LOFT TECHNICAL REPORT LTR 129-13

MAY 12, 1978

FISSION PRODUCT INVENTORY, RELEASE FRACTIONS, AND RADIATION
LEVELS FROM FISSION PRODUCTS RELEASED TO THE TEST CHAMBER

N. Maringas

EG&G Idaho, Inc.

IDAHO NATIONAL ENGINEERING LABORATORY

DEPARTMENT OF ENERGY

IDAHO OPERATIONS OFFICE UNDER CONTRACT EY-76-C-07-1570

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LOFT TECHNICAL REPORT LOFT PROGRAM

FORM EG&G-229
(Rev. 12-78)

TITLE Fission Product Inventory, Release Fractions, and Radiation		REPORT NO. LTR 129-13
Levels from Fission Products Released to the Test Chamber		
AUTHOR N. Maringas	GWA NO.	
PERFORMING ORGANIZATION LOFT	DATE May 12, 1978 <i>Jh</i>	
LOFT APPROVAL <i>N. Maringas</i> PSE <i>E. B. White</i> PS&S Supvr. 7/14/78 <i>DR Meyer</i> P&CSB Mgr. <i>ECA</i> RSB Mgr.	PSB Mgr. <i>Jh</i>	

SUMMARY

The fission product inventory, fission product release fractions, and radiation levels following a blowdown into the test chamber are presented in this LTR. Operating sequences discussed are based on present knowledge and are used for the purpose of calculating radiation levels at different times.

This LTR is being released to retain documentation of information formerly an Appendix in SDD 1.2.9.

This LTR was first published in October 1972 as Appendix C to SDD 1.2.9, Volume II and was written by J. H. McFadden.

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APPENDIX C

FISSION PRODUCT INVENTORY, RELEASE FRACTIONS, AND
RADIATION LEVELS FROM FISSION PRODUCTS RELEASED
TO THE TEST CHAMBER

TABLE OF CONTENTS

<u>Section</u>		<u>Page</u>
A.	COMPUTER CODES	3
B.	FISSION PRODUCT INVENTORY.	3
C.	FISISON PRODUCT RELEASE.	6
D.	FISSION PRODUCT TRANSPORT TO AND DISTRIBUTION IN THE CONTAINMENT VESSEL	9
E.	HV OPERATION DURING BLOWDOWN INTO CONTAINMENT.	10
F.	RADIATION LEVELS IMMEDIATELY FOLLOWING BLOWDOWN.	10
G.	RADIATION LEVELS DURING THE FIRST DAY AFTER BLOWDOWN . . .	17
H.	RADIATION LEVELS FROM FISSION PRODUCTS ON CONTAINMENT SURFACES	17
I.	RADIATION LEVELS IN BASEMENT OF CONTAINMENT VESSEL	17
J.	RADIATION LEVELS FROM FISSION PRODUCTS IN PRIMARY SYSTEM .	21
K.	DOSE RATE FROM CSM SYSTEM.	21
L.	FILTER TRAIN VAULT	22
M.	RADIATION LEVELS FOLLOWING AN MHA.	22
N.	HIGH-LEVEL RADIOACTIVE WASTE TANKS	23
O.	REFERENCES	23

ATTACHMENT I -- LOFT FILTER SYSTEM RADIATION LEVELS

FIGURES

C-1.	Decay of LOFT fission products after 200 hours at 55 MW. .	4
C-2.	Percent noble gas release vs percent pin perforation . . .	9
C-3.	Gamma dose rate outside containment vessel	12

<u>Section</u>	<u>FIGURES (contd.)</u>	<u>Page</u>
C-4.	Gamma dose rate inside containment vessel, 0-12 hr	18
C-5.	Gamma dose rate inside containment vessel, 12-24 hr.	18
C-6.	Gamma dose rate inside containment vessel, 1-90 days	19
C-7.	Gamma dose rate outside containment vessel, 1 day.	20
C-8.	Gamma dose rate from fission products in primary loop.	24
C-9.	Gamma dose rate 1 hr after MHA	25
C-10.	Gamma dose rate 200 ft from centerline	26
C-11.	Radiation levels at time of MHA in LOFT.	27
C-12.	Radiation levels at 1 hr after MHA in LOFT	28
C-13.	Radiation levels at 1 day after MHA in LOFT.	29

TABLES

C-I.	LOFT Fission Product Inventory Following 200 Hr Operation at 55 MW	5
C-II.	LOFT Fission Product Release Data.	7
C-III.	Fission Product Release and Distribution	10
C-IV.	Radiation Levels After (During) Blowdown into Containment Vessel	18

APPENDIX CFISSION PRODUCT INVENTORY, RELEASE FRACTIONS,
AND RADIATION LEVELS FROM FISSION PRODUCTS
RELEASED TO THE TEST CHAMBER

The fission product inventory, fission product release fractions, and radiation levels following a blowdown into the test chamber are presented in this appendix. It should be noted that the operating sequences discussed in this appendix are based on present knowledge and are used for the purpose of calculating radiation levels at different times.

