E.J. Mroczka
Form Approved by Station Superintendent

8-25-83
Effective Date

STATION PROCEDURE COVER SHEET

A. IDENTIFICATION

Number EPIP 4226 Rev. 0

Title UNIT 3 CORE DAMAGE ESTIMATE PROCEDURE

Prepared By Mari J. Jaworsky

B. REVIEW

I have reviewed the above procedure and have found it to be satisfactory.

TITLE	SIGNATURE	DATE
DEPARTMENT HEAD	John F. Langley	7-2-84
Radiological Engineer	Mari Jaworsky	7/3/84

C. UNREVIEWED SAFETY QUESTION EVALUATION DOCUMENTATION REQUIRED:

(Significant change in procedure method or scope as described in FSAR)
(If yes, document in PORC/SORC meeting minutes) YES [ ] NO [X]

ENVIRONMENTAL IMPACT

(Adverse environmental impact)
(If yes, document in PORC/SORC meeting minutes) YES [ ] NO [X]

D. PROCEDURE REQUIRES ~~PORC~~/SORC REVIEW YES [X] NO [ ]

E. ~~PORC~~/SORC APPROVAL

~~PORC~~/SORC Meeting Number 84-26

F. APPROVAL AND IMPLEMENTATION

The attached procedure is hereby approved, and effective on the date below:

E J Mroczka
Station/Service/Unit Superintendent

7-20-84
Effective Date

SF-301
Rev. 6

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UNIT 3 CORE DAMAGE ESTIMATE PROCEDURE

PAGE NO.	EFF. REV.
1-25	0

Responsible Individual Radiological Services Supervisor
Title

1. OBJECTIVE

To provide a methodology to determine the extent of core damage under accident conditions.

2. DISCUSSION

2.1 Accident Description

2.1.1 Clad Damage

2.1.1.1 An increasing potential for inadequate core cooling exists.

2.1.1.2 Loose part indication is observed.

2.1.1.3 No significant overheating has been observed at this point.

2.1.2 Fuel Overheating

2.1.2.1 The fuel is suspected to be at least partially uncovered for a period of time greater than a few minutes.

2.1.2.2 Loss of inventory in the pressurizer is observed.

2.1.2.3 Hot leg temperatures are increasing.

2.1.2.4 Voiding in the core is detected (use of picoameter across readout of in-core instrumentation in control room).

2.1.2.5 Ex-core countrate increasing (occurs when uncovered core is no longer shielded by water).

2.1.2.6 High in-core thermocouple readings are observed.

2.1.2.7 Fuel clad oxidation is detected by excess hydrogen in the containment (>½%).

2.1.3 Fuel Meltdown

2.1.3.1 The core has been uncovered for an appreciable period of time.

2.1.3.2 In-core thermocouples are off-scale.

2.1.3.3 In-core and ex-core instrumentation display erratic readings.

2.1.3.4 In-core flux detectors cannot be moved properly (not normally expected to be done).

2.2 Isotopic Analysis

2.2.1 Most of the noble gases will be seen in containment air samples unless the break has not occurred inside the containment, e.g. a Steam Generator Tube Rupture.

2.2.2 The appearance of noble gases and iodines in either containment gas or Reactor Coolant Sample without the presence of other fission products is a fair indication of clad damage and perhaps some degree of fuel overheat.

2.2.3 Iodine could be found in both the reactor coolant and containment air samples, depending on the accident scenario and on the physical and chemical form of the release. If both samples are available, then the total iodine released can be determined from both samples. However, iodine should not be used as the sole means of determining an estimate of core damage since it is difficult to determine the extent to which iodine will plate-out on containment walls and other surfaces and on piping walls. Also, spiking due to power excursions can lead to inaccurate results in this analysis.

2.2.4 If core temperatures are below 2,300 °F or if the core has not been at least partially uncovered for an appreciable amount of time, then no <u>significant</u> quantity of cesiums (i.e., >30% of the inventory) should be found. (It should be noted that core thermocouples may not show an accurate indication of actual core temperatures.) Therefore, the presence of an appreciable amount of cesium will be indicative of a fuel overheat situation. The amount of hydrogen in the sample(s) will serve as a confirmation. It should also be noted that just as in the case of iodines, the cesiums from both containment air and reactor coolant samples should be taken together.

