotope concentrations may be measured in the sample. The ratios of isotopes released from either the fuel gap or from the molten fuel are significantly different as shown in Table 3, thus the source (fuel or gap) of release may be identified.

(Refer to Section 5.3). Furthermore, some less volatile elements in the core may also start to release as the fuel starts to melt. If the less volatile fission products such as isotopes of Sr, Ba, La, and Ru are found to have unusually high concentrations in the water sample as compared to baseline reactor water concentrations, some degree of fuel melting may be assumed. The isotopes 2.7h Sr-92 (1.384 MeV) and 40h La-140 (1.597 Mev) in a mixture of fission products should be relatively easy to identify and measure from a gamma spectrum.

5.2 Estimation Procedure

5.2.1 Obtain the samples from the Post Accident Sampling System in accordance with N1-PSP-13, "Sampling and Analysis of Reactor Water and Containment Air Using the PASS".

5.2.2 Using the GeLi-1 or GeLi-2 Gamma Spectrometer, determine the concentrations of fission products, namely I-131, Cs-137, Xe-133, and Kr-85. (C_{wi} in water, C_{gi} in gas)

5.2.3 Correct the measured concentrations for sample dilution, pressure and decay (to the time of reactor shutdown). See steps 5.6.1.4 and 5.6.1.5 of N1-PSP-13.

5.2.4 Correct the measured gaseous activity concentrations for temperature and pressure difference in the sample vial and the containment atmosphere per Section 5.4 of this procedure.

5.2.5 Calculate the fission product inventory correction factor, F_{Ii}, per Section 5.6.

5.2.6 Calculate the plant parameter correction factors (F_w and F_g), per Section 5.7.

5.2.7 Calculate the normalized concentrations, C_{wi}^{Ref} or C_{gi}^{Ref} by using the correction factors per Section 5.5.

5.2.8 Utilize C_{wi}^{Ref} or C_{gi}^{Ref} to estimate the extent of fuel or cladding damage from Figures 1-4.

5.3 Identification of Release Source by Isotopic Ratio

5.3.1 Determine the concentrations of the shorter-lived isotopes shown in Table 3 with the GeLi-1 or GeLi-2 Gamma Spectrometers.

5.3.2 Correct the measured fission products to the time or reactor shutdown.

5.3.3 Calculate isotopic ratios where

$$\text{Noble Gas Ratio} = \frac{\text{noble gas isotope concentration}}{\text{Xe-133 concentration}}$$

$$\text{Iodine Ratio} = \frac{\text{iodine isotope concentration}}{\text{I-131 concentration}}$$

5.3.4 Determine release source by comparing results obtained in Section 5.3.3 to the noble gas and iodine ratios supplied in Table 3.

5.4 Temperature and Pressure Corrections for Gas Sample Vial

$$C_{gi} = C_{gi}\,(\text{vial}) \times \frac{P_2\ T_1}{P_1\ T_2}$$

where

C_{gi} (vial) = sample vial isotopic concentration
C_{gi} = containment isotopic concentration
P_1, T_1 = atmospheric pressure and temperature, respectively (i.e., 14.7 psia and 298°K)
P_2, T_2 = containment pressure and temperature, respectively

5.5 Calculation of Normalized Concentration C_{wi}^{Ref} or C_{gi}^{Ref}

NOTE: Omit isotope decay correction if already accounted for in step 5.2.3.

$$C_{wi}^{Ref} = C_{wi}e^{\lambda_i t} \times F_{Ii} \times F_w$$

or

$$C_{gi}^{Ref} = C_{gi}e^{\lambda_i t} \times F_{Ii} \times F_g$$

5.5 (Cont.)

where

C_{wi}^{Ref} = concentration of isotope i in the reference plant coolant (μCi/g)

C_{gi}^{Ref} = concentration of isotope i in the reference plant containment gas (μCi/cc)

C_{wi} = measured concentration of isotope i in the operating coolant at time, t (μCi/g) (See Section 5.8)

C_{gi} = measured concentration of isotope i in the operating containment gas at time, t (μCi/cc) (See Sections 5.4 and 5.8)

$e^{\lambda_i t}$ = decay correction to the time of reactor shutdown

λ_i = decay constant of isotope i (day^{-1})

t = time between the reactor shutdown and the sample time (day)

F_{Ii} = inventory correction factor for isotopic i (see Section 5.6)

F_g = containment gas volume correction factor (see Section 5.7)

F_w = primary coolant mass correction factor (see Section 5.7)

5.6 Fission Product Inventory Correction Factor

NOTE: See Appendix A for an example

$$F_{Ii} = \frac{\text{Inventory in reference plant}}{\text{Inventory in operating plant}}$$

$$= \frac{3651\,(1-e^{-1095\,\lambda_i})}{\sum_j \left[P_j\,(1-e^{-\lambda_i T_j})\; e^{-\lambda_i T_j^0} \right]}$$

where:

P_j = steady reactor power operated in period j (MWt)**

T_j = duration of operating period j (day)**

T^0_j = time between the end of operating period j and time of the last reactor shutdown (day)

**In each period, the variation of steady power should be limited to $\pm$ 20%.

5.6 (Cont.)

For a particular short-lived isotope, i, a calculation for only a period of approximately 6 half-lives of reactor operation time before reactor shutdown should be accurate enough. It should be pointed out that the computer calculation of core inventory takes into account the fuel burnings, plutonium fission and neutron capture reactions. The correction factor calculated from this equation may not be entirely accurate, but the error is insignificant in comparison to the uncertainties in the fission product release fractions (Table 4) and other assumptions.