A. COMPUTER CODES

The fission product inventory was calculated by the RSAC Code^[C-1 C-2]. This code calculates fission product buildup and decay for 90 decay chains. For the analysis of the LOFT shielding, the reactor was assumed to operate for 200 hr at 55 MW. The fission products were grouped by energy into eight groups with average energies of 0.25, 0.5, 0.7, 0.9, 1.1, 1.35, 1.75, and 4.0 MeV.

The gamma dose rates were calculated using the shielding code QAD-P5A^[C-3 C-4], a point kernel code designed to calculate gamma-ray penetration of various shield configurations. The QAD-P5A is a version of QAD-P5 which includes a built-in library of gamma-ray attenuation coefficients and buildup factor coefficients. The point kernel method used involves representing the gamma source by a number of point isotropic sources and computing the line-of-sight distance from each of these source points to the detector point. From the distance through the shielding regions and the characteristics of the shielding materials, the geometric attenuation and material attenuation are calculated. The energy transferred along the line of sight is then calculated based on this attenuation and the appropriate buildup factor to account for the scattered radiation. With a distributed source, the point kernel including the buildup factor is integrated over the source volume for each source energy considered.

B. FISSION PRODUCT INVENTORY

The decay of the solid, iodine, noble gas, and cesium fission products following 200 hr of reactor operation at 55 MW is shown in Figure C-1. A minimum time between experiments of 60 days is expected for the LOFT test series. The curves in Figure C-1 indicate that the fission product inventories for the four groups at 60 days are less than 1% of the shutdown inventories. Thus, 200 hr of reactor operation is sufficient to determine radiation levels resulting from decay of fission products released during a LOCE.

The fission product inventory is listed in Table C-I for various times after shutdown. The section of the table for the halogen fission products includes bromine and iodine, with the bromine isotopes in energy groups 4, 5, and 8 and the iodine isotopes in groups 1, 2, 3, and 6.

TABLE C-I

LOFT FISSION PRODUCT INVENTORY FOLLOWING 200 HR OPERATION AT 55 MW

		Fission Product Gamma Inventory (MeV/sec) for the Eight Energy Groups								
Time after Shutdown		0.25	0.5	0.7	0.9	1.1	1.35	1.75	4.0	Total ^[a]
Noble Gas										
0 SEC		3.35(16)	1.12(17)	0.0	0.0	2.37(16)	1.25(17)	0.0	0.0	3.00(17)
1 HR		3.27(16)	2.22(16)	0.0	0.0	1.40(16)	9.73(16)	0.0	0.0	1.72(17)
8 HR		2.50(16)	6.70(15)	0.0	0.0	3.36(14)	1.72(16)	0.0	0.0	5.50(16)
1 DAY		1.06(16)	1.28(15)	0.0	0.0	6.65(10)	3.28(14)	0.0	0.0	1.77(16)
2 DAY		2.18(15)	1.07(14)	0.0	0.0	1.84(05)	8.64(11)	0.0	0.0	7.51(15)
4 DAY		6.84(13)	7.84(11)	0.0	0.0	0.0	5.98(06)	0.0	0.0	4.29(15)
7 DAY		3.14(11)	3.78(10)	0.0	0.0	0.0	0.0	0.0	0.0	2.89(15)
10 DAY		1.39(09)	3.73(10)	0.0	0.0	0.0	0.0	0.0	0.0	1.95(15)
20 DAY		1.34(01)	3.72(10)	0.0	0.0	0.0	0.0	0.0	0.0	5.24(14)
30 DAY		0.0	3.71(10)	0.0	0.0	0.0	0.0	0.0	0.0	1.41(14)
Halogen										
0 SEC		9.59(15)	6.27(16)	1.62(17)	3.29(16)	7.77(14)	3.14(17)	0.0	1.39(17)	7.21(17)
1 HR		9.61(15)	6.16(16)	1.23(17)	9.94(15)	7.60(11)	2.47(17)	0.0	0.0	4.52(17)
8 HR		9.48(15)	4.95(16)	1.15(17)	1.05(12)	0.0	6.31(16)	0.0	0.0	2.37(17)
1 DAY		9.10(15)	2.90(16)	9.96(16)	8.64(02)	0.0	1.18(16)	0.0	0.0	1.50(17)
2 DAY		8.50(15)	1.31(16)	8.02(16)	0.0	0.0	9.91(14)	0.0	0.0	1.03(17)
4 DAY		7.27(15)	2.64(15)	5.21(16)	0.0	0.0	6.92(12)	0.0	0.0	6.20(16)
7 DAY		5.66(15)	2.40(14)	2.73(16)	0.0	0.0	4.03(09)	0.0	0.0	3.32(16)
10 DAY		4.38(15)	2.18(13)	1.43(16)	0.0	0.0	2.35(06)	0.0	0.0	1.87(16)
20 DAY		1.86(15)	7.33(09)	1.64(15)	0.0	0.0	0.0	0.0	0.0	3.50(15)
30 DAY		7.84(14)	2.47(06)	1.90(14)	0.0	0.0	0.0	0.0	0.0	9.74(14)
Solid										
0 SEC		2.22(17)	1.91(17)	6.57(17)	1.35(17)	6.23(16)	7.22(17)	2.86(16)	1.40(14)	2.03(18)
1 HR		1.45(17)	8.38(16)	4.16(17)	1.28(17)	6.26(16)	2.33(17)	2.41(16)	1.43(14)	1.09(18)
8 HR		1.02(17)	2.61(16)	2.42(17)	7.13(16)	6.48(16)	1.92(17)	4.31(15)	1.43(14)	5.30(17)
1 DAY		8.30(16)	1.08(16)	1.11(17)	1.76(16)	6.84(16)	4.48(14)	8.23(13)	1.42(14)	2.92(17)
2 DAY		6.31(16)	4.93(15)	4.31(16)	3.48(15)	7.11(16)	4.39(14)	2.16(11)	1.36(14)	1.86(17)
4 DAY		3.92(16)	3.28(15)	1.26(16)	7.76(14)	7.04(16)	2.25(13)	1.50(06)	1.25(14)	1.26(17)
7 DAY		2.23(16)	2.92(15)	8.10(15)	6.50(14)	6.34(16)	8.95(12)	0.0	1.09(14)	9.76(16)
10 DAY		1.46(16)	2.74(15)	7.81(15)	6.14(14)	5.49(16)	3.67(12)	0.0	9.52(13)	8.09(16)
20 DAY		6.14(15)	2.30(15)	7.78(15)	5.09(14)	3.23(16)	4.53(11)	0.0	6.07(13)	4.92(16)
30 DAY		3.56(15)	1.93(15)	7.72(15)	4.22(14)	1.89(16)	3.14(11)	0.0	3.87(13)	3.27(16)