2.2.5 Nearly complete release of noble gases, iodines, and cesium from extensively damaged fuel clad is expected even if fuel temperatures remain below the melting point.

2.2.6 As the fuel temperature increases (and fuel melting is suspected to have occurred), the likelihood of finding significant quantities above the baseline of other core solids (Groups 4 to 8 in Table 6) increases. However, these fission products will not be found in reactor coolant samples unless the core has been covered and a recirculation mode has been established. Many of the fission products and most of the actinides which occur as refractory oxides are released only in relatively small amounts even at elevated temperatures. However, if damaged fuel pellets are rewetted some of the more refractory radioactive material will be leached out.

2.2.7 Significant releases of tellurium, ruthenium and more refractory materials will occur only if the temperature approaches the fuel melting point (5,200 °F). However, the presence of ruthenium and tellurium does not "prove" melting, but their absence in long-term sampling analysis is a good indicator that melt has not occurred.

2.2.8 A fixed inventory of radioisotopes exists within the fuel pellet, assuming equilibrium conditions have been reached. The relative ratios of the isotopes which have reached equilibrium can be considered a constant value. The distribution of isotopes in the gap are not in the same proportion as in the fuel pellet. This is due to the differing diffusion rates from the pellet to the gap for each of the isotopes. In an accident situation, the ratios of the isotopic activities obtained from the PASS sample can be compared to the ratios in Table 8. If the ratios from the PASS sample are higher than the gap activity ratios, then this can be indicative of more severe failures, e.g. fuel overheat or even melt.

2.2.9 If conflicting data exist, then all indications involved should be reanalyzed.

3. INSTRUCTIONS

3.1 A "first-cut" estimate of the extent of core damage can be obtained by using the containment high range monitors as given in Drywell/Containment Curie Level Estimation EPIP 4212. The percent inventory of noble gases released, divided by 100, can be used as "F_{REL}" in Part III.6, Table 3 for noble gases.

3.2 Samples will be obtained using EPIP 4224, Unit 3 Reactor Coolant Post-Accident Sampling, and EPIP 4225, Unit 3 Containment Air Post-Accident Sampling.

3.3 Samples will be analyzed using EPIP 4224 and EPIP 4225 for the gamma spectrum and hydrogen analysis. The results must be decay-corrected to the time of reactor shutdown. Half-lives of selected isotopes are given in Table 7.

3.4 The results from both reactor coolant and containment air samples should be used for this analysis whenever possible and if appropriate.

3.5 The sampling point to be utilized to draw a sample will be determined using Table 1.

3.6 The Plant Parameter Sheet (Table 2) should be completed to the extent possible using EPIP 4219 "MP3 NESS" available on TSO's in the Control Room, TSC, and EOF or directly from the Control Room.

3.7 A dilution and pressure and temperature correction will be performed using Part I of Table 3.

3.8 A baseline subtraction should be performed unless baseline activity concentrations are negligible compared to accident activity concentrations.

3.9 A density correction will be performed on Reactor Coolant samples using Tables 3 and 4.

3.10 The total curies released, percent of core inventory released, and type of release will be determined using Table 3 in conjunction with Tables 5 and 6.

3.11 As an additional confirmatory piece of information, a ratio of each of the noble gases to Xe133 activity and each of the iodines to I131 will have to be determined. Once these ratios are obtained they will be compared against the fuel pellet activity ratios and the gap activity ratios in Table 8. A choice will have to be made in Table 3, Part III regarding which ratios the post-accident values are most similar to.

3.12 This information will be reported to the Manager of Radiological Dose Assessment (MRDA).

4. TABLES

MJJ:jlc

Table 1

POST ACCIDENT SAMPLING POINTS

Sampling Point	Limitations
1. Loop A Hot Leg	Break should not be upstream of the sampling point.
2. Loop C Hot Leg	Break should not be upstream of the sampling point.
3. Containment Sump via Containment Spray System (To be verified).	System should be in operation and sump recirculation actuation signal should be in effect prior to sampling.
4. Containment Air	Sampling may not need to be performed for an isotopic analysis if indications are that a release to the containment atmosphere has not occurred, e.g. steam generator tube rupture. (Please note there are two samplng points available since the hydrogen recombiner intake lines are used and this system is redundant. They are located more than 90 feet apart.)

