Study IV-313
Revision 1
EGCR

ACNP-61535
Revision 1

OAK RIDGE OPERATIONS OFFICE
ATOMIC ENERGY COMMISSION

STUDY IV-313

HAZARDS ANALYSIS

RADIOLOGICAL HAZARDS

MASTER

EXPERIMENTAL GAS COOLED REACTOR

Facsimile Price \$ 12.50

Microfilm Price \$ 5.48

Available from the
Office of Technical Services
Department of Commerce
Washington 25, D. C.

LEGAL NOTICE

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:

A. Makes any warranty or representation, expressed or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or

B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission, or employee of such contractor, to the extent that such employee or contractor of the Commission, or employee of such contractor prepares, disseminates, or provides access to, any information pursuant to his employment or contract with the Commission, or his employment with such contractor.

Prepared By

ALLIS-CHALMERS MANUFACTURING COMPANY
Atomic Energy Division
Nuclear Power Department
Washington, D. C.

107263

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

Study IV-313
Revision 1
EGCR

Prepared By: J. C. Courtney Date: Aug. 31, 1962
J. C. Courtney
Responsible Engineer

Approved By: D. F. Luse Date: Aug. 31, 1962
D. F. Luse
Responsible Engineer

Approved By: S. Matovich Date: Sept. 5, 1962
S. Matovich
Project Manager
ALLIS-CHALMERS MANUFACTURING COMPANY

Approved for Kaiser Engineers:

By: G. Humphreys Date: Nov. 30, 1962

Approved for Union Carbide Nuclear Company:

By: G. D. Whitman Date: Jan. 25, 1963

Approved for Atomic Energy Commission:

By: L. H. Jackson Date: Nov. 23, 1962

APPROVED
Nov. 23, 1962
Revision 1
July 11, 1963

Sm
DO L
OK

CONTENTS

I. OBJECTIVES	1
II. RESULTS	1
A. Doses Following the MCA	1
B. Doses to the Public Due to Normal Operation.	3
III. DISCUSSION	4
A. Definition of the MCA	4
B. Assumptions Concerning the MCA	5
C. Assumptions Concerning Normal Operational Release	6
IV. REFERENCES	9
V. FIGURES	10

RADIOLOGICAL HAZARDS

EGCR HAZARDS ANALYSIS

I. OBJECTIVES

The objectives of this study are to determine the doses received by persons located both off site and in the EGCR control room following the maximum credible accident, and to determine the maximum doses received by persons off the EGCR site due to the normal operational stack release.

II. RESULTS

A. Doses Following the MCA

1. The thyroid, bone, and whole body doses at 200 meters following the MCA are given in Table I.

TABLE I

Dose at 200 meters after MCA

ORGAN	INVERSION CONDITIONS		DOSE (REM)	
	1/2 hour	1 hour	1-1/2 hour	2 hours
Thyroid	1.238	2.529	3.830	5.121
Bone	0.083	0.165	0.292	0.375
Whole Body	0.023	0.046	0.070	0.094

ORGAN	LAPSE CONDITIONS		DOSE (REM)	
	1/2 hour	1 hour	1-1/2 hour	2 hours
Thyroid	0.0235	0.0481	0.0728	0.0973
Bone	0.0016	0.0031	0.0056	0.0071
Whole Body	0.0078	0.0162	0.0247	0.0334

2. The thyroid, bone, and whole body doses following the MCA for a two hour exposure at 1060 meters are shown in Table 2.

TABLE 2

ORGAN	DOSE (rem) AT 1060 m FOR 2 HOUR EXPOSURE	
	Inversion	Lapse
Thyroid	0.3280	0.0051
Bone	0.0235	0.0004
Whole Body	0.0040	0.0001

3. Thyroid, bone, and whole body doses resulting from the MCA at distances ranging from 4600 to 10,000 meters are given in Figures 1, 2 and 3.

4. The dose rate for distances from 1060 meters to 10,000 meters due to washout of radioactive particles is shown in Figures 4 and 5.

5. The dose rate due to dry fallout is given in Figure 6.

6. The deposition of fission products in Melton Hill Lake for both washout and dry fallout is presented in Table 3.

TABLE 3

CONCENTRATION

	Inversion	Lapse
Washout	$1.63 \times 10^{-7} \mu\text{c/ml}$	$8.33 \times 10^{-8} \mu\text{c/ml}$
Dry fallout	$7.07 \times 10^{-22} \mu\text{c/ml}$	$8.93 \times 10^{-16} \mu\text{c/ml}$

7. The submersion dose rate received by personnel in the control room after the MCA is presented in Figure 7. The thyroid and bone doses are presented in Table 4(7).

TABLE 4

ISOTOPES	ORGAN	81 HOUR DOSE	
		Inversion	Lapse
I ¹³¹ , I ¹³³ , I ¹³⁵ Sr ⁸⁹ , Sr ⁹⁰ , Cs ¹³⁷ , Ba ¹⁴⁰ , La ¹⁴⁰	Thyroid	9.29 rem	6.05 rem
	Bone	4.02 rem	2.62 rem

B. Doses to the Public Due to Normal Operation

The sources of normal stack release of activity are A^{41} , due to activation of shield coolant air; H^3 , from the $He^3(n,p)H^3$ reaction with reactor coolant; and fission product contamination of the coolant. Maximum ground concentration of radioactivity released from the stack occurs at 9095 meters for inversion conditions and at 407 meters for lapse conditions.

1. Whole body doses at these distances for various filter efficiencies are presented in Table 5.

TABLE 5

FILTER EFFICIENCY	DOSE IN REM/YR	
	Inversion	Lapse
0%	0.193	1.137
25%	0.169	0.996
50%	0.146	0.858
75%	0.122	0.719

If no filtration for iodine isotopes is assumed, the yearly thyroid dose at these distances would be 0.545 rem for inversion conditions and 3.203 rem for lapse conditions.

2. The whole body dose at 1060 meters during lapse conditions for various filter efficiencies is presented in Table 6. If inversion conditions prevail, the doses are negligible.

TABLE 6

FILTER EFFICIENCY	DOSE IN REM/YR
0%	0.474
25%	0.415
50%	0.357
75%	0.299

Assuming no filtration for iodine, the yearly thyroid dose at 1060 meters is 1.34 rem for lapse conditions and is negligible for inversion conditions.

3. The deposition of fission products in Melton Hill Lake during inversion and lapse for both washout and dry fallout is presented in Table 7.

TABLE 7

	<u>CONCENTRATION</u> $\frac{\mu\text{C}}{\text{ml}}$		<u>CONCENTRATION</u> (MPC) _w	
	Inversion	Lapse	Inversion	Lapse
Washout	2.08×10^{-9}	1.06×10^{-9}	2.08×10^{-2}	1.06×10^{-2}
Dry Fallout	9.09×10^{-24}	2.43×10^{-8}	9.09×10^{-17}	2.43×10^{-1}

4. The thyroid doses at the points of maximum ground concentration due to release of coolant system activity through the electromatic relief valves following a steam system failure are presented in Table 8. These results are summarized from A-C Study IV-334, Approved Issue, dated September 2, 1962.

TABLE 8

Condition	<u>Connected to TVA Network</u>		<u>Disconnected from TVA Network</u>	
	Lapse	Inversion	Lapse	Inversion
Distance of Maximum Ground Concentration	407 m	9095 m	407 m	9095 m
Maximum Thyroid Dose	0.0306 rem	0.005 rem	1.33 rem	0.224 rem
Minimum Thyroid Dose	negligible	negligible	0.24 rem	0.040 rem

III. DISCUSSION

A. Definition of the MCA

The MCA for the EGCR is defined as a depressurization accident which suppresses core coolant flow for 30 seconds. The forces across equipment which result from the depressurization cause internal failure of the steam generator in that coolant circuit which contains the failure. From the end of the depressurization to the end of the accident, the most severe reactor

condition from the standpoint of reactor cooling is assumed. From one-half hour to three days after the accident, the emergency coolant loop and the nitrogen purge system are assumed to be in operation to control graphite oxidation.

Approximately 330 fuel elements fail during the first 30 seconds of the accident. No subsequent fuel element failures occur; (1) however, it is assumed that the reactor contained ten failed fuel elements at the time of the accident. The activity released by the 340 fuel elements to the containment building following the MCA was calculated from the "Source Term" computations given in reference 11.

B. Assumptions Concerning the MCA

For purposes of calculating activity release from the containment building, a constant internal pressure of 9 psig is assumed for the first 24 hours after the accident (2) (3). It is next assumed that the containment building internal pressure is reduced to 4.2 psig and remains constant from 24 hours to 72 hours after the accident. Between 72 hours and 81 hours after the accident, the pressure in the containment building is assumed to be 0.75 psig⁽¹⁰⁾. At 81 hours after the MCA, the pressure is calculated to be essentially zero. Containment building leakage is based on 0.3% of the contained mixture per day at 9 psig.

The assumed containment building internal pressures are conservatively based upon the calculated pressure transient following the accident, and the capacity of the containment building vent system. It is assumed that the reactor operator places this filtered vent system into operation 24 hours after the accident.

For the first 24 hours after the accident, the dose to the public is due only to the assumed ground level leakage from the containment building. From 24 hours to 81 hours, the dose is due both to containment building leakage and the effluent at stack level from the filtered vent system. The stack discharge rate is assumed to be constant at 512 SCFM from 24 hours to 72 hours, and 217 SCFM from 72 hours to 81 hours after the accident.

One-half hour after the MCA, a 1000 SCFM nitrogen purge is started. Two hours after the MCA, the purge is reduced to 200 SCFM. This rate remains constant until 72 hours after the MCA at which time it is stopped. The pressure in the containment building then decays exponentially and is essentially zero 81 hours after the accident.

Other assumptions used in the calculation are as follows:

1. All activity leaking from the containment shell is released from a point source at ground level even though complete mixing is also assumed.

2. No credit is taken for deposition or filtration within the containment building.

3. The meteorological conditions prevail during the full course of the accident with no variation in wind direction.

Assumptions used in the calculation of dose rate and dose to control room personnel are as follows:

1. An infinite cloud is present both inside and outside the control room.

2. The concentration of activity in the cloud inside the control room is conservatively evaluated at equilibrium conditions which could not occur for the duration of the accident.

Assumptions used in calculation of the concentration of radionuclides in the lake and dose rates due to rainout and dry fallout are as follows:

1. Particulates are 15 micron diameter.

2. Rainfall removes 1.0×10^{-3} of the cloud per second.

3. The meteorological conditions for each case prevail with no variation of wind direction.

4. The maximum rate of activity release was used to calculate the concentration of fission products in the lake.

C. Assumptions Concerning Normal Operational Release

1. Activation of the Biological Shield Cooling Air

The only significant neutron reaction with the constituents of air in analyzing activation of the biological shield coolant is:

The calculated rate of formation of argon-41 is 367 curies/day. This is conservative since the activation flux used in the calculation is the maximum thermal neutron flux in the reactor vault. Also, in considering air flow through the vault, it was assumed that all the air with the exception of the baffle coolant flow entered the vault at the bottom and traversed the full height of vault before being discharged at the top. Actually, portions of the total flow enter at various levels in the vault and have shorter residence times than those used in the calculations.

2. Tritium Formation in the Reactor Coolant

Tritium is formed in the reactor coolant by the He^3 (n,p) H^3 reaction. Although the relative isotopic concentration of He^3 is small (1.3×10^{-4} per cent), its thermal neutron cross section is large (5500 barns). The maximum activity due to tritium in the EGCR is calculated to be 105 curies. This is based on the assumption that fresh helium is added at a rate equal to the coolant system leak rate and that operation time is one year.

3. Activity in the Stack Effluent

Stack effluent activity consists of (1) argon-41 in the biological shield cooling air, and (2) tritium and fission products in the reactor coolant which pass to the stack by coolant system and auxiliary system leakage, venting of service and charge machines and venting of reactor coolant.

Venting will be controlled so that the rate of activity release from the stack during prevailing conditions will not cause downwind concentrations to exceed MPC's. Leakage of helium to the stack is expected to be 0.07 per cent/day of the contained volume⁽⁶⁾. For the purpose of calculation, the fission-product activity in the coolant is assumed to be 1000 curies at all times and to have the isotopic activity distribution given in EGCR Study IV-302.

The allowable release of radioactivity in stack effluents to unrestricted areas is governed by the regulations set forth in Reference 9, which require that releases shall not subject anyone downwind to a whole-body dose in excess of 0.5 rem in one year. To determine the fraction of the MPC for all radioisotopes that is released in any one year, it is permissible to average concentrations over one year. This is done in the calculations by averaging the helium release over a year and assuming all criteria are met during venting operations. Thus,

the average isotopic emission rate from the stack is computed by dividing the yearly helium consumption by time and the weight of contained helium and multiplying the quotient by the isotopic activities in the reactor coolant. From these figures and the assumed weather conditions, the average downwind ground-level concentrations at the point of maximum concentration are calculated. These concentrations are expressed as fractions of the MPC in air for unrestricted areas for each isotope and the fractions are summed as follows:

$$F = \sum_i \bar{x}_i / (\text{MPC})_i$$

where F is the fraction of the MPC for all radioisotopes that is released in any one year and $\bar{x}_i$ is the yearly average concentration of the i^{th} radioisotope at the point of maximum ground-level concentration for the weather conditions specified. It is assumed that if F is unity, the whole-body dose at the point of interest on a yearly basis is 0.5 rem. Thus the dose, D , in rem, is $0.5 F$.

Some of the air going to the stack is filtered to remove iodine and all particles larger than 0.3 micron. However, since the exact means by which the fission products in the helium are released are unknown, accurate filtration efficiencies cannot be predicted. Therefore, doses were calculated for various filtration efficiencies. Even without filtration, the maximum allowable yearly whole-body dose is not exceeded for constant inversion conditions. For lapse conditions at the point of maximum ground concentration, 407 meters, the maximum allowable yearly whole-body dose is exceeded. However, it is unlikely that anyone would stay at that point for an entire year nor is it conceivable that meteorological conditions would remain constant over that period of time.

The results obtained are therefore conservative for the following reasons:

1. The maximum thermal-neutron flux is used to compute the activation of argon in the biological-shield cooling air.
2. It is assumed that all air passing through the reactor vault required the full transit time and is thus irradiated to the maximum possible extent.
3. The fission-product activity in the reactor coolant is assumed to be 1000 curies at all times.

4. No credit is taken for plume rise above the top of the stack due to effluent temperature or velocity.

IV. REFERENCES

1. ORNL Memo CF-62-4-32, 4-16-62, EGCR Fuel Element Failures in Depressurization Accidents, T. H. Row.
2. ORO TWX NR 01, 6-7-62, Jackson to Bush, Re: Assumptions for Study-313, Radiological Hazards Analysis.
3. A-C TWX No. 777, 6-11-62. Re: Clarification of Items of Reference 2.
4. KE TWX No. 12-20, 6-15-62, Item 2. Re: Infiltration Data to Control Room.
5. EGCR Hazards Summary Report, Section 8, as revised 7-24-62.
6. Teletype message from Kaiser Engineers to Allis-Chalmers, February 13, 1962.
7. Letter, Jackson to Bush, July 27, 1962, Enclosure Table 1.
8. Report of ICRP Committee II on Permissible Dose for Internal Radiation (1959), Health Physics, Vol. 3, June 1960.
9. NBS Handbook, 69, Maximum Permissible Body Burden and MPC of Radionuclides in Air and in Water for Occupational Exposure.
10. A-C TWX No. 973, 5-13-63. Re: EGCR MCA Source Term.
11. Row, T. H., EGCR Maximum Credible Accident Source Term, ORNL CF 62-7-1, July 16, 1962.

FIGURE 3
WHOLE BODY DOSE OVER
DURATION OF MCA VS DISTANCE

D.L. 6-63

DOSE RATE VS DISTANCE
FROM WASHOUT AFTER
MCA-INVERSION CONDITIONS

FIGURE 4

DL 6-63

DL 6-63

SUBMERSION DOSE RATE TO CONTROL ROOM
PERSONNEL VS TIME FOLLOWING MCA

FIGURE 7

A   B   C

CALCULATIONS - STUDY III-313

APPENDIX A

I. PRESSURES in CONTAINMENT SHELL
AFTER THE MCA

II INTEGRATED ACTIVITIES FOLLOWING
THE MCA

III ATMOSPHERIC DILUTION FACTORS

IV DOSE TO CRITICAL ORGAN PER μ C
INTAKE

APPENDIX B

I DOSE TO THE PUBLIC FOLLOWING THE
MCA

APPENDIX C

I DOSE TO CONTROL ROOM PERSONNEL
FOLLOWING THE MCA.

APPENDIX D

I EVALUATION OF RADIOLOGICAL HAZARDS
TO THE PUBLIC FROM NORMAL OPERATION
OF EGCR.

APPENDIX E

I DOSE SUMMARY DUE TO STEAM SYSTEM
FAILURE.

				313	
				SIMILAR TO	
DR'N	CH'D	APP'D	SCALE = 12	SHEET OF	ISSUE
ALLIS-CHALMERS MFG. CO.			DEPT.		

A

B

A   B   C

PRESSURES IN THE CONTAINMENT SHELL AFTER MCA

In the period from 0 hrs to 24 hrs after the MCA, the pressures in the shell are given by K.E. calculations by G. Humphreys transmitted from P.D. Bush to L.H. Jackson on 12-27-62. The maximum pressure reached is about 9 psig at about 8 minutes after the MCA. This pressure is reduced by the spray cooling system. At 30 minutes after the MCA, a N_2 purge of 1000 scfm begins and this lasts until 2 hours after the MCA. From 2 hours to 72 hours after the MCA the purge rate is 200 scfm of Nitrogen. Since there is NO VENTING during the first 24 hrs after the MCA, the pressure in the shell will rise from a minimum of 3.1 psig at 4 hrs after the MCA to about 7.6 psig at 24 hours after the MCA. At 24 hrs after the MCA venting is begun at a rate of 750 scfm at 9 psig. This vent rate will be modified for the pressure in the shell.

The time to depressurize the shell will be calculated herein. The purge will supply pressure to the shell until 72 hours after the MCA. From 24 hrs to 72 hrs the pressure will decrease due to venting and leakage. After the purge stops, the pressure will decay exponentially to essentially zero.

PRESSURES IN CONTAINMENT SHELL
AFTER THE MCA

313
APP A - I

SIMILAR TO

DR'N LCC

CH'D DFL

APP'D

SCALE = 12

SHEET 1 OF 10

ISSUE

ALLIS-CHALMERS MFG. CO.

DEPT.

5-83

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

Pressure in the Containment Shell in psig

Plot of Pressure in Shell vs. Time
after MCA.

313
APP A-I

DR'N *DC*

CH'D *DFL*

APP'D

SCALE = 12

SIMILAR TO

SHEET 2 OF 10

ISSUE

ALLIS-CHALMERS MFG. CO.

DEPT.

5-63

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

Now a calculation will be made to determine the containment shell pressure vs. time curve for the duration of the accident (after 24 hrs after MCA)

$$pV = NRT$$

Ideal Gas Relation

$$V dp = RT dN$$

constant volume and temperature

$$dp = \frac{RT}{V} dN$$

$$\frac{dp}{dt} = \frac{RT}{V} \frac{dN}{dt}$$

This relates the rate of pressure change to the rate of ~~volume~~ change of the Moles in the shell

the gas flow from the containment shell is proportional to the square root of the ~~the~~ containment pressure, p , when p is gage pressure

$$\frac{dN_{out}}{dt} = C_1 \sqrt{p}$$

The gas entering during this period due to a CONSTANT purge rate is:

$$\frac{dN_{in}}{dt} = C_2$$

$$C_2 = \frac{200 \text{ scfm}}{359 \frac{\text{scf}}{\text{lb-mol}}} = 0.557 \frac{\text{mol-lb}}{\text{min}}$$

the NET change in N with respect to time is:

$$\frac{dN}{dt} = \frac{dN_{in}}{dt} - \frac{dN_{out}}{dt}$$

Thus the differential equation can be written:

$$\frac{dp}{dt} = \frac{RT}{V} \frac{dN}{dt} = \frac{RT}{V} [C_2 - C_1 \sqrt{p}]$$

$$\text{let } \frac{RT}{V} = C_3, \quad C_2 C_3 = C', \quad \text{and } C_3 C_1 = C''$$

PRESSURES IN CONTAINMENT SHELL 24 TO 72 HRS AFTER THE MCA

313
App A-I

SIMILAR TO

DR'N ACE

CH'D DFL

APP'D

SCALE = 12

SHEET 3 OF 10

ISSUE

ALLIS-CHALMERS MFG. CO. DEPT.

5-63

Rewriting the D.E.

$$\frac{dp}{dt} = c' - c''\sqrt{p}$$

or $\frac{dp}{c' - c''\sqrt{p}} = dt$

Let $y^2 = p$, $y = \sqrt{p}$
 $2y dy = dp$

or $\frac{2y dy}{c' - c''y} = dt$ [which is of the form $\frac{x dx}{a+bx}$]

$$\int \frac{x dx}{a+bx} = \frac{x}{b} - \frac{a}{b^2} \ln(a+bx) + C_i$$

[From page 796
 Korn & Korn
 Math. Hndbk. for
 Scientists & Engne.]

Re substituting

$$2 \left[\frac{y}{-c''} - \frac{c'}{(c'')^2} \ln(c' - c''y) \right] + C_i = t$$

since $y = \sqrt{p}$

$$\frac{2\sqrt{p}}{-c''} - \frac{2c'}{(c'')^2} \ln(c' - c''\sqrt{p}) + C_i = t$$

or

$$\ln(c' - c''\sqrt{p}) = \left(-t + \frac{2\sqrt{p}}{-c''} + C_i \right) \frac{(c'')^2}{2c'}$$

$$c' - c''\sqrt{p} = \exp \left[\frac{t(c'')^2}{2c'} - \frac{(c'')\sqrt{p}}{c'} - \frac{C_i(c'')^2}{2c'} \right]$$

or since last term in exponent is a constant

we... Let $e^{\left[\frac{C_i(c'')^2}{2c'} \right]} = C$

$$c' - c''\sqrt{p} = C e^{-\frac{t(c'')^2}{2c'} - \frac{c''\sqrt{p}}{c'}}$$

Now to calculate constants

PRESSURES IN THE CONTAINMENT SHELL 24 to
 72 hrs after MCA

3/3
 App A-I

SIMILAR TO

DR'N JEC	CH'D DFL	APP'D	SCALE = 12	SHEET 4 OF 10	ISSUE
ALLIS-CHALMERS MFG. CO. DEPT.				5-63	

A

B

$$C_2 = 0.557 \frac{\text{mole-lb}}{\text{min}}$$

$$C_3 = \frac{RT}{V} = \frac{10.73(560)}{1.28 \times 10^6} = 4.69 \times 10^{-3} \quad (@ 100^\circ F = T)$$

$$C' = C_2 C_3 = 0.557 \times 4.69 \times 10^{-3} = 2.61 \times 10^{-3}$$

$$C_1 = + \frac{750 \text{ scfm}}{359 \frac{\text{scf}}{\text{lb-mol}} \sqrt{9 \text{ psi}}} = + 0.696$$

for vent rate of 750 scfm @ 9psig

$$C'' = C_1 C_3 = + 0.696 \times 4.69 \times 10^{-3} = + 3.26 \times 10^{-3}$$

Inserting these constants in the Equation,

$$2.61 \times 10^{-3} - 3.26 \times 10^{-3} \sqrt{p} = C e^{-1.25 \sqrt{p} - 2.036 \times 10^{-3} t}$$

$$\text{Since } \frac{(C'')^2}{2C'} = \frac{(3.26)^2 \times 10^{-6}}{2 \times 2.61 \times 10^{-3}} = 2.036 \times 10^{-3}$$

$$\text{and } \frac{C''}{C'} = \frac{+ 3.26 \times 10^{-3}}{2.61 \times 10^{-3}} = + 1.25$$

$$\sqrt{p} = C^* e^{-1.25 \sqrt{p} - 2.036 \times 10^{-3} t} + 0.801$$

Now from G. Humphrey's calcs @ $t=0$ (24 hrs after MCA)
 $p = 7.6 \text{ psig} \quad \therefore \sqrt{p} = 2.758$

$$C^* = \frac{2.758 - 0.801}{e^{-3.447}} = \frac{1.957}{0.0318} = 61.54$$

$$\boxed{\sqrt{p} = 61.54 e^{-1.25 \sqrt{p} - 2.036 \times 10^{-3} t} + 0.801}$$

Now calculate the times for p to fall to various lower values. which will be assumed

PRESSURES IN CONTAINMENT SHELL after MCA
 24 hrs to 72 hrs

313
 App. - A-I

DR'N *DL*

CH'D DFL

APP'D

SCALE

=12

SIMILAR TO

SHEET 5 OF 10

ISSUE

ALLIS-CHALMERS MFG. CO. DEPT.

5-63

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

Calc. t for p to be 6 psig

$$p=6 \quad \sqrt{p} = 2.45$$

$$2.45 = 61.54 e^{-3.06 - 2.036 \times 10^{-3} t} + 0.801$$

$$e^{( )} = \frac{2.45 - 0.801}{61.54} = 0.0268$$

$$\therefore ( ) = -3.61 = -3.06 - 2.036 \times 10^{-3} t$$

$$t = \frac{3.61 - 3.06}{2.036 \times 10^{-3}} = 270 \text{ min} = 4.5 \text{ hr}$$

Calc. t for p to be 4 psig $\sqrt{p} = 2$

$$2 = 61.54 e^{-2.5 - 2.036 \times 10^{-3} t} + 0.801$$

$$e^{( )} = \frac{2 - 0.801}{61.54} = 0.0195$$

$$( ) = -3.95$$

$$t = \frac{3.95 - 2.5}{2.036 \times 10^{-3}} = 712 \text{ min} = 11.9 \text{ hr}$$

Calc t for p to be 3 psig $\sqrt{p} = 1.73$

$$1.73 = 61.54 e^{-2.16 - 2.036 \times 10^{-3} t} + 0.801$$

$$e^{( )} = \frac{1.73 - 0.801}{61.54} = 0.0151$$

$$( ) = -4.2$$

$$t = \frac{4.2 - 2.16}{2.036 \times 10^{-3}} = 1007 \text{ min} = 16.8 \text{ hr}$$

Calc t for p to be 2 psig $\sqrt{p} = 1.41$

$$1.41 = 61.54 e^{-1.76 - 2.036 \times 10^{-3} t} + 0.801$$

$$e^{( )} = \frac{1.41 - 0.801}{61.54} = 0.00989$$

$$( ) = -4.63$$

$$t = \frac{4.63 - 1.76}{2.036 \times 10^{-3}} = 1409 \text{ min} = 23.5 \text{ hr}$$

Calculation of Pressures in Containment
Shell from 24 to 72 hrs after MCA

313
App. A-I

SIMILAR TO

DR'N JCC

CH'D DFL

APP'D

SCALE

=12

SHEET 6 OF 10

ISSUE

ALLIS-CHALMERS MFG. CO. DEPT.

5-63

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

Calc t for p to be 1 psig $\sqrt{p} = 1$

$$1 = 61.54 e^{-1.25 - 2.036 \times 10^{-3} t} + 0.801$$

$$e^{C_1} = \frac{1 - 0.801}{61.54} = 0.00323$$

$$C_1 = -5.72$$

$$t = \frac{5.72 - 1.25}{2.036 \times 10^{-3}} = 2195 \text{ min} = 36.58 \text{ hr}$$

Calc t for p to be 0.75 $\sqrt{p} = 0.865$

$$0.865 = 61.54 e^{-1.08 - 3.036 \times 10^{-3} t} + 0.801$$

$$e^{C_1} = \frac{0.865 - 0.801}{61.54} = 0.00103$$

$$C_1 = -6.89$$

$$t = \frac{6.89 - 1.08}{2.036 \times 10^{-3}} = 2854 \text{ min} = 47.6 \text{ hrs}$$

Now $24 + 47.6 = 71.6 \text{ hrs} \approx 72 \text{ hr}$ at this point in time purge stops. Now calculate the time for the pressure to decay to zero since no more gas is being fed into the shell.

The D.E. for times after 72 hrs is now

$$\frac{dp}{dt} = -\frac{RT}{V} C_1 \sqrt{p} = -\frac{0.696 RT}{V} \sqrt{p} \quad \text{Since } C_2 = 0$$

$$\frac{V}{RT(0.696)} p^{-1/2} dp = dt$$

$$-\frac{2V}{0.696 RT} p^{1/2} = t + C_i$$

$$\frac{V}{RT(0.696)} = \frac{1.28 \times 10^6}{10.72(560)(0.696)} = 311.6$$

$$-2(311.6) \sqrt{p} = t + C_i$$

CONTAINMENT SHELL PRESSURES after PCA

313
App. A-I

SIMILAR TO

DR'N

ACC

CH'D DFC

APP'D

SCALE

= 12

SHEET

7

OF

10

ISSUE

ALLIS-CHALMERS MFG. CO.

DEPT.

5-63

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

To evaluate C_i

@ $t=0$ 72 hrs after accident $p=0.75 \text{ psi}$

$$-623.2 \sqrt{0.75} = 0 + C_i$$

$$C_i = -539.0$$

$$t = 539 - 623.2 \sqrt{p}$$

This equation relates pressure to time in the period 72 hrs ~~until~~ until the containment shell pressure decays to atmospheric.

Now pressure = 0 at time = 539 minutes

$$t = 539 - 623.2 \sqrt{0} = 539 \text{ min} = 9.0 \text{ hrs}$$

i.e., pressure decays to atmospheric at 72 hrs plus 9 hrs = 81 hrs after MCA for the given Vent rate.

Picking up some intermediate points

$$p = 0.6 \quad \sqrt{p} = 0.775$$

$$t = \frac{539 - 623.2 (0.775)}{60 \text{ min/hr}} = 0.939 \text{ hr}$$

= 72.939 hr after MCA

$$p = 0.4 \quad \sqrt{p} = 0.632$$

$$t = \frac{539 - 623.2 (0.632)}{60 \text{ min/hr}} = 2.4 \text{ hr}$$

= 74.4 hr after MCA

Pressures in Containment shell after 72 hrs after MCA

313
App. A-I

SIMILAR TO

DR'N *DFL*

CH'D DFL

APP'D

SCALE

= 12

SHEET 5 OF 10

ISSUE

ALLIS-CHALMERS MFG. CO. DEPT.

5-63

$$p = 0.2 \quad \sqrt{p} = 0.446$$

$$t = \frac{539 - 623.2 (0.466)}{60 \text{ min/hr}} = 4.34 \text{ hr.}$$

$$= 76.34 \text{ hrs after MCA}$$

Now the leak rate from the containment shell would be 0.3% day⁻¹ of contained volume at $p = 9 \text{ psig}$

$$\therefore \text{Leakage} = 10^{-3} \sqrt{p} \quad p \text{ in psig}$$

$$@ p = 9 \text{ psig} \quad L = 10^{-3} \sqrt{9} = 0.3\% \text{ day}^{-1}$$

Now modifying the pressure from 9 psig to what was calculated for the period 24 hrs to 72 hrs.

$$L \text{ day}^{-1} = 10^{-3} \sqrt{p}$$

The Containment Building holds at 100°F

$$N_0 = \frac{pV}{RT} = \frac{(p+14.2) 1.28 \times 10^6}{10.73 (560)} = 213 (p+14.2) \text{ moles}$$

for p in psig and atmospheric pressure at the EGCR site of 14.2 psi

The Number of moles that leak out per hour can be calculated by $L \times N_0 \times \frac{1}{24} \frac{\text{day}}{\text{hr}} = 10^{-3} \sqrt{p} 213 (p+14.2) \frac{1}{24}$

TIME	p (psig)	L (day ⁻¹)	N_0 (moles)	N_{leak} (mole/hr)
24	7.6	0.00276	4643	0.533
28.5	6.0	0.00245	4260	0.433
35.9	4.0	0.00200	3876	0.322
40.8	3.0	0.00173	3663	0.264
47.5	2.0	0.00141	3451	0.203
60.6	1.0	0.00100	3238	0.135
71.6	0.75	0.00086	3184	0.114
72.0	0.75	0.00086	3184	0.114
72.9	0.60	0.00077	3152	0.101
74.4	0.40	0.00063	3110	0.082
76.3	0.20	0.00045	3067	0.057
81.0	0	0	3025	0

Pressures and leakages from Containment Shell 24 hrs to 81 hrs after MCA.

313
App. A-I

SIMILAR TO

DR'N JEC

CH'D DFL

APP'D

SCALE = 12

SHEET 9 OF 10

ISSUE

of ALLIS-CHALMERS MFG. CO. DEPT.

5-63

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

It can be seen from the plot of pressure vs time that the pressures in the containment shall that are assumed for ~~the~~ calculations in this study are conservative. These constant pressures for each time interval with step changes at 24 hr, 72 hr and 81 hr after the MCA will ^(produce) conservative (higher) dose rates. The area under the p vs. t curve for the assumed p is greater than the area under the p vs. t curve for calculated pressures.

PRESSURES IN CONTAINMENT SHELL
After MCA.

313
App. A-I

SIMILAR TO

DR'N <i>dee</i>	CH'D DFL	APP'D	SCALE = 12	SHEET 10 OF 10	ISSUE
ALLIS-CHALMERS MFG. CO. DEPT.				5-63	

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

The source term for a single fuel pin failure is given by ORNL 62-7-1 (due to T.H. Row).

The 340 fuel pin failures are made up of 330 accidental failures and 10 operational failures. The approximation will be made that the activity release from the operational failures is the same as the activity release from the accidental failures. This assumption will allow us to generate a source term for the MCA by multiplying the release from a single failed pin by 340.

The total activity release is made up of an initial release from the pin and an activity release due to UO_2 oxidation. These activities will be calculated for the time from the MCA to 81 hours after the MCA. It is assumed that 81 hours is the duration of the accident (from calculation of contained pressure in the containment shell). The activities will be calculated for times = 0, 1, 2, 3, 4, 12, 24, 32, 40, 48, 56, 64, 72, and 81 hours. The total activity due to EACH isotope will be plotted vs. time. Integrated activities will be found from these curves using a planimeter over the time required. Activity of any isotope at any time during the accident can be read directly from these plots.

CALCULATION OF SOURCE TERM for EGCR
MCA from ORNL 62-7-1

313
APP A - II

SIMILAR TO

DR'N dce

CH'D dL

APP'D

SCALE = 12

SHEET 1 OF 27

ISSUE

ALLIS-CHALMERS MFG. CO. DEPT.

5-63

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

The activities at 8 hr after the MCA for the 3 isotopes that attain their peak activities during the first 24 hours. Using the parameters given ORNL CF-62-7-1 for I^{135} , Kr^{85m} and Xe^{135} and time = 8 hrs = 2.88×10^4 sec, the Activity due to initial release and the activity due to oxidation of the fuel are found.

$$Q_c(t) = f A_0 [e^{-\lambda t} (1 - e^{-bt})] + A_1 e^{-\lambda t}$$

Formula and notation follow ORNL CF-62-7-1

$$A_0 = 0.838 P(\text{watts}) \gamma$$

$$b = 10^{-6} \quad t = 2.88(4)$$

For Maximum Power Element = 22.424 KW

Isotope $\rightarrow$	I^{135}	Kr^{85m}	Xe^{135}
f	0.30	1.0	1.0
γ	0.061	0.013	0.063
$f A_0$	$0.30(838)(22.424)(0.061)$	$1.0(838)(22.424)(0.013)$	$1.0(838)(22.424)(0.063)$
λ	$2.87(-5)$	$4.38(-5)$	$2.09(-5)$
λt	0.83	1.26	0.6
$e^{-\lambda t}$	0.436	0.284	0.549
$b t$	0.03	0.03	0.03
$e^{-b t}$	0.97	0.97	0.97
$(1 - e^{-b t})$	0.03	0.03	0.03
OXIDATIVE Release/failure	4.50 C.	2.08 C.	19.50 C.
A_1	5.0	0.95	9.2
$A_1 e^{-\lambda t}$	2.18	0.27	5.05
TOTAL Release / Failure	6.68	2.35	24.55
Failures	340	340	340
TOTAL Release	2271.2 Curies	799 Curies	8347 Curies

These releases were used to help determine the Activity-time curves during the first 24 hrs after the MCA.