5.7 Plant Parameter Correction Factors

$$F_W = \frac{\text{operating plant coolant mass (g)*}}{\text{reference plant coolant mass } (3.92 \times 10^9 \text{ g})}$$

$$F_g = \frac{\text{operating plant containment gas volume (cc)*}}{\text{reference plant containment gas volume } (4 \times 10^{10} \text{ cc})}$$

5.8 Sample Concentration (Cwi or Cgi) Averaging

If the fission product concentrations are measured separately for the reactor water and suppression pool water or the drywell gas and the torus gas, the measured concentrations C_{wi} of C_{gi} would be averaged from the separate measurements:

$$C_{wi} = \frac{\text{(conc. in Rx water)x(Rx water mass)+(conc. in pool)x(pool water mass)}}{\text{Reactor water mass + pool water}}$$

$$C_{gi} = \frac{\text{(conc. in drywell)x(drywell gas vol)+(conc. in torus)x(torus gas vol)}}{\text{Reactor water mass + pool water}}$$

6.0 ASSESSMENT OF CORE DAMAGE USING OTHER SIGNIFICANT PARAMETERS

6.1 Containment Hydrogen Measurement

6.1.1 Determine the % hydrogen in the primary containment by reference to #11 and #12 H_2/O_2 monitoring systems, or by gas chromatographic analysis of a containment atmosphere sample obtained from the PASS (see IV.A.22 and N1-PSP-13).

6.1.2 Using the curve in Figure 5, determine the % metal-water reaction for the reference plant, % MW_{ref}. The reference plant used here has a Mark I/II Containment (500 bundles/350,000 ft^3 containment volume) and is not the reference plant described in 2.1.

*assumes torus down comer submergence of 3 ft. (570,000 gal total). Adjust if necessary to account for HPCI or Containment Spray Raw Water additions.

6.1.3 Find the % metal-water reaction at NMP-1, %MW, using the equation below:

% MW = (%MW ref) (0.94) (0.89)

where:

0.94 = ratio of number of bundles at reference plant to bundles at NMP-1 (500/532)

0.89 = ratio of NMP-1 containment volume to reference plant containment volume ($8.80 \times 10^{9*}/9.90 \times 10^{9}$)

6.2 High Range Containment Monitors

6.2.1 See EPP-8. This procedure provides a method for estimating the fraction of the total core inventory available for release (hence, the % core damage) based on readings from #11 and #12 High Range Drywell Penetration Monitors in the main control room.

6.3 Reactor Water Level Indications

6.3.1 Reactor water level indications can be used to establish if there has been an interruption of adequate core cooling. Significant periods of core uncovery, as evidenced by reactor vessel water level readings, would be an indication of a situation where core damage is likely. Water level measurement may be useful in distinguishing between bulk core damage situations caused by loss of adequate cooling to the entire core and localized core damage situations caused by a flow blockage in some portion of the core.

6.4 Ba, Sr, La, Ru Analyses

6.4.1 Isotopically analyze a sample of reactor water in accordance with N1-PSP-13.

6.4.2 Determine the concentration (C_{wi} in µCi/g - see section 5.5) of those less volatile elements (i.e., Ru-103, Sr-91, Sr-92, Ba-140, La-140) which are indicators of core melt from the isotopic analysis printout, and which can be determined from the isotopic.

6.4.3 Calculate the normalized concentration of each isotope, i, in the reference plant $\left(C_{wi}^{Ref} \right)$ in accordance with section 5.5 of this procedure.

6.4.4 Calculate the fraction of each isotope released from the core, FR_i (approximately equal to the fraction of core meltdown) using the equation.

$$FR_i = \frac{C_{wi}^{Ref} \times (3.92 \times 10^{9})}{I_i}$$

*assumes torus down comer submergence of 3 ft. (570,000 gal total). Adjust if necessary to account for HPCI or Containment Spray Raw Water additions.

6.4.4 (Cont.)

where 3.92×10^9 = Total primary coolant mass (g), reference plant

I_i^{Ref} = total core inventory of isotope i in the reference plant (see Table 1)

7.0 REFERENCES

7.1 Lin, Chien C, Procedure for the Determination of Core Damage Under Accident Conditions, General Electric Co., NEDO 22215, 1982

7.2 Nuclear Services Department, Post Accident Sampling System Evaluation, General Electric, 1983.

7.3 Counting Room Instrument Procedure No. V.A.7-N, "Operation and Calibration of the GeLi-1 and GeLi-2 Gamma Spectroscopy System".

