Form Approved by Station Superintendent 12-28-81
Effective Date

STATION PROCEDURE COVER SHEET

A. IDENTIFICATION

Number EPIP 4221 Rev. 0

Title Unit-1 Core Damage Estimate Procedure

Prepared By Mari Jaworsky

B. REVIEW

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

TITLE	SIGNATURE	DATE
DEPARTMENT HEAD		3-28-83
Engineer-Radiological Assessment	M. J. Jaworsky	3-29-83

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. ~~PORC~~/SORC APPROVAL

PORC/SORC Meeting Number 83-13

E. APPROVAL AND IMPLEMENTATION

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

Station/Service/Unit Superintendent 3-31-83
Effective Date

SF-301
Rev. 5

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PDR ADOCK 05000213
F PDR

UNIT 1
CORE DAMAGE ESTIMATE PROCEDURE

PAGE NO.	EFF. REV.
1-22	0

Responsible Individual: Radiological Services Supervisor
Title

UNIT 1 CORE DAMAGE ESTIMATE PROCEDURE

1.0 OBJECTIVE

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

2.0 DISCUSSION

2.1 Accident Description

2.1.1 Clad Damage

2.1.1.1 Mechanical clad failure is suspected.

2.1.1.2 An abnormal shutdown has occurred and an increasing potential for inadequate core cooling exists.

2.1.1.3 No significant overheating has been observed at this point.

2.1.1.4 Increasing conductivity of reactor water is observed.

2.1.2 Fuel Overheating

2.1.2.1 An abnormal shutdown has occurred.

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

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

2.1.2.4 Fuel clad oxidation is detected by excess hydrogen in the containment (> 10%).

2.1.3 Fuel Meltdown

2.1.3.1 An abnormal shutdown has occurred.

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

2.1.3.3 In-core instrumentation display erratic readings.

2.1.3.4 Traversing in-core probes cannot be moved properly.

2.2 Isotopic Analysis

2.2.1 Most of the noble gases will be seen in containment air samples unless the reactor coolant has not been depressurized.

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 No <u>significant</u> quantity of cesiums (>30% of the inventory) should be found 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. 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 If conflicting data exist, then all indications involved should be reanalyzed.

3.0 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 EPIP 4212, Drywell/Containment Curie Level Estimation.

3.2 Samples will be obtained using EPIP 4214, Unit 1 Reactor Coolant Post-Accident Sampling and EPIP 4215, Unit 1 Containment Air Post-Accident Sampling.

3.3 Samples will be analyzed using EPIP 4214 and 4215 for the gamma spectrum and hydrogen analysis. The result must be decay-corrected to the time of reactor shutdown.

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 the MP-1 Plant Data and Status Sheet available in TSO's in the Control Room, TSC and EOC or directly from the Control Room.

3.7 Any dilution or pressure and temperature correction should be performed prior to using the measured activity concentration in this procedure.