[a] Includes low energizes (<.1 MeV) gamma decay.

C. FISSION PRODUCT RELEASE

It is expected that during a part of the loss-of-coolant experiments, there will be no fuel pin cladding failure. If this occurs, the radiation levels following blowdown will be essentially the same as after a normal reactor shutdown, and the values given in Appendix B may be used. Fuel melting is not expected to occur during the LOCEs. However, there is a possibility that some fraction of the fuel pins will undergo cladding failure, resulting in the release of the fission products from the gap between the fuel and the cladding of these pins.

The thermomigration model [C-5 C-6] was used to calculate the noble gas inventory in the fuel-cladding gap for the LOFT core. The fraction of the noble gas fission products in the gap of the fuel pins is dependent on the heat rating of each pin during steady-state operation. This fraction is given by:

$$\frac{\sum_{i=1}^k n_i P_i F_i}{\sum_{i=1}^k n_i P_i} \quad (C-1)$$

where

n_i = number of pins in a given core group operating at an average heat rating (P_i)

P_i = average heat rating ($/KdT$) for each pin in a given core group (W/cm)

F_i = noble gas release fraction to the fuel-cladding gap for pins with average heat rating (P_i)

k = number of groups in which the core pins have been divided.

The LOFT Core I was divided into groups according to the group average to core average radial power ratio. These groups along with heat ratings, volume fractions, and release fractions are given in Table C-II.

Table C-II can also be used to determine the fraction of the core inventory released to the coolant as a function of pin failure.

The fraction of noble gas released to the reactor primary system for various numbers of pin perforations may be calculated by the expression in Equation C-2:

$$\begin{aligned} \text{Fractional release to the reactor primary system for pin perforations} &= \underbrace{\frac{\sum_{i=1}^k a_i n_i P_i F_i}{\sum_{i=1}^k a_i n_i P_i}}_{\text{Term 1}} * \underbrace{\frac{\sum_{i=1}^k a_i n_i P_i / \sum_{i=1}^k a_i n_i}{\sum_{i=1}^k n_i P_i / \sum_{i=1}^k n_i}}_{\text{Term 2}} * \underbrace{\frac{\sum_{i=1}^k a_i n_i}{\sum_{i=1}^k n_i}}_{\text{Term 3}} \quad (C-2) \end{aligned}$$

TABLE C-II

LOFT FISSION PRODUCT RELEASE DATA

No. of Pins per Core Group	Radial Profile	Average Linear Heat Rating For Core Region	Average Heat Rating For Core Region	Group Pin Fraction of Total Core	Percent Pin Noble Gas in Gap	P*N	P*N*F
		(KW/ft)	P (W/cm)	$N = \frac{\sum_{i=1}^k n_i}{\sum_{i=1}^k n_i}$	F(%)		
92	1.55	11.5	30.0	0.071	41.4	2.13	0.88
44	1.45	10.7	28.0	0.034	39.5	0.95	0.37
140	1.35	10.0	26.1	0.108	32.7	2.82	0.92
116	1.25	9.2	24.0	0.089	31.0	2.13	0.66
100	1.15	8.5	22.2	0.077	24.0	1.71	0.41
144	1.05	7.8	20.3	0.111	17.8	2.25	0.40
144	0.95	7.0	18.3	0.111	14.5	2.03	0.29
128	0.85	6.3	16.4	0.098	10.2	1.61	0.16
132	0.75	5.5	14.3	0.102	4.6	1.46	0.07
68	0.65	4.8	12.5	0.052	3.5	0.65	0.02
100	0.55	4.1	10.7	0.077	1.1	0.82	0.01
68	0.45	3.3	8.6	0.052	0.8	0.45	0.003
24	0.35	2.6	6.8	0.018	0	0.12	0
---	---	---	---	---	---	---	---
1300	---	---	---	1.000	---	19.13	4.19

Fig. C-2 Percent noble gas release vs percent pin perforation.

where

a_1 = fraction of pins that perforate per core group

* = multiply

Other parameters are defined in Equation C-1.