Calculation of Activities of I^{135} , Kr^{85m} and Xe^{135} at 8 hrs after MCA

313
APP A-II

DR'N	CH'D	APP'D	SCALE	SHEET	OF	ISSUE
JCC	J.L.		=12	1A	27	
ALLIS-CHALMERS MFG. CO. DEPT.				5-63		

FOR 340 FAILURES Activity 0 → 24 hrs							
Time After accident	Number of Failures	Sr ⁸⁹	Sr ⁹⁰	Cs ¹³⁷	Ba ¹⁴⁰	La ¹⁴⁰	I ¹³¹
<u>0 hr</u>							
INITIAL RELEASE	340	374	6.8	1428	54.4	54.4	4420
<u>1 hr</u>							
Initial Activity	340	374	6.8	1428	54.4	54.4	4420
Oxidation Release	340	8.5	1.2	1.3	14.5	14.5	202.6
		382.5	8.0	1429.3	68.9	68.9	4622.6
<u>2 hr</u>							
Initial Activity	340	374	6.8	1428	54.4	54.4	4420
Oxid. Release	340	17	2.4	2.5	28.9	28.9	404.6
		391	9.2	1430.5	83.3	83.3	4824.6
<u>3 hr</u>							
Initial Activity	340	374	6.8	1428	54.4	57	4420
Oxid. Release	340	25.3	3.6	3.8	42.8	40.8	601.8
		399.3	10.4	1431.8	97.2	91.8	5021.8
<u>4 hr</u>							
Initial Activity	340	374	6.8	1428	54.4	51	4420
Oxid. Release	340	33.8	4.9	5.1	67.5	53.4	805.8
		407.8	11.7	1433.1	111.9	104.4	5225.8
<u>12 hr</u>							
Initial Activity	340	374	6.8	1428	54.4	44.2	4420
Oxid. Release	340	102	14.7	15.3	173.4	138.0	2441.2
		476	21.5	1443.3	227.8	182.2	6861.2
<u>24 hr</u>							
Initial Activity	340	374	6.8	1428	51	37.4	4420
Oxid. Release	340	195.5	28.1	29.3	314.5	219.0	4284
		569.5	34.9	1457.3	365.5	256.4	8704

Activities from 0 to 24 hrs after MCA

313
App A-II

SIMILAR TO

DR'N <i>lee</i>	CH'D <i>J.L.</i>	APP'D	SCALE = 12	SHEET <i>3</i> OF 27	ISSUE
ALLIS-CHALMERS MFG. CO. DEPT.				5-63	

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

For 340 FAILURES		Activity 0 → 24 hr				
Time after Accident	Number of Failures	I ¹³³	I ¹³⁵	Kr ^{85m}	Xe ¹³³	Xe ¹³⁵
<u>0 hr</u>						
Initial Release	340	3400	1700	323	11,560	3128
<u>1 hr</u>						
Initial Activity	340	3400	1530	275.4	11,560	2890
Oxid. Release	<u>340</u>	<u>479.4</u>	<u>380.8</u>	<u>254.7</u>	<u>1516.4</u>	<u>1339.6</u>
		3879.4	1910.8	530.1	13,076.4	4229.6
<u>2 hr</u>						
Initial Activity	340	3196	1394	234.6	11,560	2686
Oxid Release	<u>340</u>	<u>894.2</u>	<u>686.8</u>	<u>435.2</u>	<u>3036.2</u>	<u>2482</u>
		4090.2	2080.8	669.8	14,596.2	5168
<u>3 hr</u>						
Initial Activity	340	3094	1058	200.6	11,560	2482
Oxid. Release	<u>340</u>	<u>1285.5</u>	<u>921.4</u>	<u>554.2</u>	<u>4522</u>	<u>3434</u>
		4379.5	2179.4	754.8	16,082	5916
<u>4 hr</u>						
Initial Activity	340	2992	1122	173.4	11,560	2312
Oxid. Release	<u>340</u>	<u>1659.2</u>	<u>1111.8</u>	<u>632.4</u>	<u>6018</u>	<u>4250</u>
		4651.2	2233.8	805.8	17,578	6562
<u>12 hr</u>						
Initial Activity	340	2278	476	47.6	10,880	1258
Oxid Release	<u>340</u>	<u>3842</u>	<u>1468.8</u>	<u>530.4</u>	<u>16,694</u>	<u>6868</u>
		6120	1944.8	578.0	27,574	8126
<u>24 hr</u>						
Initial Release	340	1530	146.2	7.1	10,200	510
Oxid Release	<u>340</u>	<u>4964</u>	<u>826.2</u>	<u>155.</u>	<u>30,600</u>	<u>5440</u>
		6494	972.4	162.1	40,800	5950

Activities from 0 to 24 hours after the MCA

313
App A-II

SIMILAR TO

DR'N <i>DL</i>	CH'D <i>D.L.</i>	APP'D	SCALE = 12	SHEET <u>3</u> OF <u>27</u>	ISSUE
ALLIS-CHALMERS MFG. CO. DEPT.				5-63	

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

For 340 FAILURES		Activity 32 → 81 hours					
TIME after accident	Number of Failures	Sr ⁸⁹	Sr ⁹⁰	Cs ¹³⁷	Ba ¹⁴⁰	La ¹⁴⁰	I ¹³¹
<u>32 hrs</u>							
Initial Activity	340	252.0	4.6	969	34	22.1	2679.2
Oxid. Release	340	189.2	26.4	227.5	289.7	178.8	3910.0
		434.2	31.0	996.5	323.7	200.9	6589.2
<u>40 hrs</u>							
Initial Activity	340	193.5	3.6	748	25.8	14.8	2040
Oxid. Release	340	191.4	27.9	29.1	300.9	164.9	4012
		384.9	31.5	777.1	326.7	179.7	6052
<u>48 hrs</u>							
Initial Activity	340	164.6	3.0	639.2	21.6	11.1	1696.6
Oxid. Release	340	215.6	31.7	33.0	334.9	162.5	4416.6
		380.2	34.8	672.2	356.5	173.6	6113.2
<u>56 hrs</u>							
Initial Activity	340	151.6	2.8	591.6	19.6	8.9	1526.6
Oxid. Release	340	250.6	37.1	388.4	384.2	165.9	5032
		402.2	39.9	630.4	403.8	174.8	6558.6
<u>64 hrs</u>							
Initial Activity	340	145.9	2.7	571.2	18.6	7.5	1431.4
Oxid. Release	340	290.7	43.5	45.6	445.4	167.3	5780.0
		438.6	46.2	616.8	464.0	174.8	7211.4
<u>72 hrs</u>							
Initial Activity	340	143.1	2.7	561	18	6.4	1370.2
Oxid. Release	340	337.6	50	52.7	510	169.0	6494.8
		480.7	52.7	613.7	528	175.4	7864.2
<u>81 hrs</u>							
Initial Activity	340	128.5	2.4	510	16	5.0	1200.2
Oxid. Release	340	357.0	56.1	55.8	530.4	153	6664.0
		485.5	58.5	565.8	546.4	158.0	7864.2
Activities from 32 hrs to 81 hrs after MCA					343 App A-II		
SIMILAR TO							
DR'N	CH'D	APP'D	SCALE	=12	SHEET	4 OF 27	ISSUE
doc	DOZ				5-63		
ALLIS-CHALMERS MFG. CO.		DEPT.					

A		B		C		
FOR 340 FAILURES		Activity 32 to 81 hours				
TIME AFTER accident	Number of Failures	I ¹³³	I ¹³⁵	Kr ^{85m}	Xe ¹³³	Xe ¹³⁵
<u>32 hrs</u>						
Initial Activity	340	795.6	~~43.2~~ 43.2	1.4	6630	189.4
Oxid. Release	340	3536	336.6	34.3	27,472	2801.6
		4331.6	~~380.5~~ 379.8	35.7	34,102	2991.0
<u>40 hrs</u>						
Initial Activity	340	469.2	14.5	0.3	4896	80.6
Oxid Release	340	2869.6	155.7	10.9	27,846	1621.8
		3338.8	170.2	11.2	32,742	1702.4
<u>48 hrs</u>						
Initial Activity	340	306	5.44	0.1	4012	37.8
Oxid. Release	340	2482	76.84	3.6	30,192	1006.4
		2788	82.3	3.7	34,204	1044.2
<u>56 hrs</u>						
Initial Activity	340	217.3	2.2	0.02	3536	19.2
Oxid Release	340	2210	39.1	1.2	33,898	639.2
		2427.3	41.3	1.2	37,434	658.4
<u>64 hrs</u>						
Initial Activity	340	160.8	0.9	0	3274.2	10.2
Oxid. Release	340	1989.	19.8	0.4	38,420	391
		2149.8	20.7	0.4	41,694.2	401.2
<u>72 hrs</u>						
Initial Activity	340	121.4	0.4	0	3090.6	5.5
Oxid. Release	340	1798.6	10.3	0.1	42,500	252.6
		1920.0	10.7	0.1	45,590.6	258.1
<u>81 hrs</u>						
Initial Activity	340	81.3	0.1	0	2662.2	2.5
Oxid Release	340	1411.	4.3	0	42,840	138
		1492.3	4.4	0	45,502.2	140.5

Activities from 32 hrs to 81 hrs
after the MCA

313
App. A-II

SIMILAR TO

DR'N dce	CH'D BPL	APP'D	SCALE =12	SHEET 5 OF 27	ISSUE
ALLIS-CHALMERS MFG. CO. DEPT.				5-63	

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

Fig 8

Sr 89

TIME	$\int a dt$ in $\mu C-SEC$	
0 $\rightarrow$ 1 hr	6.77 (11)	(0.47 μN^2)
0 $\rightarrow$ 1 hr	1.38 (12)	(0.96 μN^2)
0 $\rightarrow$ 1 1/2 hr	2.07 (12)	(1.44 μN^2)
0 $\rightarrow$ 2 hr	2.79 (12)	(1.94 μN^2)
0 $\rightarrow$ 24 hr	4.08 (13)	(28.35 μN^2)

$$1 \mu N^2 = 400 \text{ C-HRS}$$

$$1 \mu N^2 = 1.44 \times 10^{12} \mu C-SEC$$

5-63
JCC
CHD DFL

FIG. 10

C 5 137

$$1 \text{ IN}^2 = 500 \text{ C. IN.}$$

$$1 \text{ IN}^2 = 2.58 \times 10^{12} \text{ MC. SEC.}$$

Activity in Curies

TIME	$\int A dt$ (hr-sec.)	
0 $\rightarrow$ 1/2	2.56(12)	(0.89 IN ²)
0 $\rightarrow$ 1	5.13(12)	(1.78 IN ²)
0 $\rightarrow$ 1 1/2	7.70(12)	(2.67 IN ²)
0 $\rightarrow$ 2	1.03(13)	(3.58 IN ²)
0 $\rightarrow$ 24	1.25(14)	(43.27 IN ²)

TIME HRS

APC 5-63
AND DFC

Time	Σa dt in MC-sec	
0 → 1/2	1.01 (11)	(0.07 in ²)
0 → 1	2.16 (11)	(0.15 in ²)
0 → 1 1/2	3.31 (11)	(0.23 in ²)
0 → 2	4.75 (11)	(0.33 in ²)
0 → 24	1.89 (13)	(13.10 in ²)

FIG 11

Ba 140

1 in² = 400 C-hr

1 in² = 1.44 x 10¹² MC-sec

AND DFL 5-68

313 App A-II

9 OF 27

FIG 12

LA 140

$1 \text{ m}^2 = 400 \text{ c-hr}$
 $1 \text{ m}^2 = 1.44 \times 10^{12} \text{ MC-sec}$

TIME	$\int \text{Adt (hr-sec.)}$	
$0 \rightarrow 1/2$	1.01(11)	(0.07 m^2)
$0 \rightarrow 1$	2.16(11)	(0.15 m^2)
$0 \rightarrow 1 1/2$	3.44(11)	(0.24 m^2)
$0 \rightarrow 2$	4.90(11)	(0.34 m^2)
$0 \rightarrow 24$	11.51(13)	(10.52 m^2)

Activity - C

400
300
200
100

0 4 8 12 16 20 24

TIME - HRS

Dec 563

Q440 BFL

FIG 12

LA 140

$1 \text{ m}^2 = 400 \text{ c-hr}$
 $1 \text{ m}^2 = 1.44 \times 10^{12} \text{ MC-sec}$

TIME	$\int \text{Adt (hr-sec.)}$	
$0 \rightarrow 1/2$	1.01(11)	(0.07 m^2)
$0 \rightarrow 1$	2.16(11)	(0.15 m^2)
$0 \rightarrow 1 1/2$	3.44(11)	(0.24 m^2)
$0 \rightarrow 2$	4.90(11)	(0.34 m^2)
$0 \rightarrow 24$	11.51(13)	(10.52 m^2)

Activity - C

400

300

200

100

0

4

8

12

16

20

24

TIME - HRS

Dec 563

Q440 BFL

313 App A-II

10 of 27

FIG 13

I 131

$$1 \text{ IN}^2 = 8000 \text{ @-hN}$$

$$2 \text{ IN}^2 = 2.88 \times 10^{13} \text{ @-hN}$$

FIG 13

I 131

$$1 \text{ IN}^2 = 8000 \text{ @-hN}$$

$$2 \text{ IN}^2 = 2.88 \times 10^{13} \text{ @-hN}$$

Time	$\int A dt$ (MC-sec)	
0 $\rightarrow$ 1/2	3.24 (12)	(0.45 IN ²)
0 $\rightarrow$ 1	6.76 (12)	(0.93 IN ²)
0 $\rightarrow$ 1 1/2	11.04 (13)	(1.44 IN ²)
0 $\rightarrow$ 2	11.39 (13)	(1.93 IN ²)
0 $\rightarrow$ 24	11.56 (14)	(21.68 IN ²)

FIG 15

I 135

1 IN² = 2000 C-hr
 1 IN² = 7.2×10^{12} MC-sec

CHD. DFC 5-63

313 App A-II
 13 OF 27

FIG 16

TIME	$\int A dt$ (MC-SEC)	
0 $\rightarrow$ 1/2	6.62 (11)	(0.23 IN ²)
0 $\rightarrow$ 1	11.50 (12)	(0.52 IN ²)
0 $\rightarrow$ 1 1/2	21.48 (12)	(0.96 IN ²)
0 $\rightarrow$ 2	31.66 (12)	(1.27 IN ²)
0 $\rightarrow$ 24	41.55 (13)	(15.79 IN ²)

K_r 85 m

$$1 \text{ IN}^2 = 800 \text{ MC-SEC}$$

$$1 \text{ IN}^2 = 2.88 \times 10^{12} \text{ MC-SEC}$$

Fig 17

Xe¹³³

Time	$\int A dt$ (mc-sec)	
$0 \rightarrow \frac{1}{2}$	2.16 (13)	(0.15 IN^2)
$0 \rightarrow 1$	4.46 (13)	(0.31 IN^2)
$0 \rightarrow 1\frac{1}{2}$	6.71 (13)	(0.48 IN^2)
$0 \rightarrow 2$	9.50 (13)	(0.66 IN^2)
$0 \rightarrow 24$	2.38 (15)	(16.50 IN^2)

$$1 IN^2 = 4 \times 10^4 \text{ c-hr}$$

$$1 IN^2 = 1.44 \times 10^{14} \text{ mc-sec}$$

TIME	SADT (μC-hr)	
0 → 1/2	6.05 (12)	(0.21 IN ²)
0 → 1	1.41 (13)	(0.47 IN ²)
0 → 1 1/2	2.10 (13)	(0.73 IN ²)
0 → 2	3.02 (13)	(1.05 IN ²)
0 → 24	6.11 (14)	(21.21 IN ²)

FIG 18

Xe 135

$$1 \text{ IN}^2 = 8000 \text{ e-hr}$$

$$1 \text{ IN}^2 = 2.88 \times 10^{13} \text{ e-hr}$$

JCC
CHD DR 5-63
313 App A-II
16 of 27

313 APP A-II
17 OF 27

313 APP A - II
18 00 37

313 APP A-II
19 OF 27

313 App A-II
20 of 27

313 APP A-II
21 OF 23

313 APP A-II
22 OF 27

313 APP A-II
23 OF 27

313 APP A-II
24 05 27

313 APPA-II
35 OF 37

313 App. A. II
26 0121

313 App P-II
2705-21

313 App P-II
27 Oct 71

Calculation of Atmospheric Dilution Downwind from the Source.

Meteorological Parameters

LAPSE CONDITIONS

$\bar{u}$ = wind velocity (average) in $\frac{m}{sec} = 2.3 \text{ m/sec}$

n = stability parameter = 0.23

C_y, C_z = Diffusion Coefficients for y & z coordinates

$$C_y = C_z = 0.3$$

INVERSION CONDITIONS

$\bar{u} = 1.5 \text{ m/sec}$ $n = 0.35$

$$C_y = 0.3 \quad C_z = 0.033$$

$$\sigma_y = \left[\frac{1}{2} C_y^2 d^{2-n} \right]^{1/2} \quad \sigma_z = \left[\frac{1}{2} C_z^2 d^{2-n} \right]^{1/2}$$

where d is distance downwind.

the concentration of an isotope downwind of a continuous source is given by:

$$X \left(\frac{\mu C}{m^3} \right) = \frac{Q \left(\frac{\mu C}{sec} \right)}{\pi \bar{u} \sigma_y \sigma_z} = \frac{2 Q \left(\frac{\mu C}{sec} \right)}{\pi \bar{u} C_y C_z d^{2-n}}$$

This assumes a ground level release

If the activity is released from a stack which has a height of h meters,

$$X \left(\frac{\mu C}{m^3} \right) = \frac{Q \left(\frac{\mu C}{sec} \right)}{\pi \bar{u} \sigma_y \sigma_z} e^{-\frac{h^2}{2\sigma_z^2}} = \frac{Q \left(\frac{\mu C}{sec} \right)}{\pi \bar{u} \sigma_y \sigma_z} e^{-\frac{h^2}{C_z^2 d^{2-n}}}$$

Concentration formulae given on p. 47 AECU 3066 "Meteorology & Atomic Energy"
Meteorological Parameters given by letter Charpie (ORNL) to JACKSON (ORO) of 2-16-61

Calculation of Atmospheric Dilution
Factors

313
APP A-III

DR'N	JCC	CH'D	DL	APP'D	SCALE	=12	SHEET	1 OF 4	ISSUE
ALLIS-CHALMERS MFG. CO.				DEPT.		5-63			

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

To calculate the dose rate due to dry fallout of particulate matter, an activity per unit area may be calculated by:

$$\Delta \left(\frac{\mu\text{C}}{\text{m}^2} \right) = \frac{2Q_0(\mu\text{C})V_g}{\bar{u}\pi C_y C_d d^{2-n}} e^{-\left[\frac{4V_g d^{n/2}}{n\bar{u}\pi^{1/2} C_y} \right]} e^{-\left[\frac{h^2}{C_y^2 d^{2-n}} \right]} \quad (1)$$

Here V_g is a settling velocity in m/sec for dry fallout. The dry particle is assumed to be 15 microns in diameter which yields a V_g of 2×10^{-2} m/sec⁽²⁾. This large size was selected to yield a high settling velocity which should yield a higher value of Δ .

Q_0 is a release of activity in μ Curies.

The above formula neglects horizontal diffusion rendering the results conservative.

To calculate the dose rate due to the washout of particulate matter, the deposited activity per unit area may be calculated by

$$P \left(\frac{\mu\text{C}}{\text{m}^2} \right) = \frac{\lambda Q_0(\mu\text{C})}{\pi^{1/2} \bar{u} C_y d^{2-n}} e^{-\frac{\lambda d}{\bar{u}}} \quad (3)$$

This also neglects horizontal diffusion rendering the answers conservative.

Here λ is the proportion of the cloud rained out per second. λ will be assumed to be 10^{-3} , a proportion associated with a heavy rainfall of 0.15 in/hr.⁽⁴⁾ This parameter is also chosen to give a conservative answer.

References

- (1) WASH 740 "Theoretical Consequences and Possibilities of Major Accidents in Large Nuclear Power Plants" page 50 equation (4)
- (2) WASH 740, page 50 Table 4
- (3) WASH 740, page 51 Equation (5)
- (4) Wash 740, page 51 Table 5

Calculation of ATMOSPHERIC DILUTION
FACTORS.

313
App A-III

SIMILAR TO

DR'N *del*

CH'D *del*

APP'D

SCALE = 12

SHEET 2 OF 4

ISSUE

ALLIS-CHALMERS MFG. CO. DEPT.

6-63

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

ATMOSPHERIC DILUTION FOR INVERSION CONDITIONS

GROUND RELEASE

DISTANCE

$X_i(t) / Q_i(t)$

200 m

6.83×10^{-3}

1060 m

4.37×10^{-4}

4600 m

3.88×10^{-5}

6000 m

2.503×10^{-5}

7500 m

1.732×10^{-5}

9095 m

1.260×10^{-5}

10,000 m

1.077×10^{-5}

RELEASE FROM A STACK OF 61 METERS HEIGHT

DISTANCE

$X_i(t) / Q_i(t)$

4600 m

1.765×10^{-6}

6000 m

3.412×10^{-6}

7500 m

4.359×10^{-6}

9095 m

4.591×10^{-6}

10,000 m

4.564×10^{-6}

ATMOSPHERIC DILUTION FOR LAPSE CONDITIONS

GROUND RELEASE

DISTANCE

$X_i(t) / Q_i(t)$

200 m

1.30×10^{-4}

1060 m

6.80×10^{-6}

4600 m

5.06×10^{-7}

6000 m

3.16×10^{-7}

7500 m

2.13×10^{-7}

9095 m

1.51×10^{-7}

10,000 m

1.28×10^{-7}

RELEASE FROM 61 m HIGH STACK

DISTANCE

$X_i(t) / Q_i(t)$

4600 m

4.99×10^{-7}

6000 m

3.13×10^{-7}

7500 m

2.12×10^{-7}

9095 m

1.50×10^{-7}

10,000 m

1.28×10^{-7}

SUMMARY OF ATMOSPHERIC DILUTION FACTORS

313
App. A-III

SIMILAR TO

DR'N

JCE

CH'D

SL

APP'D

SCALE

=12

SHEET

3 OF 4

ISSUE

of ALLIS-CHALMERS MFG. CO.

DEPT.

Calculation of Dilution Factors DURING LAPSE.

$$X/Q = \frac{1}{\pi \bar{u} c_y c_z d^{2-n}} = \frac{1}{\pi (2.3)(.3)^2 d^{2-0.23}}$$

$$X/Q = \frac{d^{-1.77}}{0.64998} = 1.539 d^{-1.77} \quad (\text{gnd level release})$$

d	log d	1.77 log d	d ^{1.77}	X/Q) ^{gnd level}
200	2.30103	4.02282	1.1826(4)	1.30(-4)
1060	3.02531	5.35480	2.2636(5)	6.80(-6)
4600	3.66276	6.40309	3.0415(6)	5.06(-7)
6000	3.77815	6.68738	4.8678(6)	3.16(-7)
7500	3.87506	6.85886	7.2253(6)	2.13(-7)
9095	3.95880	7.00708	1.0164(7)	1.51(-7)
10000	4.00000	1.08000	1.2023(7)	1.28(-7)

For release from 61 m high stack the above X/Q is multiplied by

$$e^{-\frac{h^2}{9.2 d^{1-n}}}$$

where h=61   c_y=0.3

or $e^{-\frac{4.134 \times 10^4}{d^{1.77}}}$

d	(4.134 x 10 ⁴ /d ^{1.77})	e ⁻⁽⁾	(X/Q) ^{stack level}
4600	0.014	0.986	4.99(-7)
6000	0.008	0.992	3.13(-7)
7500	0.006	0.994	2.12(-7)
9095	0.004	0.996	1.50(-7)
10,000	0.003	0.997	1.28(-7)

EXAMPLE CALCULATION OF DILUTION FACTORS FOR LAPSE CONDITIONS

313
App A-III

DR'N

DL

CH'D

DL

APP'D

SCALE

=12

SIMILAR TO

SHEET

4 OF 4

ISSUE

of ALLIS-CHALMERS MFG. CO.

DEPT.

6-63

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

The maximum dose D_i in rem to a body organ of mass m grams from an intake I_i in μC over a short period of time is given as *

$$D = \sum D_i = \frac{745 I_i T_i \sum E(RBE)N}{m}, \text{ rem}$$

where

f = fraction of intake deposited in organ

$$T_i = \text{effective half-life} = \frac{T_b T_r}{T_b + T_r}, \text{ days}$$

T_b = biological half-life, days

T_r = radiological half-life, days

$\sum E$ = effective energy delivered to organ, MeV/dis

RBE = relative biological effectiveness

N = distribution factor

i = refers to isotopes

* H. Etherington, Nuclear Eng. Handbook, p 7-44, McGraw-Hill 1958,

Thyroid

$$m = 20\text{g.}$$

$$f = 0.23 \text{ (inhalation)}$$

Isotope	T_i (days)	$\sum E(RBE)N$	$D_i/I_i = S_i$ rem/ μC
I^{131}	7.6	0.23	1.488
I^{133}	0.87	0.54	0.400
I^{135}	0.29	0.52	0.124

Above data from "Report of ICRP Committee II on Permissible dose for Internal Radiation (1959)" as published in Health Physics, Vol 3, June 1960

CALCULATION OF S_i (REMS/ μC) TO ORGANS OF INTEREST FOR MAJOR ISOTOPES

313
APP. A - II

SIMILAR TO

DR'N D.L.	CH'D d.Y.	APP'D	SCALE = 12	SHEET 1 OF 2	ISSUE
ALLIS-CHALMERS MFG. CO. DEPT.				663	

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

Total Body

$$m = 7.0 \times 10^4 \text{ g}$$

Isotope	f	T_i (days)	$\Sigma E(RBE)N$	$S_i (\text{rem}/\mu\text{e}) \times 10^3$
^{89}Sr	0.4	50.3	0.55	11.697
^{90}Sr	0.4	5700.0	0.21	506.16
^{137}Cs	0.75	70.0	0.59	32.74
^{140}Ba	0.28	10.7	0.40	1.267
^{140}La	0.25	1.68	1.9	0.843
^{131}I	0.75	7.6	0.44	2.651
^{133}I	0.75	0.87	0.84	0.579
^{135}I	0.75	0.28	1.2	0.266

Bone

Isotope	S_i	T_i (days)	$\Sigma E(RBE)N$	$S_i (\text{rem}/\mu\text{e})$
^{89}Sr	0.28	50.4	2.8	0.42
^{90}Sr	0.12	6.4 (3)	5.5	49.65
^{137}Cs	0.03	138	1.4	0.06
^{140}Ba	0.19	10.7	4.2	0.09
^{140}La	0.10	1.68	2.7	0.005

Calculation of $S_i (\text{rem}/\mu\text{e})$ to Organs
of Interest for Major Isotopes

3/3
App. A - IV

SIMILAR TO

DR'N D.L.	CH'D D.L.	APP'D	SCALE = 12	SHEET 2 OF 2	ISSUE
ALLIS-CHALMERS MFG. CO. DEPT.				6-63	

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

DOSE VS TIME at 200 Meters at 1/2, 1, 1 1/2, & 2 Hours

At d = 200 m

$$\left. \begin{aligned} K_i(t) &= 6.83 \times 10^{-3} L d_i(t) \text{ Inversion} \\ K_i(t) &= 2.02 \times 10^{-4} L d_i(t) \text{ Lapse} \end{aligned} \right\} \text{Ground Release* (Leakage)}$$

$d_i(t)$ = activity in containment shell at time t
Now $L = 0.3\%$ /day of contained volume at an internal pressure of 9 psig. This pressure will be assumed to be held for the first 24 hours. Converting the leakage constant to units of 1/sec we get:

$$3 \times 10^{-3} \text{ /day} \times \frac{1}{3600 \times 24} \frac{\text{day}}{\text{sec}} = 3.47 \times 10^{-8} \text{ 1/sec} = L$$

The Intake, I_i , equals the Breathing Rate times the concentration K_i . $B.R. = 3.5 \times 10^{-4} \text{ m}^3/\text{sec}$

$$I_i = 3.5 \times 10^{-4} \times 3.47 \times 10^{-8} \times 6.83 \times 10^{-3} \int d_i(t) dt$$

$$I_i = 0.83 \times 10^{-13} \int_0^T d_i(t) dt \quad [\text{For } d_i \text{ in } \mu\text{C and Inversion}]$$

$\int_0^T d_i(t) dt$ evaluated graphically, see figs 8 thru 15.
Intake I_i in μC

Isotope	0 → 1/2 hr	0 → 1 hr	0 → 1 1/2 hr	0 → 2 hr
Sr 89	0.056	0.115	0.172	0.232
Sr 90	0.001	0.002	0.004	0.005
Cs 137	0.116 ^{8.2, 12}	0.426	0.640	0.855
Ba 140	0.008	0.018	0.028	0.039
La 140	0.008	0.018	0.029	0.041
I 131	0.669	0.361	2.058	2.747
I 133	0.526	1.087	1.652	2.224
I 135	0.269	0.556	0.863	1.154

$\left. \begin{aligned} &K_{r85m} \\ &Xe^{133} \\ &Xe^{135} \end{aligned} \right\}$ It is not necessary to calculate intakes for rare gases since their internal retention is taken to be 0

* App A-III

The thyroid, bone, and whole body dose will be calculated using R.B.E. values of rem/μC from Health Physics vol 3 June 1960. The whole body dose will have components due to inhalation, submersion, and direct radiation.

DOSE VS TIME @ 200 Meters

For times = 1/2, 1, 1 1/2, & 2 hrs after MCA

313

App B

SIMILAR TO

DR'N JAL

CH'D JAL

APP'D

SCALE = 12

SHEET 1 OF 50

ISSUE

ALLIS-CHALMERS MFG. CO.

DEPT.

5-63

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

Thyroid Dose		Dose = $\sum S_i I_i$			
Isotope	S_i (thyroid)*	0 $\rightarrow$ 1/2 hr	0 $\rightarrow$ 1 hr	0 $\rightarrow$ 1 1/2 hr	0 $\rightarrow$ 2 hr
I ¹³¹	1.488 ~~2.4~~	0.995	2.025	3.062	4.088
I ¹³³	0.400 "	0.210	0.435	0.661	0.890
I ¹³⁵	0.124 "	0.033	0.069	0.107	0.143
Total dose in rems		1.238	2.529	3.830	5.121

Bone Dose		Dose = $\sum S_i I_i$			
Isotope	S_i (bone)*	0 $\rightarrow$ 1/2 hr	0 $\rightarrow$ 1 hr	0 $\rightarrow$ 1 1/2 hr	0 $\rightarrow$ 2 hr
Sr ⁸⁹	0.42	0.024	0.048	0.072	0.097
Sr ⁹⁰	44.65	0.045	0.089	0.179	0.223
Cs ¹³⁷	0.06	0.013	0.026	0.038	0.051
Ba ¹⁴⁰	0.09	0.001	0.002	0.003	0.004
La ¹⁴⁰	0.005	—	—	—	—
Total dose in rems		0.083	0.165	0.292	0.375

Total Body Dose

Component due to Inhalation		Dose = $\sum S_i I_i$			
Isotope	S_i (body)*	0 $\rightarrow$ 1/2 hr	0 $\rightarrow$ 1 hr	0 $\rightarrow$ 1 1/2 hr	0 $\rightarrow$ 2 hr
Sr ⁸⁹	11.7(-3)	0.001	0.001	0.002	0.003
Sr ⁹⁰	0.5062	0.001	0.001	0.002	0.003
Cs ¹³⁷	0.0327	0.007	0.014	0.021	0.028
Ba ¹⁴⁰	1.3(-3)	—	—	—	—
La ¹⁴⁰	0.8(-3)	—	—	—	—
I ¹³¹	2.7(-3)	0.002	0.004	0.006	0.007
I ¹³³	0.6(-3)	—	0.001	0.001	0.001
I ¹³⁵	0.3(-3)	—	—	—	—
Total Dose in Rems		0.011	0.021	0.032	0.042

* SEE App A - III

The Component due to submersion of the body in a cloud of fission products may be calculated from:

$$DOSE = 2.6 \times 10^{-7} E_s L \cdot 6.83 \times 10^{-3} \int_0^T A_i(t) dt \text{ rem} \quad \text{for Inversion Conditions}$$

$$\text{where } L = 3.47 \times 10^{-8} \text{ sec}^{-1} \quad E_s = 1.5 \text{ mev/ds}$$

$$DOSE = 9.243 \times 10^{-17} \int_0^T A_i(t) dt \text{ rem.}, \text{ where } \int_0^T A_i(t) dt \text{ is in } \mu\text{C-sec, see Page 8 and 18.}$$

DOSE AT 200 METERS INVERSION CONDITIONS

313

App B

DR'N <i>lcc</i>	CH'D <i>lcc</i>	APP'D	SCALE = 12	SHEET 2 OF 50	ISSUE
ALLIS-CHALMERS MFG. CO. DEPT.				5-63	

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

A

B

C

Submersion Dose in Rem $\times 10^6$				
ISOTOPE	0 $\rightarrow$ 1/2 hr	0 $\rightarrow$ 1 hr	0 $\rightarrow$ 1 1/2 hr	0 $\rightarrow$ 2 hr
Sr ⁸⁹	62.58	127.55	191.33	257.88
Sr ⁹⁰	1.20	2.46	3.93	5.32
Cs ¹³⁷	236.62	474.17	711.71	952.03
Ba ¹⁴⁰	9.34	19.96	30.59	43.91
La ¹⁴⁰	9.34	19.96	31.80	45.29
I ¹³¹	744.99	1515.85	2292.26	3059.43
I ¹³³	586.01	1210.83	1839.36	2477.12
I ¹³⁵	299.47	619.28	961.27	1284.78
Kr ^{85m}	61.19	138.65	229.23	338.29
Xe ¹³³	1996.49	4122.38	6386.91	8780.85
Xe ¹³⁵	559.20	1303.26	1941.03	2791.39
Dose (rem)	0.0045	0.0094	0.0146	0.0200

The next component of the whole body dose is that due to the direct dose by radiation from the containment shell. Consider the shell as a point source since the distance is 200 meters from the shell.

$$\text{Dose Rate} = \frac{\beta}{4\pi d^2} e^{-\mu d} \sum E_i A_i(t) \cdot \gamma, \text{ r/sec}$$

where $A_i(t)$ is activity of i^{th} isotope @ time t in dis/sec

γ is a conversion factor rem/sec-m^2 to $\text{r/sec} = 1.8 \times 10^{13}$

μ is attenuation coeff for air

β is Buildup Factor for Air = 4.33 for avg. F.P. energy and $d = 200$ meters in air

α is building attenuation coefficient = 0.2

E_i is energy of i in mev/dis

Since 1 Curie = 3.7×10^{10} dis/sec and $d = 200$ meters

$$d^2 = 4 \times 10^4 \text{ m}^2 \quad e^{-\mu d} = 0.1353$$

Changing Dose Rate to Dose by using integrated activity

$$\text{Dose}^{200\text{m}} = \frac{0.2 \times 4.33 \times 0.1353 \times 3.7 \times 10^{10} E_i}{4\pi \times 4 \times 10^4 \times 1.8 \times 10^{13}} \int A_i(t) dt \quad \text{for } \int A_i(t) dt \text{ in curie-sec}$$

$$\text{Dose} = 4.79 \times 10^{-16} E_i \int_0^T A_i(t) dt, \text{ rem (for } \int A_i(t) dt \text{ in } \mu\text{C-sec)}$$

DOSE AT 200 METERS FOR INVERSION CONDITIONS

313

App B

SIMILAR TO

DR'N *JCC*

CH'D *DL*

APP'D

SCALE

= 12

SHEET 3 OF 50

ISSUE

ALLIS-CHALMERS MFG. CO. DEPT.

5-63

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

		DIRECT DOSE IN R x 10 ⁴			
ISOTOPE	E _γ [*]	Y=1800 sec	Y=3600 sec	Y=5400 sec	Y=7200 sec
Sr 89	none	—	—	—	—
Sr 90	none	—	—	—	—
Cs 137	0.66	8.09	16.22	24.34	32.56
Ba 140	1.6	0.77	1.66	2.54	3.64
La 140	1.6	0.77	1.66	2.64	3.76
I 131	0.36	13.90	28.28	42.77	57.08
I 133	0.53	16.10	33.26	50.52	68.04
I 135	1.23	19.09	39.47	61.27	81.89
Kr 85m	0.15	0.48	1.08	1.78	2.63
Xe 133	0.08	8.28	17.09	26.48	36.40
Xe 135	0.25	7.25	16.89	25.15	36.17
TOTAL DIRECT DOSE (Reme)		0.0075	0.0156	0.0238	0.0322

* This assumes major γ 's are 100% abundant and daughters of Sr isotopes emit negligible γ radiations and there are no γ 's from Sr 89 and Sr 90.

The total whole body dose is made up of the sum of the 3 components.

	0 → 1/2 hr	0 → 1 hr	0 → 1 1/2 hr	0 → 2 hr
Wbd. due to inhalation	0.011	0.021	0.032	0.042
" " " submersion	0.0045	0.0094	0.0146	0.0200
direct radiation to body	0.0075	0.0156	0.0238	0.0322
TOTAL W.B.D. (Reme)	0.0230	0.0460	0.0704	0.0942

DOSE SUMMARY vs TIME @ 200 METERS for INVERSION

ORGAN	0 → 1/2 hr	0 → 1 hr	0 → 1 1/2 hr	0 → 2 hr
THYROID	1.238 Rem	2.529 Rem	3.830 Rem	5.121 Rem
BONE	0.083 "	0.165 "	0.292 "	0.375 "
WHOLE BODY	0.023 "	0.046 "	0.070 "	0.094 "

DOSE AT 200 m for Inversion Conditions

313
App B

DR'N <i>LCR</i>	CH'D <i>d. L.</i>	APP'D	SCALE = 12	SIMILAR TO	ISSUE
I ALLIS-CHALMERS MFG. CO. DEPT.				SHEET 4 OF 50 5-63	

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

To calculate the doses at 200 meters from the shell, for lapse conditions, we may scale down the doses calculated for INVERSION by the ratio of the Dilution Factor at 200 meters:

$$\frac{1.30 \times 10^{-4}}{6.83 \times 10^{-3}} = 0.0190 \quad (\text{grid release})$$

This factor may be applied to all calculated doses for inversion conditions except the whole body dose component due to direct radiation. This will not change since it is ~~the~~ independent of meteorological conditions.

WHOLE BODY DOSE				
SOURCE	0 → 1/2 hr	0 → 1 hr	0 → 1 1/2 hr	0 → 2 hr
Inhalation	0.0002	0.0004	0.0006	0.0008
Submersion	0.0001	0.0002	0.0003	0.0004
Direct	0.0075	0.0156	0.0238	0.0322
Total wbd (Rema)	0.0078	0.0162	0.0247	0.0334

DOSE SUMMARY vs TIME @ 200 Meters for Lapse:

ORGAN	0 → 1/2 hr	0 → 1 hr	0 → 1 1/2 hr	0 → 2 hr
Thyroid	0.0235	0.0481	0.0728	0.0973
Bone	0.0016	0.0031	0.0056	0.0071
Whole Body	0.0078	0.0162	0.0247	0.0334

~~It is seen that inversion conditions give higher doses to personnel at 200 m from the shell than lapse conditions.~~

DOSE AT 200 meters at 1/2, 1, 1 1/2, 2 hrs after MCA for Lapse Conditions

313
App. B

DR'N <i>dcc</i>	CH'D <i>d.L.</i>	APP'D	SCALE = 12	SIMILAR TO	SHEET <i>5</i> OF 50	ISSUE
ALLIS-CHALMERS MFG. CO. DEPT.				5-63		

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

The dose at 1060 meters from the shell will be calculated for a ground release of activity

$$K_i(t) = 4.37 \times 10^{-4} Q_i(t) \quad \text{Inversion Conditions} \quad **$$

$$K_i(t) = 6.80 \times 10^{-5} Q_i(t) \quad \text{Lapse Conditions}$$

$$Q_i(t) = L A_i(t) \quad \text{where } L = 3.47 \times 10^{-8} \text{ sec}^{-1} \text{ (leakage constant)}$$

The calculation will be made for inversion conditions and downscaled for lapse conditions.

$$\text{Intake} = I_i = (\text{B.R.}) K_i(t) = 4.37 \times 10^{-4} \times 3.47 \times 10^{-8} \times 3.5 \times 10^{-4} \int_0^t A_i(t) dt$$

$$= 5.31 \times 10^{-15} \int_0^t A_i(t) dt. \mu\text{C}$$

$$\text{where (B.R.)} = 3.5 \times 10^{-4} \text{ m}^3/\text{sec} = 350 \text{ cc/sec}$$

$$\text{Intake} = 5.31 \times 10^{-15} \int_0^t A_i(t) dt$$

THYROID DOSE, $D_i = S_i I_i$

Isotope	$\int_0^{24\text{hr}} A_i(t) dt$	$I_i (\mu\text{C})$	$S_i^{\text{thyroid}} \times$ (rem/ μC)	Dose to thyroid
I^{131}	3.31 (13)	0.176	1.488	0.262
I^{133}	2.68 (13)	0.142	0.400	0.057
I^{135}	1.39 (13)	0.074	0.124	0.009

~~(S. from Health Physics Vol 3, Ch. 6)~~

$$\text{TOTAL THYROID DOSE} = 0.328 \text{ Rem}$$

Now dose to bones at 1060 meters for a 2 hour exposure

$$\text{Dose} = \sum D_i = \sum \frac{74 f I_i T_i \sum E(RBE) N}{m_b} = \sum S_i I_i$$

$$m_b = \text{mass of bones in body} = 7 \text{ kg} = 7000 \text{ gm}$$

T_i is associated with the biological turnover ~~in~~ the body for the particular isotope.

f is the fraction of the activity deposited ~~in~~ the skeleton

$$S_i = \frac{74 f}{m_b} T_i \sum E(RBE) N \quad (\text{Etherington N.E. Handbook p 7-44})$$

Isotope	f	T_i (days)	$\sum E(RBE) N$	$S_i^{\text{bone}} \times$	$I_i (\mu\text{C})$	Dose (rem)
Sr^{89}	0.28	50.4	2.8	0.42	0.0148	0.0062
Sr^{90}	0.12	6.4 (3)	5.5	44.65	0.00031	0.0138
Cs^{137}	0.03	138	1.4	0.06	0.0547	0.0033
Ba^{140}	0.19	10.7	4.2	0.09	0.0025	0.0002
La^{140}	0.10	1.68	2.7	0.005		

* App A-IV ** App A-III

$$\text{Total Bone Dose} = 0.0235$$

CALCULATION OF 2 HOUR DOSE at 1060 Meters

313

App. B

SIMILAR TO

DR'N <i>lee</i>	CH'D <i>N.L.</i>	APP'D	SCALE = 12	SHEET 6 OF 50	ISSUE
ALLIS-CHALMERS MFG. CO. DEPT.				5-63	

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

Total Body Dose @ 1060 M for 2 hr Exposure (Inversion)

INHALATION COMPONENT = $\sum S_i I_i$

Isotope	Intake (μ)	S_i ($\frac{\text{rem}}{\mu\text{C}} \times 10^3$)	Dose $\times 10^3$ Rems
Sr 89	0.0148	11.7 rem/ μ C	0.173
Sr 90	3.06 (-4)	506.2 "	0.157
Cs 137	0.055	32.7 "	1.789
Ba 140	2.52 (-3)	1.3 "	0.003
La 140	2.88 (-3)	0.9 "	0.002
I 131	0.176	2.7 "	0.475
I 133	0.142	0.6 "	0.085
I 135	0.074	0.3 "	0.022

Dose = 0.0027

Rems

~~For potential radiation from 1060 M~~

SUBMERSSION COMPONENT

$$\text{Dose} = 2.6 \times 10^{-7} E_s 4.37 \times 10^{-4} L d_i(t) = 5.91 \times 10^{-18} \int_0^{2h} d_i(t) dt \quad d_i \text{ in } \mu\text{C}$$

$$L = 3.47 \times 10^{-8} \text{ sec}^{-1}, \quad E_s = 1.5 \text{ meV/dis}$$

Isotope	$\int_0^{2h} d_i(t) dt$ [$\mu\text{C-sec}$]	Dose (in Rems $\times 10^4$)
Sr 89	2.79 (12)	16.49
Sr 90	5.76 (10)	0.34
Cs 137	1.03 (13)	60.87
Ba 140	4.75 (11)	2.81
La 140	4.90 (11)	2.90
I 131	3.31 (13)	195.62
I 133	2.68 (13)	158.39
I 135	1.39 (13)	82.15
Kr 85m	3.66 (12)	21.63
Xe 133	9.50 (13)	561.45
Xe 135	3.02 (13)	178.48

Dose 0.0013

Rem

DIRECT RADIATION COMPONENT

(assuming a point source using same notation as for the similar calculation at 200 meters)

Calculation of 2 hour dose @ 1060 meters

313

App. B

SIMILAR TO

DR'N *ccc*

CH'D *d. v. l.*

APP'D

SCALE = 12

SHEET 7 OF 50

ISSUE

ALLIS-CHALMERS MFG. CO. DEPT.