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

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

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

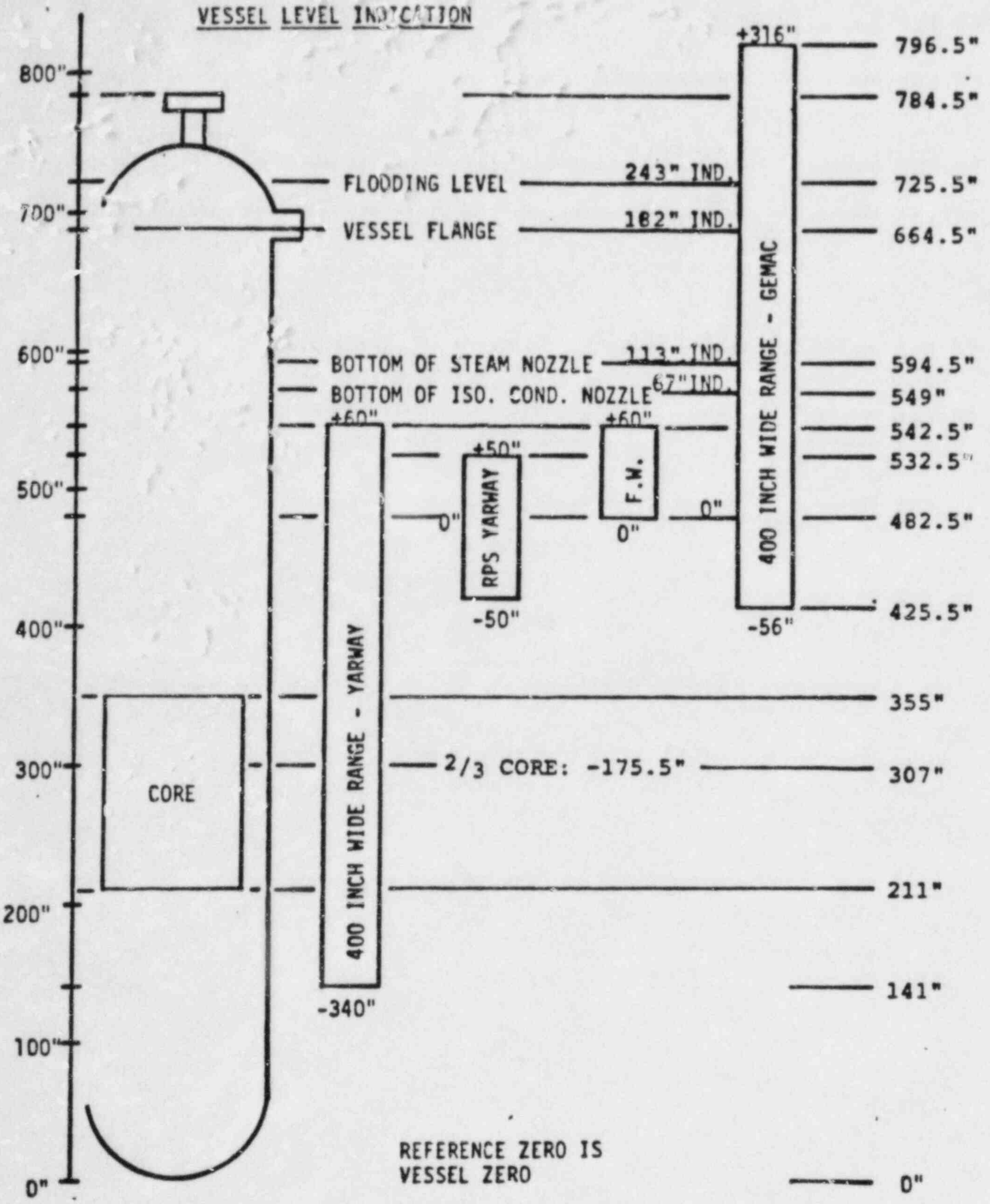
3.11 This information will be reported to the Manager of Radiological Consequence Assessment (MRCA).

4.0 FIGURES

5.0 TABLES

Figure 1

VESSEL LEVEL INDICATION



REFERENCE ZERO IS
VESSEL ZERO

REFERENCE:
OP 506
ATTACHMENT I

Table 1

POST-ACCIDENT SAMPLING POINTS

Sampling Point	Limitations
1. Reactor Water Clean-up System (Loop A, Discharge or Loop B, Discharge via Low Pressure Coolant Injection System (LPCI) Crostie)	1. The RWCU isolation valve (220-44) should be open.
	2. Break should not be upstream of crosstie on Loop B or between the crosstie and the RWCU tie-in on Loop A.
2. Shutdown Cooling System (Loop A, Suction)	1. Shutdown Cooling (SDC) system should be in operation or the SDC isolation valve (MO-100-1) should be open.
	2. Break should not be upstream of SDC system tie-in into Loop A.
3. Torus water via LPCI system	1. LPCI system should be in operation and in a recirculation mode.
	2. In severe accidents this may be the most favorable sampling point for finding solid fission products which may have been leached out through recirculation of the torus water.
4. Upper and Lower Drywell Air	1. Either sampling point is favorable unless drywell air stratifies, then <u>both</u> should ideally be used to draw a sample.
	2. In the case where the Reactor Vessel pressure relief valves have opened, the upper sampling point <u>may</u> yield a sample with higher curie concentrations.