Table 2

MP-3 Plant Parameters

Time of Sampling: ______________

1. Time of reactor shutdown: . . . . ______________

2. a. Refueling Water Storage Tank (RWST) Level . . ______________ % capacity (Initial)

   ______________ % capacity (at time of sampling)

   (Circle One)

   b. Accumulator Tank 1 Isolation Valve . . . . . Open/Closed

   Tank 2 Isolation Valve . . . . . Open/Closed

   Tank 3 Isolation Valve . . . . . Open/Closed

   Tank 4 Isolation Valve . . . . . Open/Closed

3. Emergency Cooling Systems: . . . . Yes ___ No ___
   Which ? ______________
   Recirc mode: Yes __ No __

4. Containment Hi-Range Monitor Reading: . . . . . . a) ____________ R/hr

   b) ____________ R/hr

   "First Cut" Damage Estimate (From EPIP 4212): ____________ % Inventory Released

5. Containment: . . . . Pressure ______________ psig

   Temperature ______________ °F

6. Reactor Coolant Temperature (average): . . . . . . ______________ °F

7. Reactor Coolant Pressure . . . . ______________ psig

Table 3

DATA SHEET FOR CORE DAMAGE ESTIMATE

Part I

Isotope ____________________________

1\. a) C_{mRC} = measured activity concentration in Reactor Coolant in uCi/cc = ____________________________uCi/cc

b) C_{mair} = measured activity concentration in Containment Atmosphere in uCi/cc = ____________________uCi/cc

2\. DECAY CORRECTION (If the half-life of an isotope is much longer than the time since shutdown, this step can be eliminated. Therefore, the value for C_{mRC} and C_{mair} will be placed in C_{RC} or C_{air}, as appropriate).

t = time since reactor shutdown to time of sampling = (1)_________________ hrs (Table 2, #1)

$\lambda = (0.692/T_{\frac{1}{2}})$ = (0.692/__________________hrs)
(Table 7)

λ = (2)____________________ hrs^{-1}

a) Reactor Coolant: $C_{RC} = C_{mRC} \exp[\lambda t]$

C_{RC} = ____________________μCi/cc x exp [(2)____________ hrs^{-1} x (1)______________ hrs]
(#1a above)

C_{RC} = ____________________μCi/cc

b) Containment Air: $C_{air} = C_{mair} \exp[\lambda t]$

C_{air} = ____________________μCi/cc x exp [(2)____________ hrs^{-1} x (1)______________ hrs]
(#1b above)

C_{air} = ____________________μCi/cc

Table 3

DATA SHEET FOR CORE DAMAGE ESTIMATE (Cont'd)

Part I

3. DL = Dilution correction = ______________________________ (Reactor Coolant Sample)

= ______________ 1 ______________ if accounted for previously. (Use DL=1 if uncertain).

4. DC = Density correction = ______________________________ (Table 4) (Reactor Coolant Sample)

Sample Temperature __________°F Reactor Coolant Average Temperature = _______°F (#6, Table 2)

5. Vol^*_{RC} = Volume of Reactor Coolant in cc = (1) 3.31 x 10^8cc (If a Steam Generator Tube Rupture has occurred, an estimate will have to be made regarding the amount of Reactor Coolant left inside the primary system; in other words, only a portion of the above amount will be used for this calculation).

*The total volume of Reactor Coolant used will be determined by which emergency cooling systems are used, if any, and what source of cooling water is used for these systems.

a. Total RWST water used = (_________% initial capacity - ________% at time of sampling) x 1,206,556 gal/100
(See #2a, Table 2)

= ___________ gal x 3785 cc/gal

= (2) __________ cc

b. The amount of water volume added from the accumulator tanks can be calculated by determining how many, if any, of the tanks have been used for emergency cooling. This can be done by referring to section 2b on Table 2. Also, Reactor Coolant pressure has to be below 600 psig (see Table 2, #7). Therefore:

The amount of water volume added from the accumulator tanks in cc = 2.69 x 10^7 cc x ______________________*
Number of Valves Opened
(Table 2, #2b)

= (3) __________ cc

*If uncertain about how many valves have been opened, then assume all four have opened if the Reactor Coolant pressure is below 600 psig (see Table 2, #7).