5-63

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

$$D.R. = \frac{2.38 \times 10^{-14}}{4\pi d^2} \frac{E_i \int_0^{2h} A_i(t) dt}{f} \quad \text{Ex } A_i(t) \quad 3.7 \times 10^{10}$$

Now the dose is time integral D.R. This is obtained by using the activity integrated over 2 hours = 7200 sec.

$$\text{Dose} = 3.55 \times 10^{-14} E_i \int_0^{2h} A_i(t) dt \quad \text{For } \int A_i(t) dt \text{ in c-sec}$$

or $\text{Dose} = 3.55 \times 10^{-20} E_i \int_0^{2h} A_i(t) dt$ Now since E_i is on the order of 1.0 and the integrated activities in (μc-sec) is on the order of 10^{12} to 10^{14} it can be seen that the Dose over 2 hours will be on the order of 10^{-6} R which, compared to other components, will be negligible. The total body dose at 1060 meters will be due only to inhalation and submersion.

DOSE SUMMARY FOR 2 hr EXPOSURE at 1060 Meters

THYROID = 0.328 Rem

BONE = 0.0235 Rem

WHOLE BODY* = 0.0040 Rem

} Inversion Conditions.

* SUM OF SUBMERGION AND INHALATION

To get doses over 2 hours at 1060 meters for LAPSE conditions, the doses for inversion may be scaled down by the ratio of the dilution factors for lapse & inversion at 1060 meters for a GROUND Release.

$$\frac{6.80 \times 10^{-6} Q_i(t)}{4.37 \times 10^{-4} Q_i(t)} = \frac{0.0156}{0.0235}$$

Since Direct Dose component to the whole body was negligible, the doses may be scaled down directly.

DOSE SUMMARY FOR 2 Hr. EXPOSURE at 1060 Meters

THYROID = 0.00515 Rem

BONE = 0.0004 Rem

WHOLE BODY = 0.0001 Rem

} LAPSE CONDITIONS

It is seen that inversion conditions give higher doses at 1060 meters over the 2 hour period.

Calculation of 2 hr dose at 1060 meters
Dose Summary for Inversion & Lapse Conditions

313

App.B

SIMILAR TO

DR'N *[Signature]*

CH'D *[Signature]*

APP'D

SCALE = 12

SHEET 8 OF 50

ISSUE

F ALLIS-CHALMERS MFG. CO.

DEPT.

5-63

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

The Dose at 4600 METERS DURING the FIRST 24 HOURS

During the first 24 hours the escape of fission products from the shell is due only to a ground level release at a constant leak rate of 0.3% per day of contained volume.

$$0.3\% / \text{day} = 3.47 \times 10^{-8} \text{ sec}^{-1}$$

The atmospheric dilutions for a ground release at 4600 meters are:

$$K_i(t) = 3.88 \times 10^{-5} Q_i(t) \quad \text{Inversion}$$

$$K_i(t) = \overset{5.06}{\cancel{3.88}} \times 10^{-7} Q_i(t) \quad \text{Lapse}$$

$$\text{Intake} = I = 3.88 \times 10^{-5} (\text{B.R.}) 3.47 \times 10^{-8} \int_0^{24} d_i(t) dt \quad \text{for Inversion}$$

$$I = 0.04712 \times 10^{-14} \int_0^{24} A_i(t) dt \quad [\text{for } \int A_i(t) dt \text{ in } \mu\text{C-sec}]$$

Isotope	$\int_0^{24} A_i(t) dt$ ($\mu\text{C-sec}$)	I (μC)	S_i ($\text{rem}/\mu\text{C}$)	Dose (rema)
Sr 89	4.08 (13)	0.0192	0.42	0.0081
Sr 90	1.78 (12)	0.0008	44.65	0.0357
Cs 137	1.25 (14)	0.0589	0.06	0.0035
Ba 140	1.89 (13)	0.0089	6.09	0.0008
La 140	1.57 (13)	0.0079	0.005	—
I 131	5.83 (14)	0.2747	1.488	0.4088
I 133	4.92 (14)	0.2318	0.400	0.0927
I 135	1.56 (14)	0.0735	0.124	0.0091

$$\begin{aligned} \text{THYROID DOSE} &= 0.5106 \text{ Rem} \\ \text{Bone Dose} &= 0.0481 \text{ Rem} \end{aligned} \quad \left. \vphantom{\begin{aligned} \text{THYROID DOSE} \\ \text{Bone Dose} \end{aligned}} \right\} \text{Inversion Conditions}$$

The whole body dose will have components due to inhalation and submersion. The direct radiation component will be negligible. Considering the shell as a point source:

$$\text{Dose}_{\text{direct}} = \frac{0.2 \times 752 \times 1.05 \times 10^{-20} \times 3.7 \times 10^{10}}{4\pi \times 2.116 \times 10^7 \times 1.8 \times 10^{13}} E_i \int_0^{24} A_i(t) dt$$

Using same notation as for calculation at 200m & 1060 m

$$\text{Dose}_{\text{direct}} = 12.20 \times 10^{-30} E_i \int_0^{24} d_i(t) dt \quad (\text{for } \int d_i(t) dt \text{ in c-sec})$$

* App A - III

CALCULATION OF 24 HOUR DOSE AT 4600 METERS

313
App. B

DR'N	CH'D	APP'D	SCALE = 12	SIMILAR TO	SHEET 9 OF 50	ISSUE
ALLIS-CHALMERS MFG. CO. DEPT.				5-63		

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

$\text{Dose} = 12.2 \times 10^{-36} E_i \int_0^{24} A_i(t) dt$ (for $\int A_i(t) dt$ in $\mu\text{C-sec}$)
 Since $\int_0^{24 \text{ hr}} A_i(t) dt$ is on the order of 10^{14} and E_i is about 1.0
 it can be seen that this contribution is negligible!

<u>INHALATION COMPONENT</u>		Dose = $\sum S_i I_i$ (Inversion conditions)
Isotope	S_i (TOT BODY)	Dose $\times 10^3$ Rems
Sr 89	11.7 (-3) $\mu\text{m}/\mu\text{C}$	0.2246
Sr 90	506.2 (-3) "	0.4050
Cs 137	32.7 (-3) "	1.9260
Ba 140	1.3 (-3) "	0.0816
La 140	0.8 (-3) "	0.0057
I 131	2.7 (-3) "	0.7417
I 133	0.6 (-3) "	0.1391
I 135	0.3 (-3) "	0.0221

Inhalation whole body dose = 0.0035 Rems

SUBMERSION COMPONENT
 $\text{Dose} = 2.6 \times 10^{-7} E_s \int_0^{24} A_i(t) dt$ (for $\int A_i(t) dt$ in $\mu\text{C-sec}$)
 $\text{Dose} = 5.251 \times 10^{-19} \int_0^{24} A_i(t) dt$ (Inversion conditions)

Isotope	$\int_0^{24} A_i(t) dt$ [$\mu\text{C-sec}$]	Dose $\times 10^5$ Rems
Sr 89	4.08 (13)	21.42
Sr 90	1.78 (12)	0.94
Cs 137	1.25 (14)	65.64
Ba 140	1.89 (13)	9.92
La 140	1.87 (13)	8177.93
I 131	5.83 (14)	306.13
I 133	4.92 (14)	258.35
I 135	1.56 (14)	81.92
Kr 85m	4.55 (13)	23.89
Xe 133	2.38 (15)	1249.74
Xe 135	6.11 (14)	320.84

SUBMERSION WHOLE BODY DOSE = 0.0023 Rems

Whole body dose = 0.0035 + 0.0023 = 0.0058 Rems

Calculation of 24 hour dose at 4600 m

3/3
App. B

DR'N	CH'D	APP'D	SCALE = 12	SIMILAR TO	ISSUE
ALLIS-CHALMERS MFG. CO. DEPT.				SHEET 10 OF 50	
				5-63	

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

ORGAN	Dose
Brain	0.0001
Heart	0.0001
Liver	0.0001
Spleen	0.0001
Stomach	0.0001
Intestine	0.0001
Uterus	0.0001
Vagina	0.0001
Bladder	0.0001
Prostate	0.0001
Testis	0.0001
Epididymis	0.0001
Penis	0.0001
Scrotum	0.0001
Perineum	0.0001
Rectum	0.0001
Anal	0.0001
Urethra	0.0001
Uterus	0.0001
Vagina	0.0001
Bladder	0.0001
Prostate	0.0001
Testis	0.0001
Epididymis	0.0001
Penis	0.0001
Scrotum	0.0001
Perineum	0.0001
Rectum	0.0001
Anal	0.0001
Urethra	0.0001

Thyroid	0.5106	Rem
Bone	0.0481	"
Whole Body	0.0058	"

For lapse conditions these doses may be scaled down by the ratio of the atmospheric dilution for a ground release at 4600 meters.

$$\frac{5.06 \times 10^{-7}}{3.00 \times 10^{-5}} = 0.0130$$

DOSE SUMMARY AT 4600 METERS - LAPSE CONDITIONS

ORGAN	DOSE
ADRENAL	100 mg
BLADDER	100 mg
BRAIN	100 mg
BREAST	100 mg
COLON	100 mg
ESOPHAGUS	100 mg
HEART	100 mg
KIDNEY	100 mg
LIVER	100 mg
MUSCLE	100 mg
NERVE	100 mg
SKIN	100 mg
SPLEEN	100 mg
STOMACH	100 mg
TESTIS	100 mg
THYROID	100 mg
UTERUS	100 mg

Thyroid	0.0066 ~~0.0000~~	Rem
Bone	0.0006	Rem
Whole Body	0.0001 ~~0.0000~~	Rem

Summary of Doses for 24 hour Exposure at 4600 Meters for Inversion and Lapse Conditions.

313

App. B

SIMILAR TO

DR'N *200*

CH'D

APP'D

SCALE **= 12**

SHEET 11 OF 50

ISSUE

ALLIS-CHALMERS MFG. CO.	DEPT.

5-63

Dose During First 24 hrs at Various Distances downwind after the MCA may be found by down scaling by the ratios of the Atmospheric dilutions at the desired distance to 4600 meters. The source terms, RBE's, leak rates, etc., will be invariant with distances.

The downscaling ratios are, for diversion: (see App. A-III)

at 6000 m

$$\frac{2.503 (-5)}{3.88 (-5)} = 0.645$$

at 7500 m

$$\frac{1.732 (-5)}{3.88 (-5)} = 0.447$$

at 9095 m

$$\frac{1.260 (-5)}{3.88 (-5)} = 0.324$$

at 10,000 m

$$\frac{1.077 (-5)}{3.88 (-5)} = 0.278$$

The downscaling ratios are, for lapse:

at 6000 m

$$\frac{3.16 (-7)}{5.06 (-7)} = 0.625$$

at 7500 m

$$\frac{2.13 (-7)}{5.06 (-7)} = 0.420$$

at 9095 m

$$\frac{1.51 (-7)}{5.06 (-7)} = 0.298$$

at 10,000 m

$$\frac{1.28 (-7)}{5.06 (-7)} = 0.253$$

Since dose due to direct radiation is negligible at these distances. All doses, thyroid, bone, whole body, may be downscaled.

Calculation of 24 hr dose downwind at distances of 6000 m, 7500 m, 9095 m, and 10,000 m.

313

App. B

SIMILAR TO

SHEET 12 OF 50

ISSUE

5-63

DR'N LCC

CH'D d. L.

APP'D

SCALE

= 12

ALLIS-CHALMERS MFG. CO.

DEPT.

A

B

C

DOSE (Rem)

DISTANCE	ORGAN	INVERSION	LARGE
4600m	Thyroid	0.5106	0.0065
	Bone	0.0481	0.0006
	Whole body	0.0058	0.0001
6000m	Thyroid	0.3293	0.0041
	Bone	0.0310	0.0004
	Whole body	0.0037	0.0001
7500m	Thyroid	0.2282	0.0028
	Bone	0.0215	0.0003
	Whole body	0.0026	—
9095m	Thyroid	0.1654	0.0020
	Bone	0.0156	0.0002
	Whole body	0.0019	—
10,000m	Thyroid	0.1420	0.0017
	Bone	0.0134	0.0002
	Whole body	0.0016	—

DOSES FOR FIRST 24 Hours After MCA
at Various Distances Downwind from the
Containment Shell

313
App. B

SIMILAR TO

DR'N <i>JCE</i>	CH'D <i>A. Y.</i>	APP'D	SCALE = 12	SHEET 13 OF 50	ISSUE
ALLIS-CHALMERS MFG. CO. DEPT.				5-63	

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

The dose during the period 24 hrs to 72 hrs after the MCA will be due to leakage from the containment shell and venting from a 61 meter high stack.

The leakage rate will be determined by assuming that at time = 24 hours after the MCA, a step change in pressure in the shell occurs. It will suddenly be reduced from 9 psig to 4.2 psig. This internal pressure change will change the leakage rate

$$L_{24 \text{ hr} \rightarrow 72 \text{ hr}} = L_{0 \rightarrow 24 \text{ hr}} \sqrt{4.2/9.0} = 3.47 \times 10^{-8} \text{ sec}^{-1} (0.6831) = 2.37 \times 10^{-8} \text{ sec}^{-1}$$

The atmospheric dilutions for a ground level release at 4600 meters are:

$$X_i(t) = 3.88 \times 10^{-5} Q_i(t) \quad \text{INVERSION}$$

$$X_i(t) = \frac{5.06}{2.178} \times 10^{-7} Q_i(t) \quad \text{LAPSE}$$

$$\text{Intake} = I_i = 3.88 \times 10^{-5} \times (\text{B.R.}) \int_{24}^{72} A_i(t) dt$$

$$\text{Since B.R.} = 3.5 \times 10^{-4} \text{ m}^3/\text{sec}$$

$$\text{and for } \int A_i(t) dt \text{ in } \mu\text{C-sec}$$

$$\text{Intake} = I = 0.322 \times 10^{-15} \int_{24}^{72} A_i(t) dt \quad [I \text{ in } \mu\text{C for } A_i(t) \text{ in } \mu\text{C}]$$

Isotope	$\int_{24}^{72} A_i(t) dt (\mu\text{C-sec})^*$	Intake (μC)	$S_i (\text{rem}/\mu\text{C})$	Dose (rem)
Sr ⁸⁹	7.29 (13)	0.0235	0.42	0.0099
Sr ⁹⁰	6.60 (12)	0.0021	44.65	0.0938
Cs ¹³⁷	1.36 (14)	0.0438	0.06	0.00263
Ba ¹⁴⁰	6.60 (13)	0.0213	0.09	0.0019
La ¹⁴⁰	3.24 (13)	0.0104	0.005	0.0001
I ¹³¹	1.16 (15)	0.3735	1.488	0.5558
I ¹³³	5.57 (14)	0.1794	0.400	0.0718
I ¹³⁵	3.21 (13)	0.0103	0.124	0.0013

Bone
THYROID

$$\text{Thyroid Dose} = \Sigma \text{Dose from Iodine Isotopes} = 0.6289 \text{ Rem}$$

$$\text{Bone Dose} = \Sigma \text{Dose from Sr, Cs, Ba, \& La} = 0.1083 \text{ Rem}$$

* See Figs. 19 thru 26

CALCULATION OF DOSES AT 4600 Meters during the period 24 to 72 hours after the MCA

313
App. B

DR'N <i>[Signature]</i>	CH'D <i>[Signature]</i>	APP'D	SCALE = 12	SIMILAR TO	SHEET 14 OF 50	ISSUE
ALLIS-CHALMERS MFG. CO. DEPT.				5-63		

TOTAL BODY DOSE FOR INVERSION

From previous calculations it can be seen that the direct component of dosage from the shell will be negligible.

INHALATION

Isotope	Intake (μC)	S_i whole body ($\frac{\text{rem}}{\mu\text{C}}$)	Dose $\times 10^3$ Rem.
Sr 89	0.0235	11.7×10^{-3}	0.2750
Sr 90	0.0021	506.3×10^{-3}	1.0632
Cs 137	0.0438	32.7×10^{-3}	0.4323
Ba 140	0.0213	1.3×10^{-3}	0.0277
La 140	0.0104	0.8×10^{-3}	0.0083
I 131	0.3735	2.7×10^{-3}	1.0085
I 133	0.1794	0.6×10^{-3}	0.1076
I 135	0.0103	0.3×10^{-3}	0.0031

Dose 0.0039 Rem

SUBMERSION

All Isotopes contribute to Dose $\text{Dose} = 2.6(-7) L E_3 3.88(-5) \int_{24}^{72} A_i(t) dt \text{ rem}$
 $\text{Dose} = 2.6 \times 10^{-7} \times 2.37 \times 10^{-8} \times 1.5 \times 3.88 \times 10^{-5} \int_{24}^{72} A_i(t) dt \text{ rem}$
 $\text{Dose} = 3.586 \times 10^{-19} \int_{24}^{72} A_i(t) dt \text{ rem} \text{ [where } A_i(t) \text{ is in } \mu\text{C-sec}]$

Isotope	$\int_{24}^{72} A_i(t) dt \mu\text{C-sec}$	Dose $\times 10^6$ Rem
Sr 89	7.29(13)	26.14
Sr 90	6.60(12)	2.37
Cs 137	1.36(14)	48.77
Ba 140	6.60(13)	23.67
La 140	3.24(13)	11.62
I 131	1.16(15)	415.98
I 133	5.57(14)	199.74
I 135	3.21(13)	11.51
Kr 85m	3.31(12)	1.19
Xe 133	6.36(15)	2280.70
Xe 135	2.82(14)	101.13

Dose = 0.0031 Rem

whole body dose = 0.0039 + 0.0031 = 0.0070 Rem

Calculation of Doses at 4600 Meters during the period 24 hrs to 72 hrs after the MCA

313

App. B

SIMILAR TO

DR'N SCC	CH'D D.L.	APP'D	SCALE = 12	SHEET 15 OF 50	ISSUE
ALLIS-CHALMERS MFG. CO. DEPT.				5-63	

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

Summary of Dose due to Leakage for Inversion Conditions at 4600 Meters.

Thyroid	0.6289	Rems
Bone	0.1083	Rems
Whole Body	0.0700	Rems

For Lapse conditions these doses can be down scaled by the ratio of the atmospheric dispersions for a ground release at 4600 meters.

$$\frac{5.06 \times 10^{-7}}{3.88 \times 10^{-5}} = 0.0130$$

Summary of Doses due to Leakage for Lapse Conditions at 4600 Meters.

Thyroid	0.0083	Rem
Bone	0.0014	Rem
Whole Body	0.0009	Rem

Dose at 4600 Meters due to Leakage for Inversion & Lapse Conditions

B13
APP.B

SIMILAR TO

DR'N JCC	CH'D d.d.	APP'D	SCALE = 12	SHEET 16 OF 50	ISSUE
ALLIS-CHALMERS MFG. CO. DEPT.				5-63	

ALLIS-CHALMERS MFG. CO. DEPT.

5-63

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

There is another component of the dose during the period from 24 hours to 72 hours. This is due to the venting from a 61 meter high stack. The venting rate will be converted to an equivalent leak rate constant in sec^{-1} by the relation:

$$L = \frac{\text{Venting Rate (scfm)}}{\text{Vol @ STP (ft}^3\text{)} \times 60 \frac{\text{sec}}{\text{min}}} = L (\text{sec}^{-1})$$

The elevation of the stack (61 meters) and the filter efficiency for each isotope will be considered in the dose calculation. Aside from this, the calculations of the doses will follow the previous procedure for calculation of doses due to leakages. However, the direct dose from the containment shell has already been considered. (It was shown to be negligible at these distances)

The internal pressure will be considered to be constant at 4.2 psig in the period 24 to 72 hours. For a vent capacity of 750 scfm at 9 psig, the venting rate at 4.2 psig will be:

$$750 \text{ scfm} \sqrt{\frac{4.2}{9.0}} = 512.33 \text{ scfm at } 4.2 \text{ psig.}$$

It will be assumed that the venting rate remains constant at 512.25 scfm until 72 hours after the MCA. At this time it will be assumed that there will be another step change of internal pressure. This third internal pressure will last for the rest of the accident. That is, until the pressure in the shell has dropped to atmospheric.

Calculation of equivalent leakage constant.

$$L = \frac{512.33 \text{ scfm}}{\text{Vol @ STP} \times 60 \frac{\text{sec}}{\text{min}}}$$

Now the Volume ^{of gas in} the shell at STP may be calculated from the known volume of gas in the shell at 100°F & 4.2 psig which is $1.30 \times 10^6 \text{ ft}^3$

DOSE AT 4600 Meters due to Venting
(from 24 hrs to 72 hrs after the MCA)

313
App. B

SIMILAR TO

DR'N

JCC

CH'D

d.L.

APP'D

SCALE

=12

SHEET

17 OF 50

ISSUE

ALLIS-CHALMERS MFG. CO.

DEPT.

5-83

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

$$(1.30)10^6 \frac{18.4 \text{ psi}}{14.2 \text{ psi}} \times \frac{460^\circ \text{R}}{560^\circ \text{R}} = 1.38 \times 10^6 \text{ ft}^3 @ \text{STP}$$

$$L = \frac{512.25 \text{ ft}^3/\text{Min}}{1.38 \times 10^6 \text{ ft}^3 \times 60 \text{ sec/Min}} = 6.2 \times 10^{-6} \text{ sec}^{-1}$$

Now at 4600 Meters for release from the stack, the atmospheric dilution coefficient is $1.765(-6) Q_i(t)^*$

$$\text{Intake} = I = L (\text{BR}) f_i 1.765 \times 10^{-6} \int_{24}^{72} A_i(t) dt \quad (\text{INVERSION})$$

where $L = 6.2 \times 10^{-6} \text{ sec}^{-1}$ & $\text{BR}_i = 3.5 \times 10^{-4} \text{ m}^3/\text{sec}$
 f_i is the fraction of the i^{th} isotope PASSING the filters
 Reference: TWX NRO1 JACKSON TO BUSH (dated 6-7-62)

$$\text{INTAKE} = I = 3.83 \times 10^{-15} f_i \int_{24}^{72} A_i(t) dt \quad (\text{I in } \mu\text{C for } \text{Add in } \mu\text{C-sec})$$

Isotope	f_i	$f_i \int_{24}^{72} A_i(t) dt$	Intake (μC)	S_i	Dose
Sr 89	0.01	7.29(11)	0.002792	0.42	0.00117
Sr 90	0.01	6.60(10)	0.000253	44.65	0.01130
Cs 137	0.01	1.36(12)	0.005209	0.06	0.00031
Ba 140	0.01	6.60(11)	0.002528	0.09	0.00023
La 140	0.01	3.24(11)	0.001241	0.025	0.00001
I 131	0.05	5.80(13)	0.222140	1.488	0.33054
I 133	0.05	2.79(13)	0.106857	0.400	0.04274
I 135	0.05	1.61(12)	0.006166	0.124	0.00076

Thyroid Dose = Σ (Dose from each Iodine Isotope)

$$\text{Thyroid Dose} = 0.37404 \text{ Rems}$$

Bone Dose = Σ (Dose from Sr, Ba, La, Cs Isotopes)

$$\text{Bone Dose} = 0.01302 \text{ Rems}$$

The Whole Body Dose will have 2 components, inhalation and submersion. For the submersion dose, the filter efficiencies for Kr^{85m} , Xe^{133} , and Xe^{135} will be taken as zero.

* APP A-III

DOSE AT 4600 Meters due to Venting
 (24 $\rightarrow$ 72 hrs after MCA)

313

App. B

SIMILAR TO

DR'N LCC

CH'D B.L.

APP'D

SCALE

=12

SHEET

10

OF

50

ISSUE

ALLIS-CHALMERS MFG. CO.

DEPT.

5-63

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

TOTAL Body Dose - Inversion Conditions

INHALATION

Isotope	Intake (μC)	S_i	Dose ($\text{Rem} \times 10^3$)
Sr ⁸⁹	0.002792	11.7(-3)	0.03267
Sr ⁹⁰	0.000253	506.2(-3)	0.12807
Cs ¹³⁷	0.005209	32.7(-3)	0.17033
Ba ¹⁴⁰	0.002528	1.3(-3)	0.00329
La ¹⁴⁰	0.001241	0.8(-3)	0.00099
I ¹³¹	0.222140	2.7(-3)	0.59978
I ¹³³	0.106857	0.6(-3)	0.06411
I ¹³⁵	0.006166	0.3(-3)	0.00185

TOTAL Inhalation Dose = 0.0010 Rems

SUBMERSSION

$$\text{Dose} = 3.6 \times 10^{-7} L E_3 1.765 \times 10^{-6} f_i \int_{24}^{72} A_i(t) dt \text{ Rems}$$

$$E_3 = 1.5 \quad L = 6.2 \times 10^{-6}$$

$$\text{Dose} = 7.27 \times 10^{-18} f_i \int_{24}^{72} A_i(t) dt$$

Isotope	f_i	$f_i \int_{24}^{72} A_i(t) dt$ ($\mu\text{C-sec}$)	Dose (10^3 Rems)
Sr ⁸⁹	0.01	7.29(11)	0.1764 3.113
Sr ⁹⁰	0.01	6.60(10)	0.0180 0.282
Cs ¹³⁷	0.01	1.36(12)	0.3294 5.807
Ba ¹⁴⁰	0.01	6.60(11)	0.1597 2.818
La ¹⁴⁰	0.01	3.24(11)	0.0704 1.383
I ¹³¹	0.05	5.80(13)	14.038 147.660
I ¹³³	0.05	2.79(13)	6.7518 118.133
I ¹³⁵	0.05	1.61(12)	0.3896 6.875
Kr ^{85m}	1.0	3.31(12)	0.8010 14.134
Xe ¹³³	1.0	6.36(15)	4539.120 27157.200
Xe ¹³⁵	1.0	2.82(14)	68.244 1204.140

TOTAL SUBMERSSION Dose = 0.0016 ~~0.0288~~ Rems

$$\text{Total Body Dose} = 0.0010 + 0.0016 = 0.0026 \text{ Rems}$$

Note: At this distance the dose due to direct radiation from the containment shell is negligible.

Dose at 4600 Meters due to Venting
24 hrs to 72 hrs after the MCA

313

App B

SIMILAR TO

DR'N C.C.C.

CH'D

APP'D

SCALE

=12

SHEET 19 OF 50

ISSUE

ALLIS-CHALMERS MFG. CO.

DEPT.

5-63

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

Thyroid	0.3740	Rams
Bone	0.0130	Rams
WHOLE BODY	~~0.0026~~ 0.0298	Rams

$$\frac{4.99 \times 10^{-7}}{1.765 \times 10^{-6}} = 0.283$$

Thyroid	0.1058	Rems
Bone	0.0085	Rems
Whole Body	0.0084	Rems

3/3
App. 8

DR'N <i>Lee</i>	CH'D <i>A. L.</i>	APP'D	SCALE = 12	SHEET <i>20</i> OF <i>50</i>	ISSUE
I ALLIS-CHALMERS MFG. CO. DEPT.				<i>5-63</i>	

TOTAL DOSE AT 4600 METERS

INVERSION CONDITIONS

Thyroid

$$\begin{array}{rcl} \text{Due to Leakage} + \text{Due to Venting} & = & \text{Total} \\ 0.6289 & + & 0.3740 & = & 1.003 \text{ Rem} \end{array}$$

Bone

$$\begin{array}{rcl} \text{Due to Leakage} + \text{Due to Venting} & = & \text{Total} \\ 0.1083 & + & 0.0130 & = & 0.121 \text{ "} \end{array}$$

WHOLE BODY

$$\begin{array}{rcl} \text{Due to Leakage} + \text{Due to Venting} & = & \text{Total} \\ 0.0700 & + & \cancel{0.0025} & = & \cancel{0.073} \\ & & 0.0299 & = & 0.100 \text{ "} \end{array}$$

LAPSE CONDITIONS

Thyroid

$$\begin{array}{rcl} \text{Due to Leakage} + \text{Due to Venting} & = & \text{Total} \\ \cancel{0.0082} & + & \cancel{0.1058} & = & \cancel{0.1140} \\ 0.0082 & + & 0.1058 & = & 0.1140 \text{ Rem} \end{array}$$

Bone

$$\begin{array}{rcl} \text{Due to Leakage} + \text{Due to Venting} & = & \text{Total} \\ \cancel{0.0014} & + & \cancel{0.0037} & = & \cancel{0.0051} \\ 0.0014 & + & 0.0037 & = & 0.0051 \text{ "} \end{array}$$

Whole Body

$$\begin{array}{rcl} \text{Due to Leakage} + \text{Due to Venting} & = & \text{Total} \\ \cancel{0.0009} & + & \cancel{0.0084} & = & \cancel{0.0093} \\ 0.0009 & + & 0.0084 & = & 0.0093 \text{ "} \end{array}$$

DOSES AT 4600 METERS DUE TO
LEAKAGE & VENTING 24hr → 72 hr
INVERSION & LAPSE CONDITIONS

313
App. B.

DR'N *JCC*

CH'D *D.L.*

APP'D

SCALE = 12

SIMILAR TO

SHEET 21 OF 50

ISSUE

5-63

ALLIS-CHALMERS MFG. CO. DEPT.

To calculate the dose at 6000, 7500, 9095, and 10,000 meters, the doses at 4600 meters can be downscaled by the atmospheric dilution for the proper meteorological condition. Note that the dose due to leakage and the dose due to venting must be ~~separately~~ scaled down SEPERATLY since the leakage is a ground release and venting is done through a stack.

INVERSION CONDITIONS

Distance	Leakage Dose Scaling Factor (See App A-III)	ORGAN.	Dose
6000 m	$\frac{2.523 (-5)}{3.88 (-5)} = 0.645$	Thyroid	~~0.647~~ 0.406
		Bone	~~0.078~~ 0.070
		Whole Body	~~0.047~~ 0.045
7500 m	$\frac{1.1732 (-5)}{3.88 (-5)} = 0.446$	Thyroid	~~0.447~~ 0.280
		Bone	~~0.054~~ 0.048
		Whole Body	~~0.033~~ 0.031
9095 m	$\frac{1.260 (-5)}{3.88 (-5)} = 0.324$	Thyroid	~~0.325~~ 0.204
		Bone	~~0.039~~ 0.035
		Whole Body	~~0.024~~ 0.023
10,000 m	$\frac{1.077 (-5)}{3.88 (-5)} = 0.278$	Thyroid	0.175
		Bone	0.030
		Whole Body	0.019
Venting Dose Scaling Factor (See App A-III)			
6000 m	$\frac{3.412 (-6)}{1.765 (-6)} = 1.94$	Thyroid	0.726
		Bone	0.025
		Whole Body	0.058
7500 m	$\frac{4.359 (-6)}{1.765 (-6)} = 2.48$	Thyroid	0.928
		Bone	0.032
		Whole Body	0.074
9095	$\frac{4.591 (-6)}{1.765 (-6)} = 2.60$	Thyroid	0.972
		Bone	0.034
		Whole Body	0.077

Doses from 24 hrs → 72 hrs after MCA
AT DISTANCES 6000 m, 7500 m, 9095 m, and
10,000 m From the Containment Shell

313
App. B.

DR'N <i>ACE</i>	CH'D <i>A.D.</i>	APP'D	SCALE = 12	SIMILAR TO	ISSUE
ALLIS-CHALMERS MFG. CO. DEPT.				SHEET 22 OF 50	
				5-63	

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

$$10000m \quad \frac{4.564(-6)}{1.765(-6)} = 2.59$$

LAPSE CONDITIONS
Leak Dose (See App A-III)

$$6000m \quad \frac{3.16(-7)}{5.06(-7)} = 0.625$$

$$7500m \quad \frac{2.13(-7)}{5.06(-7)} = 0.421$$

$$9095m \quad \frac{1.51(-7)}{5.06(-7)} = 0.298$$

$$10,000m \quad \frac{1.28(-7)}{5.06(-7)} = 0.253$$

VENT Dose (See App A-III)

$$6000m \quad \frac{3.13(-7)}{4.99(-7)} = 0.627$$

$$7500m \quad \frac{2.12(-7)}{4.99(-7)} = 0.425$$

$$9095m \quad \frac{1.50(-7)}{4.99(-7)} = 0.301$$

$$10,000m \quad \frac{1.28(-7)}{4.99(-7)} = 0.257$$

Thyroid	0.969
Bone	0.834
Whole Body	0.077

Organ	Dose (Rm)
Thyroid	0.0051
Bone	0.0009
Whole Body	0.0006

Thyroid	0.0035
Bone	0.0006
Whole Body	0.0004

Thyroid	0.0024
Bone	0.0004
Whole Body	0.0003

Thyroid	0.0021
Bone	0.0004
Whole Body	0.0002

Thyroid	0.0663
Bone	0.0023
Whole Body	0.0053

Thyroid	0.0450
Bone	0.0016
Whole Body	0.0036

Thyroid	0.0318
Bone	0.0011
Whole Body	0.0025

Thyroid	0.0272
Bone	0.0010
Whole Body	0.0022

Doses from 24 → 72 hrs after MCA at
Distances 6000, 7500, 9095 and 10000 meters
from Containment Shell

313
App. B

SIMILAR TO

DR'N Lee

CH'D N. L.

APP'D

SCALE

=12

SHEET 23 OF 50

ISSUE

ALLIS-CHALMERS MFG. CO.

DEPT.

5-63

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

		DOSES FOR INVERSION CONDITIONS		
DISTANCE	ORGAN	LEAK DOSE + VENT DOSE = TOTAL DOSE (Rem)		
4600	Thyroid	0.6289	+ 0.3740	= 1.003
	Bone	0.1083	+ 0.0130	= 0.121
	Whole Body	0.10700	+ ~~0.0026~~ 0.0298	= ~~0.073~~ 0.100
6000	Thyroid	0.406	+ 0.726	= 1.132
	Bone	0.070	+ 0.025	= 0.095
	Whole Body	0.045	+ ~~0.005~~ 0.058	= ~~0.050~~ 0.103
7500	Thyroid	0.280	+ 0.928	= 1.208
	Bone	~~0.054~~ 0.048	+ 0.032	= 0.080
	Whole Body	0.031	+ ~~0.006~~ 0.074	= ~~0.037~~ 0.105
9095	Thyroid	0.204	+ 0.972	= 1.176
	Bone	0.035	+ 0.034	= 0.069
	Whole Body	0.023	+ ~~0.007~~ 0.077	= ~~0.030~~ 0.100
10,000	Thyroid	0.175	+ 0.969	= 1.144
	Bone	~~0.034~~ 0.030	+ 0.034	= ~~0.064~~ 0.068
	Whole Body	0.019	+ ~~0.007~~ 0.077	= ~~0.026~~ 0.096

DOSE FOR LAPSE CONDITIONS

DISTANCE	ORGAN	LEAK DOSE + VENT DOSE = TOTAL DOSE		
4600	Thyroid	0.0082	+ 0.1058	= 0.1140
	Bone	0.0014	+ 0.0037	= 0.0051
	Whole Body	0.0009	+ ~~0.0007~~ 0.0087	= ~~0.0016~~ 0.0093
6000	Thyroid	0.0051	+ ~~0.0146~~ 0.0165	= ~~0.0697~~ 0.0714
	Bone	0.0009	+ 0.0023	= 0.0032
	Whole Body	0.0006	+ ~~0.0004~~ 0.0053	= ~~0.0010~~ 0.0059
7500	Thyroid	0.0035	+ ~~0.0430~~ 0.0450	= ~~0.0473~~ 0.0485
	Bone	0.0006	+ 0.0016	= 0.0022
	Whole Body	0.0004	+ ~~0.0003~~ 0.0036	= ~~0.0007~~ 0.0040

SUMMARY OF DOSES from 24 → 72 hrs
after MCA at 6000, 7500, 9095, and 10,000
meters from shell

313
App. B

DR'N LCC	CH'D <i>[Signature]</i>	APP'D	SCALE = 12	SIMILAR TO	ISSUE
ALLIS-CHALMERS MFG. CO. DEPT.				SHEET 24 OF 50	
				5-63	

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

A		B		C	
DOSES FOR LAPSE CONDITIONS					
DISTANCE	ORGAN	Dose from Leuk + Dose from Vent =		Total Dose	
9095	Thyroid	0.0024	+ 0.0318	=	0.0342
	Bone	0.0004	+ 0.0011	=	0.0015
	Whole Body	0.0003	+ 0.0002	=	0.0005
10,000	Thyroid	0.0021	+ 0.0272	=	0.0293
	Bone	0.0004	+ 0.0010	=	0.0014
	Whole Body	0.0002	+ 0.0022	=	0.0024

SUMMARY OF DOSES From 24 to 72 hours after the MCA at 6000, 7500, 9095, and 10,000 meters from Containment Shell.				3/3 App. B	
DR'N	CH'D	APP'D	SCALE	SIMILAR TO	
JOE	D.L.		=12	SHEET 25 OF 50	
ALLIS-CHALMERS MFG. CO. DEPT.				5-63	

The dose during the period 72 hours to 81 hours after the MCA would be due to leakage from the containment shell and venting from a 81 meter high stack.