7.4 Process Survey Procedure N1-PSP-13, "Sampling and Analysis of Reactor Water and Containment Air Using the PASS".

7.5 Chemical Analytical Procedure S-CAP-60, "Dilution of Liquid and Gas Samples of High Activity"

FLOW CHART 1

SEQUENCE OF ANALYSIS FOR
ESTIMATION OF CORE DAMAGE

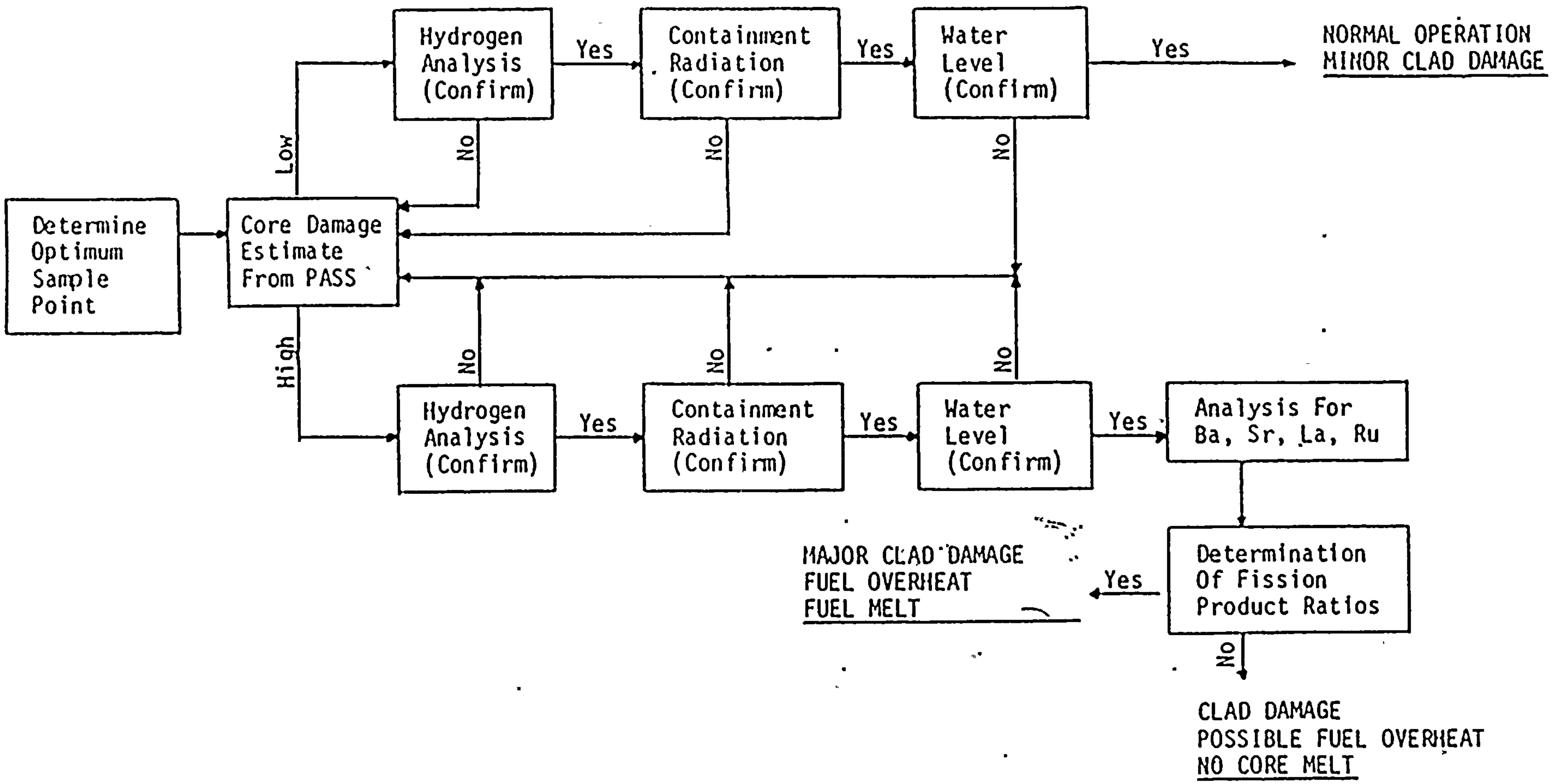

Table 1

CORE INVENTORY OF MAJOR FISSION PRODUCTS IN A
REFERENCE PLANT OPERATED AT 3651 MWt FOR THREE YEARS

Chemical Group	Isotope*	Half-Life	Inventory** 10^6 Ci	Major Gamma Ray Energy (Intensity) KeV (γ/d)
Noble gases	Kr-85m	4.48h	24.6	151(0.753)
	Kr-85	10.72y	1.1	514(0.0044)
	Kr-87	76.3m	47.1	403(0.495)
	Kr-88	2.84h	66.8	196(0.26),1530(0.109)
	Xe-133	5.25d	202.0	81(0.365)
	Xe-135	9.11h	26.1	250(0.899)
Halogens	I-131	8.04d	96.0	364(0.812)
	I-132	2.3h	140	668(0.99,773(0.762)
	I.133	20.8h	201	530(0.86)
	I-134	52.6m	221	847(0.954),884(0.653)
	I-135	6.61h	189	1132(0.225),1260(0.286)
Alkali Metals	Cs-134	2.06y	19.6	605(0.98),796(0.85)
	Cs-137	30.17y	12.1	662(0.85)
	Cs-138	32.2m	178.0	463(0.307),1436(0.76)
Tellurium Group	Te-132	78.2h	138	228(0.88)
Noble Metals	Mo-99	66.02h	183	740(0.128)
	Ru-103	39.4d	155	497(0.89)
Alkaline Earths	Sr-91	9.5h	115	750(0.23),1024(0.325)
	Sr-92	2.71h	123	1388(0.9)
	Ba-140	12.8d	173	537(0.254)
Rare Earths	Y-92	3.54h	124	934(0.139)
	La-140	40.2h	184	487(0.455),1597(0.955)
	Ce-141	32.5d	161	145(0.48)
	Ce-144	284.3d	129	134(0.108
Refractories	Zr-95	64.0d	161	724(0.437),757(0.553)
	Zr-97	16.9h	166	743(0.928)

*Only the representative isotopes which have relatively large inventory and considered to be easy to measure are listed here.

**At the time of reactor shutdown.

Table 2

FISSION PRODUCT CONCENTRATIONS IN REACTOR WATER
AND DRYWELL GAS SPACE DURING REACTOR SHUTDOWN UNDER NORMAL CONDITIONS

Isotope	Reactor Water, μCi/g Upper Limit	Reactor Water, μCi/g Nominal	Drywell Gas (μCi/cc) Upper Limit	Drywell Gas (μCi/cc) Nominal
I-131	29	0.7	---	---
Cs-137[c]	0.3[a]	0.03[b]	---	---
Xe-133	---	---	10^{-4}[a]	10^{-5}[b]
Kr-85	---	---	4×10^{-5}[a]	4×10^{-6}[b]

[a]Observed experimentally, in an operating BWR-3 with MK I containment, data obtained from GE unpublished document, DRF 268-DEV-0009.

[b]Assuming 10% of the upper limit values.

[c]Release of Cs-137 activity would strongly depend on the core inventory which is a function of fuel burnup.

Table 3

RATIOS OF ISOTOPES IN CORE INVENTORY AND FUEL GAP

Isotope	Half-Life	Activity Ratio* in Core Inventory	Activity Ratio* in Fuel Gap
Kr-87	76.3 m	0.233	0.0234
Kr-88	2.84h	0.33	0.0495
Kr-85m	4.48h	0.122	0.023
Xe-133	5.25d	1.0*	1.0*
I-134	52.6 m	2.3	0.155
I-132	2.3 h	1.46	0.127
I-135	6.61h	1.97	0.364
I-133	20.8 h	2.09	0.685
I-131	8.04d	1.0*	1.0*

$$\text{*Ratio} = \frac{\text{noble gas isotope concentration}}{\text{Xe-133 concentration}} \quad \text{for noble gases}$$

$$= \frac{\text{Iodine isotope concentration}}{\text{I-131 concentration}} \quad \text{for iodines}$$