Table 3

DATA SHEET FOR CORE DAMAGE ESTIMATE (Cont'd)

Part I

c. Total Vol_{RC} = (1) ____________ cc + (2) ____________ cc + (3) ____________ cc = ____________ cc

6. Vol_{air} = Volume of Containment Air = 6.5×10^{10} cc.

7. PT = pressure & temperature correction of a gas sample = 1 if previously accounted for.

= $P_c T_s / P_s T_c$ otherwise.

P_c = containment presssure (psig) + 14.7 psia

P_c = ____________________ psig (#5 of Table 2) + 14.7 psia = ____________________ psia

P_s = sample pressure (psig) + 14.7 psia

T_s = temperature of sample + 459°F

T_s = *____________________ °F + 459°F = ____________________ °R

*Use 70°F if actual temperature is not known.

T_c = containment temperature °F + 459°F

Table 3

DATA SHEET FOR CORE DAMAGE ESTIMATE (Cont'd)

Part I

T_c = ____________________°F (#5 of Table 2) + 459°F = __________________________°R

PT = P_cT_s/P_sT_c = (_________psia x _____________°R)/(__________psia x ___________°R)

PT = __________________________________

8. C_{INV} = Curies of Isotopes in core in Curies (obtained from Table 5) = ________Ci

Table 3

CALCULATION OF FRACTION OF INVENTORY RELEASED

Part II

Isotope ______________________

a. Reactor Coolant

Total Curies in Reactor Coolant = $A_{RC} = C_{RC} \times DL \times DC \times Vol_{RC}$

$$A_{RC} = \underset{(\#2a,\ \text{Part I})}{\underline{\hspace{3cm}}}\ \text{uCi/cc} \times \underset{(\#3,\ \text{Part I})}{\underline{\hspace{3cm}}} \times \underset{(\#4,\ \text{Part I})}{\underline{\hspace{3cm}}} \times \underset{(\#5,\ \text{Part I})}{\underline{\hspace{3cm}}}\ \text{cc} \times \frac{1\ \text{Ci}}{10^6\,\text{uCi}}$$

A_{RC} = ______________________ Ci

b. Containment Air

Total Curies in Containment air = $A_{air} = C_{air} \times PT \times Vol_{air}$

$$A_{air} = (\underset{(\#2b,\ \text{Part I})}{\underline{\hspace{3cm}}}\ \text{uCi/cc}) \times \underset{(\#7,\ \text{Part I})}{\underline{\hspace{3cm}}} \times \underset{(\#6,\ \text{Part I})}{\underline{\hspace{3cm}}}\ \text{cc} \times \frac{1\ \text{Ci}}{10^6\,\text{uCi}}$$

A_{air} = ______________________ Ci

c. Fraction Release

Fraction of Core Inventory Released = $F_{REL} = (A_{RC} + A_{air})/C_{INV}$

$$F_{REL} = (\underline{\hspace{3cm}}\ \text{Ci} + \underline{\hspace{3cm}}\ \text{Ci})/\underset{(\#8,\ \text{Part I})}{\underline{\hspace{3cm}}}\ \text{Ci}$$

F_{REL} = ______________________

(F_{REL} for a noble gas can be compared with #4 of Table 2, i.e., % Inventory Released from EPIP 4212.)

Table 3

CORE DAMAGE ESTIMATE

Part III

Isotope ________________________

1. The release fraction, F_{REL}, obtain in Part II of this attachment, will be compared against the values in Table 6.

2. The first step is to determine the "group" to which the isotope belongs. For example, I135 belongs in group 2 (rated by relative volatility), Halogens. Cs134 belongs in group 3, Alkali Metals.

3. Once the group to which the isotope belongs has been found, the range of release fractions can be determined using the same table. For example, if $F_{REL} = 0.25$ for I135, then the range is 0.20 to 0.50 under "fuel overheating" since 0.25 falls within that range.

4. The higher number of the range will be used to determine the extent of core damage. For example:

   F_{REL} = 0.25 Isotope I135

   Isotope Group 2 Type Halogens Type of Damage Fuel overheating

   Release Fraction Range 0.20 to 0.50

   F_{comp} = fraction used for comparison = 0.50

   Fraction of fuel overheating = $F = F_{REL}/F_{comp} = 0.25/0.50 = .50$

   Comments: Up to 50% percent of the fuel has experienced overheating.