The leakage rate will be determined by assuming that at time = 72 hours after the MCA, a step decrease in pressure in the shell occurs. It will suddenly be reduced from 4.2 psig to 0.75 psig. This 0.75 psig will be assumed to be held until the end of the accident, 81 hours after the MCA. At this time it was calculated that the pressure would be essentially zero, hence there would be no pressure differential to eject fission products from the shell.

The internal pressure change will change the leakage rate:

$$L_{72 \rightarrow 81 \text{ hr}} = L_{0 \rightarrow 72} \sqrt{\frac{0.75}{9.0}} = 3.47 \times 10^{-8} \text{ sec}^{-1} \sqrt{0.0836} = 1.01 \times 10^{-8} \text{ sec}^{-1}$$

The atmospheric dilution for a ground release at 4600 meters are:

$$X_i(t) = 3.88 \times 10^{-5} Q_i(t) \quad \text{INVERSION}$$

$$X(t) = \frac{5.06}{4.78} \times 10^{-7} Q_i(t) \quad \text{LAPSE}$$

$$\text{Intake} = I_i = 3.88 \times 10^{-5} (B.R.) \times 1.01 \times 10^{-8} \int_{72}^{81} A_i(t) dt \quad [I_i \text{ in } \mu\text{C for } A_i \text{ in } \mu\text{C-sec}]$$

$$B.R. = 3.5 \times 10^{-4} \text{ m}^3/\text{sec}$$

$$\text{Intake} = 1.37 \times 10^{-16} \int_{72}^{81} A_i(t) dt \quad (\text{Inversion Conditions})$$

THYROID DOSE

Isotope	$\int_{72}^{81} A_i(t) dt (\mu\text{C-sec})$	Intake (μC)	$S_i \mu\text{m}/\mu\text{C}$	Dose (Rem)
I ¹³¹	2.62 (14)	0.03589	1.488	0.05340
I ¹³³	5.36 (13)	0.00734	0.400	0.00294
I ¹³⁵	1.73 (11)	0.00002	0.124	—

$$\text{thyroid dose} = 0.05634$$

* Figs 24, 25, 26

Calculation of DOSES AT 4600 METERS DURING the PERIOD from 72 hrs → 81 hrs after the MCA due to leakage

313

App. B

SIMILAR TO

DR'N <i>DC</i>	CH'D <i>J.L.</i>	APP'D	SCALE = 12	SHEET 26 OF 50	ISSUE

ALLIS-CHALMERS MFG. CO. DEPT.

5-63

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

BONE DOSE				
Isotope	$\int_{72}^{81} A_i(t) dt \text{ (}\mu\text{C-sec)}^*$	Intake (μC)	$S_i \text{ (}\frac{\text{rem}}{\mu\text{C}}\text{)}$	Dose (rem)
Sr ⁸⁹	1.58 (13)	0.00216	0.42	0.00091
Sr ⁹⁰	1.91 (12)	0.00026	44.65	0.01161
Cs ¹³⁷	1.91 (13)	0.00262	0.06	0.00016
Ba ¹⁴⁰	1.76 (13)	0.00241	0.09	0.00022
La ¹⁴⁰	5.47 (12)	0.00075	0.005	0.00000

TOTAL BONE DOSE 0.0129 Rem

The whole body dose will have components due to inhalation and submersion. For Inversion.

INHALATION

Isotope	Intake (μC)	$S_i \text{ whole body (}\frac{\text{rem}}{\mu\text{C}}\text{)}$	Dose $\times 10^3 \text{ Rem}$
Sr ⁸⁹	0.00216	11.7 (-3)	0.02527
Sr ⁹⁰	0.00026	506.3 (-3)	0.13164
Cs ¹³⁷	0.00262	32.7 (-3)	0.08567
Ba ¹⁴⁰	0.00241	1.3 (-3)	0.00313
La ¹⁴⁰	0.00075	0.8 (-3)	0.00060
I ¹³¹	0.03589	2.7 (-3)	0.09690
I ¹³³	0.00734	0.6 (-3)	0.00440
I ¹³⁵	0.00002	0.3 (-3)	0.00001

$$\text{Dose} = 0.347 \times 10^{-3} \text{ rem} \\ = 0.0003 \text{ rem}$$

SUBMERSION

All isotopes contribute $\text{Dose} = 2.6(-7) \text{ LEs } 3.88(-5) \int_{72}^{81} A_i(t) dt \text{ rem}$
 $\text{Dose} = 2.6 \times 10^{-7} \times 1.01 \times 10^{-8} \times 1.5 \times 3.88 \times 10^{-5} \int_{72}^{81} A_i(t) dt \text{ rem s}$
 $\text{Dose} = 1.53 \times 10^{-19} \int_{72}^{81} A_i(t) dt \text{ rem s} \quad [\text{where } \int A_i(t) dt \text{ in } \mu\text{C-sec}]$

Isotope	$\int_{72}^{81} A_i(t) dt \text{ (}\mu\text{C-sec)}$	Dose $\times 10^6 \text{ Rem}$
Sr ⁸⁹	1.58 (13)	2.417
Sr ⁹⁰	1.91 (12)	0.292
Cs ¹³⁷	1.91 (13)	2.922
Ba ¹⁴⁰	1.76 (13)	2.693
La ¹⁴⁰	5.47 (12)	0.837
I ¹³¹	2.62 (14)	40.086
I ¹³³	5.36 (13)	8.201

* Tips 19 thru 23

Calculation of Doses at 4600 m from 72 to 81 hrs after MCA due to leakage

313
App. B.

DR'N JCE	CH'D J.Y.	APP'D	SCALE = 12	SHEET 27 OF 60	ISSUE
ALLIS-CHALMERS MFG. CO. DEPT.				5-63	

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

	A	B	C
Isotope	$\int_{T_0}^{T_1} A_i(t) dt$ [μC-sec]		Dose $\times 10^6$ Rems
I ¹³⁵	1.73 (11)		0.027
Kr ^{85m}	0		0
Xe ¹³³	1.53 (15)		234.090
Xe ¹³⁵	6.62 (12)		1.013

Total Whole Body Dose = $\frac{0.0003 \text{ Rem}}{0.0003} + 0.0003 = 0.0006 \text{ Rem}$

SUMMARY OF Doses Due to Leakage at 4600m Inversion

Thyroid 0.056

Bone 0.013

Whole Body ~~0.001~~

Now to find the doses due to leakage at 4600 m with Lapse conditions the above doses may be down scaled by the ratio of the atmospheric dilutions at 4600 m for a ground release:

$$\frac{5.06 \times 10^{-7}}{3.88 \times 10^{-5}} = 0.0130$$

SUMMARY OF DOSES DUE TO LEAKAGE at 4600m ~~XXXXXX~~
for LARSE conditions

Thyroid 0.00 ⁰⁷~~12~~

Bone 0.0002

Whole Body —

~~Handwritten musical notation on a staff, mostly illegible due to heavy scribbles and corrections.~~

Calculation of dose at 4600 m from 72 to 81 hours after the MCA due to leakage - DOSE SUMMARY

313
App. B.

SIMILAR TO

DR'N LCC

CH'D *al*

APP'D

SCALE = 12

SHEET 29 OF 50

ISSUE

ALLIS-CHALMERS MFG. CO.	DEPT.

5-63

there will be another component of the dose during the period 72 to 81 hours after the MCA. This is due to venting from a 61 meter high stack. This will be converted to an equivalent leak rate constant by the relation:

$$L = \frac{\text{vent rate (scfm)}}{\text{Vol @ STP (ft}^3\text{)} \times 60 \left(\frac{\text{sec}}{\text{min}}\right)} = L \text{ sec}^{-1}$$

Since the vent rate was 750 scfm at 9 psig, the vent rate at 0.75 psig will be:

$$750 \text{ scfm} \sqrt{\frac{0.75}{9.0}} = 750 \sqrt{0.0833} = 217.5 \text{ scfm}$$

The volume at STP has been calculated to be $1.38 \times 10^6 \text{ ft}^3$

$$L = \frac{217.5 \text{ ft}^3/\text{min}}{1.38 \times 10^6 \text{ ft}^3 \times 60 \text{ sec/min}} = 2.63 \times 10^{-6} \text{ sec}^{-1}$$

Now for inversion conditions, 4600 m from the shell, and a stack release, the atmospheric dilution is $1.765 \times 10^{-6} Q_i(t)$

$$\text{Intake} = I_i = L (BR) f_i \int_{72}^{81} A_i(t) dt$$

$L = 2.63 \times 10^{-6} \text{ sec}^{-1}$, $BR = 3.5 \times 10^{-4} \text{ m}^3/\text{sec}$ f_i is fraction of the i^{th} isotope passing filters.

$$\text{Intake} = 2.63(-6) 3.5(-4) 1.765(-6) f_i \int_{72}^{81} A_i(t) dt$$

$$\text{Intake} = 1.62 \times 10^{-15} f_i \int_{72}^{81} A_i(t) dt$$

Isotope	f_i	$f_i \int_{72}^{81} A_i(t) dt$	Intake (ci)	S_i	Dose
Sr ⁸⁹	0.01	1.58 (11)	0.00026	0.42	0.00011
Sr ⁹⁰	0.01	1.91 (10)	0.00003	44.65	0.00134
Cs ¹³⁷	0.01	1.91 (11)	0.00031	0.06	0.00002
Ba ¹⁴⁰	0.01	1.76 (11)	0.00029	0.09	0.00003
La ¹⁴⁰	0.01	5.47 (10)	0.00001	0.005	—
I ¹³¹	0.05	1.31 (13)	0.02122	1.482	0.03158
I ¹³³	0.05	2.68 (2)	0.00434	0.400	0.00174
I ¹³⁵	0.05	2.65 (9)	—	0.124	—
Kr ^{85m}	1.00	0	0	0	—
Xe ¹³³	1.00	—	—	0	—
Xe ¹³³	1.00	—	—	0	—

Calculation of Dose at 4600 m from 72 to 81 hrs after MCA due to venting.

313
App. B

SIMILAR TO

DR'N *dcc* CH'D *D.L.* APP'D _____ SCALE = 12 SHEET 29 OF 50 ISSUE

ALLIS-CHALMERS MFG. CO. DEPT.

5-63

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

$$\text{Thyroid Dose} = \sum (\text{Dose from Iodine Isotopes})$$

$$\text{Thyroid Dose} = 0.0333$$

$$\text{Bone Dose} = \sum (\text{Dose from Sr, Ba, La \& Cs})$$

$$\text{Bone Dose} = 0.0015$$

The whole body dose will have inhalation and sub-
mersion components.

INHALATION

Isotope	Intake (mc)	Si: whole body (rem/mc)	Dose $\times 10^3$ Rem
Sr 89	0.00026	11.7(-3)	0.00304
Sr 90	0.00003	506.2(-3)	0.01519
Cs 137	0.00031	32.7(-3)	0.01014
Ba 140	0.00029	1.3(-3)	0.00038
La 140	0.00001	0.8(-3)	—
I 131	0.02122	2.7(-3)	0.05729
I 133	0.00434	0.6(-3)	0.00260
I 135	—	0.3(-3)	—

Inhalation Dose 0.00009 Rem

SUBMERSION

$$\text{Dose} = 2.6 \times 10^{-7} L E_s 1.765 \times 10^{-6} f_i \int_{72}^{81} A_i(t) dt \text{ Rem}$$

$$E_s = 1.5 \quad L = 2.63 \times 10^{-6}$$

$$\text{Dose} = 1.81 \times 10^{-18} f_i \int_{72}^{81} A_i(t) dt$$

Isotope	$f_i \int_{72}^{81} A_i(t) dt$	Dose $\times 10^6$ Rem
Sr 89	1.58 (11)	0.286
Sr 90	1.91 (10)	0.035
Cs 137	1.91 (11)	0.345
Ba 140	1.76 (11)	0.319
La 140	5.47 (10)	0.099
I 131	1.31 (13)	23.711
I 133	2.68 (12)	4.851
I 135	8.65 (9)	0.016
Kr 85m	0	—
Xe 133	1.53 (15)	2769.300
Xe 135	6.62 (12)	11.982

Calculation of Dose at 4600 m due
to venting during period 72 to 81 hours
after the MCA.

313
App. B

DR'N <i>dcl</i>	CH'D	APP'D	SCALE = 12	SIMILAR TO	ISSUE
ALLIS-CHALMERS MFG. CO. DEPT.				SHEET 30 OF 50	
				5-63	

Total Submersion Dose = 0.00282 Rems
 Whole Body Dose = 0.00009 + 0.00281 = 0.00290 Rems

SUMMARY OF Doses at 4600 M from 72 → 81 hrs due to venting (for Inversion Conditions)

Thyroid	0.0333	Rem
Bone	0.0015	"
Whole Body	0.00290	"

For these doses at 4600 M for Lapse Conditions, the above doses may be down scaled by the ratio of the dispersion coefficients for 4600 m and a STACK release.

$$\frac{4.99 \times 10^{-7}}{1.765 \times 10^{-6}} = 0.283$$

SUMMARY OF Doses at 4600 M from 72 → 81 hrs due to venting (FOR lapse Conditions)

Thyroid	~~0.0333~~	~~Rem~~	0.0094 Rem
Bone	~~0.0015~~	~~"~~	0.0004 "
Whole Body	~~0.00290~~	~~"~~	0.0008 "

Dose Summary at 4600 Meters due to Venting for Lapse and Inversion Conditions (72 hrs → 81 hours)

313
App.B

SIMILAR TO

DR'N LEE

CH'D D.L.

APP'D

SCALE

=12

SHEET 31 OF 50

ISSUE

ALLIS-CHALMERS MFG. CO.

DEPT.

5-63

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

A   B   C

TOTAL Dose at 4600 Meters
INVERSION CONDITIONS

Thyroid

$$\begin{array}{rcl} \text{Leakage} & + & \text{Venting} & = & \text{Total Dose} \\ 0.056 & + & 0.0333 & = & 0.0893 \text{ Rem} \end{array}$$

Bone

$$\begin{array}{rcl} \text{Leakage} & + & \text{Venting} & = & \text{Total Dose} \\ 0.013 & + & 0.0015 & = & 0.0145 \text{ Rem} \end{array}$$

Whole Body

$$\begin{array}{rcl} \text{Leakage} & + & \text{Venting} & = & \text{Total Dose} \\ \cancel{0.0348} & + & 0.00290 & = & \cancel{0.03509} \text{ Rem} \\ 0.001 & & & = & 0.0039 \end{array}$$

LAPSE CONDITIONS

Thyroid

$$\begin{array}{rcl} \text{Leakage} & + & \text{Venting} & = & \text{Total Dose} \\ \cancel{0.0012} & + & \cancel{0.0158} & = & \cancel{0.0168} \text{ Rem} \\ 0.0007 & + & 0.0094 & = & 0.0101 \text{ Rem} \end{array}$$

Bone

$$\begin{array}{rcl} \text{Leakage} & + & \text{Venting} & = & \text{Total Dose} \\ 0.0002 & + & 0.0004 & = & 0.0006 \text{ Rem} \end{array}$$

Whole Body

$$\begin{array}{rcl} \text{Leakage} & + & \text{Venting} & = & \text{Total Dose} \\ \cancel{0.0015} & + & \cancel{0.0014} & = & \cancel{0.0029} \text{ Rem.} \\ 0.0000 & + & 0.0008 & = & 0.0008 \text{ Rem} \end{array}$$

DOSES AT 4600 Meters due to Leak-
age and VENTING 72 hr → 01 hrs
Inversion and Lapse Conditions.

313
App B

SIMILAR TO

DR'N *ddl*

CH'D *A.L.*

APP'D

SCALE = 12

SHEET 32 OF 50

ISSUE

ALLIS-CHALMERS MFG. CO.

DEPT.

5-63

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

To calculate the dose at 6000, 7500, 9095, and 10,000 meters, the doses at 4600 meters can be scaled by the ratios of the atmospheric dilutions for the proper conditions. Note that the dose due to leakage and the dose due to venting must be scaled down separately since the leakage is a ground release and venting is done through a stack.

Inversion Conditions

Distance	LEAKAGE Dose Scaling Factor	ORGAN	LEAKAGE Dose
6000 m	0.645	Thyroid	0.0361
		Bone	0.0084
		Whole Body	~~0.0084~~ 0.0086
7500 m	0.446	Thyroid	0.0250
		Bone	0.0058
		Whole Body	~~0.0058~~ 0.0061
9095 m	0.324	Thyroid	0.0181
		Bone	0.0042
		Whole Body	~~0.0042~~ 0.0043
10,000 m	0.278	Thyroid	0.0156
		Bone	0.0036
		Whole Body	~~0.0036~~ 0.0037

VENTING Dose Scaling Factor

6000 m	1.94	Thyroid	0.0646
		Bone	0.0029
		Whole Body	0.0056
7500 m	2.48	Thyroid	0.0826
		Bone	0.0037
		Whole Body	0.0072
9095 m	2.60	Thyroid	0.0866
		Bone	0.0039
		Whole Body	0.0076

Doses from 72 → 81 hours after MCA at distances 6000 m, 7500 m, 9095 m and 10,000 m from the containment shell

313
App. B

DR'N LCC	CH'D D.L.	APP'D	SCALE =12	SHEET 33 OF 50	ISSUE
ILLIS-CHALMERS MFG. CO. DEPT.				6-63	

A		B	C	
10,000 m	2.59		Thyroid	0.0862
			Bone	0.0039
			Whole Body	0.0075
LAPSE CONDITIONS				
Distance	Leakage Dose Scaling Factor	ORGAN	Dose	
6000 m	~~0.622~~ 0.625	Thyroid	0.0004	
		Bone	0.0001	
		Whole Body	~~0.0002~~ 0.0000	
7500 m	~~0.422~~ 0.421	Thyroid	0.0003	
		Bone	0.0001	
		Whole Body	~~0.0002~~ 0.0000	
9095 m	~~0.298~~ 0.298	Thyroid	0.0002	
		Bone	0.0001	
		Whole Body	~~0.0001~~ 0.0000	
10,000 m	~~0.253~~ 0.253	Thyroid	0.0002	
		Bone	0.0001	
		Whole Body	~~0.0001~~ 0.0000	
DISTANCE VENTING DOSE SCALING Factor		ORGAN	Dose	
6000 m	~~0.625~~ 0.627	Thyroid	0.0059	
		Bone	0.0003	
		Whole Body	0.0005	
7500 m	~~0.425~~ 0.425	Thyroid	0.0045	
		Bone	0.0002	
		Whole Body	0.0003	
9095 m	~~0.301~~ 0.301	Thyroid	0.0022	
		Bone	0.0001	
		Whole Body	0.0002	
10,000 m	~~0.257~~ 0.257	Thyroid	0.0024	
		Bone	0.0001	
		Whole Body	0.0002	

Doses from 72 to 81 hours after MCA at distances 6000 m, 7500 m, 9095 m, and 10,000 m from the Containment Shell

313
App. B.

DR'N	LCC	CH'D	J. L.	APP'D		SCALE	=12	SIMILAR TO		SHEET	34 OF 50	ISSUE	
ILLIS-CHALMERS MFG. CO. DEPT.								6-63					

ILLIS-CHALMERS MFG. CO.

DEPT.

A

B

C

DOSES FOR INVERSION CONDITIONS

DISTANCE	ORGAN	LEAK DOSE	+ VENT DOSE	= TOTAL DOSE	
4600	Thyroid	0.056	+ 0.0333	= 0.0893	Rem
	Bone	0.013	+ 0.0015	= 0.0145	"
	Whole Body	~~0.048~~ 0.001	+ 0.0029	= ~~0.0509~~ 0.0039	"
6000	Thyroid	0.0361	+ 0.0646	= 0.1007	"
	Bone	0.0084	+ 0.0029	= 0.0113	"
	Whole Body	~~0.048~~ 0.0006	+ 0.0056	= ~~0.0536~~ 0.0062	"
7500	Thyroid	0.0250	+ 0.0826	= 0.1076	"
	Bone	0.0058	+ 0.0037	= 0.0095	"
	Whole Body	~~0.048~~ 0.0004	+ 0.0072	= ~~0.0552~~ 0.0076	"
9095	Thyroid	0.0181	+ 0.0866	= 0.1047	"
	Bone	0.0042	+ 0.0039	= 0.0081	"
	Whole Body	~~0.048~~ 0.0003	+ 0.0076	= ~~0.0556~~ 0.0079	"
10000	Thyroid	0.0156	+ 0.0862	= 0.1018	"
	Bone	0.0036	+ 0.0039	= 0.0075	"
	Whole Body	~~0.048~~ 0.0003	+ 0.0075	= ~~0.0553~~ 0.0078	"

DOSES FOR ^{LAPSE} ~~NEARBY~~ CONDITIONS

DISTANCE	ORGAN	LEAK DOSE	+ VENT DOSE	= TOTAL DOSE	
4600	Thyroid	0.0007	+ 0.0094	= 0.0101	Rem
	Bone	0.0002	+ 0.0004	= 0.0006	"
	Whole Body	~~0.0003~~ 0.0000	+ 0.0008	= ~~0.0003~~ 0.0008	"
6000	Thyroid	0.0004	+ 0.0059	= 0.0063	"
	Bone	0.0001	+ 0.0003	= 0.0004	"
	Whole Body	~~0.0003~~ 0.0000	+ 0.0005	= ~~0.0003~~ 0.0005	"
7500	Thyroid	0.0003	+ 0.0040	= 0.0043	"
	Bone	0.0001	+ 0.0002	= 0.0003	"
	Whole Body	~~0.0003~~ 0.0000	+ 0.0003	= ~~0.0003~~ 0.0003	"

SUMMARY OF DOSES from 72 → 81 Hours
after MCA @ 6000, 7500, 9095 ~~m~~, and 10000
meters from the Containment Shell

313

App. B

SIMILAR TO

DR'N JCC

CH'D

APP'D

SCALE

=12

SHEET 35 OF 50

ISSUE

ALLIS-CHALMERS MFG. CO.

DEPT.

E-63

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

A

B

C

Dose for Lapse CONDITIONS

DISTANCE	ORGAN	Dose from Leak + Dose from Venting = Total Dose		
9095 m	Thyroid	0.0002	+ 0.0002 ²⁸	= 0.0004 ³⁰ Rem
	Bone	0.0001	+ 0.0002	= 0.0002 "
	Whole Body	~~0.0002~~ 0.0001	+ 0.0002	= ~~0.0002~~ 0.0002 "
10,000 m	Thyroid	0.0002	+ 0.0002 ²⁴	= 0.0004 "
	Bone	0.0001	+ 0.0001	= 0.0002 "
	Whole Body	~~0.0002~~ 0.0000	+ 0.0002	= ~~0.0002~~ 0.0002 "

Summary of Doses from 72 → 81 hrs
after MCA at 4600, 6000, 7500, 9095, and
10,000 meters from the Containment Shell

313
App. B

SIMILAR TO

DR'N *LCR*CH'D *A. L.*

APP'D

SCALE = 12

SHEET 36 OF 50

ISSUE

ALLIS-CHALMERS MFG. CO. DEPT.

6-63

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

The doses to the organs in each time interval may be added to yield a total accident dosage to each organ:

INVERSION

4600	Thyroid	=	0.5706	+	1.003	+	0.0893	=	1.6629	Rem
	Bone	=	0.0481	+	0.121	+	0.0145	=	0.1836	"
	Whole Body	=	0.0058	+	~~0.0073~~ 0.100	+	~~0.0039~~ 0.0039	=	~~0.0169~~ 0.1097	"
6000	Thyroid	=	0.3293	+	1.132	+	0.1007	=	1.5620	"
	Bone	=	0.0310	+	0.095	+	0.0113	=	0.1373	"
	Whole Body	=	0.0037	+	~~0.0050~~ 0.103	+	~~0.0001~~ 0.0062	=	~~0.0088~~ 0.1129	"
7500	Thyroid	=	0.2282	+	1.208	+	0.1076	=	1.5438	"
	Bone	=	0.0215	+	0.080	+	0.0095	=	0.1110	"
	Whole Body	=	0.0026	+	~~0.0037~~ 0.105	+	~~0.0004~~ 0.0076	=	~~0.0064~~ 0.1152	"
9095	Thyroid	=	0.1654	+	1.176	+	0.1047	=	1.4461	"
	Bone	=	0.0156	+	0.069	+	0.0081	=	0.0927	"
	Whole Body	=	0.0019	+	~~0.0030~~ 0.100	+	~~0.0004~~ 0.0079	=	~~0.0053~~ 0.1098	"
10,000	Thyroid	=	0.1420	+	1.144	+	0.1018	=	1.3878	"
	Bone	=	0.0134	+	~~0.0088~~ 0.088	+	0.0075	=	0.0849	"
	Whole Body	=	0.0016	+	~~0.0026~~ 0.096	+	~~0.0002~~ 0.0078	=	~~0.0044~~ 0.1054	"

LAPSE

4600	Thyroid	0.0066	+	0.1140	+	0.0101	=	0.1307	Rem
	Bone	0.0006	+	0.0051	+	0.0006	=	0.0063	"
	Whole Body	0.0001	+	~~0.0016~~ 0.0093	+	~~0.0003~~ 0.0008	=	~~0.0019~~ 0.0102	"
6000	Thyroid	0.0041	+	~~0.0697~~ 0.0714	+	0.0063	=	~~0.0801~~ 0.0818	"
	Bone	0.0004	+	0.0032	+	0.0004	=	0.0040	"
	Whole Body	0.0001	+	~~0.0010~~ 0.0059	+	~~0.0003~~ 0.0005	=	~~0.0013~~ 0.0065	"
7500	Thyroid	0.0028	+	~~0.0473~~ 0.0485	+	0.0043	=	~~0.0544~~ 0.0556	"
	Bone	0.0003	+	0.0022	+	0.0003	=	0.0028	"
	Whole Body	—	+	~~0.0007~~ 0.0040	+	~~0.0002~~ 0.0003	=	~~0.0009~~ 0.0043	"
9095	Thyroid	0.0020	+	~~0.0374~~ 0.0342	+	0.0030	=	~~0.0424~~ 0.0392	"
	Bone	0.0002	+	0.0015	+	0.0002	=	0.0019	"
	Whole Body	—	+	~~0.0003~~ 0.0005	+	~~0.0002~~ 0.0005	=	~~0.0005~~ 0.0030	"

DOSES FOR DURATION OF ACCIDENT
4600 TO 10,000 meters

313

App. B

SIMILAR TO

DR'N	dcc	CH'D	D.L.	APP'D	SCALE	=12	SHEET	37 OF 50	ISSUE
ALLIS-CHALMERS MFG. CO.				DEPT.	6-63				

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

	A	B	C	
10,000 Thyroid	0.0017	+ ~~0.0286~~ 0.0293	+ 0.0026 =	0.0336 ~~0.0329~~ Rem
Bone	0.0002	+ 0.0014	+ 0.0002 =	0.0018 "
Whole Body	—	~~0.0004~~ 0.0024	+ ~~0.0003~~ 0.0002 =	~~0.0017~~ 0.0026 "

Dose For Duration of Accident
4600 To 10,000 meters

313
App B

DR'N *LCC*

CH'D *D.P.*

APP'D

SCALE = 12

SIMILAR TO

SHEET 38 OF 50

ISSUE

ALLIS-CHALMERS MFG. CO.

DEPT.

6-63

A

B

CALCULATION OF DOSE RATES vs. Distance [due to FALLOUT and RAINOUT OF FISSION PRODUCTS]

The radiation dose rate due to fallout from the MCA will be computed. The man (detector) is assumed to be 3' away from an infinite plane source. Since the source is assumed to be an ∞ plane, no credit will be taken for attenuation by distance. No material attenuation due to the 3' of air will be considered; this results in a buildup factor of unity.

To support this

Air at STP has a density of $1.3 \times 10^{-3} \text{ g/cm}^3$ for air and 1.5 Mev γ 's, $\mu = 0.0256 \text{ cm}^2/\text{gm}$

Ref. page 152 of Lecture Notes on REACTOR SHIELDING - M. Grotenhuis

$$\therefore \mu_0 = \mu \rho = 2.56 \times 10^{-2} \text{ cm}^2/\text{gm} \times 1.3 \times 10^{-3} \text{ g/cm}^3 = 3.3 \times 10^{-5} / \text{cm}$$

$$\text{Now } r = 3' = 91.4 \text{ cm}$$

$$\therefore \mu_0 r = 91.4 \text{ cm} \times 3.3 \times 10^{-5} / \text{cm} = 3.04 \times 10^{-3}$$

$$\therefore e^{-\mu_0 r} \approx 1.0 \quad \text{No material attenuation}$$

Assume Linear Buildup Factor $B = (1 + \mu_0 r) \approx 1.0$
Since Fission products contain both β & γ emitters, an energy of 1.5 Mev/disintegration is assumed. No credit is taken for decay of the fission products.

The assumptions result in a VERY conservative analysis.

Now the dose rate can be related to the energy flux by the fact that $1.8 \times 10^{13} \text{ Mev/m}^2\text{-sec} = 1 \text{ R/sec}$ in this energy range. The energy flux may be obtained from the activity by the relations.

$$1 \mu\text{C} = 3.7 \times 10^4 \text{ dis/sec}$$

$$\text{Average Energy Assumed} = 1.5 \text{ Mev/dis}$$

An Activity per unit Area is given by WASH 740, "Theoretical Consequences of Major Accidents in Large Nuclear Power Plants", page 50. as:

$$\Delta = \frac{2 Q_0 V_g}{u \pi C_y C_\gamma X^{2-n}} \exp\left(\frac{-4 V_g X^{n/2}}{n u \pi^{1/2} C_\gamma}\right) \exp\left[\frac{-1}{X^{2-n}}\left(\frac{y^2}{C_y^2} + \frac{h^2}{C_\gamma^2}\right)\right]$$

DOSE RATES due to Dry Fallout and WASHOUT at distances from 1060 m to 10,000 m

313
App B

SIMILAR TO

DR'N LCC

CH'D J. J.

APP'D

SCALE = 12

SHEET 39 OF 50

ISSUE

ALLIS-CHALMERS MFG. CO.

DEPT.

6-63

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

This gives the dry fallout Δ in $\mu\text{C}/\text{m}^2$ for Q_0 in $\mu\text{C}/\text{sec}$. The equation will be simplified by setting $y=0$ so that the A will be computed without taking credit for horizontal diffusion

For WASHOUT without horizontal diffusion, the activity per unit area is given by the equation:

$$P = \frac{1}{u} \frac{Q_0 \exp(-\lambda x / u)}{\pi^{1/2} C_y X^{3/2}} \quad \left(P \text{ in } \frac{\mu\text{C}}{\text{m}^2} \text{ for } Q_0 \text{ in } \mu\text{C} \right)$$

from WASH 740 page 51

(IN the preceding equations x is the distance from the containment shell, notation follows that of WASH 740)

The Source Term, Q_0 , will be computed as follows:

① The integrated activity of each isotope during the intervals $0 \rightarrow 24$ hrs, $24 \rightarrow 72$ hrs, and $72 \rightarrow 81$ hours will be presented in $\mu\text{C}-\text{sec}$

② The leak rate for the time interval will be multiplied by the integrated activity for each isotope. For venting through the stack an equivalent leak rate will be used. Filter effectiveness will be considered. The filters will pass 1% of La, Ba, Sr, and Cs, 5% of iodine, and 100% of the noble gases. (Ref. TUX NRO1 JACKSON to Bush dated 6-7-62)

This analysis will assume the following parameters for the calculations. These parameters should give conservative (high dose rates) results.

Particle size - 15 microns

Settling Velocity for Dry fallout $V_g = 2 \times 10^{-2} \text{ m/sec}$

A, Proportion of cloud removed per second - 10^{-3} (corresponds to a heavy rainfall of 0.15 in/hr)

This last parameter assumed tends to give a higher dose rate closer to the shell and a lower dose rate further from the shell than if a smaller proportion, λ , had been assumed. The dose rate will be higher nearer the shell no matter what parameter λ is assumed.

DOSE RATES DUE TO DRY Fallout & Washout
1060 m $\rightarrow$ 10,000 m

313
App B

DR'N JCE

CH'D D.L.

APP'D

SCALE

=12

SIMILAR TO

SHEET 40 OF 50

ISSUE

ALLIS-CHALMERS MFG. CO.

DEPT.

6-63

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

A		B		C				
SOURCE TERMS								TIME PERIOD
Sr 89	Sr 90	Cs 137	Ba 140	La 140	I 131	I 133	I 135	
0.408	$\int_{0}^{24} A_i(t) dt$	$(\ln \mu C - \text{sec} \times 10^{-14})$						0 → 24 hrs
1.416	$L_1 \int_{0}^{24} A_i(t) dt$	$(\ln \mu C \times 10^{-6})$			$L_1 = 3.47 \times 10^{-8} \text{ sec}^{-1}$			← Q ₀
0.729	$\int_{24}^{72} A_i(t) dt$	$(\ln \mu C - \text{sec} \times 10^{-14})$						24 → 72 hrs
1.73	$L_2 \int_{24}^{72} A_i(t) dt$	$(\ln \mu C \times 10^{-6})$			$L_2 = 2.37 \times 10^{-8} \text{ sec}^{-1}$			Leakage Source
0.729	$f_i \int_{24}^{72} A_i(t) dt$	$(\mu C - \text{sec} \times 10^{-12})$			~~58.00~~	~~27.85~~		+
4.52	$L_v f \int_{24}^{72} A_i(t) dt$	$(\ln \mu C \times 10^{-6})$			~~359.60~~	~~172.67~~		Venting Source
6.25	$(L_2 + L_v f) \int_{24}^{72} A_i(t) dt$	$(\ln \mu C \times 10^{-6})$			~~387.09~~	~~185.87~~		TOTAL SOURCE TERM, Q ₀
15.8	$\int_{72}^{81} A_i(t) dt$	$(\mu C - \text{sec} \times 10^{-12})$						72 → 81 hours
0.158	$F \int_{72}^{81} A_i(t) dt$	$(\mu C - \text{sec} \times 10^{-12})$			~~13.10~~	~~2.68~~		Venting Source Term
0.416	$L_v F \int_{72}^{81} A_i(t) dt$	$(\mu C \times 10^{-6})$			$L_v = 2.63 \times 10^{-6} \text{ sec}^{-1}$			+
0.160	$L_3 \int_{72}^{81} A_i(t) dt$	$(\mu C - \text{sec} \times 10^{-6})$			$L_3 = 1.01 \times 10^{-8} \text{ sec}^{-1}$			Leakage Source Term
0.576	$(L_3 + L_v F) \int_{72}^{81} A_i(t) dt$	$(\ln \mu C \times 10^{-6})$			37.096	7.591		TOTAL SOURCE TERM, Q ₀
Now the Total Source terms for each time interval are found by adding the activity of the isotopes for the periods of interest 0 → 24 hrs Q₀(t) = $49.708 \times 10^6 \mu \text{ Curies}$ 24 → 72 hrs Q₀(t) = $610.544 \times 10^6 \mu \text{ Curies}$ 72 → 81 hrs Q₀(t) = $46.892 \times 10^6 \mu \text{ Curies}$								
Dose Rates vs Distance Source Terms For WASHOUT and DRY FALLOUT							313 App. B	
DR'N	CH'D	APP'D	SCALE	= 12		SIMILAR TO		
						SHEET 41 OF 50		
ALLIS-CHALMERS MFG. CO. DEPT.						6-63		

WASHOUT

$$P = \frac{\Lambda \exp\left(-\frac{\Lambda x}{\bar{u}}\right) Q_0}{\bar{u} \pi^{1/2} C_y x^{3/2}}$$

INVERSION

$n = 0.35, \bar{u} = 1.5 \text{ m/sec}, C_y = 0.3, \Lambda = 10^{-3}$					
X	$x^{3/2}$	$\Lambda x / \bar{u}$	$e^{-\Lambda x / \bar{u}}$	$\Lambda / \bar{u} \pi^{1/2} C_y$	$\frac{\Lambda \exp(-\Lambda x / \bar{u})}{\bar{u} \pi^{1/2} C_y x^{3/2}}$
1060	3.132(2)	0.705	0.493	1.25 (-3)	1.97 (-6)
2500	6.358(2)	1.67	0.188		3.70 (-7)
4600	1.051(3)	3.06	0.0469		5.58 (-8)
6000	1.309(3)	4.00	0.0183		1.75 (-8)
7500	1.574(3)	5.00	0.0067		5.33 (-9)
10000	1.996(3)	6.66	0.0013		8.14 (-10)

For Q_0 in μC , P in $\mu\text{C}/\text{m}^2$ below

X	0 → 24 hrs	24 hrs → 72 hrs	72 hrs → 81 hrs
1060	97.92	~~2,525.81~~ 1802.87	92.37
2500	18.38	~~497.83~~ 225.92	17.35
4600	2.77	~~74.35~~ 34.07	2.62
6000	0.87	~~23.45~~ 10.69	0.82
7500	0.27	~~7.14~~ 3.25	0.25
10,000	0.04	~~1.09~~ 0.50	0.04

By multiplying P in $\mu\text{C}/\text{m}^2$ by a factor of 1.107×10^{-2} one obtains a dose rate in mr/hr

$$3.6 \times 10^3 \text{ sec/hr} \times 10^3 \text{ m/R} \times 0.556 \times 10^{-13} \frac{\text{R/sec}}{\text{Mr/hr}} \times 5.53 \times 10^4 \frac{\text{Mr}}{\text{m}^2 \cdot \text{sec}} / \mu\text{C}/\text{m}^2 = 1.107 \times 10^{-2}$$

DOSE RATES IN MR/HR FOR WASHOUT - INVERSION

X	0 → 24 hrs	24 hrs → 72 hrs	72 hrs → 81 hrs
1060	1.0840	~~2,525.81~~ 13.32	~~1,077.4~~ 1.02
2500	0.2035	~~5.507~~ 2.50	0.1926
4600	0.0307	~~0.323~~ 0.38	0.0288
6000	0.0096	~~0.260~~ 0.12	0.0091
7500	0.0030	~~0.079~~ 0.04	0.0028
10,000	0.0004	~~0.012~~ 0.01	0.0004

Now for Lapse Conditions $n = 0.23, \bar{u} = 2.3 \text{ m/sec}$
 $C_y = 0.3, \Lambda = 10^{-3}$

Dose Rates due to Dry Fallout & Washout
 1060 m → 10,000 m

313
 App B

SIMILAR TO

DR'N LCC	CH'D D.L.	APP'D	SCALE = 12	SHEET 42 OF 50	ISSUE
ALLIS-CHALMERS MFG. CO. DEPT.				6-63	

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

LAPSE					
X	$X^2 - \frac{1}{2}$	$\Delta X / \bar{u}$	$e^{-\frac{\Delta X}{\bar{u}}}$	$\frac{1}{\bar{u}} \pi^{1/2} C_y$	$\frac{1}{\pi^{1/2} \bar{u} C_y} e^{-\frac{\Delta X}{\bar{u}}} X^{2-\frac{1}{2}}$
1060	4.758(2)	0.461	0.631	0.18(-4)	1.08(-6)
2500	1.017(3)	1.09	0.336		2.69(-7)
4600	1.744(3)	2.00	0.135		6.35(-8)
6000	2.206(3)	2.61	0.074		2.74(-8)
7500	2.683(3)	3.25	0.039		1.19(-8)
10000	3.467(3)	4.34	0.013		3.07(-9)

X	0 → 24 hr	$P_{in} \mu C/m^2$ 24 hr → 72 hr	72 hr → 81 hr
1060	53.68	~~448.58~~ 659.44	50.64
2500	13.37	~~86.07~~ 164.25	12.61
4600	3.16	~~35.71~~ 38.77	2.98
6000	1.36	~~15.94~~ 16.73	1.28
7500	0.59	~~4.11~~ 7.27	0.56
10000	0.15		0.14

$P (\mu C/m^2) \times 1.107 \times 10^{-2} = D.R. \text{ MR/hr.}$

Dose Rates in MR/hr for WASHOUT - LAPSE

X	0 → 24 hr	24 hr → 72 hr	72 → 81 hr
1060	0.3942	~~4.08~~ 7.30	0.5606
2500	0.1480	~~3.98~~ 1.82	0.1396
4600	0.0350	~~0.94~~ 0.43	0.0330
6000	0.0151	~~0.40~~ 0.19	0.0142
7500	0.0065	~~0.17~~ 0.08	0.0062
10000	0.0017	~~0.04~~ 0.02	0.0016

DOSE RATES DUE TO DRY FALLOUT & WASHOUT 1060 m → 10,000 m.				313 App B	
SIMILAR TO					
DR'N <i>Lee</i>	CH'D <i>D.L.</i>	APP'D	SCALE = 12	SHEET 43 OF 50	ISSUE
ALLIS-CHALMERS MFG. CO. DEPT.				6-63	

DRY Fallout

INVERSION $n = 0.35$, $\bar{u} = 1.5 \text{ m/sec}$, $C_g = 0.3$, $C_g = 0.033$, $V_g = 2 \times 10^{-2}$

$$\Delta = \frac{2V_g Q_0}{\bar{u} \pi C_g C_g x^{2-n}} \exp\left(\frac{-h^2}{C_g x^{2-n}}\right) \exp\left(\frac{-4V_g x^{n/2}}{\pi \bar{u} n C_g}\right)$$

X	$\frac{2V_g}{\pi \bar{u} C_g C_g x^{2-n}}$	$\times e^{-\left[\frac{4V_g x^{n/2}}{\pi \bar{u} n C_g}\right]}$	$= \Delta/Q_0 \Big]_{\text{Leak}}^{\text{gnd}}$	$\times e^{-\frac{h^2}{C_g x^{2-n}}} = \Delta/Q_0 \Big]_{\text{Release}}^{\text{Stack}}$
1060	~~0.874~~ (-5)	~~1.492~~ (-4)	~~1.30~~ (-9)	~~7.55~~ (-16) = ~~9.82~~ (-25)
2500	~~2.122~~ (-6)	~~3.571~~ (-5)	~~7.58~~ (-11)	~~2.14~~ (-4) = ~~1.62~~ (-14)
4600	~~0.776~~ (-6)	~~1.120~~ (-5)	~~0.869~~ (-11)	~~0.0455~~ = ~~3.95~~ (-13)
6000	~~0.500~~ (-6)	~~6.52~~ (-6)	~~3.26~~ (-12)	~~0.1367~~ = ~~4.46~~ (-13)
7500	~~0.346~~ (-6)	~~4.04~~ (-6)	~~1.40~~ (-12)	~~0.2516~~ = ~~3.52~~ (-13)
10000	~~0.216~~ (-6)	~~1.88~~ (-6)	~~3.95~~ (-13)	~~0.4232~~ = ~~1.67~~ (-13)

Applying these factors to the source terms gives Δ in $\mu\text{C}/\text{m}^2$ below

X	0 → 24 hrs	24 → 72 hrs	72 → 81 hrs.
1060	~~0.0646~~	~~0.794~~ + — = ~~1.5174~~	~~0.0618~~ + — = ~~0.0618~~
2500	0.0038	~~0.1034~~ + — = ~~0.1034~~	0.0036 + — = 0.0036
4600	0.0004	~~0.0119~~ + ~~0.0002~~ = ~~0.0121~~	0.0004 + — = 0.0004
6000	0.0002	~~0.0043~~ + ~~0.0003~~ = ~~0.0046~~	0.0002 + — = 0.0002
7500	0.0001	~~0.0009~~ + ~~0.0002~~ = ~~0.0011~~	0.0001 + — = 0.0001
10,000	—	~~0.0003~~ + ~~0.0001~~ = ~~0.0004~~	— + — = —

Multiplying Δ in $\mu\text{C}/\text{m}^2$ by 1.1×10^{-2} yields dose rates in mR/hr .