For simplicity, Equation C-2 has been broken into three terms: Term 1 is the average fractional release to the fuel-cladding gap for perforated pins. Terms 2 and 3 define the fraction of the total core inventory in the perforated pins. (Term 2 is the average heat rating for the perforated pins divided by the average core heat rating, and Term 3 is the average fraction of perforated pins for total core having pin perforation.)

This expression was used to obtain Figure C-2 where the noble gas release is plotted versus the fraction of the fuel pins ruptured, with the assumption that the pins in the hottest part of the core are the ones that fail. If the hottest 1% of the fuel pins fail, 0.65% of the noble gas core inventory will be released. If 20% of the pins fail, the corresponding release fraction is 11%. These two release assumptions will be used in the subsequent discussion. The consequences of other pin failure assumptions can be determined by multiplying by the ratio of the release fractions obtained from Figure C-2. For example, if all the pins fail the release fraction will be 21.9%. This is 34 times the release for 1% pin rupture, and dose rates may be scaled upon this basis, if desired^[a].

The necessary thermodynamic data are not available to calculate the iodine fission product fraction in the gap. Experimental data show this fraction ranges from 0.01 to equal that of the noble gas fraction^[C-7]. Since iodine is a precursor for xenon, the iodine fraction in the gap should not be greater than the xenon and is, thus, assumed to be the same as the noble gas fraction. Other halogens are assumed to have the same release fraction as iodine. The solid fission product fraction in the gap is assumed to be 1% of the noble gas fraction. These values are summarized in Table C-III.

It is to be noted that the center element will be removed if 1% or more of the pins fail during a LOCE. At the present time, a failure of 20% of the pins is considered to be an upper limit. Subsequent discussion of the shielding system will consider the 1% case which provides the most rapid turn around and the 20% case which provides the most stringent requirement for bulk shielding.

D. FISSION PRODUCT TRANSPORT TO AND DISTRIBUTION IN THE CONTAINMENT VESSEL

Following release from the fuel pins, the combination of deposition on the internal surfaces of the primary system and retention in the emergency core coolant (ECC) can readily result in a reduction of the iodine and solid fission products which reach the containment by a factor of 1000. The lack

[a] It must be noted that the curve in Figure C-2 applies only to the release of noble gases in the fuel pin plenum. Any additional release due to fuel melting is not included, and thus the information in Figure C-2 can be applied only if no fuel melting is assumed.

of experimental data precludes any definite reduction factor; however, two conservative assumptions are used in these calculations: The first assumes all released fission products reach the containment, and the second assumes a factor of 10 reduction for iodine, other halogen, and solid fission products.

All the fission products reaching the containment atmosphere are assumed to be uniformly distributed in the containment atmosphere for the first 12 hr after the blowdown. This is a conservative assumption because the estimated half-life of molecular iodine in the LOFT containment is approximately 25 min and the aerosol half-life is approximately 12 min[C-8].

For time periods greater than 12 hr, all the solid fission products and 50% of the iodine fission products which reach the containment are assumed to be uniformly deposited on the surfaces within the containment. The noble gas and bromine fission products which have not decayed will be removed by this time.

After the experiment, the radiation levels resulting from fission products deposited on containment surfaces can be reduced by decontamination. The decontamination process will decrease the solid fission products by about 90% (factor of 10 reduction) but appears to be ineffective for iodine removal[C-9]. These values are summarized in Table C-III.

E. HV OPERATION DURING BLOWDOWN INTO CONTAINMENT

The operational plans are to close all HV valves when a blowdown to containment occurs and not to open them until the containment vessel is decompressed and the containment decontamination operation has been completed. Then the HV outlet to the filters will be opened and the containment air recirculated through the filter train until airborne activity reaches a safe limit for release to the exhaust stack.

F. RADIATION LEVELS IMMEDIATELY FOLLOWING BLOWDOWN

The highest dose rates will occur during the period immediately following blowdown and prior to deposition. For this condition, the fission products which are released from the reactor vessel are assumed to be uniformly distributed in the containment volume. The dose rate, as a function of distance from the center of the containment vessel, is given in Figure C-3, with shielding provided only by the containment shell. Curve 1 assumes that 20% of the pins fail, the fission products are instantaneously transported to the containment, and there is no retention in the primary system. Curve 2 assumes that 90% of the solid, iodine, and other halogen fission products are retained in the primary loop. To obtain the corresponding radiation levels for 1% pin failure, these dose rates are divided by 17. The N-16 activity from the primary coolant system results in a dose of less than 100 mrem just outside the containment vessel during this time.