Table 2

MP-1 Plant Parameters

Time of Report: ____________

1. Time of reactor shutdown: . . . . ____________

2. Reactor Water: *(See Figure 1 for reference) . .

   Level* ____________ in

   Average Temperature ____________ °F

3. Condensate Storage Tank Level . . . . *____________ % capacity (initial)

   ____________ % capacity (at time of report)

   *Default value = 90%

4. Emergency Cooling Systems: . . . . Yes ___ No ___
   Recirc mode: Yes __ No __

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

   b) ____________ R/hr

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

6. Drywell: . . . . Pressure ____________ psig

   Temperature ____________ °F

7. Torus: . . . . Temperature ____________ °F

   Pressure ____________ psig

   (Circle One)
   Level Max Min ____________ in

8. Reactor Vessel Pressure: . . . . ____________ psig

9. Safety Relief Valves Open? . . . . Yes ___ No ___

Table 3

DATA SHEET FOR CORE DAMAGE ESTIMATE

Part I

Isotope ______________________________

1. a) C_m = measured activity concentration in Reactor Coolant in uCi/cc = ______________________________ uCi/cc

   b) C_m = measured activity concentration in Containment Atmosphere in uCi/cc = ______________________ uCi/cc

2. a) C_b = baseline activity concentration in Reactor Coolant in uCi/cc = ______________________________ uCi/cc

   = ____0____ if negligible compared to #1a.

   b) C_b = baseline activity concentration in Containment Air in uCi/cc = ______________________ uCi/cc

   = ____0____ if negligible compared to #1b.

3. DL = Dilution correction = ______________________________ .

   = ______________1______________ if accounted for previously.

4. DC = Density correction = ______________________________ (Table 4)

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

5. Vol^*_{RC} = Volume of Reactor Coolant in cc = (1) 2.87×10^8cc

   *If Emergency Cooling has been initiated, then the amount of water added to the system at the time of sampling has to be included in the Reactor Coolant Volume.

   a. If Torus water level is at a minimum (#7, Table 2)

   Vol_{RC} = (2) 3.07×10^9cc

Table 3

DATA SHEET FOR CORE DAMAGE ESTIMATE (Cont'd)

Part I

b. If condensate water has been used for cooling, then its volume will have to be added also. (Maximum condensate which can be added to the torus = 4.3×10^8cc).

Condensate Storage tank at 100% Capacity = 1.74×10^9cc

% Capacity Initial = (C1) ____________ (#3, Table 2)

% Capacity at time of report = (C2) ____________ (#3, Table 2)

Total condensate water used = [(C1) ____ - (C2) ____]/100 x 1.74×10^9 cc

= (3) ___________cc

Vol_{RC} = ___________ + (1 or 2 above) ___________

Vol_{RC} = ___________ cc

6. Vol^*_{AIR} = Volume of Containment Air in cc = 4.16×10^9cc

*If the safety relief valves have been opened, then the volume used will be the drywell plus the torus volume.

a. If the torus water volume is at a minimum (#7, Table 2)

$Vol_{AIR} = 7.70 \times 10^9$cc

b. If the torus water volume is at a maximum (#7, Table 2)

$Vol_{AIR} = 7.27 \times 10^9$cc

7. PT = pressure & temperature correction of a gas sample = _1_ if previously accounted for.

$= P_cT_s/P_sT_c$ otherwise.

P_c = drywell presssure (psig) + 14.7 psia

P_c = ____________________psig (#6 of Table 2) + 14.7 psia = ______________________psia

Table 3

DATA SHEET FOR CORE DAMAGE ESTIMATE (Cont'd)

Part I

P_s = sample pressure (psig) + 14.7 psia

P_s = ____________________psig + 14.7 psia = ______________________psia

T_s = temperature of sample + 459°R

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

T_c = drywell temperature °F + 459°R

T_c = _____________________°F (#6 of Table 2) + 459°R = ___________________________°R

PT = $P_c T_s / P_s T_c$ = (__________psia x _____________°R)/(__________psia x ___________°R)

PT = ____________________________________

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

Table 3

CALCULATION OF FRACTION OF INVENTORY RELEASED

II

e ______________________________

. **Reactor Coolant**

Total Curies in Reactor Coolant = $C_{RC} = (C_m - C_b) \times DL \times DC \times Vol_{RC}$

$$C_{RC} = [\underset{(\#1a,\ Part\ I)}{\underline{\qquad\qquad}}\,uCi/cc - \underset{(\#2a,\ Part\ I)}{\underline{\qquad\qquad}}\,uCi/cc] \times \underset{(\#3,\ Part\ I)}{\underline{\qquad\qquad}} \times \underset{(\#4,\ Part\ I)}{\underline{\qquad\qquad}} \times \underset{(\#5,\ Part\ I)}{\underline{\qquad\qquad}}\,cc \times \frac{1\ Ci}{10^6 uCi}$$