Dry Fallout Dose Rate - Inversion - in mR/hr

X	0 → 24 hrs	24 → 72 hrs	72 → 81 hrs.
1060	0.0007	~~0.0119~~	0.0007
2500	—	~~0.0089~~	—
4600	—	~~0.0005~~	—
6000	—	0.0001	—
7500	—	—	—
10,000	—	—	—

The Above Dose Rates apply when Inversion Conditions prevail.

DOSE RATE DUE TO DRY FALLOUT AND WASHOUT AT DISTANCES FROM 1060 m TO 10,000 m

313
App. B

DR'N <u>DCC</u>	CH'D <u>G. L.</u>	APP'D	SCALE = 12	SIMILAR TO	SHEET <u>44</u> OF <u>50</u>	ISSUE
ALLIS-CHALMERS MFG. CO. DEPT.				6-63		

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

DRY FALLOUT

LAPSE $n = 0.23$ $\bar{u} = 2.3$ m/sec $C_y = C_g = 0.3$ $V_g = 2 \times 10^{-2}$

$$\Delta = \frac{2Q_0 V_g}{\bar{u} \pi C_y C_g x^{2-n}} \exp\left(\frac{-h^2}{C_g^2 x^{2-n}}\right) \exp\left(\frac{-4V_g x^{n/2}}{\pi \bar{u} n C_g}\right)$$

X	$\frac{2V_g}{\bar{u} \pi C_y C_g x^{2-n}}$	$\times$	$e^{-\left[\frac{4V_g x^{n/2}}{\pi \bar{u} n C_g}\right]}$	$= A/Q_0$	$\times$	$e^{-\frac{h^2}{C_g^2 x^{2-n}}}$	$= A/Q_0$	STACK RELEASE
1060	2.71(-7)	$\times$	0.538	= 1.44(-7)	$\times$	0.83	= 1.20(-7)	
2500	5.91(-8)	$\times$	0.496	= 2.96(-8)	$\times$	0.96	= 2.86(-8)	
4600	2.05(-8)	$\times$	0.467	= 9.59(-9)	$\times$	0.985	= 9.44(-9)	
6000	1.27(-8)	$\times$	0.460	= 5.84(-9)	$\times$	0.99	= 5.78(-9)	
7500	8.70(-9)	$\times$	0.448	= 3.90(-9)	$\times$	0.99	= 3.78(-9)	
10,000	5.16(-9)	$\times$	0.438	= 2.26(-9)	$\times$	0.00	= 2.26(-9)	

Applying these factors to the source terms gives Δ in $\mu\text{C}/\text{m}^2$ below

X	0 $\rightarrow$ 24 hr	24 $\rightarrow$ 72 hr	72 $\rightarrow$ 81 hr
1060	7.16	~~87.93~~ + ~~73.27~~ = ~~161.20~~	6.75 + 5.63 = 12.38
2500	1.47	~~35.62~~ + ~~38.32~~ = ~~73.94~~	1.39 + 1.34 = 2.73
4600	0.48	~~18.07~~ + ~~17.46~~ = ~~35.53~~	0.45 + 0.44 = 0.89
6000	0.29	~~5.96~~ + ~~5.76~~ = ~~11.72~~	0.27 + 0.27 = 0.54
7500	0.19	~~3.57~~ + ~~3.53~~ = ~~7.10~~	0.18 + 0.18 = 0.36
10,000	0.11	~~2.38~~ + ~~2.31~~ = ~~4.69~~	0.11 + 0.11 = 0.22
		~~1.38~~ + ~~1.38~~ = ~~2.76~~	

Multiplying Δ in $\mu\text{C}/\text{m}^2$ by 1.1×10^{-2} yields dose rates in mr/hr
 DRY Fallout Dose Rate - lapse - in mr/hr .

X	0 $\rightarrow$ 24	24 $\rightarrow$ 72 hr	72 $\rightarrow$ 81 hr
1060	0.0793	~~3.924~~ 1.784	0.1370
2500	0.0163	~~0.863~~ 0.393	0.0302
4600	0.0053	~~0.252~~ 0.129	0.0099
6000	0.0032	~~0.112~~ 0.079	0.0060
7500	0.0021	~~0.114~~ 0.052	0.0040
10,000	0.0012	~~0.067~~ 0.031	0.0024

The Above Dose Rates apply when Lapse Conditions prevail.
 It is seen that Lapse conditions cause the higher Dose Rates.

DOSE RATE DUE TO DRY FALLOUT and
 WASHOUT AT DISTANCES FROM 1060 m to
 10,000 m.

313
 App B

SIMILAR TO

DR'N <i>JCR</i>	CH'D <i>B.L.</i>	APP'D	SCALE = 12	SHEET 45 OF 50	ISSUE
ALLIS-CHALMERS MFG. CO. DEPT.				6-63	

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

Fission Product deposition in Melton Hill Lake by WASHOUT and Dry Fallout after EGCR MCA

WASHOUT

Particulate fission products will be removed from a radioactive cloud by ~~and~~ rain falling through that cloud. This activity can be deposited over the area of the lake.

$$P = \frac{1 Q_0 e^{-\lambda x/\bar{u}}}{\pi \bar{u} C_y x^{3/2}} \text{ } \mu\text{C}/\text{m}^2 \cdot \text{sec}, \text{ when } Q_0 \text{ is } \mu\text{C}/\text{sec}$$

This is the same formula used to calculate the Dose Rates due to washout. Here it is modified in that Q_0 will be a rate of release in $\mu\text{C}/\text{sec}$ and P will have units of $\mu\text{C}/\text{sec} \cdot \text{m}^2$. To be conservative, (obtain high concentrations of F.P.) the atmospheric dilution due to stack height is not considered. An integration over the lake surface must be performed since the total particulate deposition on the lake is required to compute radionuclide concentration. Simpson's Rule will be used to ~~approximately~~ numerically integrate the lake's surface area. The lake extends from 200 m to 1060 m from EGCR. Let $\Delta x = 86 \text{ m}$ and $\lambda = 10^{-3}$

INVERSION

$$f(x) = \frac{1}{x^{3/2}} e^{-\lambda x/\bar{u}} = \frac{1}{x^{3/2}} e^{-6.66 \times 10^{-4} x} \quad n = 0.35$$

X	$\frac{1}{x^{3/2}}$	$e^{-\lambda x/\bar{u}}$	f(x)	Simpson's Rule Coeff.	coeff. x f(x)
200	1.26(-2)	0.878	1.11(-2)	1	1.11(-2)
286	0.94(-2)	0.827	7.78(-3)	4	3.11(-2)
372	0.76(-2)	0.779	5.91(-3)	2	1.18(-2)
458	0.64(-2)	0.733	4.70(-3)	4	1.88(-2)
544	0.55(-2)	0.698	~~3.84~~ 3.84(-3)	2	0.77(-2)
630	0.49(-2)	0.657	3.22(-3)	4	1.28(-2)
716	0.45(-2)	0.619	2.79(-3)	2	0.56(-2)
802	0.40(-2)	0.583	2.33(-3)	4	0.93(-2)
888	0.37(-2)	0.554	2.05(-3)	2	0.41(-2)
974	0.34(-2)	~~0.520~~ 0.520	1.78(-3)	4	0.71(-2)
1060	0.32(-2)	0.492	1.57(-3)	1	0.16(-2)

Contamination of Melton Hill Lake after MCA by WASHOUT and FALLOUT

313
APP B

SIMILAR TO

DR'N	CH'D	APP'D	SCALE	SHEET	OF	ISSUE
JCC	D. L.		=12	46	50	
ALLIS-CHALMERS MFG. CO.			DEPT.	6-63		

ALLIS-CHALMERS MFG. CO. DEPT.

$$\sum [f(x_0) + 4f(x_1) + 2f(x_2) + \dots + f(x_{10})] = 12.11 (-2)$$

$$\frac{86}{3} [\sum (\text{coeff} \times f(x))] = \frac{86}{3} (0.1214) = 3.48 = \int_{200}^{1060} f(x) dx$$

$$P = \frac{1}{4\pi h C_y} \int_{200}^{1060} f(x) dx = 1.25 \times 10^{-3} \times 3.48 Q_0 = 4.35 \times 10^{-3} Q_0$$

LAPSE

$f(x) = \frac{1}{x^{\frac{2-n}{n}}} e^{-\frac{1x}{u}} = \frac{1}{x^{\frac{2-n}{n}}} e^{-4.35 \times 10^{-4} x} \quad n = 0.23$					
x	$\frac{1}{x^{0.85}}$	$e^{-1x/u}$	f(x)	Simpson's Rule Coeff.	Coeff x f(x)
200	0.92(-2)	0.917	8.44(-3)	1	8.44(-3)
286	0.67(-2)	0.887	5.92(-3)	4	23.64(-3)
372	0.53(-2)	0.852	4.51(-3)	2	9.02(-3)
458	0.44(-2)	0.819	3.61(-3)	4	14.40(-3)
544	0.38(-2)	0.787	2.98(-3)	2	5.98(-3)
630	0.33(-2)	0.763	2.52(-3)	4	10.08(-3)
716	0.30(-2)	0.733	2.20(-3)	2	4.40(-3)
802	0.27(-2)	0.705	1.90(-3)	4	7.61(-3)
888	0.25(-2)	0.680	1.70(-3)	2	3.40(-3)
974	0.23(-2)	0.657	1.58(-3)	4	6.04(-3)
1060	0.21(-2)	0.631	1.33(-3)	1	1.33(-3)

$$\sum [f(x_0) + 4f(x_1) + 2f(x_2) + \dots + f(x_{10})] = 94.34 (-3)$$

~~$$\frac{86}{3} [\sum (\text{coeff} \times f(x))] = \frac{86}{3} (0.09434) = 2.70 = \int_{200}^{1060} f(x) dx$$~~

$$P = \frac{1}{4\pi h C_y} \int_{200}^{1060} f(x) dx = \frac{8.18}{8.22 \times 10^{-4}} \times 2.70 Q_0 = 2.21 \times 10^{-3} Q_0$$

It can be seen that Inversion will yield higher concentrations of F.P. in the Lake

$$P = 4.35 \times 10^{-3} Q_0 \quad \text{INVERSION}$$

$$P = 2.21 \times 10^{-3} Q_0 \quad \text{LAPSE}$$

Contamination of Melton Hill Lake
after MCA by WASHOUT & FALLOUT

313
App. B

DR'N LEE

CH'D D.L.

APP'D

SCALE = 12

SIMILAR TO

SHEET 47 OF 50

ISSUE

ALLIS-CHALMERS MFG. CO. DEPT.

6-63

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

The source term, Q_0 , must be a rate of activity release. The highest release will be found for each time interval. The method will be to find the MAXIMUM activity of the non-rare gas isotopes at a time within this interval and multiply this by the total release rate constant to obtain a release rate in C/sec.

From addition & inspection of activity vs time tabulations the maximum activities for each interval are found to be

INTERVAL	Time of Max. Activity	MAX. ACTIVITY
0 → 24	24	18,854.0 Curies
24 → 72	24	18,854.0 Curies
72 → 81	72	11,645.4 Curies

During the interval 0 → 24 hrs the leak rate is $3.47 \times 10^{-8} \text{ sec}^{-1}$

$$\therefore Q_0 = 3.47 \times 10^{-8} \text{ sec}^{-1} \times 18,854.0 \text{ C} = 6.54 \times 10^{-4} \text{ C/sec}$$

$$Q_0 = 6.54 \mu\text{C/sec} \quad 0 \rightarrow 24 \text{ hrs}$$

During the interval 24 → 72 hrs, the activity leaks out with a rate constant of $2.37 \times 10^{-8} \text{ sec}^{-1}$ and it leaves the stack after filtering with a rate constant of $6.2 \times 10^{-6} \text{ sec}^{-1}$. The activities must be reduced if they pass through the filters.

$$Q_0 \text{ due to leak} = 2.37 \times 10^{-8} \text{ sec}^{-1} \times 18,854.0 \text{ C} = 4.49 \times 10^{-4} \text{ C/sec}$$

$$Q_0 \text{ due to vent} = \begin{cases} 16,170 \text{ C} \times 0.05 = 808.50 \text{ C} \\ 2,684.0 \text{ C} \times 0.01 = 26.84 \text{ C} \end{cases}$$

$$835.34 \text{ C}$$

$$\text{Vent } Q_0 = 835.34 \text{ C} \times 6.2 \times 10^{-6} \text{ sec}^{-1} = 5.18 \times 10^{-3} \text{ C/sec}$$

$$\text{Total } Q_0 = 4.49 \times 10^{-4} + 5.18 \times 10^{-3} = 5.63 \times 10^{-3} \text{ C/sec} \quad 24 \rightarrow 72 \text{ hr}$$

During the interval 72 → 81 hrs, the activity leaks out with a rate constant of $2.01 \times 10^{-8} \text{ sec}^{-1}$ and it leaves the stack after filtering with a rate constant of $2.63 \times 10^{-6} \text{ sec}^{-1}$.

$$Q_0 \text{ due to leak} = 11,645.4 \text{ C} \times 1.01 \times 10^{-8} \text{ sec}^{-1} = 1.18 \times 10^{-4} \text{ C/sec}$$

$$Q_0 \text{ due to vent} = \begin{cases} 9,794.9 \text{ C} \times 0.05 = 489.75 \text{ C} \\ 1,850.5 \text{ C} \times 0.01 = 18.50 \text{ C} \end{cases}$$

$$508.25 \text{ C}$$

$$\text{Vent } Q_0 = 508.25 \text{ C} \times 2.63 \times 10^{-6} \text{ sec}^{-1} = 1.34 \times 10^{-3} \text{ C/sec}$$

$$\text{Total } Q_0 = 1.18 \times 10^{-4} + 1.34 \times 10^{-3} = 1.46 \times 10^{-3} \text{ C/sec}$$

CONTAMINATION OF LAKE AFTER MCA

313

App. B

SIMILAR TO

DR'N <i>dee</i>	CH'D <i>d.L.</i>	APP'D	SCALE = 12	SHEET 48 OF 50	ISSUE
ALLIS-CHALMERS MFG. CO. DEPT.				6-63	

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

Release Rates can now be calculated & compared

0 → 24 hrs	(@ 24 hrs)	654 $\mu\text{C/sec}$
24 → 72 hrs	(@ 24 hrs)	5630 $\mu\text{C/sec}$
72 → 8/hrs	(@ 72 hrs)	1460 $\mu\text{C/sec}$

It is seen that the absolute maximum rate of activity release occurs 24 hours after the MCA when the venting begins. $Q_0 = 5630 \mu\text{C/sec}$

For Inversion $P = 4.35 \times 10^{-3} Q_0$

$P = 4.35 \times 10^{-3} \times 5630 \mu\text{C/sec} = \frac{24.491}{24.534} \mu\text{C/sec}$ are deposited.

For Lapse $P = 2.22 \times 10^{-3} Q_0$

$P = 2.22 \times 10^{-3} \times 5630 \mu\text{C/sec} = \frac{12.500}{12.521} \mu\text{C/sec}$ are deposited

Now the flow in the lake is $150 \text{ m}^3/\text{sec}$ or $1.5 \times 10^8 \text{ cm}^3/\text{sec}$ or $1.5 \times 10^8 \text{ ml/sec}$. (Ref. "The Melton Hill Project" TVA REPORT No. 36-100-1)

For these rates of deposition & lake flow, the concentration would be:

$\frac{P \mu\text{C/sec}}{\text{Flow rate ml/sec}} = \frac{\frac{24.491}{24.534}}{1.5 \times 10^8} = 16.33 \times 10^{-8} = 1.633 \times 10^{-7} \mu\text{C/ml}$

For inversion conditions and

$\frac{P \mu\text{C/sec}}{\text{Flow rate ml/sec}} = \frac{12.500}{1.5 \times 10^8} = 8.33 \times 10^{-8} \mu\text{C/ml}$

for lapse.

The $(\text{MPC})_w$ for an unknown mixture of Fission products is $10^{-7} \mu\text{C/ml}$.

For Inversion: Concentration exceeds $(\text{MPC})_w$ by factor of 1.633

For Lapse: Concentration ~~exceeds~~ ^{is less than} $(\text{MPC})_w$ by a factor of 0.83

WASHOUT OF FISSION PRODUCTS exceeds slightly the $(\text{MPC})_w$ for Inversion conditions.

CONTAMINATION OF LAKE AFTER MCA

313

App B

SIMILAR TO

DR'N

JEL

CH'D

D.L.

APP'D

SCALE

= 12

SHEET 49 OF 50

ISSUE

ALLIS-CHALMERS MFG. CO.

DEPT.

6-63

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

DRY FALLOUT

$$R_A = \frac{Q \cdot V_g L e^{-\left[\frac{z^2 x^{n-2}}{c_1}\right]}}{\pi c_2 c_3 \bar{u} x^{2-n}}$$

The above equation will govern the fallout due to gravity from a cloud of fission products. Once again an integration must be performed over the area of the lake. This has already been done in calculations for the operational stack release. The result obtained may be used with Q_0 derived for the MCA rather than for the operational stack release:

$$R_A = \frac{2.0 \times 10^{-2} \times 20.5 \times 2.14 \times 10^{-19} Q_0}{\pi \times 0.3 \times 0.033 \times 1.5} = 1.882 \times 10^{-17} Q_0 \quad \text{INVERSION}$$

$$R_A = \frac{2.0 \times 10^{-2} \times 2.95 \times 2.62 \times 10^{-12} Q_0}{\pi \times 0.3 \times 0.3 \times 2.3} = 2.378 \times 10^{-11} Q_0 \quad \text{LAPSE}$$

The maximum release rate is unchanged since source term is unchanged from WASHOUT calculations after MCA.
i.e. $Q_0 = 5630 \mu\text{C/sec}$ @ 24 hrs after the MCA.

FOR INVERSION

$$R_A = 1.882 \times 10^{-17} \times 5630 \mu\text{C/sec} = 1.06 \times 10^{-13} \mu\text{C/sec}$$

FOR LAPSE

$$R_A = 2.378 \times 10^{-11} \times 5630 \mu\text{C/sec} = 1.34 \times 10^{-7} \mu\text{C/sec}$$

$$\text{LAKE FLOW} = 150 \text{ m}^3/\text{sec} = 1.5 \times 10^8 \text{ ml/sec}$$

Concentrations

$$\frac{1.06 \times 10^{-13} \mu\text{C/sec}}{1.5 \times 10^8 \text{ ml/sec}} = 7.07 \times 10^{-22} \mu\text{C/ml for Inversion}$$

$$\frac{1.34 \times 10^{-7} \mu\text{C/sec}}{1.5 \times 10^8 \text{ ml/sec}} = 8.93 \times 10^{-16} \mu\text{C/ml for Lapse}$$

The concentrations are far below the (MPC)_w. For ~~the~~ inversion conditions they are below the (MPC)_w of an unknown mix of fission products by a factor of 7.07×10^{-15} and for lapse conditions they are below (MPC)_w by a factor of 8.93×10^{-9} .

CONTAMINATION OF MELTON HILL LAKE
After MCA by WASHOUT & DRY FALLOUT

313
App. B

SIMILAR TO

DR'N ICC

CH'D J. L.

APP'D

SCALE

=12

SHEET 50 OF 50

ISSUE

ALLIS-CHALMERS MFG. CO.

DEPT.

6-63

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

Dilution Factor For Ground Release Calculation

Method A

From Nuclear Safety, Vol II Number 2, p.56
Atmospheric Dispersion Calculations Using the
Generalized Gaussian Plane Model - by F.A. Gifford Jr.

$$D_b = \frac{1}{c A_1 \bar{u}}$$

$$A_1 = 15,360 \text{ ft}^2 = 1426.9 \text{ m}^2$$

Projected Area of Shell

$c = \text{a constant - Assumed to equal } 1/2 \text{ to be conservative}$

$$\bar{u} = 1.5 \frac{\text{m}}{\text{sec}} \text{ for Inversion}$$

$$\bar{u} = 2.3 \frac{\text{m}}{\text{sec}} \text{ for Lapse}$$

$$D_b = \frac{1}{1/2 (1426.9) (1.5)} = \frac{1}{1070.2}$$

$$D_b = 0.935 \times 10^{-3} \frac{\text{sec}}{\text{m}^3}$$

for Inversion

$$D_b = \frac{1}{1/2 (1426.9) (2.3)} = 0.609 \times 10^{-3}$$

$$D_b = 0.609 \times 10^{-3} \frac{\text{sec}}{\text{m}^3} \text{ for Lapse}$$

Method B

$$D_b = \frac{1}{A_2 \bar{u}}$$

where

$$A_2 = 2\pi r h$$

$A_2 = \text{Area subtended by a } 45^\circ \text{ solid } \angle$

$r = \text{distance from containment shell to control room} = 30 \text{ m}$

$$r^2 = 900 \text{ m}^2$$

$$l = r \cos 45^\circ = 0.707r$$

$$h = r - l = r - 0.707r = 0.293r$$

$$A_2 = 2\pi r (0.293r)$$

$$A_2 = 0.586\pi r^2 = 0.586\pi 900 = 1656 \text{ m}^2$$

For Inversion

$$D_b = \frac{1}{1656 (1.5)} = 0.403 \times 10^{-3} \frac{\text{sec}}{\text{m}^3}$$

For Lapse

$$D_b = \frac{1}{1656 (2.3)} = 0.264 \times 10^{-3} \frac{\text{sec}}{\text{m}^3}$$

Dilution Factor for Ground Release
in Vicinity of Containment Building

313
App C

DR'N SCC

CH'D J. L.

APP'D

SCALE = 12

SIMILAR TO

SHEET 1 OF 21

ISSUE

ALLIS-CHALMERS MFG. CO.

DEPT.

4-63

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

Results from Method A will be used to be conservative.

INVERSION

$$D_i = 0.935 \times 10^{-3} \frac{\text{sec}}{\text{m}^3}$$

LAPSE

$$D_b = 0.609 \times 10^{-3} \frac{\text{sec}}{\text{m}^3}$$

Dilution Factor for Ground
Release in Vicinity of Containment
Building

313

App. C

SIMILAR TO

DR'N JCC

CH'D J.L.

APP'D

SCALE = 12

SHEET 2 OF 21

ISSUE

of ALLIS-CHALMERS MFG. CO.

DEPT.

4-63

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

The worst case in the control room has 5" of ordinary concrete to attenuate the γ 's. For concrete and 0.7 Mev γ 's $\mu_0 = 0.177 \text{ cm}^{-1}$ *

$$r = 5" = 5 \times 2.54 \text{ cm}$$

$$\mu_0 r = 0.177 \times 5 \times 2.54 = 2.25$$

Assuming the cloud of radioactivity acts as an ∞ plane source

$$\alpha = D/D_0 = B_r e^{-\mu_0 r}$$

To Calculate a buildup factor B_r use the exponential approximation

$$B_r = A e^{-\alpha_1 \mu_0 r} + (1-A) e^{-\alpha_2 \mu_0 r} \quad \dagger$$

Since this applies to a point source the B_r obtained should give a conservative answer.

For Concrete and 0.7 Mev γ 's with $\mu_0 r = 2.25$

$$A = 11.5 \quad -\alpha_1 = 0.10, \quad \alpha_2 = 0.015 \quad \ddagger$$

$$B_r = 11.5 e^{+0.225} - 10.5 e^{-0.034}$$

$$B_r = 11.5(1.25) - 10.5(.967) = 4.22$$

$$\therefore \alpha = 4.22 e^{-2.25} = 0.45$$

The Attenuation Factor for the Control Room = 0.45

REFERENCES

* ANL-6000, LECTURE NOTES ON REACTOR SHIELDING - H. Grotenhuis
page 131, March '59

† FUNDAMENTAL ASPECTS OF REACTOR SHIELDING - Goldstein,
(Addison-Wesley Reading, Mass 1959), page 367

‡ Ibid. page 376

Calculation of Control Room
Attenuation Factor

313 ~~XXX~~

App C

SIMILAR TO

DR'N JCC

CH'D ~~XX~~

APP'D

SCALE = 12

SHEET 2a OF 21

ISSUE

ALLIS-CHALMERS MFG. CO.

DEPT.

6-62

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

Note- The floor above the Control Room is 18" thick (concrete). The roof of the control building contains another 5" of concrete. Radiation from the cloud above the building does not provide the worst shielding case.

SKETCH OF CONTROL ROOM WITH
EQUIVALENT WALL THICKNESSES OF
CONCRETE

313 ~~X~~
App C

SIMILAR TO

DR'N JCC

CH'D

J. X.

APP'D

SCALE

= 12

SHEET 3 OF 21

ISSUE

ALLIS-CHALMERS MFG. CO. DEPT.

6-62

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

CALCULATION OF DOSE RATE vs TIME after the MCA

From 0 → 24 hrs after the MCA

Activity in Curies

Isotope	t=0	t=4	t=8	t=12	t=16	t=20	t=24
Sr ⁸⁹	374	408	445	476	509	540	570
Sr ⁹⁰	6.8	11.7	16.8	21.5	26.0	30.5	34.9
Cs ¹³⁷	1428	1433	1439	1443	1450	1453	1457
Ba ¹⁴⁰	54.4	112	170	228	~~276~~ 213	325	366
La ¹⁴⁰	54.4	105	146	182	~~228~~ 213	240	256
I ¹³¹	4420	5226	6000	6861	7600	8280	8704
I ¹³³	3400	4657	5551	6120	6310	6420	6494
I ¹³⁵	1700	2234	~~2271~~ 2130	1945	1650	1290	972
Kr ^{85m}	323	806	~~799~~ 799	578	391	267	162
Xe ¹³³	11,560	17,578	22,800	27,574	32,500	36,800	40,800
Xe ¹³⁵	3,128	6562	~~8347~~ 8347	8126	7720	6950	5950

From 24 → 72 hrs after the MCA

Activity in Curies

Isotope	t=24	t=32	t=40	t=48	t=56	t=64	t=72
Sr ⁸⁹	570	434	385	380	402	439	481
Sr ⁹⁰	34.9	31	31.5	34.7	39.9	~~46.2~~ 46.2	52.7
Cs ¹³⁷	1457	997	777	672	~~630~~ 630	617	614
Ba ¹⁴⁰	366	324	327	357	404	464	528
La ¹⁴⁰	~~256~~ 256	201	180	174	175	175	175
I ¹³¹	8704	6589	6050	6113	6558	~~7211~~ 7211	7864
I ¹³³	6494	4332	3339	2788	2427	2150	1920
I ¹³⁵	972	380	170	82.2	41.3	20.7	10.7
Kr ^{85m}	162	35.7	11.2	3.7	1.2	0.4	0.1
Xe ¹³³	40,800	34,112	32,742	34,204	37,434	40,694	45,591
Xe ¹³⁵	5950	2991	1702	1044	658	401	258

ACTIVITIES AT TIMES 0 TO 72 hrs

313

App. C

SIMILAR TO

DR'N JCC

CH'D *[Signature]*

APP'D

SCALE

=12

SHEET 4 OF 21

ISSUE

of ALLIS-CHALMERS MFG. CO.

DEPT.

5-63

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

FOR CALCULATION OF DOSE RATE VS TIME AFTER THE MCA

Isotope Activity in Curies
time 81 hr

Sr 89	485*
Sr 90	58.5
Cs 137	~~555~~ 566
Ba 140	548.4
La 140	158
I 131	7864*
I 133	1492
I 135	4.4
Kr 85m	0
Xe 133	45,502
Xe 135	141

$$\Sigma A_i = 58,818.9 \text{ c}$$

Activity at 81 hours after MCA

313

App c

SIMILAR TO

DR'N *lsc*

CH'D *lsc*

APP'D

SCALE = 12

SHEET 5 OF 21

ISSUE

y of ALLIS-CHALMERS MFG. CO.

DEPT.

5-63

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

Calculation of Dose Rate due to an Infinite Cloud of Radioactivity Outside Control Room

$$\text{Dose Rate} = D.R. = 2.6 \times 10^{-7} \alpha E_s X_i(t) = 2.6 \times 10^{-7} \alpha E_s D_b Q_i(t)$$

$$D.R. = 2.6 \times 10^{-7} \alpha E_s D_b L_c Q_i(t) \quad \frac{\text{rem}}{\text{sec}}$$

where α is the attenuation factor due to shielding of the control room, E_s is the effective energy per disintegration $E_s = 0.7 \text{ Mev/dis}$ since only γ 's will penetrate to the control room, D_b is the dilution factor for a ground release L_c is the leakage constant which is $0.3\%/day = 3.47 \times 10^{-8} \frac{1}{\text{sec}}$ for the interval $0 \rightarrow 24 \text{ hrs}$ and $0.2049\%/day = 2.37 \times 10^{-8} \frac{1}{\text{sec}}$ for the interval $24 \text{ hrs} \rightarrow 72 \text{ hrs}$. $Q_i(t)$ is the activity due to the i^{th} isotope at time t .

Period $0 \rightarrow 24 \text{ hrs}$

$$D.R. = 2.6 \times 10^{-7} (0.45)(0.7) 3.47 \times 10^{-8} D_b Q_i(t) = 2.842 \times 10^{-15} D_b Q_i(t)$$

$$\text{Inversion } D_b = 0.935 \times 10^{-3} \text{ sec/m}^3$$

$$\text{Lapse } D_b = 0.609 \times 10^{-3} \text{ sec/m}^3$$

D.R. for inversion conditions will yield a more conservative (higher D.R.) Answer

$$D.R. = 2.842 \times 10^{-15} \times 0.935 \times 10^{-3} \frac{\text{sec}}{\text{m}^3} Q_i(t) = 2.66 \times 10^{-18} \frac{\text{sec}}{\text{m}^3} Q_i(t)$$

when $Q_i(t)$ is expressed in μCuries

Since the $Q_i(t)$ are tabulated in curies

$$D.R. = 2.66 \times 10^{-12} Q_i(t) \text{ rem/sec for } Q_i(t) \text{ in Curies}$$

Using the activities for $0 \rightarrow 24 \text{ hrs}$, one obtains D.R.'s of.

DOSE RATE IN CONTROL ROOM ($0 \rightarrow 24 \text{ hrs}$)
For ∞ cloud outside Control Room

313
App c

DR'N	CH'D	APP'D	SCALE = 12	SIMILAR TO	ISSUE
of ALLIS-CHALMERS MFG. CO. DEPT.				SHEET 6 OF 21	
				4-63	

	Dose Rate in 10^{-9} rem/sec						
Isotope	T=0	T=4	T=8	T=12	T=16	T=20	T=24
Si ⁸⁹	0.995	1.085	1.184	1.266	1.354	1.436	1.516
~~Si⁹⁰~~	~~0.018~~	~~0.031~~	~~0.045~~	~~0.057~~	~~0.069~~	~~0.081~~	~~0.092~~
Cs ¹³⁷	3.798	3.812	3.828	3.838	3.857	3.865	3.876
Ba ¹⁴⁰	0.145	0.298	0.452	0.606	0.734	0.865	0.974
La ¹⁴⁰	0.145	0.279	0.388	0.484	~~0.567~~	~~0.638~~	~~0.681~~
I ¹³¹	11.757	13.901	15.960	18.258	20.216	22.025	23.153
I ¹³³	~~10.338~~	12.372	14.766	16.279	16.785	17.077	17.274
I ¹³⁵	~~9.044~~	5.942	6.041	5.174	4.389	3.431	2.586
K ⁸⁵	~~1.478~~	2.144	2.125	1.537	1.040	0.710	0.431
Xe ¹³³	~~30.750~~	46.757	60.648	73.347	86.450	97.888	108.528
Xe ¹³⁵	~~17.352~~	17.455	22.203	21.615	20.535	18.478	15.827
	~~8.320~~						
Σ(DR):	7.97(-8)	1.04(-7)	1.28(-7)	1.42(-7)	1.56(-7)	1.67(-7)	1.75(-7)

This is total dose rate at each time.

$$D.R. \left(\frac{\text{rem}}{\text{sec}} \right) \times 10^3 \left(\frac{\text{mrem}}{\text{rem}} \right) \times 3600 \left(\frac{\text{sec}}{\text{hr}} \right) = 3.6 \times 10^6 \text{ mrem/hr/sec}$$

Time	T=0	T=4	T=8	T=12	T=16	T=20	T=24
DR (mrem/hr)	~~0.287~~	0.374	0.461	0.511	0.562	0.601	0.630
	0.252						

These dose rates may be scaled down for lapse conditions by the ratios of the dilution factors:

$$\frac{0.609 \times 10^{-3}}{0.935 \times 10^{-3}} = 0.651$$

Therefore for Lapse conditions the dose rates are

Time	T=0	T=4	T=8	T=12	T=16	T=20	T=24
(DR) mrem/hr	~~0.167~~	0.243	0.300	0.333	0.366	0.391	0.410
	0.164						

DOSE RATE IN CONTROL ROOM (0-24hrs)
FOR ∞ Cloud OUTSIDE CONTROL ROOM

313
App C

DR'N LCC	CH'D d. L.	APP'D	SCALE =12	SHEET 7 OF 21	ISSUE
of ALLIS-CHALMERS MFG. CO. DEPT.				6-63	

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

Calculation of Dose Rate due to an Infinite Cloud Inside the Control Room.

$D.R. = 2.6 \times 10^{-7} \propto E_s X_i(t)$ Since this cloud is inside the control room $\alpha = 1.0$ and $E_s = E_p + E_f = 1.5 \frac{mc}{dis}$
Leakage rate is again $3.47 \times 10^{-8} \frac{1}{sec}$ for first 24 hours and $2.37 \times 10^{-8} \frac{1}{sec}$ for the next interval. The Diffusion factors will not change

Inside the Control Room $X_{in}(t)$ is given by:

$$\frac{dX_{in}}{dt} = L_b X_{out}(t) - [L_b + \lambda] X_{in}(t)$$

where L_b is the leak rate into the control room.

To be conservative $X_{in}(t)$ will be evaluated at equilibrium i.e., $\frac{dX_{in}}{dt} = 0$ for which

$$X_{in}(t) = \frac{L_b}{L_b + \lambda} X_{out}(t)$$

Since the leak rate is quite low, it would take until after the accident's end to come to equilibrium.

$$X_{out}(t) = D_b L_c A_i(t) = D_b 3.47 \times 10^{-8} A_i(t) \quad (\text{First 24 hrs})$$

for Inversion

$$X_{out}(t) = 3.24 \times 10^{-11} A_i(t)$$

$$\text{and } D_b = 0.935 \times 10^{-3}$$

$$X_{in}(t) = \left[\frac{L_b}{L_b + \lambda} \right] 3.24 \times 10^{-11} A_i(t)$$

$$\text{Now } L_b = 5\% / \text{day} = 5.79 \times 10^{-7} \frac{1}{sec}$$

λ is decay constant for each isotope

$$\therefore D.R. = 2.6 \times 10^{-7} (1.5) X_{in}^i(t) = 3.9 \times 10^{-7} X_{in}^i(t) \quad X_{in}^i(t) \text{ in } \frac{mc}{cm^3}$$

$$D.R. = 3.9 \times 10^{-7} X_{in}^i(t) \text{ if } X_{in}^i(t) \text{ is in } \frac{mc}{cm^3}$$

L_b is the rate constant for leakage into (and also out of) the Control Room.