Radiation levels in the LOFT support areas at the time of blowdown are given in Table C-IV, along with the occupancy time (hr/8 hr or hr/shift). These levels assume all released fission products are in the containment atmosphere (Figure C-3, Curve 1). The area access classifications for all areas at the time of blowdown are included in the table. The classifications are based

TABLE C-III

FISSION PRODUCT RELEASE AND DISTRIBUTION

Fission Product Group	Percent Released From Fuel		Reduction in PCS		Distribution in Con- tainment (after ~12 hr)		Decontamination Factors	
	1% Pin Failure	20% Pin Failure	Minimum	Maximum	Airborne Fraction	Deposition Fraction	Minimum	Maximum
Noble gas	0.65	11.0	1	1	1.0	0.0	---	---
Iodine	0.65	11.0	1	10	0.5	0.5	1	1
Solids	0.0065	0.11	1	10	0.0	1.0	1	10
Other halogen	0.65	11.0	1	10	1.0	0.0	---	---

Fig. C-3 Gamma dose rate outside containment vessel.

TABLE C-IV

RADIATION LEVELS AFTER (DURING) BLOWDOWN INTO CONTAINMENT VESSEL

Item	Room Number	Room Description	Distance From CV (ft)	Thick Earth/Concrete	Access [a] Classification at Time of Blowdown	Radiation Levels (mrem/hr) for 20% Pin Failure at		Time After Blowdown When Access is Needed	Time of Occupancy (hr/8 hr)	Radiation Levels (mrem/hr) at Access Time (Column 3)	
						0 sec	1 hr			1% Pin Failure	20% Pin Failure
1.	201	Personnel shielded entrance	95	4	C	20	<0.25	0 sec	0.5	1.5	20
2.	202	Shielded vestibule	80	4	C	30	0.3	0 sec	0.5	2	30
3.	203	Hallway	40	2	E	7500	1300	7 day	1	<0.25	3.5
4.	204	Dressing room	55	2	E	4800	900	7 day	1	<0.25	2.5
5.	205	Shower	55	2	E	4800	900	7 day	1	<0.25	2.5
6.	206	Change room No. 1	50	2	E	5400	1000	7 day	1	<0.25	3
7.	206A	Pipe space	--	-	E	--	--	--	-	--	-
8.	207	Personnel airlock No. 1	--	-	E	2.7×10^7	1.8×10^7	30 day	0.5	850	1.5×10^4
9.	208	Personnel airlock shielding room	40	2	E	7500	1300	7 day	0.5	<0.25	3.5
10.	209		--	-	E	--	--	--	--	--	--
11.	210		--	-	E	--	--	--	--	--	--
12.	211	Piping labyrinth	40	2	E	7500	1300	30 day	0.5	<0.25	<0.25
13.	212	Vestibule	55	3	C	425	20	0 sec	2	25	425
14.	213	Conduit tunnel	40	0	E	4×10^6	3×10^6	30 day	0.5	135	2.2×10^3
15.	214		--	-	E	--	--	--	--	--	--
16.	215	Test chamber [b]	--	-	F	2.7×10^7	1.8×10^7	30 day	8	850	1.5×10^4
17.	217	Cable tray space	--	-	E	--	--	--	--	--	--
18.	218	Preamp equipment room	60	3.75	B	60	1	0 sec	2	3.5	60
19.	219	Preamp equipment room	60	3.75	B	60	1	0 sec	2	3.5	60
20.	220	HV duct labyrinth	40	0	E	4×10^6	3×10^6	30 day	2	1.35	2.2×10^3

TABLE C-IV (contd.)

Item	Room Number	Room Description	Distance From RV (ft)	Thick Earth/Concrete	Access ^[a] Classification at Time of Blowdown	Radiation Levels (mrem/hr) for 20% Pin Failure at		Time After Blowdown When Access is Needed	Time of Occupancy (hr/8-hr)	Radiation Levels (mrem/hr) at Access Time (Column 3)	
						0 sec	1 hr			1% Pin Failure	20% Pin Failure
21.	224	Electrical equipment room	100	6	A	0.25	<0.25	0 sec	2	<0.25	0.25
22.	225	Air-conditioning equipment room	70	4.5	A	30	0.3	0 sec	2	2	30
23.	226	Toilet	55	4	C	45	0.5	0 sec	1	3	45
24.	227	Duct enclosure	40	0	E	4x10 ⁶	3x10 ⁶	30 day	1	135	2200
25.	229		40	3	E	645	30	7 day	2	<0.25	<0.25
26.	B-105	Manuever space	100	5	B	2	<0.25	0 sec	4	<0.25	2
27.	B-106	Air intake	100	5	B	3	<0.25	0 sec	0.5	<0.25	3
28.	B-107	Air intake	100	5	B	3	<0.25	0 sec	0.5	<0.25	3
29.	B-201	Electrical equipment room	85	5	B	3	<0.25	0 sec	4	<0.25	3
30.	B-202	Hallway	85	5	B	3	<0.25	0 sec	1	<0.25	3
31.	B-203	HV and piping equipment room	40	5	B	7	<0.25	0 sec	2	0.4	7
32.	B-203A		55	5	B	5	<0.25	0 sec	2	0.3	5
33.	B-203B		55	5	B	5	<0.25	0 sec	0.5	0.3	5
34.	B-204	Stair No. 5	60	4	C	30	0.4	0 sec	1	2.5	38
35.	B-205	Janitor closet	50	3	C	480	25	0 sec	0.5	30	480
36.	B-206	Piping labyrinth	40	3	D	645	30	0 sec	1	40	645
37.	B-207	Stair No. 6	55	3	C	425	20	0 sec	3	25	425
38.	B-208	Equipment access shaft	60	3.75	C	70	1	0 sec	1	5	70
39.	B-209	Shielded roadway	70	5	B	3	<0.25	0 sec	4	<0.25	3