C_{RC} = ____________________ Ci

. **Containment Air**

Total Curies in Reactor Coolant = $C_{air} = [(C_m \times PT) - C_B] \times Vol_{air}$

$$C_{air} = (\underset{(\#1b,\ Part\ I)}{\underline{\qquad\qquad}}\,uCi/cc \times \underset{(\#7,\ Part\ I)}{\underline{\qquad\qquad}} - \underset{(\#2b,\ Part\ I)}{\underline{\qquad\qquad}}\,uCi/cc] \times \underset{(\#6,\ Part\ I)}{\underline{\qquad\qquad}}\,cc \times \frac{1\ Ci}{10^6 uCi}$$

C_{air} = ____________________ Ci

c. **Fraction Release**

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

$$F_{REL} = (\underline{\qquad\qquad\qquad}\,Ci + \underline{\qquad\qquad\qquad}\,Ci)/\underset{(\#8,\ Part\ I)}{\underline{\qquad\qquad\qquad}}\,Ci$$

F_{REL} = ____________________

(F_{REL} for a noble gas can be compared with #5 of Table 2, i.e., % Inventory Released from EPIP 4212.)

Table 3

CORE DAMAGE ESTIMATE

: III

s tope ______________________

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

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.

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.

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 oveheating = F = R_{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 descriptio 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 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 ______________ = $F = F_{REL}/F_{comp}$ = (__________)/(__________) = ______________

Comments: ____

____

____

Performed by ______________ Date ______________

Approved by ______________ Date ______________

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-1 AT SHUTDOWN

Isotopes	Curies
Kr 83M	6.03+06*
Kr 85M	1.45+07
Kr 85	5.83+05
Kr 87	2.41+07
Kr 88	3.62+07
Kr 89	4.42+07
Kr 90	5.03+07
Kr 91	3.82+07
Xe 131M	3.54+05
Xe 133M	3.93+06
Xe 133	1.11+08
Xe 135M	1.95+07
Xe 135	1.49+07
Xe 137	9.85+07
Xe 138	9.45+07
Xe 139	7.84+07
Xe 140	5.23+07
Xe 141	2.01+07
Br 84	1.09+07
Br 85	1.35+07
Br 86	1.99+07
Br 87	2.41+07
Br 88	3.02+07
Br 89	3.02+07
Br 90	3.02+07
I 131	5.43+07
I 132	7.64+07
I 133	1.11+08
I 134	1.19+08
I 135	1.03+08
I 136	5.63+07
I 137	6.84+07
I 138	4.22+07
I 139	2.21+07
I 140	9.45+06
Se 84	1.07+07
Se 85	1.27+07
Se 86	1.53+07
Se 87	1.33+07

*6.03 x 10^6

Table 5

FISSION PRODUCT INVENTORY FOR MP-1 AT SHUTDOWN (Cont'd)

Isotopes	Curies
Rb 88	3.62+07
Rb 89	4.63+07
Rb 90	6.03+07
Rb 91	6.03+07
Sr 89	4.83+07
Sr 91	6.03+07
Sr 92	6.64+07
Sr 93	7.64+07
Sr 94	7.84+07
Y 91M	3.66+07
Y 91	6.23+07
Y 92	6.64+07
Y 93	7.84+07
Y 94	8.25+07
Y 95	8.85+07
Y 96	8.45+07
Y 99	2.21+07
Zr 95	9.05+07
Zr 97	9.25+07
Zr 98	9.05+07
Zr 99	8.25+07
Zr 100	6.44+07
Nb 95M	1.87+06
Nb 95	9.05+07
Nb 97M	9.18+07
Nb 97	9.25+07
Nb 98M	9.25+07
Nb 99M	3.42+07
Nb 99	9.05+07
Nb 100M	5.23+07
Nb 100	5.23+07
Mo 99	1.03+08
Mo 101	9.25+07
Mo 102	8.65+07
Mo 103M	1.89+07
Mo 103	7.44+07
Mo 104	6.03+07
Tc 99M	9.05+07
Tc 100	9.25+06
Tc 101	9.25+07
Tc 102M	8.85+07
Tc 103	8.85+07
Tc 104	7.04+07