Table 4

BEST-ESTIMATE FISSION PRODUCT RELEASE FRACTIONS

	Gap Release			Meltdown Release			Oxidation Release			Vaporization Release		
	Nominal	Lower Limit	Upper Limit	Nominal	Lower Limit	Upper Limit	Nominal	Lower Limit	Upper Limit	Nominal	Lower Limit	Upper Limit
Noble Gases (Xe,Kr)	0.030	0.010	0.12	0.873	0.485	0.970	0.087	0.078	0.097	0.010	0.010	0.010
Halogens (I,Br)	0.017	0.001	0.20	0.885	0.492	0.983	0.088	0.078	0.098	0.010	0.010	0.010
Alkali Metals (Cs,Rb)	0.050	0.004	0.30	0.760	0.380	0.855	---	---	---	0.190	0.190	0.190
Tellurium Group (Te,Se,Sb)	0.0001	3×10^{-7}	0.04	0.150	0.05	0.250	0.510	0.340	0.680	0.340	0.340	0.340
Noble Metals (Ru,Rh,Pd,Mo,Tc)	---	---	---	0.030	0.01	0.10	0.873	0.776	0.970	0.005	0.001	0.024
Alkaline Earths (Sr,Ba)	1×10^{-6}	3×10^{-9}	0.0004	0.100	0.02	0.20	---	---	---	0.009	0.002	0.045
Rare Earths (Y,La,Ce,Nd,Pr, Eu,Pm,Sm,Np,Pu)	---	---	---	0.003	0.001	0.01	---	---	---	0.010	0.002	0.050
Refractories (Zr,Nb)	---	---	---	0.003	0.001	0.01	---	---	---	---	---	---

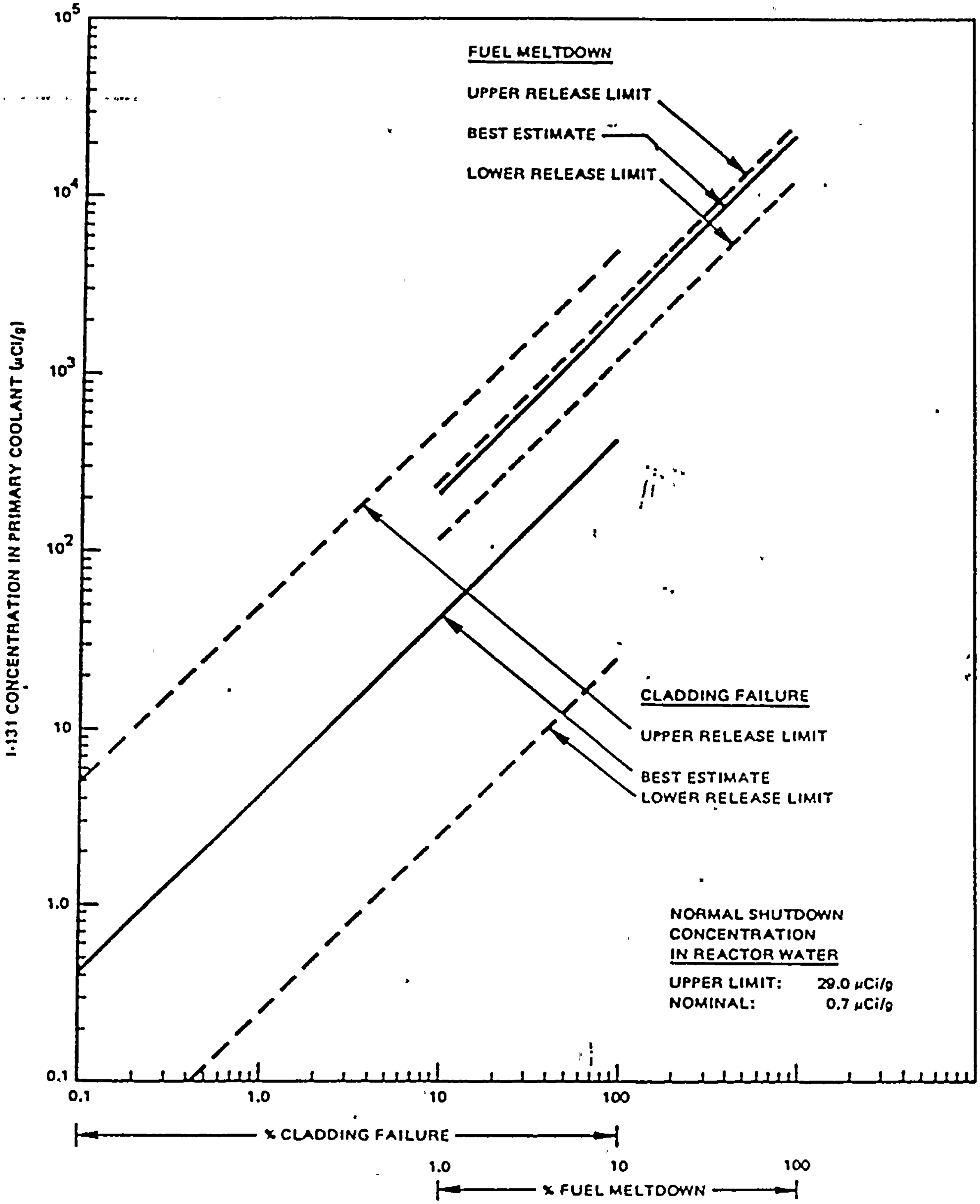

Figure 1. Relationship Between I-131 Concentration in the Primary Coolant (Reactor Water + Pool Water) and the Extent of Core Damage in Reference Plant