TABLE C-IV (cont.)

Item	Room Number	Room Description	Distance From C R (ft)	Thick Earth/Concrete	Access [a] Classification at Time of Blowdown	Radiation Levels (mrem/hr) for 20% Pin Failure at		Time After Blowdown When Access is Needed	Time of Occupancy (hr/8 hr)	Radiation Levels (mrem/hr) at Access Time (Column 3)	
						0 sec	1 hr			1% Pin Failure	20% Pin Failure
40.	B-211	Personnel airlock No. 2	40	3	D	645	30	0 sec	1	40	645
41.	B-212	Cable labyrinth	40	3	D	645	30	0 sec	1	40	645
42.	B-213	Sample control center	55	5	B	5	<0.25	0 sec	8	0.3	5
43.	B-214	CSM sample room	45	5	B	6	<0.25	0 sec	8	0.4	6
44.	B-215	Sample room	55	5	B	5	<0.25	0 sec	8	0.3	5
45.	B-216	Locker room	65	5	B	4	<0.25	0 sec	1	<0.25	4
46.	B-217	Change room	65	5	B	4	<0.25	0 sec	1	<0.25	4
47.	B-218	Loading area	85	6	B	0.25	<0.25	0 sec	4	<0.25	0.25
48.	B-219	Filter fan room	70	5	B	3	<0.25	0 sec	1	<0.25	3
49.	B-220	Filter shielding space	70	5	B	3	<0.25	0 sec	1	<0.25	3
50.	B-221	Corridor	85	5	B	2.5	<0.25	0 sec	0.5	<0.25	2.5
51.	B-222	Sample filter train room	80	5	B	4	<0.25	0 sec	1	<0.25	4
52.	B-223	Filter train chamber vault	--	--	E	--	--	--	--	--	--
53.	B-224	Duct enclosure	40	0	E	4x10 ⁶	3x10 ⁶	30 day	0.5	135	2.2x10 ³
54.	B-225	Valve pit [c]	40	2	E	7500	1300	30 day	0.5	<0.25	<0.25
55.	B-225A [c]		55	2	E	5000	900	30 day	0.5	<0.25	<0.25
56.	B-225B [c]		75	2	E	3000	550	30 day	0.5	<0.25	<0.25
57.	B-226	Stair No. 9	60	1	E	2x10 ⁵	1x10 ⁵	30 day	0.5	7.5	125
58.	B-226A	Stair No. 10	50	2	E	5000	900	30 day	0.5	<0.25	<0.25
59.	B-227	Railroad door machine room	55	1	E	3x10 ⁵	2x10 ⁵	30 day	1	7.5	125

15

TABLE B-IV (contd.)

Item	Room Number	Room Description	Distance From RV (ft)	Thick Earth/Concrete	Access [a] Classification at Time of Blowdown	Radiation Levels (mrem/hr) for 20% Pin Failure at		Time After Blowdown When Access is Needed	Time of Occupancy (hr/8 hr)	Radiation Levels (mrem/hr) at Access Time (Column 3)	
						0 sec	1 hr			1% Pin Failure	20% Pin Failure
60.	B-228	Railroad door enclosure	--	-	E	--	--	--	--	--	--
61.	B-229	Railroad door frame	--	-	E	--	--	--	--	--	--
62.	B-230	Stair No. 13	55	0	E	3x10 ⁶	2x10 ⁶	30 day	0.5	75	1200
63.	B-231	Railroad bridge enclosure	40	0	E	4x10 ⁶	3x10 ⁶	30 day	0.5	135	2.2x10 ³
64.	B-233	Equipment room [c]	40	6	E	0.7	<0.25	7 day	1	<0.25	<0.25
65.	B-234	Valve access aisle [c]	40	6	E	0.7	<0.25	7 day	1	<0.25	<0.25
66.	B-236	Decontamination equipment room [c]	40	6	E	0.7	<0.25	7 day	1	<0.25	<0.25
67.	B-238	Void space	--	-	E	--	--	--	--	--	--
68.	B-239	ECCS equipment room	100	5	B	2	<0.25	0 sec	2	<0.25	2
69.	B-240	Stair No. 15	85	5	B	2.5	<0.25	0 sec	1	<0.25	2.5
70.	B-241	Airlock	85	5	B	2.5	<0.25	0 sec	1	<0.25	2.5
71.	B-242	Vestibule	115	5	B	2	<0.25	0 sec	0.5	<0.25	2
72.	B-243	Tank well	115	5	B	2	<0.25	0 sec	0.5	<0.25	2
73.	B-244	Stair No. 14	110	5	B	2	<0.25	0 sec	0.5	<0.25	2
74.	Building TAN-630		120	6	A	<0.25	<0.25	0 sec	8	<0.25	<0.25
75.	Air-cooled condenser		50	0	E	3x10 ⁶	2x10 ⁶	30 day	0.5	110	1800