5. It is important to remember this kind of determination must be both quantitative and qualitative since in a situation where core degradation can, or has, occurred, conflicting data can exist. Section 2.1 contains an operational description of the various states of core degradation. A qualitative description of what the isotopic analysis can indicate is given in Section 2.2. These should be referred before a final decision is made regarding the extent of core damage.

Table 3

CORE DAMAGE ESTIMATE (Cont'd)

Part III

6. Please note that although the table in Table 6 gives discrete limits to each type of core damage, in reality no one state exists alone. In other words, if it is calculated that extensive clad damage (e.g., 90%) has occurred, then a portion of the fuel is probably experiencing overheating, and perhaps localized melting of fuel has also occurred.

F_{REL} = ____________________ Isotope = ____________________

Isotope Group ____________________ Type ____________ Type of Damage ____________________

Release Fraction Range ____________________

F_{comp} = fraction used for comparison = ____________________

Fraction of ____________________ = $F = F_{REL}/F_{comp}$ = (__________)/(__________) = ____________________

From Table 8 the isotope ratios are comparable to: Gap Activity/Fuel Pellet Activity.
(Circle One)

Table 3

CORE DAMAGE ESTIMATE (Cont'd)

Part III

Comments: ____

Performed by ____________________ Date __________

Approved by ____________________ Date __________

Table 5

FISSION PRODUCT INVENTORY FOR MP-3 AT SHUTDOWN

Isotopes	Curies	
Kr 83M	1.26+07*	*1.26x10^{7}
Kr 85M	2.45+07	
Kr 85	9.89+05	
Kr 87	4.09+07	
Kr 88	6.14+07	
Kr 89	7.50+07	
Kr 90	8.53+07	
Kr 91	6.48+07	
Xe 131M	6.00+05	
Xe 133M	6.67+06	
Xe 133	1.38+08	
Xe 135M	3.31+07	
Xe 135	2.53+07	
Xe 137	1.67+08	
Xe 138	1.60+08	
Xe 139	1.33+08	
Xe 140	8.87+07	
Xe 141	3.41+07	
Br 84	1.84+07	
Br 85	2.29+07	
Br 86	3.37+07	
Br 87	4.09+07	
Br 88	5.12+07	
Br 89	5.12+07	
Br 90	5.12+07	
I 131	9.21+07	
I 132	1.30+08	
I 133	1.88+08	
I 134	2.01+08	
I 135	1.74+08	
I 136	9.55+07	
I 137	1.16+08	
I 138	7.16+07	
I 139	3.75+07	
I 140	1.60+07	
Se 84	1.81+07	
Se 85	2.15+07	
Se 86	2.59+07	
Se 87	2.25+07	

Table 4

DENSITY CORRECTION FACTORS

Reactor Coolant Average Temperature °F	Sample Temperature °F				
	60	70	80	90	100
100	.994	.995	.996	.998	1.0
150	.981	.982	.983	.985	.987
200	.964	.965	.966	.968	.970
250	.943	.944	.945	.947	.949
300	.919	.920	.921	.923	.924
350	.891	.892	.894	.895	.897
400	.860	.861	.862	.864	.865
450	.825	.826	.827	.828	.830
500	.785	.786	.787	.788	.790
550	.737	.738	.739	.740	.742
560	.727	.727	.728	.729	.731
570	.716	.716	.717	.718	.720
580	.704	.705	.706	.707	.708
590	.691	.692	.693	.694	.696
600	.679	.679	.680	.681	.683
610	.665	.666	.667	.668	.669
620	.651	.651	.652	.653	.654
630	.635	.636	.637	.638	.639
640	.618	.619	.620	.621	.622
650	.600	.600	.601	.602	.603
660	.580	.580	.581	.582	.583
670	.556	.557	.558	.559	.560
680	.529	.529	.530	.531	.532
690	.494	.494	.495	.496	.497
700	.437	.438	.438	.439	.440

Table 5

FISSION PRODUCT INVENTORY FOR MP-3 AT SHUTDOWN (Cont'd)