Table 5

FISSION PRODUCT INVENTORY FOR MP-1 AT SHUTDOWN (Cont'd)

Isotopes	Curies
Tc 105	4.63+07
Tc 107	1.99+07
Tc 108	1.41+07
Ru 103	8.85+07
Ru 105	4.83+07
Ru 106	3.22+07
Ru 107	3.02+07
Ru 108	2.41+07
Ru 109	1.47+07
Rh 103M	8.65+07
Rh 104	3.62+07
Rh 105M	1.03+07
Rh 105	4.83+07
Rh 106	3.42+07
Rh 107	3.22+07
Rh 108	2.61+07
Rh 109	1.59+07
Pd 109	1.66+07
Sn 130	1.83+07
Sn 131	1.63+07
Sn 132	1.41+07
Sb 127	5.63+06
Sb 128M	8.65+06
Sb 129	1.81+07
Sb 130	2.61+07
Sb 131	4.42+07
Sb 132M	2.82+07
Sb 132	4.63+07
Sb 133	5.03+07
Sb 134	2.61+07
Sb 135	8.25+06
Te 127	7.24+06
Te 129	1.73+07
Te 131M	1.07+07
Te 131	4.83+07
Te 132	7.64+07
Te 133M	6.44+07
Te 133	4.83+07
Te 134	9.85+07
Te 135	5.03+07
Te 136	2.01+07

Table 5

FISSION PRODUCT INVENTORY FOR MP-1 AT SHUTDOWN (Cont'd)

Isotopes	Curies
Cs 134	1.08+07
Cs 137	6.66+06
Cs 138	1.01+08
Cs 139	9.85+07
Cs 140	9.05+07
Cs 141	6.84+07
Cs 142	4.22+07
Cs 143	2.01+07
Ba 139	1.01+08
Ba 140	9.65+07
Ba 141	9.25+07
Ba 142	7.84+07
Ba 143	6.44+07
Ba 144	3.82+07
La 140	1.01+08
La 141	9.25+07
La 142	8.45+07
La 143	8.04+07
La 144	7.04+07
Ce 141	9.25+07
Ce 143	8.25+07
Ce 144	7.04+07
Ce 145	5.63+07
Ce 146	4.42+07
Ce 147	3.02+07
Ce 148	1.71+07
Pr 142	7.04+06
Pr 14.	8.04+07
Pr 144	7.04+07
Pr 145	5.63+07
Pr 146	4.63+07
Pr 147	3.42+07
Pr 148	2.82+07
Pr 149	1.83+07
Nd 147	3.62+07
Nd 149	2.01+07
Nd 151	1.01+07
Pm 147	1.31+07
Pm 149	3.02+07
Pm 151	1.09+07
Sm 153	1.79+07
Eu 156	9.65+06

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	Vaporization(4)	Oxidation(5)
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	0.010	0.078 to 0.097
I131,I132,I133 I134,I135	1. Reactor Coolant 2. Containment Air	2	0.001 to 0.200	0.20 to 0.50	0.50 to 0.983	0.010	0.078 to 0.092
Cs134,Cs137* Cs138	1. Reactor Coolant 2. Containment Air	3	0.004 to 0.30	0.30 to 0.50	0.380 to 0.855	0.190	---
Te132	Reactor Coolant	4	3×10^{-7} to 0.04	0.04 to 0.05	0.05 to 0.25	0.340	0.340 to 0.680
Sr91,Sr92 Ba140	Reactor Coolant	5	3×10^{-9} to 0.0004	0.0004 to 0.02	0.02 to 0.20	0.002 to 0.045	---
Ru103*,Mo99	Reactor Coolant	6	---	<0.01	0.01 to 0.10	0.001 to 0.024	0.776 to 0.970
Ce144*,La140	Reactor Coolant	7	---	<0.001	0.001 to 0.01	0.002 to 0.050	---
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, 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.

(4) Vaporization - accident condition where melting has occurred to the point where molten core and iron penetrate the vessel.

(5) <u>Oxidation</u> - accident condition where a steam explosion in the reactor vessel has occurred and finely divided fuel material is scattered into an oxygen atmosphere and thereby undergoes extensive oxidation which liberates specific fission products.