DOSE RATE IN CONTROL ROOM (0 → 24 hr)
For ∞ cloud inside control room

313

App C

SIMILAR TO

DR'N

JCR

CH'D

D.L.

APP'D

SCALE

=12

SHEET

8

OF 21

ISSUE

of ALLIS-CHALMERS MFG. CO.

DEPT.

4-63

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

Isotope	λ (in sec^{-1})	$\frac{L_b}{\lambda + L_b}$
Sr 89	1.57 (-7)	0.787
Sr 90	7.85 (-10)	1.00
Cs 137	7.58 (-10)	1.00
Ba 140	6.27 (-7)	0.480
La 140	4.8 (-7)	~~0.108~~ 0.108
I 131	9.96 (-7)	0.368
I 133	9.25 (-6)	0.059
I 135	2.87 (-5)	0.020
~~Kr 85m~~	4.38 (-5)	0.013
Xe 133	1.52 (-6)	0.276
Xe 135	2.09 (-6)	0.217

(λ from ORNL CF 62-7-1 T.H. Row page 7)

At $t=0$ INVERSION CONDITIONS				
Isotope	$d_i(0)$ (CURIES)	$X_{out}^i = 3.24(-11) d_i$	$X_{in}^i = \frac{L_b}{L_b + \lambda} X_{out}^i$	Dose Rate = $0.39 X_{in}^i$
Sr 89	374	1.21 (-8)	9.52 (-9)	3.71 (-9)
Sr 90	6.8	2.20 (-10)	2.20 (-10)	8.58 (-11)
Cs 137	1428	4.63 (-8)	4.63 (-8)	1.81 (-8)
Ba 140	54.4	1.76 (-9)	8.45 (-10)	3.30 (-10)
La 140	54.4	1.76 (-9)	1.90 (-10)	0.74 (-10)
I 131	4420	1.43 (-7)	~~5.26~~ 5.26 (-8)	2.05 (-8)
I 133	3879	1.26 (-7)	7.43 (-9)	2.90 (-9)
I 135	1911	6.19 (-8)	1.24 (-9)	0.48 (-9)
Kr 85m	530	1.72 (-8)	2.24 (-10)	0.87 (-10)
Xe 133	13,076	4.24 (-7)	1.17 (-7)	4.56 (-8)
Xe 135	4,230	1.37 (-7)	2.97 (-8)	1.16 (-8)

$$\Sigma(DR)_i = 1.03(-7) \frac{\text{rem}}{\text{hr}}$$

$$D.P. (\text{rem/sec}) \times 3.6 \times 10^6 = DR (\text{m/hr}) = 1.03(-7) 3.6(+6) = 0.371 \text{ m/hr}$$

$$D.R. \text{ at } t=0 \text{ for inversion conditions} = 0.371 \text{ m/hr}$$

Similarly for other times at Inversion Condition It can be noted that $3.24(-11) \times 0.39$ can be factored from each isotope,

DOSE RATE IN CONTROL ROOM
For 00 cloud inside Room

313

App C

SIMILAR TO

DR'N ACE	CH'D	APP'D	SCALE = 12	SHEET 9 OF 21	ISSUE
of ALLIS-CHALMERS MFG. CO. DEPT.				C-63	

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

consequently it will save time if we list the activity of each isotope, multiply by $\frac{L_b}{L_b + \lambda}$, then sum these numbers, multiply this by $0.39 \times 3.24 (-11) = 1.26 (-11)$ to get the dose rate in rem/sec then multiply this # by 3.6×10^6 to get dose rate in mr/hr $\therefore 1.26 (-11) 3.6 (-6) = 4.55 (-5)$ will multiply the summation of $A(t) \frac{L_b}{\lambda + L_b}$ for each time period

$T = 4 \text{ hrs}$

Isotope	$A_i(4)$	$\left(\frac{L_b}{L_b + \lambda}\right) A_i(4)$
Sr^{89}	408	321.90
Sr^{90}	11.7	11.7
Cs^{137}	1433	1433
Ba^{140}	112	53.76
La^{140}	105	11.34
I^{131}	5226	1923.17
I^{133}	4651	274.41
I^{135}	2234	44.68
Kr^{85m}	806	10.48
Xe^{133}	17,578	4,851.53
Xe^{135}	6,562	1,423.95
		<u>1.04 (4)</u>

$$1.04(4) \times 4.55(-5) = 0.473$$

$$\text{D.R. @ } t=4 = 0.473 \text{ mr/hr}$$

$T = 8 \text{ hrs}$

Isotope	$A_i(8)$	$\left(\frac{L_b}{\lambda + L_b}\right) A_i(8)$
Sr^{89}	445	350.22
Sr^{90}	16.8	16.8
Cs^{137}	1439	1439
Ba^{140}	170	81.60
La^{140}	146	15.77
I^{131}	6000	2,208.
I^{133}	5551	327.51
I^{135}	2271	45.42
Kr^{85m}	799	10.39
Xe^{133}	22,800	6,292.80
Xe^{135}	8,347	1811.30
		<u>1.26 (4)</u>

$$1.26(4) \times 4.55(-5) = 0.573$$

$$\text{DR @ } t=8 = 0.573 \text{ mr/hr}$$

Similar calculations for the other times after the MCA will be carried out on the following pages.

Dose Rate in CONTROL ROOM
From ∞ CLOUD INSIDE ROOM

313

App.C

SIMILAR TO

DR'N *CC*

CH'D *D.L.*

APP'D

SCALE = 12

SHEET 10 OF 21

ISSUE

of ALLIS-CHALMERS MFG. CO.

DEPT.

6-63

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

A	B																																																																																										
$T = 12 \text{ hrs}$ <table style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="text-align: left;">Isotope</th> <th style="text-align: right;">$A_i (12)$</th> <th style="text-align: right;">$\left(\frac{L_b}{\lambda + L_b}\right) A_i (12)$</th> </tr> </thead> <tbody> <tr><td>Sr⁸⁹</td><td style="text-align: right;">476</td><td style="text-align: right;">374.61</td></tr> <tr><td>Sr⁹⁰</td><td style="text-align: right;">21.5</td><td style="text-align: right;">21.5</td></tr> <tr><td>Cs¹³⁷</td><td style="text-align: right;">1443</td><td style="text-align: right;">1443</td></tr> <tr><td>Ba¹⁴⁰</td><td style="text-align: right;">228</td><td style="text-align: right;">109.44</td></tr> <tr><td>La¹⁴⁰</td><td style="text-align: right;">182</td><td style="text-align: right;">19.66</td></tr> <tr><td>I¹³¹</td><td style="text-align: right;">6861</td><td style="text-align: right;">2524.85</td></tr> <tr><td>I¹³³</td><td style="text-align: right;">6120</td><td style="text-align: right;">361.08</td></tr> <tr><td>I¹³⁵</td><td style="text-align: right;">1945</td><td style="text-align: right;">38.90</td></tr> <tr><td>Kr^{85m}</td><td style="text-align: right;">578</td><td style="text-align: right;">7.51</td></tr> <tr><td>Xe¹³³</td><td style="text-align: right;">27,574</td><td style="text-align: right;">7,610.42</td></tr> <tr><td>Xe¹³⁵</td><td style="text-align: right;">8126</td><td style="text-align: right;">1763.34</td></tr> <tr> <td></td> <td></td> <td style="text-align: right; border-top: 1px solid black;">1.43(4)</td> </tr> <tr> <td colspan="3" style="text-align: right;">$1.43(4) \times 4.55(-5) = 0.651$</td> </tr> <tr> <td colspan="3" style="text-align: right;">$DR @ t=12 = 0.651 \text{ mR/hr}$</td> </tr> </tbody> </table>	Isotope	$A_i (12)$	$\left(\frac{L_b}{\lambda + L_b}\right) A_i (12)$	Sr ⁸⁹	476	374.61	Sr ⁹⁰	21.5	21.5	Cs ¹³⁷	1443	1443	Ba ¹⁴⁰	228	109.44	La ¹⁴⁰	182	19.66	I ¹³¹	6861	2524.85	I ¹³³	6120	361.08	I ¹³⁵	1945	38.90	Kr ^{85m}	578	7.51	Xe ¹³³	27,574	7,610.42	Xe ¹³⁵	8126	1763.34			1.43(4)	$1.43(4) \times 4.55(-5) = 0.651$			$DR @ t=12 = 0.651 \text{ mR/hr}$			$T = 16 \text{ hrs}$ <table style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="text-align: left;">Isotope</th> <th style="text-align: right;">$A_i (16)$</th> <th style="text-align: right;">$\left(\frac{L_b}{\lambda + L_b}\right) A_i (16)$</th> </tr> </thead> <tbody> <tr><td>Sr⁸⁹</td><td style="text-align: right;">509</td><td style="text-align: right;">400.58</td></tr> <tr><td>Sr⁹⁰</td><td style="text-align: right;">26.0</td><td style="text-align: right;">26.0</td></tr> <tr><td>Cs¹³⁷</td><td style="text-align: right;">1450</td><td style="text-align: right;">1450</td></tr> <tr><td>Ba¹⁴⁰</td><td style="text-align: right;">276</td><td style="text-align: right;">130.48</td></tr> <tr><td>La¹⁴⁰</td><td style="text-align: right;">288</td><td style="text-align: right;">~~23.00~~ 24.84</td></tr> <tr><td>I¹³¹</td><td style="text-align: right;">7608</td><td style="text-align: right;">2796.80</td></tr> <tr><td>I¹³³</td><td style="text-align: right;">6310</td><td style="text-align: right;">372.29</td></tr> <tr><td>I¹³⁵</td><td style="text-align: right;">1656</td><td style="text-align: right;">33.00</td></tr> <tr><td>Kr^{85m}</td><td style="text-align: right;">391</td><td style="text-align: right;">5.08</td></tr> <tr><td>Xe¹³³</td><td style="text-align: right;">32,500</td><td style="text-align: right;">8,970.</td></tr> <tr><td>Xe¹³⁵</td><td style="text-align: right;">7720</td><td style="text-align: right;">1675.24</td></tr> <tr> <td></td> <td></td> <td style="text-align: right; border-top: 1px solid black;">1.59(4)</td> </tr> <tr> <td colspan="3" style="text-align: right;">$1.59(4) \times 4.55(-5) = 0.723$</td> </tr> <tr> <td colspan="3" style="text-align: right;">$DR @ t=16 = 0.723 \text{ mR/hr}$</td> </tr> </tbody> </table>	Isotope	$A_i (16)$	$\left(\frac{L_b}{\lambda + L_b}\right) A_i (16)$	Sr ⁸⁹	509	400.58	Sr ⁹⁰	26.0	26.0	Cs ¹³⁷	1450	1450	Ba ¹⁴⁰	276	130.48	La ¹⁴⁰	288	~~23.00~~ 24.84	I ¹³¹	7608	2796.80	I ¹³³	6310	372.29	I ¹³⁵	1656	33.00	Kr ^{85m}	391	5.08	Xe ¹³³	32,500	8,970.	Xe ¹³⁵	7720	1675.24			1.59(4)	$1.59(4) \times 4.55(-5) = 0.723$			$DR @ t=16 = 0.723 \text{ mR/hr}$		
Isotope	$A_i (12)$	$\left(\frac{L_b}{\lambda + L_b}\right) A_i (12)$																																																																																									
Sr ⁸⁹	476	374.61																																																																																									
Sr ⁹⁰	21.5	21.5																																																																																									
Cs ¹³⁷	1443	1443																																																																																									
Ba ¹⁴⁰	228	109.44																																																																																									
La ¹⁴⁰	182	19.66																																																																																									
I ¹³¹	6861	2524.85																																																																																									
I ¹³³	6120	361.08																																																																																									
I ¹³⁵	1945	38.90																																																																																									
Kr ^{85m}	578	7.51																																																																																									
Xe ¹³³	27,574	7,610.42																																																																																									
Xe ¹³⁵	8126	1763.34																																																																																									
		1.43(4)																																																																																									
$1.43(4) \times 4.55(-5) = 0.651$																																																																																											
$DR @ t=12 = 0.651 \text{ mR/hr}$																																																																																											
Isotope	$A_i (16)$	$\left(\frac{L_b}{\lambda + L_b}\right) A_i (16)$																																																																																									
Sr ⁸⁹	509	400.58																																																																																									
Sr ⁹⁰	26.0	26.0																																																																																									
Cs ¹³⁷	1450	1450																																																																																									
Ba ¹⁴⁰	276	130.48																																																																																									
La ¹⁴⁰	288	~~23.00~~ 24.84																																																																																									
I ¹³¹	7608	2796.80																																																																																									
I ¹³³	6310	372.29																																																																																									
I ¹³⁵	1656	33.00																																																																																									
Kr ^{85m}	391	5.08																																																																																									
Xe ¹³³	32,500	8,970.																																																																																									
Xe ¹³⁵	7720	1675.24																																																																																									
		1.59(4)																																																																																									
$1.59(4) \times 4.55(-5) = 0.723$																																																																																											
$DR @ t=16 = 0.723 \text{ mR/hr}$																																																																																											
$T = 20 \text{ hrs}$ <table style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="text-align: left;">Isotope</th> <th style="text-align: right;">$A_i (20)$</th> <th style="text-align: right;">$\left(\frac{L_b}{\lambda + L_b}\right) A_i (20)$</th> </tr> </thead> <tbody> <tr><td>Sr⁸⁹</td><td style="text-align: right;">540</td><td style="text-align: right;">424.98</td></tr> <tr><td>Sr⁹⁰</td><td style="text-align: right;">30.5</td><td style="text-align: right;">30.5</td></tr> <tr><td>Cs¹³⁷</td><td style="text-align: right;">1453</td><td style="text-align: right;">1453</td></tr> <tr><td>Ba¹⁴⁰</td><td style="text-align: right;">325</td><td style="text-align: right;">156</td></tr> <tr><td>La¹⁴⁰</td><td style="text-align: right;">240</td><td style="text-align: right;">~~25.93~~ 24.32</td></tr> <tr><td>I¹³¹</td><td style="text-align: right;">8286</td><td style="text-align: right;">3,047.04</td></tr> <tr><td>I¹³³</td><td style="text-align: right;">6428</td><td style="text-align: right;">378.78</td></tr> <tr><td>I¹³⁵</td><td style="text-align: right;">1298</td><td style="text-align: right;">25.80</td></tr> <tr><td>Kr^{85m}</td><td style="text-align: right;">267</td><td style="text-align: right;">3.47</td></tr> <tr><td>Xe¹³³</td><td style="text-align: right;">36,800</td><td style="text-align: right;">10,156.80</td></tr> <tr><td>Xe¹³⁵</td><td style="text-align: right;">6950</td><td style="text-align: right;">1,508.15</td></tr> <tr> <td></td> <td></td> <td style="text-align: right; border-top: 1px solid black;">1.72(4)</td> </tr> <tr> <td colspan="3" style="text-align: right;">$1.72(4) \times 4.55(-5) = 0.783$</td> </tr> <tr> <td colspan="3" style="text-align: right;">$DR @ t=20 \text{ hr} = 0.783 \text{ mR/hr}$</td> </tr> </tbody> </table>	Isotope	$A_i (20)$	$\left(\frac{L_b}{\lambda + L_b}\right) A_i (20)$	Sr ⁸⁹	540	424.98	Sr ⁹⁰	30.5	30.5	Cs ¹³⁷	1453	1453	Ba ¹⁴⁰	325	156	La ¹⁴⁰	240	~~25.93~~ 24.32	I ¹³¹	8286	3,047.04	I ¹³³	6428	378.78	I ¹³⁵	1298	25.80	Kr ^{85m}	267	3.47	Xe ¹³³	36,800	10,156.80	Xe ¹³⁵	6950	1,508.15			1.72(4)	$1.72(4) \times 4.55(-5) = 0.783$			$DR @ t=20 \text{ hr} = 0.783 \text{ mR/hr}$			$T = 24 \text{ hrs}$ <table style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="text-align: left;">Isotope</th> <th style="text-align: right;">$A_i (24)$</th> <th style="text-align: right;">$\left(\frac{L_b}{\lambda + L_b}\right) A_i (24)$</th> </tr> </thead> <tbody> <tr><td>Sr⁸⁹</td><td style="text-align: right;">570</td><td style="text-align: right;">448.59</td></tr> <tr><td>Sr⁹⁰</td><td style="text-align: right;">34.9</td><td style="text-align: right;">34.9</td></tr> <tr><td>Cs¹³⁷</td><td style="text-align: right;">1457</td><td style="text-align: right;">1457</td></tr> <tr><td>Ba¹⁴⁰</td><td style="text-align: right;">366</td><td style="text-align: right;">175.68</td></tr> <tr><td>La¹⁴⁰</td><td style="text-align: right;">256</td><td style="text-align: right;">~~27.65~~ 24.45</td></tr> <tr><td>I¹³¹</td><td style="text-align: right;">8704</td><td style="text-align: right;">3203.07</td></tr> <tr><td>I¹³³</td><td style="text-align: right;">6494</td><td style="text-align: right;">383.15</td></tr> <tr><td>I¹³⁵</td><td style="text-align: right;">972</td><td style="text-align: right;">19.44</td></tr> <tr><td>Kr^{85m}</td><td style="text-align: right;">162</td><td style="text-align: right;">2.11</td></tr> <tr><td>Xe¹³³</td><td style="text-align: right;">40,800</td><td style="text-align: right;">11,260.80</td></tr> <tr><td>Xe¹³⁵</td><td style="text-align: right;">5950</td><td style="text-align: right;">1291.15</td></tr> <tr> <td></td> <td></td> <td style="text-align: right; border-top: 1px solid black;">1.83(4)</td> </tr> <tr> <td colspan="3" style="text-align: right;">$1.83(4) \times 4.55(-5) = 0.833$</td> </tr> <tr> <td colspan="3" style="text-align: right;">$DR @ t=24 \text{ hr} = 0.833 \text{ mR/hr}$</td> </tr> </tbody> </table>	Isotope	$A_i (24)$	$\left(\frac{L_b}{\lambda + L_b}\right) A_i (24)$	Sr ⁸⁹	570	448.59	Sr ⁹⁰	34.9	34.9	Cs ¹³⁷	1457	1457	Ba ¹⁴⁰	366	175.68	La ¹⁴⁰	256	~~27.65~~ 24.45	I ¹³¹	8704	3203.07	I ¹³³	6494	383.15	I ¹³⁵	972	19.44	Kr ^{85m}	162	2.11	Xe ¹³³	40,800	11,260.80	Xe ¹³⁵	5950	1291.15			1.83(4)	$1.83(4) \times 4.55(-5) = 0.833$			$DR @ t=24 \text{ hr} = 0.833 \text{ mR/hr}$		
Isotope	$A_i (20)$	$\left(\frac{L_b}{\lambda + L_b}\right) A_i (20)$																																																																																									
Sr ⁸⁹	540	424.98																																																																																									
Sr ⁹⁰	30.5	30.5																																																																																									
Cs ¹³⁷	1453	1453																																																																																									
Ba ¹⁴⁰	325	156																																																																																									
La ¹⁴⁰	240	~~25.93~~ 24.32																																																																																									
I ¹³¹	8286	3,047.04																																																																																									
I ¹³³	6428	378.78																																																																																									
I ¹³⁵	1298	25.80																																																																																									
Kr ^{85m}	267	3.47																																																																																									
Xe ¹³³	36,800	10,156.80																																																																																									
Xe ¹³⁵	6950	1,508.15																																																																																									
		1.72(4)																																																																																									
$1.72(4) \times 4.55(-5) = 0.783$																																																																																											
$DR @ t=20 \text{ hr} = 0.783 \text{ mR/hr}$																																																																																											
Isotope	$A_i (24)$	$\left(\frac{L_b}{\lambda + L_b}\right) A_i (24)$																																																																																									
Sr ⁸⁹	570	448.59																																																																																									
Sr ⁹⁰	34.9	34.9																																																																																									
Cs ¹³⁷	1457	1457																																																																																									
Ba ¹⁴⁰	366	175.68																																																																																									
La ¹⁴⁰	256	~~27.65~~ 24.45																																																																																									
I ¹³¹	8704	3203.07																																																																																									
I ¹³³	6494	383.15																																																																																									
I ¹³⁵	972	19.44																																																																																									
Kr ^{85m}	162	2.11																																																																																									
Xe ¹³³	40,800	11,260.80																																																																																									
Xe ¹³⁵	5950	1291.15																																																																																									
		1.83(4)																																																																																									
$1.83(4) \times 4.55(-5) = 0.833$																																																																																											
$DR @ t=24 \text{ hr} = 0.833 \text{ mR/hr}$																																																																																											
Dose Rate in Control Room (From CO cloud in Room)		313 App. C																																																																																									
DR'N <i>dcc</i> CH'D <i>D.F.</i> APP'D SCALE = 12		SIMILAR TO																																																																																									
of ALLIS-CHALMERS MFG. CO. DEPT.		SHEET <i>11</i> OF <i>21</i> <i>6-63</i>																																																																																									

The Dose Rate in the Control Room can now be summarized. It would be made up of the dose rates from the cloud outside the room and the cloud inside the room. For INVERSION conditions 0 → 24 hrs.

TIME	(D.R.) ^{cloud outside}	+	(D.R.) ^{cloud inside}	=	TOTAL (D.R.)
0	~~0.285~~ 0.252	+	0.371	=	~~0.658~~ 0.623 m/hr
4	0.374	+	0.473	=	0.847 "
8	0.461	+	0.578	=	1.039 "
12	0.511	+	0.651	=	1.162 "
16	0.562	+	0.723	=	1.285 "
20	0.601	+	0.783	=	1.384 "
24	0.636	+	0.833	=	1.469 "

FOR LAPSE Conditions The D.R. MAY BE scaled Down by the ratio of the dilution factors for inversion and lapse:

$$\frac{0.609 \times 10^{-3}}{0.935 \times 10^{-3}} = 0.651$$

FOR LAPSE CONDITIONS The Dose Rates 0 → 24 hrs are:

TIME	(D.R.) ^{cloud outside}	+	(D.R.) ^{cloud inside}	=	TOTAL (D.R.)
0	~~0.404~~ 0.252	+	0.242	=	~~0.646~~ 0.494 m/hr
4	0.243	+	0.308	=	0.551 "
8	0.300	+	0.378	=	0.678 "
12	0.333	+	0.424	=	0.757 "
16	0.366	+	0.471	=	0.837 "
20	0.391	+	~~0.510~~ 0.497	=	~~0.901~~ 0.888 "
24	0.410	+	0.542	=	0.952 "

DOSE RATE IN CONTROL ROOM
From both clouds - SUMMARY
LAPSE & INVERSION

313

App. C

SIMILAR TO

DR'N *[Signature]*

CH'D *[Signature]*

APP'D

SCALE

= 12

SHEET

12 OF 21

ISSUE

of ALLIS-CHALMERS MFG. CO.

DEPT.

6-63

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

PERIOD 24 → 72 hr after MCA

CLOUD OUTSIDE

$$DR = 2.6 \times 10^{-7} (0.45) (0.7) 2.37 \times 10^{-8} D_b A_i(t) = 1.95 \times 10^{-15} D_b A_i(t)$$

$$\text{INVERSION } D_b = 0.935 \times 10^{-3} \text{ sec/m}^3$$

$$\text{LAPSE } D_b = 0.609 \times 10^{-3} \text{ sec/m}^3$$

FOR INVERSION CONDITIONS

$$DR = 1.95 \times 10^{-15} \times 0.935 \times 10^{-3} A_i(t) = 1.82 \times 10^{-18} \frac{\text{sec}}{\text{m}^3} A_i(t)$$

for A_i in μC DR in rem/sec

$$DR (\text{rem/sec}) = 1.82 \times 10^{-12} A_i(t) \text{ for } A_i(t) \text{ in } \mu\text{C}$$

USING ACTIVITIES Supplied in ORNL CF C2-7-1 Dose Rates obtained are

D.R. in 10^{-9} rem/sec

Isotope	T=32	T=40	T=48	T=56	T=64	T=72
Sr^{90}	0.79	0.70	0.69	0.73	0.80	0.88
Sr^{90}	0.06	0.06	0.06	0.07	0.08	0.10
Cs^{137}	1.81	1.41	1.22	1.15	1.12	1.12
Ba^{140}	0.59	0.60	0.65	0.74	0.84	0.96
La^{140}	0.37	0.33	0.32	0.32	0.32	0.32
I^{131}	11.99	11.01	11.13	11.94	13.12	14.31
I^{133}	7.88	6.08	5.07	4.42	3.91	3.49
I^{135}	0.69	0.31	0.15	0.08	0.04	0.02
Kr^{85}	0.06	0.02	0.01	—	—	—
Xe^{133}	62.08	59.60	62.25	68.13	75.88	82.98
Xe^{135}	5.44	3.10	1.90	1.20	0.73	0.47

$$\Sigma(DR): 0.918(-7) \quad 0.832(-7) \quad 0.834(-7) \quad 0.887(-7) \quad 0.968(-7) \quad 1.045(-7)$$

$$\text{TOTAL DR} = \Sigma(DR): (DR) \text{ rem/sec} \times 3.6 \times 10^6 = (DR) \text{ mrem/hr}$$

TIME	T=32	T=40	T=48	T=56	T=64	T=72
D.R. ($\frac{\text{MR}}{\text{HR}}$)	0.330	0.300	0.300	0.320	0.348	0.376

Now for the period 24 → 72 hrs, the leak rate constant from the containment building is assumed to be $2.37 \times 10^{-8} \text{ sec}^{-1}$.

DOSE RATES IN CONTROL ROOM
From cloud outside Room

313

App C

SIMILAR TO

DR'N JCR

CH'D J.P.

APP'D

SCALE = 12

SHEET 13 OF 21

ISSUE

of ALLIS-CHALMERS MFG. CO.

DEPT.

6-63

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

$$X_{out}(t) = D_b 2.37 \times 10^{-8} A_i(t) = 2.21 \times 10^{-11} A_i(t)$$

for inversion conditions

$$X_{in}(t) = \left(\frac{L_b}{L_b + \lambda} \right) 2.21 \times 10^{-11} A_i(t)$$

Assuming a constant L_b .

As before we can factor out the coefficient common to each isotope. $2.21 \times 10^{-11} \times 0.39 \times 3.6 \times 10^6 = 3.10 \times 10^{-5}$

By multiplying this 3.10×10^{-5} by $A_i(t) \left(\frac{L_b}{L_b + \lambda} \right)$ the dose rate in mr/hr is obtained as in the 0 → 24 hr period

TIME = 32 hrs

Isotope	$A_i(32)$	$A_i(32) \left(\frac{L_b}{L_b + \lambda} \right)$
Sr 89	434	342
Sr 90	31	31
Cs 137	997	997
Ba 140	324	156
La 140	201	22
I 131	6589	2425
I 133	4332	256
I 135	380	8
Kr 85m	35,7	—
Xe 133	34,112	9415
Xe 135	2,991	649

1.43×10^4

$$3.10(-5) \times 1.43(4) = 0.444$$

$$DR @ 32 \text{ hrs} = 0.444 \text{ mr/hr}$$

TIME = 40 hrs

Isotope	$A_i(40)$	$A_i(40) \left(\frac{L_b}{L_b + \lambda} \right)$
Sr 89	385	303
Sr 90	31.5	31.5
Cs 137	777	777
Ba 140	327	157
La 140	180	19
I 131	6052	2227
I 133	3339	197
I 135	170	3
Kr 85m	11.2	—
Xe 133	32,742	9038
Xe 135	1702	369

1.31×10^4

$$3.10(-5) \times 1.31(4) = 0.406$$

$$DR @ 40 \text{ hrs} = 0.406 \text{ mr/hr}$$

DOSE RATES IN CONTROL ROOM
(From CO Cloud ~~INSIDE~~ INSIDE ROOM)

313

App. C

SIMILAR TO

DR'N *dce* CH'D *d. l.* APP'D SCALE = 12 SHEET *14* OF 21 ISSUE

of ALLIS-CHALMERS MFG. CO. DEPT.

6-63

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

A			B			C		
TIME = 48 hrs						Time = 56 hrs		
Isotope	$A_i(48)$	$A_i(48) \left(\frac{L_b}{L_b + \lambda} \right)$	Isotope	$A_i(56)$	$A_i(56) \left(\frac{L_b}{L_b + \lambda} \right)$	Isotope	$A_i(56)$	$A_i(56) \left(\frac{L_b}{L_b + \lambda} \right)$
Sr ⁸⁹	380	299	Sr ⁸⁹	402	316	Sr ⁸⁹	402	316
Sr ⁹⁰	34.7	34.7	Sr ⁹⁰	39.9	39.9	Sr ⁹⁰	39.9	39.9
Cs ¹³⁷	672	672	Cs ¹³⁷	630	630	Cs ¹³⁷	630	630
Ba ¹⁴⁰	357	171	Ba ¹⁴⁰	404	194	Ba ¹⁴⁰	404	194
La ¹⁴⁰	174	19	La ¹⁴⁰	175	19	La ¹⁴⁰	175	19
I ¹³¹	6113	2250	I ¹³¹	6558	2413	I ¹³¹	6558	2413
I ¹³³	2788	164	I ¹³³	2427	143	I ¹³³	2427	143
I ¹³⁵	82.2	2	I ¹³⁵	41.3	1	I ¹³⁵	41.3	1
Kr ^{85m}	3.7	—	Kr ^{85m}	1.2	—	Kr ^{85m}	1.2	—
Xe ¹³³	34,204	9,440	Xe ¹³³	37,434	10,332	Xe ¹³³	37,434	10,332
Xe ¹³⁵	1044	227	Xe ¹³⁵	658	143	Xe ¹³⁵	658	143
		1.33(4)			1.42(4)			1.42(4)
$3.10(-5) \times 1.33(4) = 0.412$			$3.10(-5) \times 1.42(4) = 0.440$			$3.10(-5) \times 1.42(4) = 0.440$		
DR = 0.412 m/hr			DR = 0.440 m/hr			DR = 0.440 m/hr		

TIME = 64 hrs			TIME = 72 hrs		
Isotope	$A_i(64)$	$A_i(64) \left[\frac{L_b}{L_b + \lambda} \right]$	Isotope	$A_i(72)$	$A_i(72) \left(\frac{L_b}{L_b + \lambda} \right)$
Sr ⁸⁹	439	345	Sr ⁸⁹	481	379
Sr ⁹⁰	46.2	46.2	Sr ⁹⁰	52.7	52.7
Cs ¹³⁷	617	617	Cs ¹³⁷	614	614
Ba ¹⁴⁰	464	223	Ba ¹⁴⁰	528	253
La ¹⁴⁰	175	19	La ¹⁴⁰	175	19
I ¹³¹	7211	2654	I ¹³¹	7864	2894
I ¹³³	2188	127	I ¹³³	1920	113
I ¹³⁵	20.7	—	I ¹³⁵	10.7	—
Kr ^{85m}	0.4	—	Kr ^{85m}	0.1	—
Xe ¹³³	41,694	11,508	Xe ¹³³	45,591	12,583
Xe ¹³⁵	401	87	Xe ¹³⁵	258	56
		1.56(4)			1.70(4)
$3.10(-5) \times 1.56(4) = 0.484$			$3.10(-5) \times 1.70(4) = 0.527$		
DR _i = 0.484 m/hr			DR _i = 0.527 m/hr		

DOSE Rates in CONTROL ROOM
From ∞ cloud inside ROOM.

313

App. C

SIMILAR TO

DR'N <i>Lee</i>	CH'D <i>D.L.</i>	APP'D	SCALE = 12	SHEET 15 OF 21	ISSUE
v of ALLIS-CHALMERS MFG. CO. DEPT.				6-62	

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

A   B   C

DOSE IN CONTROL ROOM 24⁺→72 Hrs after MCA

INVERSION

TIME	DR (cloud outside)	+	D.R. (cloud inside)	=	Total D.R.
32	0.330	+	0.444	=	0.774 m/hr
40	0.300	+	0.406	=	0.706 "
48	0.300	+	0.412	=	0.712 "
56	0.320	+	0.440	=	0.760 "
64	0.348	+	0.484	=	0.832 "
72	0.376	+	0.527	=	0.903 "

For LAPSE conditions the above doses may be scaled down by a factor ~~of~~ which is the ratio of the dilution factors for inversion & lapse:

$$\frac{0.609 \times 10^{-3}}{0.935 \times 10^{-3}} = 0.651$$

LAPSE

TIME	DR (cloud outside)	+	D.R. (cloud inside)	=	TOTAL D.R.
32	0.215	+	0.283	=	~~0.504~~ 0.498 m/hr
40	0.195	+	0.264	=	~~0.460~~ 0.459 "
48	0.196	+	0.268	=	0.464 "
56	0.208	+	0.286	=	0.495 "
64	0.227	+	0.315	=	0.542 "
72	~~0.254~~ 0.245	+	0.343	=	~~0.597~~ 0.588 "

DOSE Rates IN CONTROL ROOM
SUMMARY for 24⁺→72hr INVERSION & LAPSE

313

App. C

SIMILAR TO

DR'N <i>JCR</i>	CH'D <i>J.L.</i>	APP'D	SCALE = 12	SHEET 16 OF 21	ISSUE
of ALLIS-CHALMERS MFG. CO. DEPT.				6-63	

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

PERIOD 72⁺ → 81 hr after MCA

The decay rate constant for this time period was assumed to be $1.01 \times 10^{-8} \text{ sec}^{-1}$

$$D.R. = 2.6 \times 10^{-7} (0.45)(0.7) 1.01 \times 10^{-8} D_b A_i(t) = 8.27 \times 10^{-16} D_b \times 10^{-16} A_i(t)$$

FOR INVERSION CONDITIONS

$$D.R. = 8.31 \times 10^{-16} \times 0.935 \times 10^{-3} A_i(t) = 7.76 \times 10^{-19} \frac{\text{rem}}{\text{sec}} A_i(t)$$

for $A_i(t)$ in MC DR is in Rem/sec
 $D.R. = 7.76 \times 10^{-13} A_i(t)$ for $A_i(t)$ in curies

~~XXXXX~~ Activities supplied in ORNL CF 62-7-1 ~~XXXXX~~

The Activities for the isotopes @ $t = 81 \text{ hr}$ may be summed. $\Sigma q_i(81) = 56,818.9 \text{ Curies} = 5.682 \times 10^4 \text{ Curies}$

$$(DR)_{\text{outside}}^{\text{cloud}} = 7.76 \times 10^{-13} \times 5.682 \times 10^4 = 4.39 \times 10^{-8} \text{ rem/sec}$$

$$4.39 \times 10^{-8} \text{ rem/sec} \times 3.6 \times 10^6 = 0.158 \text{ mr/hr for inversion conditions}$$

This may be scaled down for lapse conditions by the factor 0.651 as before

$$(DR)_{\text{outside}}^{\text{cloud}} = 4.39 \times 10^{-8} \times 3.6 \times 10^6 \times 0.651 = 0.103 \text{ mr/hr for Lapse}$$

D.R. from cloud INSIDE ROOM

$$X_{\text{out}}(t) = D_b L A_i(t) = 0.935 \times 10^{-3} \times 1.01 \times 10^{-8} A_i(t) = 0.944 \times 10^{-11} A_i(t)$$

for INVERSION CONDITIONS

$$X_{\text{in}}(t) = \left(\frac{L_b}{L_b + \lambda} \right) 0.944 \times 10^{-11} A_i(t)$$

Isotope $q_i(81)$ $\left(\frac{L_b}{L_b + \lambda} \right) q_i(81)$

Sr 89	486	382
Sr 90	58.5	58.5
Cs 137	566	566
Ba 140	546	262
La 140	158	17.1
I 131	7864	2894
I 133	1492	843
I 135	4.4	—
Kr 85m	0	—
Xe 133	45,502	12,559
Xe 135	141	30.1
		<u>1.69 x 10⁴</u>

$$X_{\text{in}}(81) = 0.944 \times 10^{-11} \times 1.69 \times 10^4 = 1.60 \times 10^{-7}$$

$$\text{Dose} = 0.39 X_{\text{in}} = 0.39 \times 1.60 (-7) = 6.22 \times 10^{-8} \frac{\text{rem}}{\text{sec}}$$

$$6.22 \times 10^{-8} \frac{\text{rem}}{\text{sec}} \times 3.6 \times 10^6 = 2.24 \times 10^{-1} \text{ mr/hr}$$

DR @ $t = 81 \text{ hr}$ From clouds outside out-side of control room = 0.224 mr/hr

DOSE RATE IN CONTROL ROOM
 72⁺ → 81 hrs after MCA

313

App C

SIMILAR TO

DR'N dcc

CH'D d.L.

APP'D

SCALE

=12

SHEET 17 OF 21

ISSUE

of ALLIS-CHALMERS MFG. CO.

DEPT.

6-63

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

Inversion

For lapse these doses may be scaled down by the factor of 0.651.

These doses to control room personnel are calculated using a source term of radioactivity due to a ground level leak from the containment shell. The radioactivity expelled by venting from the 61m stack is not considered this close to the stack.

3/3

App. C

SIMILAR TO

DR'N

✓

CH'D

L. L.

APP'D

SCALE

= 12

SHEET

3 OF 2

ISSUE

of ALLIS-CHALMERS MFG. CO.

DEPT.

6-63

The concentration inside the control room is given as

$$X_{i, in} = \left(\frac{L_b}{L_b + \lambda_i} \right) D_b L_c A_i(t) \quad (p. 8)$$

and the intake over an interval $\tau_2 - \tau_1$ is

$$I_i = (B.R.) X_{i, in} (\text{time})$$

$$I_i = \left(\frac{L_b}{L_b + \lambda_i} \right) (B.R.) D_b L_c \int_{\tau_1}^{\tau_2} A_i(t) dt$$

and the dose is

$$D_i = S_i I_i, \text{ rem.}$$

Thyroid dose

A. Inversion conditions

Then

$$B.R. = 3.5 \times 10^{-4} \text{ m}^3/\text{sec.}$$

$$D_b = 0.935 \times 10^{-3} \text{ sec}/\text{m}^3$$

and for $\tau_1 = 0$, $\tau_2 = 24 \text{ hr.}$ $L_c = 3.47 \times 10^{-8} \text{ sec}^{-1}$

$$D_i = (3.5 \times 10^{-4}) (0.935 \times 10^{-3}) (3.47 \times 10^{-8}) \left(\frac{L_b}{L_b + \lambda_i} \right) S_i \int_0^{24} A_i(t) dt$$

$$= 1.14 \times 10^{-14} \left(\frac{L_b}{L_b + \lambda_i} \right) S_i \int_0^{24} A_i(t) dt$$

$$\text{Isotope} \quad \frac{L_b}{L_b + \lambda_i} \text{ (p. 9)} \quad S_i \text{ (u)} \quad \int_0^{24} A_i(t) dt \text{ (mc-sec)} \quad D_i \text{ (rem.)}$$

I^{131}	0.368	1.488	5.83 (14)	3.6893
I^{133}	0.059	0.400	4.92 (14)	0.1334
I^{135}	0.020	0.124	1.56 (14)	0.0044
				<u>3.7761</u>

(a) App. A-II

(b) App. A-II, Figs 13, 14, & 15.