Isotopes	Curies
Rb 88	6.14+07
Rb 89	7.84+07
Rb 90	1.02+08
Rb 91	1.02+08
Sr 89	8.19+07
Sr 91	1.02+08
Sr 92	1.12+08
Sr 93	1.30+08
Sr 94	1.33+08
Y 91M	6.20+07
Y 91	1.06+08
Y 92	1.13+08
Y 93	1.33+08
Y 94	1.40+08
Y 95	1.50+08
Y 96	1.43+08
Y 99	3.75+07
Zr 95	1.54+08
Zr 97	1.57+08
Zr 98	1.54+08
Zr 99	1.40+08
Zr 100	1.09+08
Nb 95M	3.17+06
Nb 95	1.54+08
Nb 97M	1.55+08
Nb 97	1.57+08
Nb 98M	1.57+08
Nb 99M	5.80+07
Nb 99	1.54+08
Nb 100M	8.87+07
Nb 100	8.87+07
Mo 99	1.74+08
Mo 101	1.57+08
Mo 102	1.47+08
Mo 103M	3.21+07
Mo 103	1.26+08
Mo 104	1.02+08
Tc 99M	1.54+08
Tc 100	1.57+07
Tc 101	1.57+08
Tc 102M	1.50+08
Tc 103	1.50+08
Tc 104	1.19+08

Table 5

FISSION PRODUCT INVENTORY FOR MP-3 AT SHUTDOWN (Cont'd)

Isotopes	Curies
Tc 105	7.85+07
Tc 107	3.37+07
Tc 108	2.39+07
Ru 103	1.50+08
Ru 105	8.19+07
Ru 106	5.46+07
Ru 107	5.12+07
Ru 108	4.09+07
Ru 109	2.49+07
Rh 103M	1.47+08
Rh 104	6.14+07
Rh 105M	1.74+07
Rh 105	8.19+07
Rh 106	5.80+07
Rh 107	5.46+07
Rh 108	4.43+07
Rh 109	2.69+07
Pd 109	2.87+07
Sn 130	3.11+07
Sn 131	2.77+07
Sn 132	2.39+07
Sb 127	9.59+06
Sb 128M	1.40+07
Sb 129	3.07+07
Sb 130	4.43+07
Sb 131	7.50+07
Sb 132M	4.78+07
Sb 132	7.85+07
Sb 133	8.53+07
Sb 134	4.43+07
Sb 135	1.40+07
Te 127	1.23+06
Te 129	2.93+07
Te 131M	1.47+07
Te 131	8.19+07
Te 132	1.30+08
Te 133M	1.09+08
Te 133	8.19+07
Te 134	1.67+08
Te 135	8.53+07
Te 136	3.41+07

Table 5

FISSION PRODUCT INVENTORY FOR MP-3 AT SHUTDOWN (Cont'd)

Isotopes	Curies
Cs 134	1.83+07
Cs 137	1.13+07
Cs 138	1.71+08
Cs 139	1.67+08
Cs 140	1.54+08
Cs 141	1.16+08
Cs 142	7.16+07
Cs 143	3.41+07
Ba 139	1.71+08
Ba 140	1.64+08
Ba 141	1.57+08
Ba 142	1.33+08
Ba 143	1.09+08
Ba 144	6.48+07
La 140	1.71+08
La 141	1.57+08
La 142	1.43+08
La 143	1.36+08
La 144	1.19+08
Ce 141	1.57+08
Ce 143	1.40+08
Ce 144	1.19+08
Ce 145	9.55+07
Ce 146	7.50+07
Ce 147	5.12+07
Ce 148	2.97+07
Pr 142	1.19+07
Pr 143	1.36+08
Pr 144	1.19+08
Pr 145	9.55+07
Pr 146	7.85+07
Pr 147	5.80+07
Pr 148	4.78+07
Pr 149	3.11+07
Nd 147	6.14+07
Nd 149	3.41+07
Nd 151	1.71+07
Pm 147	2.22+07
Pm 149	5.12+07
Pm 151	1.84+07
Sm 153	3.03+07
Eu 156	1.64+07

TABLE 7
HALF-LIVES OF SELECTED ISOTOPES

ISOTOPE	$T_{1/2}$ (HOURS)
Xe 133	129.6
Kr 85	90228
Kr 85m	4.5
Kr 87	1.27
I 131	193.7
I 132	2.30
I 133	20.8
I 134	0.875
I 135	6.7
Cs 134	17870
Cs 137	262800
Cs 138	0.535
Te 132	78
Sr 91	9.7
Sr 92	2.7
Ba 140	307.2
Ru 103	948
Mo 99	67
Ce 144	6840
La 140	40.3
Zr 95	1560
Zr 97	17