[a] A = Full-time occupancy
 B = Full-time access
 C = Limited access
 D = Exclusion
 E = Exclusion by administrative control - no access is required.

See Tables I-I and I-II.

[b] See Section I for other possible radiation sources in this area.
 [c] See Section H for other possible radiation sources in this area.

LTR 129-13
 Appendix C

on the case with 20% pin failure and also on the need to occupy the area. Should any fission products be retained in the primary system, the radiation levels listed would decrease approximately the same as shown in Figure C-3.

G. RADIATION LEVELS DURING THE FIRST DAY AFTER BLOWDOWN

General area radiation levels in the test chamber were calculated for the first 24 hr after blowdown for the case of 20% pin failure with all of the released fission products transported to the containment vessel. The dose rate for the first 12 hr after blowdown is shown in Figure C-4. The assumption is made that all the released fission products remain airborne during this 12-hr period, with removal only by radioactive decay. During the period from 12 to 24 hr following blowdown, it is assumed that 50% of the released iodine and all the released solid fission products are deposited on the containment surfaces. The noble gas and remaining iodine fission products are removed by the HV system. The dose rate during this period is shown in Figure C-5.

Figures C-4 and C-5 both assume 20% pin failure. To obtain the corresponding dose rates for 1% pin failure the values from the curves should be divided by 17.

H. RADIATION LEVELS FROM FISSION PRODUCTS ON CONTAINMENT SURFACES

After operation of the HV system, the noble gas and airborne halogen fission products are assumed to be removed from the containment. The remaining iodine and solid fission products are assumed to be uniformly distributed on the surfaces within the containment vessel. General area radiation levels are shown in Figure C-6 as a function of time after shutdown. All three curves assume 20% pin failure: curve 1 assumes no retention in the primary loop and no decontamination; curve 2 assumes no retention in the primary loop and a solid fission product decontamination factor of 10; and curve 3 assumes retention of 90% of the iodine and solid fission products in the primary loop and a solid fission product decontamination factor of 10.

Radiation levels outside the containment at 1 day after blowdown are shown in Figure C-7 for the same three conditions. Radiation levels outside for times other than 1 day can be found by determining the amount of decay up to the time of interest from Figure C-6 and multiplying this fraction by 1-day radiation level from Figure C-7.

Radiation levels in areas not occupied at the time of blowdown are listed in Table C-IV for the time when access is required. These levels assume no retention in the primary system and no decontamination.

I. RADIATION LEVELS IN BASEMENT OF CONTAINMENT VESSEL

The radiation level in the basement (Rooms B-233, B-234, and B-236) from the decay of fission products in the containment atmosphere will be less than 1 mrem/hr immediately after a LOCE with 20% pin failure and less than 0.25 mrem/hr within an hour after the LOCE.

Fig. C-4 Gamma dose rate inside containment vessel, 0-12 hr.

Fig. C-5 Gamma dose rate inside containment vessel, 12-24 hr.

Fig. C-6 Gamma dose rate inside containment vessel, 1-90 days.

Fig. C-7 Gamma dose rate outside containment vessel, 1 day.

Three additional sources of radiation may exist which will increase the radiation level. The decay of fission products in the condensate sump and in the decontamination sump contribute less than 1 mrem/hr to the total dose rate at 1 hr after a LOCE with 20% pin failure.

The third additional source will be made up of the high-level waste transfer lines, the lines between the two sumps, and the associated pumps and valves. The activity concentration in the lines was calculated by assuming that all the released solid and iodine fission products were uniformly distributed in 20,000 gal. These 20,000 gal are made up of primary system water, ECC, and pressure reduction water and would be the minimum amount of water expected for a LOCE directed to the containment atmosphere. (See SDD 1.2.1[C-10] for pressure reduction volume.) The volume of the lines between the sumps is about 30 ft³. The radiation level for the above assumptions, from the lines between the sumps is about 100 rem/hr at 1 day after a LOCE with 20% pin failure. This 100 rem/hr level will be a general level in Room B-236 and somewhat lower in Room B-234.

J. RADIATION LEVELS FROM FISSION PRODUCTS IN PRIMARY SYSTEM

The radiation levels in the containment from fission products on the containment surfaces are shown in Figure C-6 for the 20% pin failure case. These values may be divided by 17 to find the radiation levels for the 1% pin failure LOCE. Another source of radiation will exist from fission products deposited on the internal surfaces of the primary system.