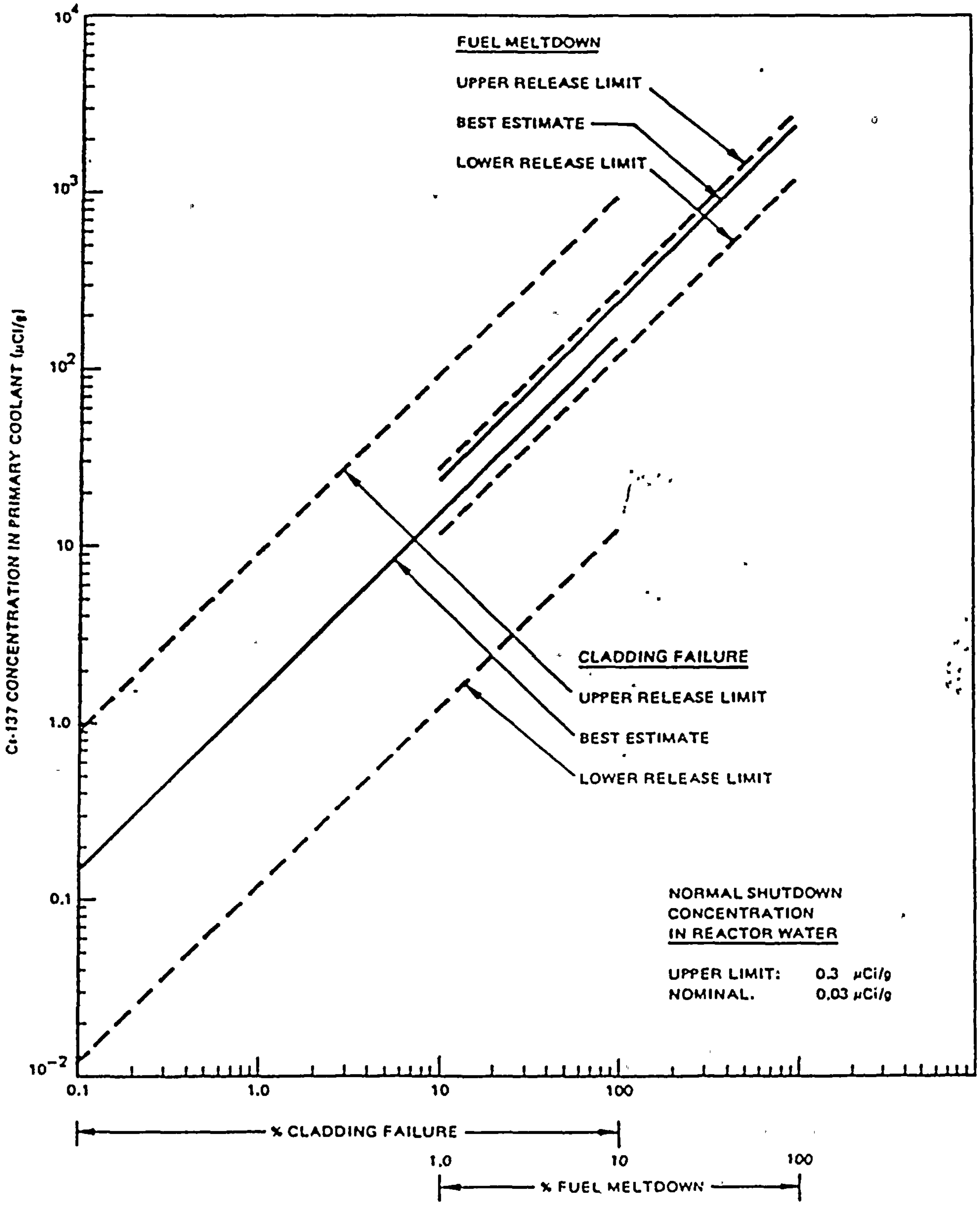

Figure 2. Relationship Between Cs-137 Concentration in the Primary Coolant (Reactor Water + Pool Water) and the Extent of Core Damage in Reference Plant