Thyroid & Bone Dose to Control Room
Personnel Following MCA

313

App. C

SIMILAR TO

DR'N <i>D. S.</i>	CH'D <i>D. S.</i>	APP'D	SCALE = 12	SHEET 19 OF 21	ISSUE
ALLIS-CHALMERS MFG. CO. DEPT.				6-63	

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

and for $\tau = 24$ to $\tau = 72$, $L_c = 2.37 \times 10^{-8} \text{ sec}^{-1}$

$$D_i = 7.76 \times 10^{-15} \left(\frac{L_b}{L_b + \lambda_i} \right) S_i \int_{24}^{72} A_i(t) dt$$

Isotope	$\frac{L_b}{L_b + \lambda_i}$	S_i	$\int_{24}^{72} A_i(t) dt$ (a)	D_i
I^{131}	0.368	1.488	1.16(15)	4.9291
I^{133}	0.059	0.400	0.557(15)	0.1020
I^{135}	0.020	0.124	0.0321(15)	0.0006

$$\sum D_i = 5.0317$$

and for $\tau = 72$ to $\tau = 81$, $L_c = 1.01 \times 10^{-8} \text{ sec}^{-1}$

$$D_i = 3.31 \times 10^{-15} \left(\frac{L_b}{L_b + \lambda_i} \right) S_i \int_{72}^{81} A_i(t) dt$$

Isotope	$\frac{L_b}{L_b + \lambda_i}$	S_i	$\int_{72}^{81} A_i(t) dt$ (a)	D_i
I^{131}	0.368	1.488	0.262(15)	0.4749
I^{133}	0.059	0.400	0.0536(15)	0.0042
I^{135}	0.020	0.124	1.73(11)	—

$$\sum D_i = 0.4821$$

$$\begin{aligned} D_{TOTAL} &= D_{0-24} + D_{24-72} + D_{72-81} \\ &= 3.7761 + 5.0317 + 0.4821 \\ &= 9.29 \text{ rem} \end{aligned}$$

B. Laguer condition

since $D \propto D_b$

$$D_{Laguer} = \frac{D_b(\text{Laguer})}{D_b(\text{inversion})} D_{inversion}$$

$$D_{Laguer} = \frac{0.609 \times 10^{-3}}{0.935 \times 10^{-3}} \times 9.29 = 6.05 \text{ rem}$$

(a) App A-II, Figs 24, 25, and 26

Thyroid & Bone dose to Control Room
Personnel Following M.C.A.

313
App C

SIMILAR TO

DR'N	D.Y.	CH'D	D.Y.	APP'D	SCALE	=12	SHEET 20 OF 21	ISSUE
ALLIS-CHALMERS MFG. CO. DEPT.							6-63	

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

Bone Dose - Inversion

0-24 hr.

$$D_i = 1.14 \times 10^{-14} \left(\frac{L_b}{L_b + \lambda_i} \right) S_i (bone) \int_0^{24} A_i(t) dt$$

Isotope	$\frac{L_b}{L_b + \lambda_i}$ (p.9)	S_i	$\int_0^{24} A_i(t) dt$	D_i
SR^{89}	0.787	0.42	0.408 (14)	0.1537
SR^{90}	1.0	44.65	0.0178 (14)	0.9060
CS^{137}	1.0	0.06	1.25 (14)	0.0855
BA^{140}	0.480	0.09	0.189 (14)	0.0093
LA^{140}	0.108	0.005	0.151 (14)	0.0001

$$\sum D_i = 1.1546$$

24-72 hr.

$$D_i = 7.76 \times 10^{-15} \left(\frac{L_b}{L_b + \lambda_i} \right) S_i \int_{24}^{72} A_i(t) dt$$

Isotope	$\frac{L_b}{L_b + \lambda_i}$	S_i	$\int_{24}^{72} A_i(t) dt$	D_i
SR^{89}	0.787	0.42	0.0729 (15)	0.1870
SR^{90}	1.0	44.65	0.0066 (15)	2.2868
CS^{137}	1.0	0.06	0.1360 (15)	0.0633
BA^{140}	0.480	0.09	0.0660 (15)	0.0221
LA^{140}	0.108	0.005	0.0324 (15)	0.0001

$$\sum D_i = 2.5593$$

72-81 hr.

$$D_i = 3.31 \times 10^{-15} \left(\frac{L_b}{L_b + \lambda_i} \right) S_i \int_{72}^{81} A_i(t) dt$$

Isotope	$\frac{L_b}{L_b + \lambda_i}$	S_i	$\int_{72}^{81} A_i(t) dt$	D_i
SR^{89}	0.787	0.42	0.0158 (16)	0.0173
SR^{90}	1.0	44.65	0.0019 (15)	0.2808
CS^{137}	1.0	0.06	0.0191 (15)	0.0038
BA^{140}	0.480	0.09	0.0176 (15)	0.0025
LA^{140}	0.108	0.005	0.0055 (15)	

$$\sum D_i = 0.3044$$

$$D_{TOTAL} = 1.1546 + 2.5593 + 0.3044$$

$$= 4.0183 \text{ rem} = 4.02 \text{ rem}$$

and for the lapse condition

a App A-III $D_{TOTAL} = \frac{0.609 \times 10^{-5}}{0.935 \times 10^{-2}} \times 4.0183 = 2.62 \text{ rem}$

b App A-II, Figs 8-12

c App A-V, Figs 19-23

Hybrid & Bone dose to Control Room
Personnel Following the MCA

313

App. C

SIMILAR TO

DR'N D.L.

CH'D D.L.

APP'D

SCALE = 12

SHEET 21 OF 21

ISSUE

ALLIS-CHALMERS MFG. CO.

DEPT.

6-63

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

A

B

C

Appendix D

EVALUATION of Radiological Hazards
to the Public from Normal Operation
of EGCR

2

2

3

3

4

4

				3/3 App D	
				SIMILAR TO	
DR'N	CH'D	APP'D	SCALE = 12	SHEET OF	ISSUE
ALLIS-CHALMERS MFG. CO.			DEPT.		

A

B

It is assumed that A^{41} is the only significant isotope formed from a standpoint of stack releases

I Data

$$P_{\text{air}} = 0.08071 \text{ lb/ft}^3$$

$$P_A = 0.11135 \text{ lb/ft}^3$$

$$f_A = 0.0094 \text{ by Vol (ft}^3 A / \text{ft}^3 \text{ air)}$$

$$\gamma = 99.6\% , \text{ isotopic abundance of } A^{40}$$

$$\sigma_a = 0.53 \text{ barns}$$

II Macroscopic cross section of A^{40} , Σ

$$\Sigma = \frac{\gamma f_w \bar{P}_a N_A \sigma_a}{A} , \text{ cm}^{-1}$$

where

$$f_w = \text{Wt. fraction of A in air}$$

$$\bar{P}_a = \text{Av. density of air in vault}$$

$$N_A = \text{Avogadro's Number}$$

$$A = \text{Atomic wt. of } A^{40}$$

$$f_w = \frac{P_A f_A}{P_{\text{air}}} = \frac{0.11135 \times 0.0094}{0.08071} = 0.013$$

$$\bar{P}_a = 0.065 \text{ lb/ft}^3 = 0.00104 \text{ g/cc (Design Data, Rev. 4 p. H0V.3)}$$

$$\Sigma = \frac{(0.996)(0.013)(0.00104)(0.6023 \times 10^{24})(0.53 \times 10^{-24})}{40}$$

$$\Sigma = 1.07 \times 10^{-7} \text{ cm}^{-1}$$

Biological Shield Coolant Activity

313 ~~REV~~
App D

SIMILAR TO

DR'N <i>N.L.</i>	CH'D <i>B.H. Dwyer</i>	APP'D	SCALE = 12	SHEET <i>1</i> OF <i>37</i>	ISSUE
ALLIS-CHALMERS MFG. CO. DEPT.				4-61	

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

III Irradiation time in baffle region

A. Volume enclosed by baffle

$$Vol = 12 \times \frac{1}{4} \times 8 \times 52 = 1248 \text{ ft}^3$$

B. Time

$$t = \frac{Vol.}{Flow} = \frac{1248 \text{ ft}^3}{7050 \text{ ft}^3/\text{min}} = 0.177 \text{ min} = 10.6 \text{ sec.}$$

Flow taken from drug No. HV-107

IV Irradiation time in vault

A. Volume of air in vault.

$$Vol. \text{ of Air} = Vol. \text{ of vault} - Vol. \text{ of pressure vessel}$$

1.) Vol. of vault, V_v

$$V_v = \text{octagon cross section area} \times \text{length} \\ = (4.83 l^2) L$$

where

$$l = \text{length of a side of the octagon} = 12' \\ L = \text{height} = 52.5'$$

$$V_v = 4.83 (12)^2 (52.5) \\ = 36,515 \text{ ft}^3$$

Biological Shielding Coolant Activity

313-~~11~~
App D

DR'N D. J.	CH'D B.H. J.	APP'D	SCALE = 12	SHEET 2 OF 32	ISSUE

of ALLIS-CHALMERS MFG. CO.

DEPT.

4-61

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

2) Vol. of pressure vessel, V_{pv}

$$V_{pv} = (\pi R^2) L_c + \frac{4\pi R^3}{3}$$

where

$$R = 10.25'$$

$$L_c = 47 - 20.5 = 26.5$$

$$\begin{aligned} V_{pv} &= (\pi)(10.25)^2(26.5) + \frac{4\pi}{3}(10.25)^3 \\ &= 13258 \text{ ft}^3 \end{aligned}$$

3) Air Vol., V_a

$$V_a = V_v - V_{pv}$$

$$= 36515 - 13258$$

$$= 23257 \text{ ft}^3$$

B. Irradiation time in the vault

$$t = \frac{23257}{41610} = 0.559 \text{ min} = 33.5 \text{ sec.}$$

V Activity

The activity concentration of a moderately short lived isotope in a single-pass effluent may be expressed as "

$$A = \Sigma \phi t \lambda, \text{ dis/sec.}$$

where

Σ = macroscopic cross section, cm^{-1}

ϕ = thermal neutron flux

t = passage time, where $t < 0.2 T^{1/2}$

λ = decay const., sec^{-1}

1) Etherington, Nuclear Eng., Table 35, p 1-41.

Biological Shield Coolant Activity

313 ~~#~~
App.D

SIMILAR TO

DR'N <i>D.I.</i>	CH'D <i>B.H.D.</i>	APP'D	SCALE = 12	SHEET <i>3</i> OF <i>37</i>	ISSUE
ALLIS-CHALMERS MFG. CO. DEPT.				4-61	

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

125

Total flow through the baffle region is 14100 cfm (HV-107)
and the activation of the A^{40} in this air is

$$A_1 = \frac{1.07 \times 10^{-7} \times 2.4 \times 10^{10} \times 10.6 \times 1.06 \times 10^{-4}}{3.7 \times 10^{10}} = 7.80 \times 10^{-11} \frac{\text{curies}}{\text{cm}^3}$$

where $\phi = 2.4 \times 10^{10} \text{ n/cm}^2\text{-sec}$ is the maximum thermal flux seen in the baffle area (Study II-105-1)

This is mixed with air in vault and

$$A_1 = 7.80 \times 10^{-11} \times \frac{14100}{41600} = 2.64 \times 10^{-11} \text{ curies/cm}^3$$

To this will be added the activity acquired in the vault
where $\phi_{\text{max}} = 1.85 \times 10^{10} \text{ n/cm}^2\text{-sec}$ (Study II-105-1)

$$A_2 = \frac{1.07 \times 10^{-7} \times 1.85 \times 10^{10} \times 33.5 \times 1.06 \times 10^{-4}}{3.7 \times 10^{10}} = \frac{19.00}{24.65} \times 10^{-11} \frac{\text{curies}}{\text{cm}^3}$$

$$A_T = A_1 + A_2 = (2.64 + \frac{19.00}{24.65}) \times 10^{-11} = \frac{2.164}{2.73} \times 10^{-10} \frac{\text{curies}}{\text{cm}^3}$$

Flow through the vault is 41,610 cfm or

$$4.161 \times 10^4 \times 2.83 \times 10^4 = 1.18 \times 10^9 \text{ cc/min}$$

and the rate of activity discharge from the vault is

$$\frac{2.164}{2.73} \times 10^{-10} \text{ c/cc} \times 1.18 \times 10^9 \text{ cc/min} = \frac{0.255}{0.322} \text{ c/min}$$

and assuming no decay depletion while traveling to the stack, the stack emission rate of A^{41} is

$$\frac{0.255}{0.322} \times 60 \times 24 = \frac{367.2}{464} \text{ curies/day}$$

or

$$\frac{367.2}{464 \times 10^6} = \frac{4.25}{8.64 \times 10^4} \mu\text{c/sec}$$

2 73

Biological Shield Coolant Activity

313 ~~114~~
App. D

SIMILAR TO

DR'N D. L.

CH'D B. H. 2.

APP'D

SCALE = 12

SHEET 4 OF 37

ISSUE

ALLIS-CHALMERS MFG. CO.

DEPT.

4-61

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

I Data

Reaction - $\text{He}^3(n, p)\text{H}^3$

Decay - $T_{1/2} = 13.4 \text{ yrs}$, $\lambda = 1.77 \times 10^{-9} \text{ sec}^{-1}$

Cross section - $\sigma = 5500 \pm 300 \text{ barns}$

Abundance of He^3 - $\gamma = 1.3 \times 10^{-6}$

Average flux in core, $\bar{\phi} = 1.5 \times 10^{13} \text{ n/cm}^2\text{-sec.}$

Average Temperature in Core

$$\bar{T} = \frac{T_{\text{in}} + T_{\text{out}}}{2} = \frac{510 + 1050}{2} = 780^\circ \text{F} = 689^\circ \text{K}$$

Average Coolant Pressure in Core

$$\bar{P} = \frac{P_{\text{in}} + P_{\text{out}}}{2} = \frac{312.5 + 303.25}{2} = 308.4 \text{ psia}$$

Average Coolant Density in Core

$$\begin{aligned} \bar{\rho} &= \rho_0 \frac{308.4}{14.7} \times \frac{293}{689} \\ &= 1.785 \times 10^{-4} \times \frac{308.4}{14.7} \times \frac{293}{689} = 0.016 \text{ g/cm}^3 \\ &= 0.1 \text{ lb/ft}^3 \end{aligned}$$

II Times

A. Cycle time in coolant loop

$$t = \frac{1350 \text{ lb} \times 3600 \text{ sec/hr.}}{427000 \text{ lb/hr.}} = 11.4 \text{ sec.}$$

B. Transit time thru core (average)

1. Flow / channel

$$\frac{427000}{234 \times 3600} = 0.51 \text{ lb/sec - channel}$$

and assuming a 0.94 : 0.06 split of flow between fuel channel and annulus

$$\text{fuel channel} = 0.51 \times 0.94 = 0.479 \text{ lb/sec.}$$

$$\text{annulus} = 0.51 \times 0.06 = 0.030 \text{ lb/sec.}$$

Tritium in Primary Coolant

313 #
APP'D

SIMILAR TO

DR'N <i>D. J.</i>	CH'D <i>B. H. J.</i>	APP'D	SCALE = 12	SHEET 5 OF 37	ISSUE
ALLIS-CHALMERS MFG. CO. DEPT.				4-61	

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3
127

The volume flows are

$$\text{fuel channel } \frac{0.479 \text{ lb/sec}}{0.1 \text{ lb/ft}^3} = 4.79 \text{ ft}^3/\text{sec}$$

$$\text{annulus } \frac{0.030}{0.1} = 0.30 \text{ ft}^3/\text{sec.}$$

2. Flow areas

$$a). \text{ Fuel channel } = \frac{\pi}{4} 3^2 - 7 \frac{\pi}{4} (0.75)^2 = 3.98 \text{ in}^2$$

$$b). \text{ Annulus } = \frac{\pi (5.250^2 - 5.000^2)}{4} = 2.01 \text{ in}^2$$

3. Linear Velocity

$$a). \text{ Fuel channel } = \frac{4.79 \times 144}{3.98} = 173.3 \text{ ft/sec}$$

$$b). \text{ Annulus } = \frac{0.30 \times 144}{2.01} = 21.5 \text{ ft/sec.}$$

4. Transit time

$$\text{Core length} = 19.33 \text{ ft}$$

$$a). \text{ Fuel channel } = \frac{19.33}{173.3} = 0.112 \text{ sec.}$$

$$b). \text{ annulus } = \frac{19.33}{21.5} = 0.9 \text{ sec.}$$

5. Av. transit time thru core

$$t_r = 0.94 \times 0.112 + 0.9 \times 0.06 = 0.159 \text{ sec.}$$

2 75

Iteration in Primary Coolant

313 ~~114~~
App. D

DR'N <i>D. J.</i>	CH'D <i>B. H. B.</i>	APP'D	SCALE = 12	SIMILAR TO	SHEET <i>6</i> OF <i>37</i>	ISSUE
ALLIS-CHALMERS MFG. CO. DEPT.				4-61		

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

128

III Initial Concentration of He^3 , atoms/cc of coolant

$$C_0 = \frac{\delta \rho N_A}{A}$$

where

δ = isotopic abundance

ρ = density

N_A = Avogadro No.

A = Atom atomic wt.

$$C_0 = \frac{1.3 \times 10^{-6} \times 0.0016 \times 6.023 \times 10^{23}}{4}$$

$$= 3.13 \times 10^{14} \text{ atoms/cc of coolant}$$

IV Av. σ_a for He^3

$$\sigma_a (2200 \text{ m/sec}) = 5500 \text{ barns}$$

$$\bar{\sigma}_a = \sigma_a \frac{\sqrt{H}}{2} \sqrt{\frac{T_0}{T_1}} = \frac{\sigma_a}{1.128} \sqrt{\frac{T_0}{T_1}}$$

$$= \frac{5500}{1.128} \sqrt{\frac{293.6}{689}}$$

$$= 3184 \text{ barns}$$

Tritium in Primary Coolant

313 ~~APP. D~~
APP. D

SIMILAR TO

DR'N	D. L.	CH'D	B. H. J.	APP'D	SCALE	= 12	SHEET	7	OF	37	ISSUE
ALLIS-CHALMERS MFG. CO.						DEPT.	4-61				

A

B

A-C MFG. CO., MILWAUKEE, WIS FORM NO. 6833-3

V H^3 build-up in coolant system

In a recirculating system the concentration of a radionuclide can be expressed as a function of time by ⁽²⁾

$$N_m = \frac{C(nT) \bar{\sigma} \bar{\phi}}{\lambda} \frac{(1 - e^{-\lambda t_1}) e^{-\lambda^* t_2} (1 - e^{-n\lambda^* T})}{(1 - e^{-\lambda^* T})} \text{ atoms/cc}$$

where

$C(nT)$ = Target isotope concentration, atoms/cc

$\bar{\sigma}$ = Av. cross section, cm^2

$\bar{\phi}$ = Av. thermal neutron flux, $n/\text{cm}^2 \text{ sec}$

t_1 = time in core, sec.

t_2 = time in loops, sec.

T = cycle time = $t_1 + t_2$, sec

n = number of cycles

λ = decay const. of formed nuclide

λ^* = net depletion^{rate} fraction^{rate}, sec^{-1} ; $\lambda^* = \lambda + \beta$

β = leakage^{rate} fraction^{rate}, sec

The leakage rate from the primary coolant system is .07 %/day per contained volume. (Ref HE TWX-13, DTD 2/13/61) then

$$\beta = \frac{0.0007}{24 \times 3600} = 8.1 \times 10^{-9} \text{ sec}^{-1}$$

(2) This is a modification of a formula given on p 7-14 of Etherington, Nuclear Eng.

Tritium in Primary Coolant

313-114

App. D

DR'N	D. L.	CH'D	B. H. J.	APP'D	SCALE	= 12	SIMILAR TO	SHEET	8 OF 37	ISSUE
ALLIS-CHALMERS MFG. CO. DEPT.							4-61			

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

Now since

$$\lambda = 1.77 \times 10^{-9}$$

$$\beta = 8.1 \times 10^{-9}$$

$$\lambda^* = \lambda + \beta = 9.87 \times 10^{-9}$$

$$t_1 = 0.159 \text{ sec}$$

$$T = 11.4 \text{ sec}$$

$$t_2 = T - t_1 = 11.4 - 0.159 = 11.24 \text{ sec}$$

then

$$e^{-\lambda t_2} = e^{-(1.77 \times 10^{-9})(11.24)} \approx 1$$

$$1 - e^{-\lambda^* T} = 1 - e^{-(9.87 \times 10^{-9})(11.4)} \approx \lambda^* T$$

$$1 - e^{-\lambda t_1} = 1 - e^{-(1.77 \times 10^{-9})(0.159)} \approx \lambda t_1$$

and

$$N_m = \frac{C(mT) \bar{\sigma} \bar{\phi} \lambda t_1 (1 - e^{-\lambda^* T})}{\lambda (\lambda^* T)}$$

$$N_m = \frac{C(mT) \bar{\sigma} \bar{\phi} F}{\lambda + \beta} [1 - e^{-(\lambda + \beta) T}] , \text{ atoms/cc}$$

where

$$F = \frac{t_1}{T} = \text{fraction of time spent in the core}$$

The target isotope concentration $C(mT)$ varies in time because of burn-up, leakage, and make up and may be expressed by the following differential equation if we assume leakage and make-up are equal

$$\frac{dC}{dt} = -C \bar{\sigma} \bar{\phi} F - \beta C + \beta C_0$$

where

C_0 = initial concentration; i.e., the concentration in make up helium.

Tritium in Primary Coolant

313.116
App. D

DR'N D. L.	CH'D B.H.D.	APP'D	SCALE = 12	SIMILAR TO	SHEET 9 OF 37	ISSUE
ALLIS-CHALMERS MFG. CO. DEPT.				4-61		

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

$$\frac{dC}{dt} = -(\bar{\sigma} \bar{\phi} F + \lambda) C + \beta C_0$$

Let

$$\alpha = \bar{\sigma} \bar{\phi} F$$

and rearranging terms

$$dC + (\alpha + \beta) C dt = \beta C_0 dt$$

$$\int d[C e^{(\alpha + \beta)t}] = \int e^{(\alpha + \beta)t} \beta C_0 dt$$

$$C e^{(\alpha + \beta)t} = \frac{\beta C_0}{\beta + \alpha} e^{(\beta + \alpha)t} + A$$

At

$$t = 0, C = C_0$$

so

$$A = C_0 - \frac{\beta C_0}{\beta + \alpha}$$

and

$$C = \frac{\beta C_0}{\beta + \alpha} + C_0 \left(1 - \frac{\beta}{\beta + \alpha}\right) e^{-(\beta + \alpha)t}$$

$$\frac{C}{C_0} = \frac{\beta}{\beta + \alpha} + \frac{\alpha}{\beta + \alpha} e^{-(\beta + \alpha)t}$$

$$\alpha = \bar{\sigma} \bar{\phi} F = (3.184 \times 10^{-21})(1.5 \times 10^{10})\left(\frac{0.154}{11.4}\right) = 0.67 \times 10^{-9}$$

$$\frac{C}{C_0} = \frac{8.1(10^{-9})}{(6.7 + 8.1)(10^{-9})} + \frac{0.67(10^{-9})}{(6.7 + 8.1)10^{-9}} [1 - e^{-8.77 \times 10^{-9} t}]$$

$$\frac{C}{C_0} = 0.924 + 0.076 [1 - e^{-8.77 \times 10^{-9} t}]$$

Assuming that full charge gets dumped each year then
 $t = 3.15 \times 10^7 \text{ sec.}$

$$\frac{C}{C_0} = 0.924 + 0.026 [1 - e^{-0.276}]$$

$$\frac{C}{C_0} = 0.942$$

Tritium in Primary Coolant

313 ~~77~~
 App. D

SIMILAR TO

DR'N

D.L.

CH'D R.L.S.

APP'D

SCALE

= 12

SHEET

10 OF 37

ISSUE

ALLIS-CHALMERS MFG. CO.

DEPT.

10-61

A

B

A-C MFG. CO., MILWAUKEE, WIS.

FORM NO. 6833-3

and then

$$N(1 \text{ yr.}) = \frac{(0.942) C_0 (\bar{\phi} F)}{\lambda + \rho} [1 - e^{-\lambda^* T}]$$

$$= \frac{(0.942)(3.13 \times 10^{-4})(0.67 \times 10^{-9})}{9.87 \times 10^{-7}} [1 - e^{-\frac{0.3119}{0.268} (9.87)(0.0315)}]$$

$$= 2.00 \times 10^{13} \times 0.268$$

$$N(1 \text{ yr.}) = 5.36 \times 10^{12} \text{ atoms/cc}$$

The specific activity after 1 year is

$$\frac{A_{H_3}}{V} = \frac{\lambda N(1 \text{ yr.})}{3.7 \times 10^{10}} \text{ curies/cc}$$

and the H_3 activity is then

$$A_{H_3} = \frac{\lambda N(1 \text{ yr.}) V}{3.7 \times 10^{10}} = \frac{1.77(10^{-9})(5.36)(10^{12})(1.45)(10^4)(2.73)(10^4)}{3.7 \times 10^{10}}$$

$$A_{H_3} = 105.2 \text{ curies}$$

where

$$V = 1.45 \times 10^4 \text{ ft}^3 \text{ (Design data, Rev. 4, P-P3.)}$$

Tritium in Binary Coolant

313 ~~11~~
App. D

DR'N DL	CH'D R.L.S.	APP'D	SCALE = 12	SHEET 11 OF 37	ISSUE
ALLIS-CHALMERS MFG. CO. DEPT.				10-61	

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

I Sources* of activity in stack effluent

A. H^3 and fission products in primary coolant which get to the stack by:

1. Primary coolant and auxiliary system leakage
2. Depressurization of service and charge machines
3. Controlled blowdown of coolant system

B. A^{14} in biological shield coolant air

II Exposure Criteria

A. 10 CFR Part 20, Par. 20.106 "Concentrations in effluents to unrestricted areas" or NBS Handbook 69

1. Concentrations, X_i , shall be such that

$$\sum_i \frac{X_i}{(MPC)_i} < 1$$

for the $(MPC)_i$'s listed in Column II of App. B when averaged over a period no greater than one (1) year.

III Primary coolant to the stack

A. Data from Design Data, Rev. 5, dtd. Feb 1961

1. Unrecovered H_2 leakage = 9 lb/day = 3285 lb/yr.
2. Annual consumption (after allowance for operational loss) = 5670 lb/yr.

Total consumption = 8955 lb/yr.

Less charge = 1400

Total H_2 release = 7555 lb/yr.

* Note: Recoils from fuel cladding are ignored as a source since it was shown in Study 3-380-3 that the equilibrium activity in the coolant from this source is only 1.3 curies

Operational Stack Release

313 ~~77~~
APP. D

2 80

SIMILAR TO

DR'N D. L.

CH'D B. H. Z.

APP'D

SCALE = 12

SHEET 12 OF 37

ISSUE

ALLIS-CHALMERS MFG. CO. DEPT.

4-61

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

IV Average release rate fraction of contained volume, R .

$$R = \frac{7555}{1400 \times 3600 \times 24 \times 365} = 1.71 \times 10^{-7} \text{ sec}^{-1}$$

V Meteorology

A. Although it is contemplated that controlled releases such as system blowdown and service and charge machine venting will be done under the "most favorable" weather conditions, "least favorable" parameters are assumed for this calculation, i.e.,

$$n = 0.35$$

$$\mu = 1.5 \text{ m/sec}$$

$$C_g = 0.3$$

$$C_z = 0.033$$

See Memo Cape to Jackson
DTG 2/27/61 EGCR HAZARDS
CALCULATIONS

B. In ORO-196 Sect. 2.3, it is stated that the vicinity of the site on an annual basis the maximum frequency of wind direction is approximately 40%. This value is used ^{to compute} the yearly average concentration resulting from operational stack release.

VI Concentration

A. Point of maximum concentration

For a continuous elevated point source, the distance, d , at which the maximum concentration occurs may be calculated from (Ref. AECU-3060, p. 99)

$$d_{max} = \left(\frac{h^2}{C_z} \right)^{\frac{1}{2-n}} \text{ meters}$$

where

h = height of source above ground level, meters.

n = dimensionless stability parameter

C_z = diffusion coefficient along vertical coordinate

Operational Stack Release

313 41
App. D 2

81

SIMILAR TO

DR'N D. L.

CH'D B. H. 2.

APP'D

SCALE

= 12

SHEET

13

OF

37

ISSUE

ALLIS-CHALMERS MFG. CO.

DEPT.

4-61

A

B

A-C MFG. CO., MILWAUKEE, WIS.

FORM NO. 6833-3

135

Assuming h is equal to stack height (cold release), then
 $h = 200 \text{ ft} = 61 \text{ m}$
 and

$$d_{\max} = \left[\frac{(61)^2}{(0.033)^2} \right]^{\frac{1}{2-0.95}}$$

$$= \left[\frac{3.4 \times 10^6}{(0.033)^2} \right]^{0.606}$$

$$= 9095 \text{ meters}$$

8-62
JCC

Since this is greater than the exclusion distance of 1060 ⁽³⁾ meters, the maximum concentrations will be calculated.

B. Max. concentrations (Av.)

The concentration at $d_{\max}$ is given as ⁽⁴⁾

$$x_{\max} = \left[\frac{2Q}{e\pi h^2 \mu} \cdot \frac{Q_z}{C_z} \right] 0.4^4$$

where

Q = source emission rate, $\mu\text{c/sec}$

μ = wind velocity, m/sec

and 0.4^4 refers to the maximum frequency of wind direction.

then

$$x_{\max} = \frac{2Q (0.2)^{0.4}}{2.7183\pi (61)^2 (1.5)} \cdot \frac{(0.033)}{0.3}$$

$$= \frac{1.85 \times 10^{-6}}{7.7 \times 10^{-11}} Q \text{ } \mu\text{c/m}^3$$

$$= \frac{1.85}{7.7} \times 10^{-12} Q \text{ } \mu\text{c/cm}^3$$

(3) Memo, DDCops to J. H. Jackson, dtd 2/27/61, subj. "EECR Hazards Calculation"

(4) AECU-3066, "Meteorology and Atomic Energy" (1955) p. 49

Operational Stack Release
 Inversion Conditions at 9095 meters

313 ~~100~~
 APP D 2 82

SIMILAR TO

DR'N D. I.

CH'D B. H. J.

APP'D

SCALE

=12

SHEET

14 OF 37

ISSUE

ALLIS-CHALMERS MFG. CO.

DEPT.

4-61

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

136

C. A^{41}

$$Q_i = 4.25 \times 10^3 \text{ } \mu\text{e/sec} \quad (p.69)$$

$$X_{A^{41}} = 1.85 \times 10^{-12} \times 4.25 \times 10^3 = 7.86 \times 10^{-9} \text{ } \mu\text{e/cm}^3$$

D. H^3

$$A_{H^3} = 105.2 \text{ curies} = 1.052 \times 10^8 \text{ } \mu\text{e} \quad (p.76)$$

$$Q_{H^3} = A_{H^3} R = 1.052 \times 10^8 \times 1.78 \times 10^{-7} = 18.0 \text{ } \mu\text{e/sec}$$

$$X_{H^3} = 1.85 \times 10^{-12} \times 18.0 = 3.33 \times 10^{-11} \text{ } \mu\text{e/cm}^3$$

Operational Stock Release
Inversion Conditions @ 9095 meters

313 ~~15~~
App. D

SIMILAR TO

DR'N D.L.	CH'D R.I.S.	APP'D	SCALE = 12	SHEET 15 OF 32	ISSUE
ALLIS-CHALMERS MFG. CO. DEPT.				10-61	

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

C - FISSION PRODUCTS

1. The fission products activity in the reactor is to be taken as 1000 Curies = $10^9 \mu\text{C}$
(Ref. TWX NR 01 6-7-62 Jackson to Bush)

Q_{FP} may be calculated as follows:

$$Q_{FP} = R \sum_i A_{FP,i} \quad \frac{\mu\text{C}}{\text{sec}}$$

and

$$Q_{FP,i} = a_i [R \sum_i A_{FP,i}] \quad \frac{\mu\text{C}}{\text{sec}}$$

where:

$Q_{FP,i}$ = activity emission rate from the stack due to isotope i

$\sum A_{FP,i}$ = total activity in coolant due to fission products

a_i = fraction of activity due to isotope i

then R = release fraction, see p

$$Q_{FP,i} = 1.71 \times 10^{-7} \times 10^9 a_i = 171 a_i \quad \frac{\mu\text{C}}{\text{sec}}$$

and the maximum contribution of the i^{th} isotope is:

$$X_{FP,i} = 1.85 \times 10^{-12} \times 171 a_i = 3.16 \times 10^{-10} a_i \quad \frac{\mu\text{C}}{\text{cm}^3}$$

Assuming the fission product distribution in the coolant is that given in Study IV-302 *

Isotope	curies Failure	(divide col 2 by 10 ⁹) $a_i \times 10$	$X_{FP,i}$ ~~$\times 10^{-13}$~~
Br 83	0.25	2.5	7.90
Br 84	0.21	2.1	6.63
Br 85	0.092	0.9	2.84

~~XXXXXXXXXXXX~~

Operational Stack Release
Inversion Conditions @ 9095 Meters

313

App. D

SIMILAR TO

DR'N	ACC	CH'D	d. L.	APP'D	SCALE	=12	SHEET	16 OF 37	ISSUE
of ALLIS-CHALMERS MFG. CO. DEPT.							1-63		

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

A	B	C
Isotope	curies Failure	$ac \times 10^3$ $X_{FP}]_c \times 10^{13}$
Kr 83m	0.48	4.7 14.85
Kr 85m	0.95	9.4 29.70
Kr 85	0.60	5.9 18.64
Kr 87	0.91	9.0 28.44
Kr 88	1.9	18.7 59.09
Kr 89	0.33	3.3 10.43
Kr 90	0.15	1.5 4.74
Rb 88	2.5	24.6 77.74
Rb 89	1.1	10.8 34.13
Rb 96	0.49	4.9 15.48
Rb 91	0.53	5.2 16.43
Sr 89	1.1	10.8 34.13
Sr 90	0.02	0.2 0.63
Sr 91	0.53	5.2 16.43
I 131	13.0	128.1 404.80
I 132	2.1	20.7 65.41
I 133	10.0	99.0 312.84
I 134	2.3	22.7 71.73
I 135	5.0	49.3 155.79
Xe 133m	0.63	6.2 19.59
Xe 133	34.0	334.9 1058.28
Xe 135	9.2	90.6 286.30
Xe 138	0.98	9.7 30.65
Cs 137	4.2	41.4 130.82
Cs 138	2.3	22.7 71.73
Cs 139	0.65	6.4 20.22
Cs 140	0.16	1.6 5.06
Ba 137m	3.9	38.4 121.34
Ba 139	0.65	6.4 20.22
Ba 140	0.16	1.6 5.06
La 140	0.16	1.6 5.06
	<u>106.5</u>	

Operational Stack Release
Inversion Conditions @ 9095m

313

App. D

SIMILAR TO

DR'N Joe	CH'D J. V.	APP'D	SCALE =12	SHEET 17 OF 37	ISSUE
of ALLIS-CHALMERS MFG. CO. DEPT.				1-63	

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

FRACTION of $(MPC)_e$, where data were available, for various filtering efficiencies

Isotope	$a_i \times 10^3$	$(MPC)_e^*$ efficiency %	$X_i / (MPC)_e [1 - \text{eff}]$			
			0%	25%	50%	75%
Kr ^{85m}	9.4	1 (-7)	2.97(-5)	2.23(-5)	1.49(-5)	7.43(-6)
Kr ⁸⁵	5.9	3 (-7)	6.21(-6)	4.66(-6)	3.11(-6)	1.55(-6)
Kr ⁸⁷	9.0	2 (-8)	1.42(-4)	1.07(-4)	7.10(-5)	3.53(-5)
Sr ⁸⁹	10.8	1 (-9)	3.41(-3)	2.56(-3)	1.71(-3)	8.52(-4)
Sr ⁹⁰	0.2	1 (-11)	6.30(-3)	4.73(-3)	3.15(-3)	1.58(-3)
Sr ⁹¹	5.2	2 (-8)	8.22(-5)	6.17(-5)	4.11(-5)	2.06(-5)
I ¹³¹	128.1	3 (-10)	1.35(-1)	1.01(-1)	6.75(-2)	3.38(-2)
I ¹³²	20.7	8 (-9)	8.18(-4)	6.14(-4)	4.09(-4)	2.05(-4)
I ¹³³	99.0	1 (-9)	3.13(-2)	2.35(-2)	1.57(-2)	7.83(-3)
I ¹³⁴	22.7	2 (-8)	3.59(-4)	2.69(-4)	1.79(-4)	8.98(-5)
I ¹³⁵	49.3	4 (-9)	3.89(-3)	2.92(-3)	1.95(-3)	9.73(-4)
Xe ¹³³	334.9	3 (-7)	8.53(-4)	2.65(-4)	1.77(-4)	8.83(-5)
Xe ¹³⁵	90.6	1 (-7)	2.86(-4)	2.15(-4)	1.43(-4)	7.15(-5)
Cs ¹³⁷	41.4	2 (-9)	6.54(-3)	4.90(-3)	3.27(-3)	1.64(-3)
Ba ¹⁴⁰	1.6	4 (-9)	1.27(-4)	9.53(-5)	6.35(-5)	3.18(-5)
La ¹⁴⁰	1.6	5 (-9)	1.01(-4)	7.58(-5)	5.05(-5)	2.53(-5)
$\sum a_i = 0.741$			0%	25%	50%	75%
$\sum \frac{X_i}{(MPC)_e} =$			0.189	0.141	0.094	0.047

* From 10 CFR Part 20, App B, Table II - Col 1, in $\mu\text{C}/\text{cm}^3$ or N.B.S. Handbook 69 Table I

(a_i is the fraction of the i^{th} isotope)

Operational Stack Release
Inversion Conditions at 9095 m

313

App. D

DR'N Lee	CH'D J.L.	APP'D	SCALE = 12	SIMILAR TO	SHEET 18 OF 37	ISSUE
of ALLIS-CHALMERS MFG. CO. DEPT.					1-63	

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

VIII Dose per year from Stack Release

A. From Exposure Criteria

$$F = \frac{X_i}{(MPC)_a} \Big]_{H_3} + \frac{X_i}{(MPC)_a} \Big]_{A^{41}} + \sum \frac{X_i}{(MPC)_{ai}} \Big]_{FP} < 1.0$$

$$F = \frac{3.33 \times 10^{-11}}{2 \times 10^{-7}} + \frac{7.86 \times 10^{-9}}{4 \times 10^{-8}} + \sum \frac{X_i}{(MPC)_{ai}} \Big]_{FP}$$

$$F = 0.00017 + 0.19650 + \sum \frac{X_i}{(MPC)_{ai}} \Big]_{FP}$$

$$F = .19667 + \sum \frac{X_i}{(MPC)_{ai}} \Big]_{FP}$$

B. For 0% Filtering

$$F = 0.19667 + 0.189 = 0.386$$

C. For 25% Filtering

$$F = 0.19667 + 0.141 = 0.338$$

D. For 50% Filtering

$$F = 0.19667 + 0.094 = 0.291$$

E. For 75% Filtering

$$F = 0.19667 + 0.047 = 0.244$$

F. Assuming the yearly whole body dose is 0.5 Rem, when $F=1$, then the doses for the various filtering efficiencies are

<u>Filter Efficiency</u>	<u>Dose in rem/yr</u>
0%	0.193
25%	0.169
50%	0.146
75%	0.122

Operational Stack Release
Inversion Conditions at 9095 meters

313
App D

DR'N	LCC	CH'D	J.L.	APP'D		SCALE	=12	SHEET	19 OF 37	ISSUE	
of ALLIS-CHALMERS MFG. CO. DEPT.								1-63			

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

Dose to the Thyroid From Operational Stack Release with no filtering assumed. for Iodine.