The radiation levels from this source were determined by assuming that 10% of the released iodine and solid fission products remain in the primary system[C-11]. These levels are shown in Figure C-8 as a function of time after blowdown for the LOCE with 20% pin failure at a position 10 ft from the MTA.

K. DOSE RATE FROM CSM SYSTEM

Radiation levels in Room B-213 will result from two sources. The first will be made up of the equipment behind the 1-ft-thick concrete shield wall which will provide effective shielding. The second source will include the 3/8-in. sample lines penetrating the concrete and the sample bombs.

To obtain an upper limit value for the second source, all the released iodine was assumed to remain airborne. The source in the CSM gas line will be drawn from the noble gas and 10% of the iodine fission products in the containment atmosphere (9×10^9 cc). The CSM liquid line will concentrate the remaining iodine fission products by a factor of 15 to 1; that is, 90% of the airborne iodine in 15 cc of atmosphere will be concentrated to 1 cc of liquid in the sample line. The sample was assumed to be collected in a 10-cc bomb.

For the 20% pin failure case, the dose rate 1000 sec after blowdown and at a position 1 ft from the lines will be 800 mrem/hr (770 mrem/hr from the liquid line and 30 mrem/hr from the gas line). The dose rate at 1 ft from a 10-cc liquid sample will be 125 mrem/hr and 5 mrem/hr from a 10-cc gas sample.

L. FILTER TRAIN VAULT

For a blowdown to the containment, airborne fission products will be removed from the containment atmosphere by the LOFT filter system. These filters will be located in the filter train vault chamber (Rooms B-223 and B-223D). The vault wall adjacent to Room B-219 will be constructed of concrete with a thickness of 4 ft.

Radiation levels from the unshielded filters are given in Attachment 1. Radiation levels in Room B-219 were calculated using the assumptions as given in Attachment 1 to Appendix D. During the filtering time (4 hr after blowdown) the radiation level in Room B-219 would be about 100 mrem/hr. During this time, Room B-219 would be an exclusion area, because the ducts are not shielded.

It is noted that this radiation level is conservative because the system of filters is assumed (Attachment 1) to contain 130% of the elemental and 210% of the particulate iodine which is in the atmosphere at the time of filtering.

M. RADIATION LEVELS FOLLOWING AN MHA

If an MHA occurs, 100% of the noble gas, 50% of the halogen, and 1% of the solid fission products are assumed to be immediately released to the containment atmosphere. These fission products are assumed to remain uniformly distributed in the containment atmosphere, with dose rate reduction occurring only because of fission product decay.

The radiation levels at 1 hr after the MHA are shown as a function of distance from the containment centerline in Figure C-9. The curve in Figure C-10 gives the radiation level at 200 ft from the containment centerline as a function of time after the MHA.

Radiation level contours of 100 rem/hr, 25 rem/hr, 1 rem/hr, 100 mrem/hr, and 5 mrem/hr are shown at the time of the MHA in Figure C-11, 1 hr after the MHA in Figure C-12, and 1 day after the MHA in Figure C-13.

The existing shielding over the reactor control room (Building TAN-630) consists of 8 in. of concrete and 6 ft of earth. This shielding will reduce the dose rate in the reactor control room to less than 1 mrem/hr at the time of the MHA (0.0 sec), satisfying the requirement of 1 mrem/hr at 100 sec.

* The dose rate in the shielded roadway at 100 sec after the MHA will be 7.5 mrem/hr and less than 0.25 mrem/hr at 30 min, which satisfies the design requirement of 7.5 mrem/hr at 30 min.

The dose received while walking from the exit of the shielded roadway to the Building TAN-602 area, at a velocity of 3 mph, will be less than 0.5 rem, assuming the receiver leaves the tunnel 1 hr after the accident. This dose will be a factor of 10 below the design dose of 5 rem.

N. HIGH-LEVEL RADIOACTIVE WASTE TANKS

The high-level radioactive waste from LOFT experiments will be stored in two 50,000-gal tanks. These tanks will be contained in an underground concrete vault. The vault will have a 1-ft-thick concrete roof and will be covered by 3 ft of dirt fill.

Radiation levels from decay of fission products in the tanks were evaluated for the MHA condition. The reactor was assumed to have operated for 2000 hr at 55 MW. Fifty percent of the iodine and 1% of the solid fission products were considered uniformly distributed in the water in the tanks. The dose rate at ground level above the tanks will be less than 1 mrem/hr 30 days after the accident.

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Fig. C-8 Gamma dose rate from fission products in primary loop.

Fig. C-9 Gamma dose rate 1 hr after MHA.

Fig. C-10 Gamma dose rate 200 ft from centerline.

Fig. C-11

Radiation levels at time
of MHA in LOFT.

Fig. C-12
Radiation levels at
1 hr after MHA in LOFT.

Fig. C-13
Radiation levels at
1 day after MHA in LOFT.