Table 6

RELEASE FRACTIONS FOR VARIOUS TYPES OF CORE DAMAGE

Suggested Isotope(s) for Analysis(1)	Sample Type	Relative Volatility(2)	Gap Release(3)	Fuel Overheating	Meltdown
Xe133*,Kr85m Kr87,Kr85*	Containment Air (Reactor Coolant if not depressurized)	1	0.010 to 0.12	0.12 to 0.50	0.50 to 0.970
I131*,I132,I133 I134,I135	Reactor Coolant Containment Air	2	0.001 to 0.200	0.20 to 0.50	0.50 to 0.983
Cs134*,Cs137* Cs138	Reactor Coolant Containment Air	3	0.004 to 0.30	0.30 to 0.50	0.380 to 0.855
Te132	Reactor Coolant	4	3×10^{-7} to 0.04	0.04 to 0.05	0.05 to 0.25
Sr91,Sr92 Ba140*	Reactor Coolant	5	3×10^{-9} to 0.0004	0.0004 to 0.02	0.02 to 0.20
Ru103*,Mo99	Reactor Coolant	6	---	<0.01	0.01 to 0.10
Ce144*,La140	Reactor Coolant	7	---	<0.001	0.001 to 0.01
Zr95*,Zr97	Reactor Coolant	8	---	<0.001	0.001 to 0.01

*Long half-lived isotopes.

Table 6

RELEASE FRACTIONS FOR VARIOUS TYPES OF CORE DAMAGE

Notes

(1) a. The isotopes listed reflect a best choice in terms of measurement and effect from ingrowth of daughter products. However, it should be noted that any short term sample will be difficult to analyze due to the large amount of short-lived isotopes in the sample. There may be many isotopes with similar peaks which will be difficult to distinguish one from another. Some isotopes may have peaks near the annhilation radiation (511KeV). Also, Compton edges could lead to difficulties in the sample analysis.

It is, therefore, recommended that confirming peaks be used in the isotopic analysis. Any other quantifying techniques, such as iodine cartridge analysis, if available, are also suggested.

b. Isotopes with asterisks are those with longer half-lives, and therefore, will serve as a better basis for analysis in long term sampling.

(2) Fission product grouping with respect to their relative volatility.

GROUP	FISSION PRODUCT TYPE
1	Noble Gases (Xe, Kr)
2	Halogens (I, Br)
3	Alkali Metals (Cs, Rb)
4	Tellurium (Te, Se, Sb)
5	Alkaline Earths (Sr, Ba)
6	Noble Metals (Ru, Rh, Pd, Mo, Tc)
7	Rare Earths and Actinides (Y, La, Ce)
8	Refractory Oxides of Zr and Nb

The categories of isotopes are grouped in order of decreasing volatility.

(3) Gap releases are due to clad damage prior to fuel overheat.

TABLE 8
ISOTOPIC ACTIVITY RATIOS

Isotope	Fuel Pellet Activity Ratio	Calculated Ratio	Gap Activity Ratio
KR85M	0.11	_____	0.022
KR87	0.22	_____	0.022
KR88	0.29	_____	0.045
Xe131M	0.004	_____	0.004
Xe133	1.0	_____	1.0
Xe133M	0.14	_____	0.096
Xe135	0.19	_____	0.051
I131	1.0	_____	1.0
I132	1.5	_____	0.17
I133	2.1	_____	0.71
I135	1.9	_____	0.39

$$\text{Noble Gas Ratio} = \frac{\text{Noble Gas Isotope Inventory}}{\text{Xe-133 Inventory}}$$

$$\text{Iodine Ratio} = \frac{\text{Iodine Isotope Inventory}}{\text{I-131 Inventory}}$$

Please Note:

The measured ratios of various nuclides found in reactor coolant during normal operation is a function of the amount of "tramp" uranium on fuel rod cladding, the number and size of "defects" (i.e. "pin holes"), and the location of the fuel rods containing the defects in the core. The ratios above are based on calculated values of relative concentrations in the fuel or in the gap. The use of the above ratios for post accident damage assessment is restricted to an attempt to differentiate between fuel overtemperature conditions and fuel cladding <u>failure</u> conditions. Thus the ratios derived here are <u>not</u> related to fuel <u>defect</u> levels incurred during normal operation.