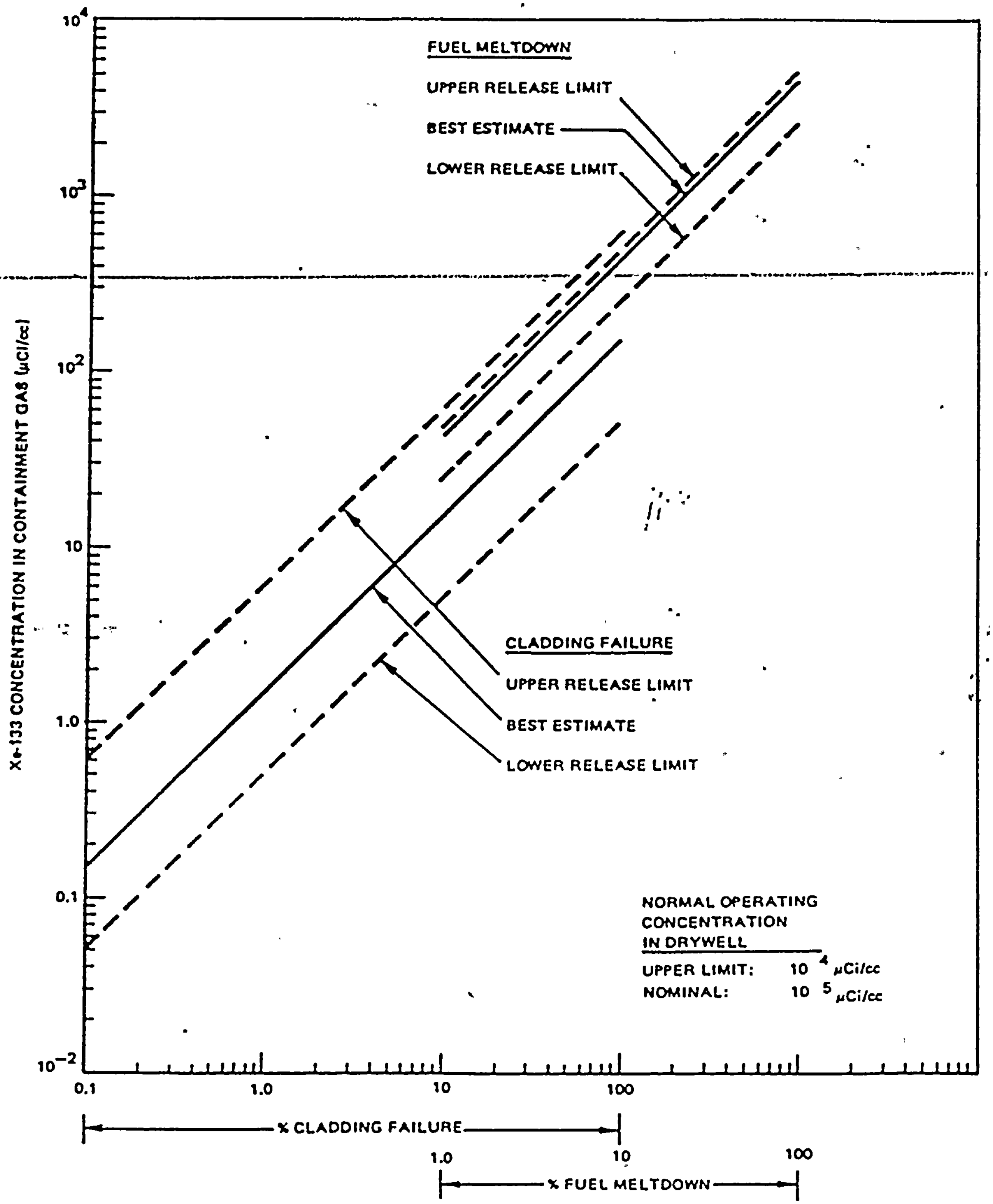

Figure 3. Relationship Between Xe-133 Concentration in the Containment Gas (Drywell + Torus Gas) and the Extent of Core Damage in Reference Plant

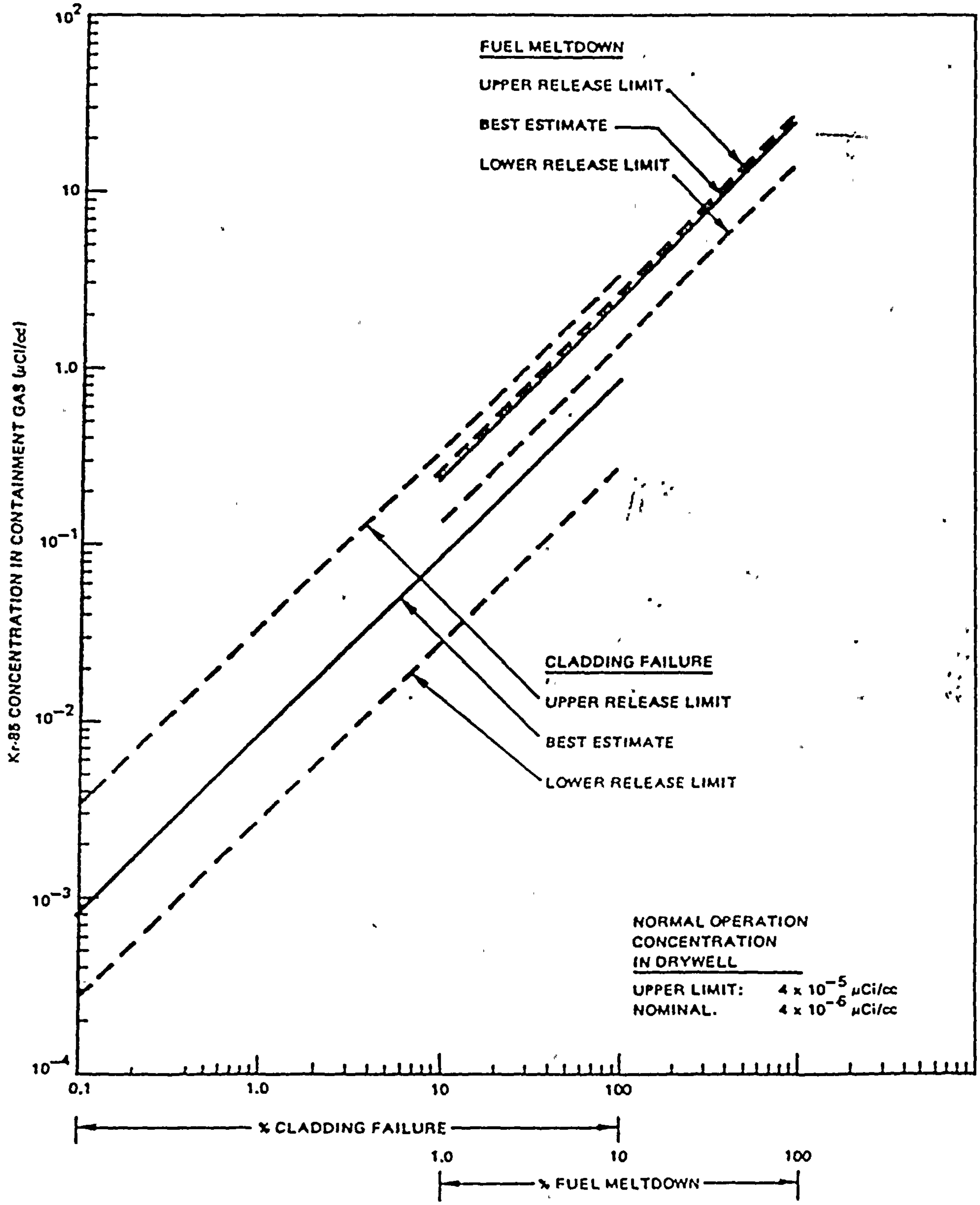

Figure 4. Relationship Between Kr-85 Concentration in the Containment Gas (Drywell + Torus Gas) and the Extent of Core Damage in Reference Plant

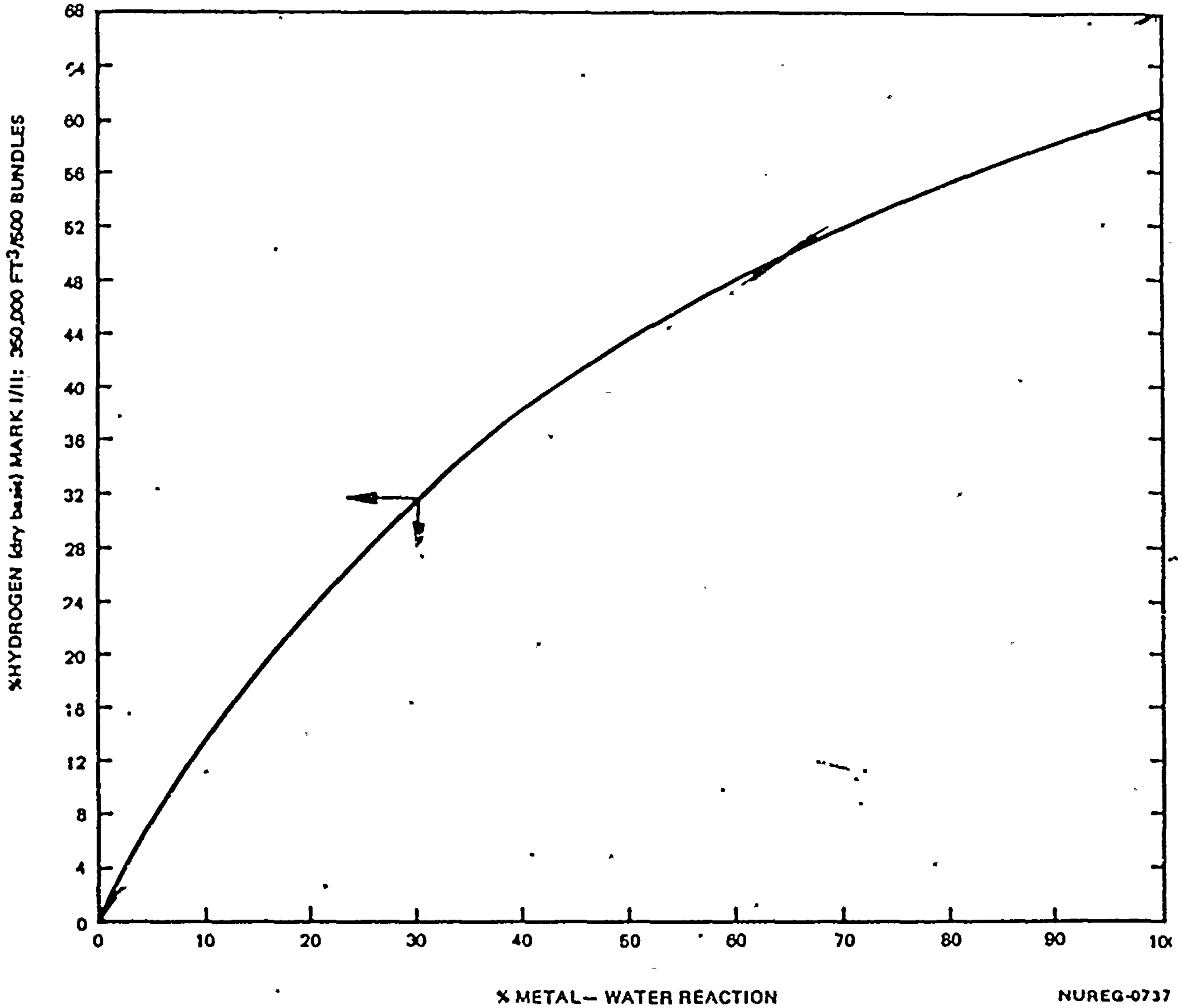

Figure 5 Hydrogen Concentration for Mark I/II Containments as a Function of Metal-Water Reaction

Appendix A

SAMPLE CALCULATION OF FISSION PRODUCT INVENTORY CORRECTION FACTOR

$$F_{Ii} = \frac{\text{Inventory of nuclide i in reference plant}}{\text{Inventory of nuclide i in operating plant}}$$

$$= \frac{3651\,(1-e^{-1095\lambda_i})}{\sum_j \left[P_j\,(1-e^{-\lambda_i T_j})\,e^{-\lambda_i T_j^0} \right]}$$

where

P_j = steady reactor power operated in period j (MWt)

λ_i = decay constant of nuclide i (day^{-1})

T_j = duration of operating period j (day)

T_j^0 = time between the end of operating period j and time of last reactor shutdown (day)

3651 = ave. operation power (in MWt) for the reference plant.

1095 = continuous operation time (in day) for the reference plant.

Assuming a reactor has the following power operation history:

Operation Period	Days Since Startup	Operation Time T_j (day)	T_j^0	Average Power P_j (MWt)
1A	1 - 60	60	254	1000
1B	61 - 70	---	---	0
2A	71 - 270	200	44	2000
2B	271 - 300	---	---	0
3	301 - 314	14	0	3000

[illegible]

- For I-131 ($\lambda = 0.0862\ \text{day}^{-1}$)

$$F_{I(I-131)} = \frac{3651(1-e^{-0.0862x1095})}{1000(1-e^{-0.0862x60})e^{-0.0862x254} + 2000(1-e^{-0.0862x200})e^{-0.0862x44} + 3000(1-e^{-0.0862x14})e^{-0.0862x0}}$$

$$= \frac{3651}{\sim 0 + .45 + 2103} = 1.7$$

- For Cs-137 ($\lambda = 6.29 \times 10^{-5}\ \text{day}^{-1}$)

$$F_{I(Cs-137)} = \frac{3651(1-e^{-6.29x10^{-5}x1095})}{1000(1-e^{-6.29x10^{-5}x60})e^{-6.29x10^{-5}x254} + 2000(1-e^{-6.29x10^{-5}x200})e^{-6.29x10^{-5}x44} + 3000(1-e^{-6.29x10^{-5}x14})e^{-6.29x10^{-5}x0}}$$

$$= \frac{243.16}{3.74 + 24.93 + 2.64} = 7.77$$

Worksheet 1

Core Damage Estimate Based on I-131, Cs-137, Xe-133 and Kr-85 Concentrations

NOTE: Follow Section 5.2 of procedure while completing this worksheet.

1) List the radionuclide concentrations (C_w or C_g) decayed to the time of reactor shutdown as determined from steps 5.6.1.4 and 5.6.1.5 of N1-PSP-13. Attach Sample Analysis Data Sheets.

C_w(I-131) = ______________________ μCi/ml

C_w(Cs-137) = ______________________ μCi/ml

uncorrected
C_g(Xe-133) = ______________________ μCi/cc at 14.7 psia, 298°K

uncorrected
C_g(Kr-85) = ______________________ μCi/cc at 14.7 psia, 298°K

2) Correct the measured gaseous activities for T, P differences between the sample vial and containment atmosphere per section 5.4.

$$C_{gi}^{\text{uncorrected}} \times \frac{P_2\,(298)}{T_2\,(14.7)} = C_{gi}$$

For Xe-133: ________ x $\frac{\_\_\_\,(298)}{\_\_\_\,(14.7)}$ = ____________ μCi/cc

For Kr-85: ________ x $\frac{\_\_\_\,(298)}{\_\_\_\,(14.7)}$ = ____________ μCi/cc

3) Calculate the Fission Product Inventory Correction Factor for I-131, Cs-137, Xe-133, Kr-85. Use Worksheet 1A, 1B, 1C or 1D as appropriate. See Appendix A for an example.

F_I(I-131) = ____________

F_I(Cs-137) = ____________

F_I(Xe-133) = ____________

F_I(Kr-85) = ____________

4) Calculate the Plant Parameter Correction Factors per section 5.7. If downcomer submergence equals 3 feet:

F_w = 2.38E9/3.92E9 = 0.61
F_g = 8.80E9/4.00E10 = 0.22

Worksheet 1
(Continued)

5) Calculate the Normalized Concentrations of the isotopes as shown below:

$$C_{wi}^{Ref} \text{ or } C_{gi}^{Ref} = C_{wi} \text{ or } C_{gi} \times F_{Ii} \times F_w \text{ or } F_g$$

For I-131: $C_{w(I-131)}^{Ref}$ = _____ x _____ x 0.61 = _________ μCi/ml

For Cs-137: $C_{w(Cs-137)}^{Ref}$ = _____ x _____ x 0.61 = _________ μCi/ml

For Xe-133: $C_{g(Xe-133)}^{Ref}$ = _____ x _____ x 0.22 = _________ μCi/ml

For Kr-85: $C_{g(Kr-85)}^{Ref}$ = _____ x _____ x 0.22 = _________ μCi/ml

6) Refer to Figures 1-4 to determine the best estimate of the extent of core damage.

Best Estimates:

I-131: ____________________% clad failure
____________________% fuel melt

Cs-137: ____________________% clad failure
____________________% fuel melt

Xe-133: ____________________% clad failure
____________________% fuel melt

Kr-85: ____________________% clad failure
____________________% fuel melt

Ave: ____________________% clad failure
____________________% fuel melt

7) Submit all data sheets/worksheets for review by a Technical Support Department Supervisor.

8) Confirm and refine the core damage estimate by applying the parameters found in sections 5.3 and 6.1-6.4 of the procedure.

Worksheet Completed by: ______________________________
Worksheet Reviewed by: ______________________________

Worksheet 1A

Fission Product Inventory Correction Factor for I-131 ($\lambda = 0.0862\ day^{-1}$)

$$F_I(I\text{-}131) = \frac{\text{Inventory of I-131 in reference plant}}{\text{Inventory of I-131 in operating plant}}$$

$$F_I(I\text{-}131) = \frac{3651}{\sum_j \left[P_j \left(1-e^{-(0.0862)\,T_j}\right) e^{-(0.0862)\,T^\circ_j} \right]}$$

Operation Period j	Days Since Startup	Operation Time T_j (day)	T_j	Average Power P_j (MWt)
1A				
1B				
2A				
2B				
3A				
3B				
4				

$F_I(I\text{-}131) = \frac{3651}{\rule{6cm}{0.4pt}}$

$F_I(I\text{-}131) = \frac{3651}{\rule{3cm}{0.4pt}} =$

Calculation Performed By: ____________

Calculation Reviewed By: ____________

Worksheet 1B

Fission Product Inventory Correction Factor for Cs-137
(λ = 6.29E-5 day^{-1})

$$F_{I}(Cs\text{-}137) = \frac{\text{Inventory of Cs-137 in reference plant}}{\text{Inventory of Cs-137 in operating plant}}$$

$$F_{I}(Cs\text{-}137) = \frac{243.2}{\sum_j \left[P_j \left(1-e^{-(6.29E-5)\,T_j}\right) e^{-(6.29E-5)\,T^{\circ}_j} \right]}$$

Operation Period j	Days Since Startup	Operation Time T_j (day)	T°_j	Average Power P_j (MWt)
1A				
1B				
2A				
2B				
3A				
3B				
4				

F_I(Cs-137) = $\dfrac{243.2}{\rule{6cm}{0.4pt}}$

F_I(Cs-137) = $\dfrac{243.2}{\rule{4cm}{0.4pt}}$ =

Calculation Performed By: ____________

Calculation Reviewed By: ____________

WORKSHEET 1C

Fission Product Inventory Correction Factor for Xe-133
(λ = 0.132 day^{-1})

$$F_I \text{ (Xe-133)} = \frac{\text{Inventory of Xe-133 in reference plant}}{\text{Inventory of Xe-133 in operating plant}}$$

$$F_I \text{ (Xe-133)} = \frac{3651}{\sum_j \left[P_j \left(1-e^{-(0.132)\, T_j}\right) e^{-(0.132)\, T^{\circ}_j} \right]}$$

Operation Period j	Days Since Startup	Operation Time T_j (day)	T°_j	Ave. Power P_j (MWT)
1A	____	____	____	____
1B	____	____	____	____
2A	____	____	____	____
2B	____	____	____	____
3A	____	____	____	____
3B	____	____	____	____
4	____	____	____	____

F_I (Xe-133) = ______________________________

F_I (Xe-133) = ____________________ =

Calculation Performed By = ____________________
Calculation Reviewed By = ____________________

WORKSHEET 1D

Fission Product Inventory Correction Factor for Kr-85
($X = 0.132\ \text{day}^{-1}$)

$$F_I\ (\text{Kr-85}) = \frac{\text{Inventory of Kr-85 in reference plant}}{\text{Inventory of Kr-85 in operating plant}}$$

$$F_I\ (\text{Kr-85}) = \frac{643}{\sum_j \left[P_j \left(1 - e^{-(1.77E\text{-}4)\, T_j}\right) e^{-(1.77E\text{-}4)\, T^{\circ}_j} \right]}$$

Operation Period j	Days Since Startup	Operation Time T_j (day)	T°_j	Ave. Power P_j (MWt)
1A				
1B				
2A				
2B				
3A				
3B				
4				

F_I (Kr-85) = ____________________

F_I (Kr-85) = ____________________ =

Calculation Performed By = ____________________
Calculation Reviewed By = ____________________