Iodine	(MPC) _a *	X _i $\frac{\mu C}{cm^3}$ **	X _i /(MPC) _a
131	3(-9)	4.05(-11)	1.35(-2)
132	8(-8)	6.54(-12)	8.18(-5)
133	1(-8)	3.13(-11)	3.13(-3)
134	2(-7)	7.17(-12)	3.59(-5)
135	4(-8)	1.56(-11)	3.90(-4)

* for 168 hr week $\mu C/cm^3$ (Health Physics, Vol 3, June 60)

** from p 82

$$I_i = (B.R.) X_i t \text{ in } \mu C$$

where B.R = breathing rate = $2 \times 10^7 \frac{cm^3}{day} = 230 cm^3/sec$
from Health Physics, Vol 3, June '60 p. 152

$$t = \text{time} = 1 \text{ year} = 3.15 \times 10^7 \text{ sec}$$

$$\text{Then } I_i = 3.15 \times 10^7 \times 230 \text{ cm}^3/\text{sec} \times X_i \frac{\mu C}{cm^3} = I_i \text{ in } \mu C$$

$$I_i = 7.245 \times 10^9 X_i$$

Now the dose is $D_i = S'_i I_i \text{ reme}$

Isotope of I	S' _i	I _i x 10 ¹	D _i (reme)
131	1.488	2.934	0.4386
132	0.054	0.474	0.0026
133	0.400	2.268	0.0907
134	0.025	0.519	0.0013
135	0.124	1.130	0.0140

$$\text{Dose} = \sum D_i = 0.5452 \text{ reme}$$

the Dose will be proportionately less for any given filtering efficiency.

Operational Stack Release
Inversion Conditions @ 9095m

313

App. D

SIMILAR TO

DR'N ICC

CH'D D.L.

APP'D

SCALE

=12

SHEET 20 OF 37

ISSUE

ALLIS-CHALMERS MFG. CO.

DEPT.

1-63

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

CONCENTRATION FOR LAPSE CONDITIONS

POINT OF MAXIMUM CONCENTRATION

For a continuous elevated point source, the distance d , at which the maximum concentration occurs may be calculated from

$$d = \left(\frac{h^2}{C_y^2} \right)^{\frac{1}{2-n}} \text{ meters}$$

from AECU - 3066, page 49

h = height of source above ground level in meters = 61

n = dimensionless stability parameter = 0.23 for Lapse

C_y = Vertical diffusion coefficient = 0.3 for Lapse

$$d = \left(\frac{61^2}{(0.3)^2} \right)^{\frac{1}{2-0.23}} = \left(\frac{3721}{0.09} \right)^{\frac{1}{1.77}} = \frac{405.6}{\cancel{407}} \text{ meters}$$

Since this lies outside the exclusion boundary of 200 meters, the dose will be calculated for Lapse conditions

The concentration at d_{max} is

$$X_{max} = \left[\frac{2Q}{e\pi h^2 \mu} \frac{C_y}{C_y} \right] \quad (\text{from AECU 3066})$$

for lapse conditions $C_y = C_y = 0.3$, $\mu = 2.3 \text{ m/sec}$

$h = 61 \text{ m}$, $h^2 = 3721 \text{ m}^2$, $e = 2.7183$, $\pi = 3.1416$

Since the maximum frequency of wind direction is 0.4, this may be included as a factor

$$X_{max} = \left[\frac{2Q}{2.7183 \times \pi \times 3721 \times 2.3} \frac{0.3}{0.3} \right] 0.4 =$$

$$X_{max} = 1.09 \times 10^{-5} Q \frac{\mu\text{C}}{\text{m}^3} = 1.09 \times 10^{-11} Q \frac{\mu\text{C}}{\text{cm}^3}$$

Since the source term of H^3 , A^{41} and Fission Products will not change, we may write:

$$A^{41} - Q_i = 4.25 \times 10^3 \frac{\mu\text{C}}{\text{sec}}, \quad H^3 - Q_i = 18 \frac{\mu\text{C}}{\text{sec}}$$

Operational Stack Release
Lapse Conditions

313

App. D

SIMILAR TO

DR'N LCC

CH'D

D.L.

APP'D

SCALE

= 12

SHEET

21 OF 37

ISSUE

ALLIS-CHALMERS MFG. CO.

DEPT.

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

and for Fission Products $Q_{FP} = 171 \text{ ai } \frac{\mu\text{C}}{\text{sec}}$

The maximum contribution of the i^{th} isotope is:

$$X_{FP} = 1.09 \times 10^{-11} \times 171 \text{ ai} = 1.86 \times 10^{-9} \text{ ai } \frac{\mu\text{C}}{\text{cm}^3}$$

Now the distribution of fission products in the coolant is the same as for inversion condition calculations as are the filter efficiencies and (MPC)'s. This allows the $\sum \frac{X_i}{(\text{MPC})_i}$ on p 83 to be scaled up by a ratio of the X_i

$$\text{Ratio} = \frac{X_{FP} \text{ for Lapse}}{X_{FP} \text{ for Inversion}} = \frac{1.86 \times 10^{-9} \text{ ai}}{3.16 \times 10^{-10} \text{ ai}} = 5.89$$

$$\text{Filter Efficiency } \sum \frac{X_i}{(\text{MPC})_i} \text{ for Inversion} \times 5.89 = \sum \frac{X_i}{(\text{MPC})_i} \text{ for Lapse}$$

$$0\% \quad 0.189 \quad \times 5.89 \quad = \quad 1.113$$

$$25\% \quad 0.141 \quad \times 5.89 \quad = \quad 0.830$$

$$50\% \quad 0.094 \quad \times 5.89 \quad = \quad 0.554$$

$$75\% \quad 0.047 \quad \times 5.89 \quad = \quad 0.277$$

If F exceeds 1.0 then whole body dose exceeds 0.5 rem in equation below

$$F = \frac{X_i}{(\text{MPC})_i} \Big]_{H^3} + \frac{X_i}{(\text{MPC})_i} \Big]_{A^{41}} + \sum \frac{X_i}{(\text{MPC})_i} \Big]_{FP} < 1.0$$

$$X_i \text{ for } H^3 = 1.09 \times 10^{-11} \times 18 = 1.96 \times 10^{-10} \frac{\mu\text{C}}{\text{cm}^3}$$

$$X_i \text{ for } A^{41} = 1.09 \times 10^{-11} \times 4.25 \times 10^3 = 4.63 \times 10^{-8} \frac{\mu\text{C}}{\text{cm}^3}$$

For these values of X_i of A^{41} and H^3 .

$$F = \frac{1.96 \times 10^{-10}}{2 \times 10^{-7}} + \frac{4.63 \times 10^{-8}}{4.0 \times 10^{-8}} + \sum \frac{X_i}{(\text{MPC})_i} \Big]_{FP}$$

$$F = 0.00098 + 1.16 + \sum \frac{X_i}{(\text{MPC})_i} \Big]_{FP} =$$

Operational Stack Release
Lapse Conditions at 407 meters

313
App. D

SIMILAR TO

DR'N LCC CH'D J. L. APP'D SCALE = 12 SHEET 22 OF 37 ISSUE

ALLIS-CHALMERS MFG. CO. DEPT.

1-63

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

$$F = 1.16098 + \sum \frac{X_i}{(MPC)_{a_i}} \Big]_{FP}$$

For 0% filtering of Fission Products

$$F = 1.16098 + 1.113 = 2.274$$

For 25% filtering of F.P.

$$F = 1.16098 + 0.830 = 1.991$$

For 50% filtering of F.P.

$$F = 1.16098 + 0.554 = 1.715$$

For 75% filtering of F.P.

$$F = 1.16098 + 0.277 = 1.438$$

Filter Efficiencies	Dose in Rem/yr (whole body)
0%	~~1.16098~~ - 1.137
25%	~~1.991~~ 0.996
50%	~~1.715~~ 0.858
75%	~~1.438~~ 0.719

Dose to the thyroid from Operational Stack release assuming no filtering

Iodine	(MPC) _a	$X_i \frac{\mu C}{cm^3}$	$X_i / (MPC)_a$
131	3(-9)	2.38 ~~(-10)~~	0.079
132	8(-8)	3.85 ~~(-11)~~	0.0005
133	1(-8)	1.84 ~~(-10)~~	0.0184
134	2(-7)	4.22 ~~(-11)~~	0.0002
134	4(-8)	9.16 ~~(-11)~~	0.0023

MPC is for 168 hr week in $\mu C/cm^3$ (Health Physics Journal)

$$I_i = B.R. X_i t \quad \mu C$$

$$B.R. = 230 \text{ cm}^3/\text{sec} \quad t = 1 \text{ yr.} = 3.15 \times 10^7 \text{ sec}$$

Operational Stack Release
Lapse Conditions at 407 meters

313
App. D

DR'N JCC	CH'D D.L.	APP'D	SCALE = 12	SHEET 23 OF 37	ISSUE

ALLIS-CHALMERS MFG. CO. DEPT.

1-63

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

$$I_i = 230 \text{ cm}^3/\text{sec} \times 3.15 \times 10^7 \text{ sec} \times X_i \frac{\mu\text{C}}{\text{cm}^3} = I_i \text{ in } \mu\text{C}$$

$$I = 7.245 \times 10^9 X_i$$

$$\text{Now Dose} = D_i = S'_i I_i \text{ (in rema)}$$

Isotope of I	S'_i	I_i	D_i (rema)
131	1.488	1.724	2.565
132	0.054	0.279	0.015
133	0.400	1.333	0.533
134	0.025	0.306	0.008
135	0.124	0.664	0.082

$$\text{Dose} = \sum D_i = 3.203 \text{ rema}$$

The dose will be proportionately less for any given filtering efficiency.

It is seen that the whole body dose exceeds the permissible 0.5 rem/year. However, it is unlikely that anyone will stay on the lake for an entire year.

The doses due to operational stack release at 1060 meters will be calculated for both lapse and inversion conditions. The same whole body and thyroid doses will be calculated.

Operational Stack Release
LAPSE CONDITIONS @ 407 meters

313

App. D

SIMILAR TO

DR'N JCC

CH'D

ad. v.

APP'D

SCALE

= 12

SHEET 24 OF 37

ISSUE

ALLIS-CHALMERS MFG. CO.

DEPT.

1-63

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

CALCULATION OF CONCENTRATION for LAPSE at 1060M

$$X = \frac{2Q}{\pi A C_y C_z X^{2-n}} \exp - \left[\frac{h^2}{C_z^2 X^{2-n}} \right]$$

$$X = 1060 \text{ m} \quad h = 61 \text{ m} \quad A = 2.3 \text{ m/sec} \quad n = 0.23 \quad C_y = C_z = 0.3$$

The maximum frequency of Wind Direction = 40% = 0.40

$$X = \frac{2(0.40)Q}{\pi 2.3 (0.3)^2 (1060)^{1.77}} \exp - \left[\frac{3721}{0.09 (2.26 \times 10^5)} \right]$$

$$(1060)^{1.77} = 2.26 \times 10^5$$

$$X = (0.4) 1.362 \times 10^{-5} \times 0.833 Q = 4.54 \times 10^{-6} \frac{\text{sec}}{\text{m}^3} Q$$

$$X = 4.54 \times 10^{-12} Q \frac{\text{sec}}{\text{cm}^3} \times \frac{\mu\text{C}}{\text{sec}}$$

Since A^{41} is given off at rate of $4.25 \times 10^3 \frac{\mu\text{C}}{\text{sec}}$
and H^3 is given off at rate of $18 \frac{\mu\text{C}}{\text{sec}} = Q$

$$X]_{A^{41}} = 4.54 \times 10^{-12} \frac{\text{sec}}{\text{cm}^3} \times 4.25 \times 10^3 \frac{\mu\text{C}}{\text{sec}} = 1.93 \times 10^{-8} \frac{\mu\text{C}}{\text{cm}^3}$$

$$X]_{H^3} = 4.54 \times 10^{-12} \frac{\text{sec}}{\text{cm}^3} \times 18 \frac{\mu\text{C}}{\text{sec}} = 8.17 \times 10^{-11} \frac{\mu\text{C}}{\text{cm}^3}$$

Assuming Coolant fission product activity to be 1000 Curies

$$Q]_{FP_i} = 171 a_i \frac{\mu\text{C}}{\text{sec}}$$

a_i = fraction of the i^{th} ISOTOPE contributing to the 1000 C activity

$$X]_{FP_i} = 171 a_i \frac{\mu\text{C}}{\text{sec}} \times 4.54 \times 10^{-12} \frac{\text{sec}}{\text{cm}^3} = 7.76 \times 10^{-10} a_i \frac{\mu\text{C}}{\text{cm}^3}$$

Since the distribution of the fission products in the coolant is the same as for previous calculation, the concentrations calculated for Inversion conditions at 9095 meters may be scaled up by the ratios of the Dilution factors. Actually the $\sum X_i / (MPC)_i$ of page 83 can be scaled up.

Operational Stack Release
Lapse Conditions at 1060 meters

313

App. D

SIMILAR TO

DR'N JCC

CH'D D.L.

APP'D

SCALE

=12

SHEET 25 OF 37

ISSUE

ALLIS-CHALMERS MFG. CO.

DEPT.

1-63

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

$$\text{Ratio of Dilutions} = \frac{7.76 \times 10^{-10} \text{ ai (for 1060 m)}}{3.16 \times 10^{-10} \text{ ai (for 9095 m)}} = 2.46$$

$$\text{Filter Efficiency } \sum \frac{X_i}{(MPC)_{ai}} (\text{for Inv. @ 9095 m}) \times 2.46 = \sum \frac{X_i}{(MPC)_{ai}} (\text{for Lapse @ 1060 m})$$

$$0\% \quad 0.189 \quad \times 2.46 = 0.4649$$

$$25\% \quad 0.141 \quad \times 2.46 = 0.3469$$

$$50\% \quad 0.094 \quad \times 2.46 = 0.2312$$

$$75\% \quad 0.047 \quad \times 2.46 = 0.1156$$

If F exceeds 1.0 then the whole body dose exceeds 0.5 rem in the equation below

$$F = \frac{X_i}{(MPC)_{ai}} \Big]_{H^3} + \frac{X_i}{(MPC)_{ai}} \Big]_{A41} + \sum \frac{X_i}{(MPC)_{ai}} \Big]_{FP} < 1.0$$

$$F = \frac{8.17 \times 10^{-11}}{2 \times 10^{-7}} + \frac{1.93 \times 10^{-8}}{4 \times 10^{-8}} + \sum \frac{X_i}{(MPC)_{ai}} \Big]_{FP}$$

$$F = 0.0004 + 0.4825 + \sum \frac{X_i}{(MPC)_{ai}} \Big]_{FP}$$

$$F = 0.4829 + \sum \frac{X_i}{(MPC)_{ai}} \Big]_{FP}$$

For 0% filtering of Fission Products

$$F = 0.4829 + 0.4649 = 0.9478$$

For 25% filtering of F.P.

$$F = 0.4829 + 0.3469 = 0.8298$$

For 50% filtering of F.P.

$$F = 0.4829 + 0.2312 = 0.7141$$

For 75% filtering of FP

$$F = 0.4829 + 0.1156 = 0.5985$$

If $F = 1.0$ then Dose = 0.5 rem/year for the whole body dose

Operational Stack Release
LAPSE CONDITIONS at 1060 m.

313

App. D

SIMILAR TO

DR'N LCC

CH'D D.L.

APP'D

SCALE

=12

SHEET 26 OF 32

ISSUE

ALLIS-CHALMERS MFG. CO.

DEPT.

1-63

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

Filter Efficiency

0%

25%

50%

75%

Dose (rem/yr) to whole body

0.474

0.415

0.357

0.299

Whole body dose is below 0.5 rem/year

Dose to the thyroid from Operational stack release assuming no filtration.

Iodine	(MPC) _a ($\frac{\mu\text{C}}{\text{cm}^3}$)	X_i $\mu\text{C}/\text{cm}^3$	X_i (MPC) _a
131	3(-9)	9.93(-11)	0.0331
132	8(-8)	1.61(-11)	0.0002
133	1(-8)	7.68(-11)	0.00768
134	2(-7)	1.76(-11)	~~0.00009~~ 0.00009
135	4(-8)	3.83(-11)	0.00096

(X_i for Iodine = 7.76×10^{10} at $\mu\text{C}/\text{cm}^3$, at from page 82)

$$I_i = X_i (B.R.) t$$

$$B.R. = 230 \text{ cm}^3/\text{sec}, t = 1 \text{ yr} = 3.15 \times 10^7 \text{ sec}$$

$$I_i = 7.245 \times 10^9 X_i$$

$$\text{Dose} = \sum I_i \text{ (in rems)}$$

Isotope of I	S_i	I_i	D_i (in rems)
131	1.488	0.7194 ~~0.5791~~	1.070 ~~0.862~~
132	0.054	0.1166	0.006
133	0.400	0.5564	0.223
134	0.025	0.1275	0.003
135	0.124	0.2775	0.034

$$\text{Dose} = \sum D_i = \frac{1.128}{1.336} \text{ rems}$$

The Dose will be proportionately less for any given filter efficiency

Operational Stack Release
Lapse Conditions @ 1060 meters

313

App. D

SIMILAR TO

DR'N JCC

CH'D

D.L.

APP'D

SCALE

=12

SHEET

27 OF 37

ISSUE

ALLIS-CHALMERS MFG. CO.

DEPT.

1-63

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

CALCULATION OF CONCENTRATION for INVERSION at 1060m

$$X = \frac{2Q}{\pi u C_y C_z X^{2-n}} \exp - \left[\frac{h^2}{C_z^2 X^{2-n}} \right]$$

$$X = 1060 \text{ m}, h = 61 \text{ m}, h^2 = 3721 \text{ m}^2, u = 2.5 \text{ m/sec}$$

$$n = 0.35, 2-n = 1.65, C_y = 0.3, C_z = 0.033$$

The maximum frequency of Wind Direction is 40% = 0.40

$$X^{2-n} = (1060)^{1.65} = 98,120 \quad e^{-\frac{h^2}{C_z^2 X^{2-n}}} = e^{-35.11} = \approx 9.9 \times 10^{-16}$$

$$X = \frac{2(0.4)Q}{\pi(2.5)(0.3)(0.033)(98,120)} \quad 9.9 \times 10^{-16} = 1.73 \times 10^{-19} Q \frac{\mu\text{C}}{\text{m}^3}$$

$$X = 1.73 \times 10^{-25} Q \frac{\mu\text{C}}{\text{cm}^3}$$

Comparing this Dilution factor for Inversion conditions with the dilution factor for Lapse conditions as calculated on page 90, it is seen to be about 13 orders of magnitude below the factor for lapse. Since the dose for lapse conditions at 1060 meters was below tolerance, the dose for inversion conditions will be less than tolerance by comparison.

Operational Stack Release
Inversion Conditions at 1060m

313

App. D

DR'N	LCC	CH'D	D. L.	APP'D	SCALE	= 12	SHEET	28 OF 37	ISSUE
ALLIS-CHALMERS MFG. CO. DEPT.							1-63		

A

B

I Activity

58% of the activity released by a fuel element failure is due to the noble gases and therefore the fission product emission rate from the stack for fallout, Q_{FO} , is

$$\begin{aligned} Q_{FO} &= 0.42 Q_{FP} \\ &= 0.42 \left(\frac{72 \text{ a/c}}{17.36} \right) 1712 \text{ a/c} \\ &= \frac{72 \text{ a/c}}{17.36} \text{ mc/sec. (from p. 81)} \end{aligned}$$

II Deposition Rate

The deposition rate per unit area, R_D , from a continuous elevated point source, when a uniform settling velocity, v , is assumed, may be expressed by ⁽⁵⁾

$$R_D^{(x,z)} = \frac{Q_{FO} v}{\pi C_y C_z u x^{2-m}} e^{-\left[x^{m-2} \left(\frac{z^2}{C_z^2} + \frac{(z')^2}{C_z^2} \right) \right]} \text{ curies/m}^2\text{-sec}$$

and at the cloud centerline $z=0$, therefore

$$R_D = \frac{Q_{FO} v}{\pi C_y C_z u x^{2-m}} e^{-\left[\frac{(z')^2}{C_z^2} x^{m-2} \right]} \text{ curies/m}^2\text{-sec}$$

The deposition rate, R_A , in curies/sec is

$$R_A = \int_{200}^{1060} R_D L dx \text{ curies/sec}$$

where

L = average cloud width over the lake

200, 1060 = lake boundaries along the x coordinate

Simpson's rule is used to integrate the function

$$f(x) = \frac{1}{x^{2-m}} e^{-\frac{(z')^2}{C_z^2} x^{m-2}}$$

by using 10 divisions so that

$$\Delta x = \frac{1060 - 200}{10} = 86$$

(5) AECU-3066, p. 93 - Eq. 7.17 multiplied by v and modified for the nonisotropic case.

Operational Stack Release
(Fallout on lake)
I

3/3 ~~11~~

App. D

2

87

SIMILAR TO

DR'N <u>A.L.</u>	CH'D <u>B.H.2.</u>	APP'D	SCALE = 12	SHEET <u>29</u> OF <u>37</u>	ISSUE
ALLIS-CHALMERS MFG. CO. DEPT.				4-61	

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

and $\int_{200}^{1060} b(x) dx = \frac{86}{3} [f(x_0) + 4f(x_1) + 2f(x_2) + 4f(x_3) + \dots + 2f(x_8) + 4f(x_9) + f(x_{10})]$

where

$$x_0 = 200$$

$$x_1 = 286$$

...

$$x_{10} = 1060$$

For this distance, 1060 m., $z' \approx h = 61$ m

and

$$\frac{(z')^2}{C_z^2} = \left(\frac{61}{0.033} \right)^2 = 3.42 \times 10^6$$

Since

$$n = 0.35$$

$$b(x) = \frac{1}{x^{1.65}} e^{-\frac{3.42 \times 10^6}{x^{1.65}}}$$

x_m	$x^{1.65}$	$1/x^{1.65}$	$e^{-\frac{3.42 \times 10^6}{x^{1.65}}}$	$b(x_m)$	Coef.	(Coef) $b(x_m)$
200	6.262×10^3	1.60×10^{-4}	1.57×10^{-46}	2.51×10^{-50}	1	2.51×10^{-50}
286					4	
372					2	
458					4	
544					2	
630					4	
716					2	
802	6.052×10^4	1.65×10^{-5}	6.86×10^{-25}	1.19×10^{-29}	4	
888	7.326×10^4	1.37×10^{-5}	4.50×10^{-21}	6.17×10^{-26}	2	
974	8.533×10^4	1.17×10^{-5}	4.25×10^{-18}	4.97×10^{-23}	4	0.20×10^{-21}
1060	9.812×10^4	1.02×10^{-5}	7.11×10^{-16}	7.25×10^{-21}	1	7.25×10^{-21}
						7.45×10^{-21}

$$\int_{200}^{1060} b(x) dx = \frac{86}{3} \times 7.45 \times 10^{-21} = 2.14 \times 10^{-19}$$

Operational Stock Release

(fallout on lake)

INVERSION CONDITIONS

313 ~~HE~~

App-D 2 88

SIMILAR TO

DR'N D.L.	CH'D B.H. J.	APP'D	SCALE = 12	SHEET 30 OF 37	ISSUE
ALLIS-CHALMERS MFG. CO. DEPT.				4-61	

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

If we assume the area of the lake covered by the cloud is a trapezoid, the average width will occur at

$$X_i = \frac{1060 - 200}{2} = 430 \text{ meters}$$

the cloud width may be calculated from (6)

$$L = 2 \left(\ln \frac{100}{P} \right)^{1/2} C_y X \frac{2-\gamma}{2} \text{ meters}$$

where P is the percent of centerline concentration. If P is set equal to 0.5, then 99% of the cloud is taken into account.

L is then

$$\begin{aligned} L &= 2 \left(\ln \frac{100}{0.5} \right)^{1/2} (0.3) (430) \frac{2-0.35}{2} \\ &= 2 (5.298)^{1/2} (0.3) (430)^{0.825} \\ &= 2 (2.3) (0.3) (148.8) \\ &= 205 \text{ meters} \end{aligned}$$

and the deposition rate is

$$\begin{aligned} RA &= \frac{Q_{F0} V L}{\pi C_y C_g u} \int_{200}^{1060} f(x) dx \quad \frac{\text{curies}}{\text{sec}} \\ &= \frac{720 (2.0 \times 10^{-2}) (205) (2.14 \times 10^{-19})}{\pi (0.3) (0.033) (1.5)} \\ &= \frac{63.0 \times 10^{-18} \text{ Ci}}{4.67 \times 10^{-2}} = 1.36 \times 10^{-15} \text{ Ci/sec} \end{aligned}$$

Let $a_i = 1.0$
 i.e., all fission products included

where V was taken from WASH-740, Table 4, p. 50 TVA Report No. 36-100-1, "The Melton Hill Project", gives as the average flow 5270 cfs = 150 m³/sec. The activity concentration is then.

$$X_w = RA/W = \frac{1.36 \times 10^{-15} \text{ Ci/sec}}{150 \text{ m}^3/\text{sec}} = 9.09 \times 10^{-18} \frac{\text{Ci}}{\text{m}^3} = 9.09 \times 10^{-24} \frac{\text{Ci}}{\text{m}^3}$$

$$\text{and } \frac{X_w}{(MPC)_w} = \frac{9.09 \times 10^{-24}}{1 \times 10^{-7}} = 9.09 \times 10^{-17} \quad (MPC)_w \text{ used here is for mixed F.P.'s}$$

(6) AECU 3066 page 49 equation 4.70

Operational Stack Release
 (fallout on lake)

INVERSION CONDITIONS

ICC 8-62

313 App. D

SIMILAR TO

DR'N DL	CH'D BHF	APP'D	SCALE = 12	SHEET 31 OF 37	ISSUE
ALLIS-CHALMERS MFG. CO. DEPT.				4-61	8-62

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

$$\int_{200}^{1060} f(x) dx = \frac{86}{3} [f(x_0) + 4f(x_1) + 2f(x_2) + \dots + 4f(x_9) + f(x_{10})]$$

where $x_0 = 200$, $x_1 = 286$, $x_2 = 372$, ..., $x_{10} = 1060$ m.

For a distance of 1060 m, z' may be approximated by the stack height, h and

$$\frac{z'^2}{C_z^2} = \left(\frac{61}{0.3}\right)^2 = 4.134 \times 10^4$$

since

$$C_z = 0.3$$

$$n = 0.23$$

$$f(x) = \frac{1}{x^{1.77}} \exp - \left[\frac{4.134 \times 10^4}{x^{1.77}} \right]$$

x	$x^{1.77}(10^4)$	$\frac{1}{x^{1.77}(10^4)}$	$\exp - \left[\frac{4.134 \times 10^4}{x^{1.77}} \right]$	$f(x)(10^6)$	Cof.	Cof $f(x)(10^6)$
200	1.182	0.846	0.0302	2.55	1	2.55
286	2.227	0.449	0.1845	8.26	4	33.12
372	3.547	0.282	0.3104	8.75	2	17.50
458	5.126	0.195	0.4449	8.68	4	34.72
544	6.950	0.144	0.5488	7.80	2	15.80
630	9.012	0.111	0.6313	7.01	4	28.04
716	11.30	0.088	0.6977	6.14	2	12.28
802	13.82	0.072	0.7408	5.33	4	21.32
888	16.55	0.060	0.7788	4.67	2	9.34
974	19.49	0.051	0.8106	4.13	4	16.52
1060	22.64	0.044	0.8353	3.68	1	3.68

$$\sum_{m=1}^{10} f(x_m) = 194.87 \times 10^{-6}$$

$$\int_{200}^{1060} f(x) dx = \frac{86}{3} (194.87 \times 10^{-6}) = 5.586 \times 10^{-3}$$

Assuming the area of the lake covered by the cloud is a Trapezoid with an average width of 430 meters (p), the cloud width may be calculated as on page

$$L = 2 \left(\ln \frac{100}{p} \right)^{\frac{1}{2}} C_z x^{\frac{2-n}{2}}, \text{ meters}$$

$$p = 0.5, C_z = 0.3 \text{ (lapse)}, n = 0.23$$

$$L = 2 \left(\ln \frac{100}{0.5} \right)^{\frac{1}{2}} (0.3) (430)^{\frac{2-0.23}{2}}$$

$$L = 2 (2.3) (0.3) (214.1)$$

$$L = 295.46 \text{ meters}$$

Operational Stack Release, Tallant
on Melton Hill Lake
Lapse Condition

3/3
App. D

SIMILAR TO

DR'N JCC

CH'D D. L.

APP'D

SCALE

= 12

SHEET 32 OF 37

ISSUE

ALLIS-CHALMERS MFG. CO.

DEPT.

1-63

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

The Deposition Rate is:

$$R_A = \frac{Q_{FO} V_L}{\pi C_y C_z u} \int_{200}^{1060} f(x) dx$$

$$R_A = \frac{72 \cdot \cancel{10^{-3}} \cdot (2.0 \times 10^{-2}) (295) (5.586 \times 10^{-3})}{\pi (0.3)(0.3)(2.3)}$$

$$R_A = \frac{3.6488}{\cancel{1.1 \times 10^{-3}}} \mu C/sec \quad [a_i = 1.00 \text{ for total F.P. activity}]$$

This assumes $V = 2.0 \times 10^{-2}$ which gives the more conservative (HIGHER R_A) case (from WASH-740 Table 4 p. 50) ($\bar{u}$ for lapse = 2.3 m/sec)

Flow Rate for LAKE = 5270 cfs = 150 m³/sec From TVA Report # 36-100-1 "The Melton Hill Project"

$$X_w = R_A / \bar{W} = \frac{3.6488}{\cancel{1.1 \times 10^{-3}}} \mu C/sec = \frac{2.433}{\cancel{1.1 \times 10^{-3}}} \frac{\mu C}{m^3}$$

$$X_w = \frac{2.433}{\cancel{1.1 \times 10^{-3}}} \frac{\mu C}{cm^3}$$

using $(MPC)_w$ for a mixture of fission products of 1×10^{-7}

$$\frac{X_w}{(MPC)_w} = \frac{2.433 \times 10^{-8}}{\cancel{1.1 \times 10^{-3}}} = \cancel{1.1 \times 10^{-3}} \cdot 0.243$$

That is the concentration of fission products from dry fallout in the lake is below the $(MPC)_w$ water by a factor of ~~1.1 x 10⁻³~~ 0.243

Operational Stack Release
FALLOUT ON LAKE
LAPSE CONDITIONS

313

APP. D

DR'N JCE

CH'D G.L.

APP'D

SCALE = 12

SIMILAR TO

SHEET 33 OF 37

ISSUE

ALLIS-CHALMERS MFG. CO. DEPT.

1-63

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

CALCULATION of CONTAMINATION of MELTON HILL LAKE by WASHOUT of FISSION PRODUCT PARTICLES.

Particulate fission products will be removed by rain and deposited in the lake. The deposition rate is assumed to be:

$$P \frac{\mu C}{\text{sec}} = \frac{\lambda Q_0 \exp\left[-\frac{\lambda x}{\bar{u}}\right]}{\bar{u} \pi^{1/2} C_y X^{\frac{2-n}{2}}} \quad \left(\text{WASH 740 page 51}\right)$$

Q_0 will be expressed in a release rate of $\mu C/\text{sec}$. To be conservative, horizontal diffusion and stack height are neglected. An integration over the surface of the lake will be performed (as for dry fallout) using Simpson's Rule.

$$P \frac{\mu C}{\text{sec}} = \frac{\lambda Q_0 \frac{\mu C}{\text{sec}}}{\bar{u} \pi^{1/2} C_y} \int_{200}^{1060} e^{-\frac{\lambda x}{\bar{u}}} \cdot \frac{1}{X^{\frac{2-n}{2}}} dx$$

Simpson's Rule with $\Delta x = 86$ (i.e., 10 divisions)

$$\int_{200}^{1060} f(x) dx = \frac{86}{3} [f(x_0) + 4f(x_1) + 2f(x_2) + \dots + 4f(x_9) + f(x_{10})]$$

where $f(x) = e^{-\frac{\lambda x}{\bar{u}}} \cdot \frac{1}{X^{\frac{2-n}{2}}}$

INVERSION

$$C_y = 0.3 \quad n = 0.35 \quad \bar{u} = 1.5 \text{ m/sec} \quad \frac{2-n}{2} = 0.825$$

A particle size of 15.0μ was assumed for conservative results. A rain fall of 0.15 in/hr was assumed to yield a value for λ , the proportion of the cloud removed per second, of 1.0×10^{-3} . This rainfall will also yield conservative results.

$$\therefore \frac{\lambda}{\bar{u}} = \frac{1.0 \times 10^{-3}}{1.5} = 6.67 \times 10^{-4} \quad \therefore e^{-\frac{\lambda x}{\bar{u}}} = e^{-6.67 \times 10^{-4} x}$$

$$\text{and } \frac{\lambda}{\bar{u} \pi^{1/2} C_y} = \frac{1 \times 10^{-3}}{1.5 (\pi)^{1/2} 0.3} = \frac{1 \times 10^{-3}}{0.797} = 1.25 \times 10^{-3}$$

Operational Stack Release
WASHOUT INTO LAKE

313

App. D

SIMILAR TO

DR'N <i>JCE</i>	CH'D <i>D.L.</i>	APP'D	SCALE = 12	SHEET 34 OF 37	ISSUE
ALLIS-CHALMERS MFG. CO. DEPT.				1-63	

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

X	X ^{0.825}	$\frac{1}{X^{0.825}}$	$e^{-.667(-2)x}$	f(x)	Simpson Rule Coeff.	Coeff x f(x)
200	0.79(2)	1.26(-2)	0.874	1.10(-2)	1	1.10(-2)
286	0.86(2)	0.94(-2)	0.825	0.78(-2)	4	3.12(-2)
372	1.32(2)	0.76(-2)	0.779	0.59(-2)	2	1.18(-2)
458	1.57(2)	0.64(-2)	0.736	0.47(-2)	4	1.88(-2)
544	1.81(2)	0.55(-2)	0.695	0.38(-2)	2	0.76(-2)
630	2.04(2)	0.49(-2)	0.657	0.32(-2)	4	1.28(-2)
716	2.23(2)	0.45(-2)	0.619	0.28(-2)	2	0.56(-2)
802	2.49(2)	0.40(-2)	0.580	0.23(-2)	4	0.92(-2)
888	2.71(2)	0.37(-2)	0.552	0.20(-2)	2	0.40(-2)
974	2.92(2)	0.34(-2)	0.522	0.18(-2)	4	0.72(-2)
1060	3.13(2)	0.32(-2)	0.492	0.16(-2)	1	0.16(-2)

$$\Sigma [f(x_0) + 4f(x_1) + \dots + f(x_{10})] = 12.08(-2)$$

$$\frac{86}{3} (\Sigma \text{coeff} \times f(x)) = \frac{86}{3} (0.1208) = 3.463 = \int_{200}^{1060} f(x) dx$$

for Inversion

$$P = \frac{1 Q_0}{u \pi^{1/2} C_y} \int_{200}^{1060} f(x) dx = 1.25 \times 10^{-3} (3.463) Q_0 = 4.33 \times 10^{-3} Q_0 \frac{\mu C}{\text{sec}}$$

$$P = 4.33 \times 10^{-3} Q_0 \frac{\mu C}{\text{sec}}$$

LAPSE

$$C_y = 0.3 \quad \bar{u} = 2.3 \text{ m/sec} \quad n = 0.23 \quad \frac{2-n}{2} = 0.885$$

Using the same 15.0 micron particle size and rainfall as in inversion conditions, Λ will remain the same, 10^{-3} .

$$\therefore \frac{\Lambda}{\bar{u}} = \frac{1 \times 10^{-3}}{2.3} = 4.35 \times 10^{-4} \quad \therefore e^{-\frac{\Lambda x}{\bar{u}}} = e^{-4.35 \times 10^{-4} x}$$

$$\text{and } \frac{\Lambda}{\bar{u} \pi^{1/2} C_y} = \frac{1 \times 10^{-3}}{2.3 (1.77) (0.3)} = \frac{10 \times 10^{-4}}{1.22} = 8.18 \times 10^{-4}$$

Operational Stack Release

WASHOUT INTO LAKE

313

App. D

SIMILAR TO

DR'N JCE

CH'D

A. L.

APP'D

SCALE

= 12

SHEET 35 OF 37

ISSUE

ALLIS-CHALMERS MFG. CO.

DEPT.

1-63

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

X	X ^{0.885}	$\frac{1}{X^{0.885}}$	$e^{-4.35(-9)x}$	f(x)	Simpson's coeff	coeff x f(x)
200	1.09(2)	0.92(-2)	0.917	8.44(-3)	1	8.44(-3)
286	1.49(2)	0.67(-2)	0.883	5.92(-3)	4	23.64(-3)
372	1.88(2)	0.53(-2)	0.852	4.51(-3)	2	9.02(-3)
458	2.26(2)	0.44(-2)	0.819	3.60(-3)	4	14.40(-3)
544	2.64(2)	0.38(-2)	0.787	2.99(-3)	2	5.98(-3)
630	3.00(2)	0.33(-2)	0.763	2.52(-3)	4	10.08(-3)
716	3.36(2)	0.30(-2)	0.733	2.20(-3)	2	4.40(-3)
802	3.72(2)	0.27(-2)	0.705	1.90(-3)	4	7.64(-3)
888	4.07(2)	0.25(-2)	0.680	1.70(-3)	2	3.40(-3)
974	4.42(2)	0.23(-2)	0.657	1.51(-3)	4	6.04(-3)
1060	4.76(2)	0.21(-2)	0.631	1.33(-3)	1	1.33(-3)

$$\Sigma [f(x) + 4f(x_1) + \dots + f(x_n)] = \frac{94.48(-3)}{94.34}$$

$$\frac{86}{3} (\Sigma \text{coeff} \times f(x)) = \frac{86}{3} \left(\frac{0.09434}{0.09442} \right) = \frac{2.77}{2.70} = \int_{200}^{1060} f(x) dx$$

for LAPSE

$$P = \frac{1}{u \pi^{1/2} c_y} \int_{200}^{1060} f(x) dx = \frac{8.18}{2.20 \times 10^{-4}} \left(\frac{2.70}{2.77} \right) Q_0 = \frac{2.21}{2.22} \times 10^{-3} Q_0 \frac{\mu C}{\text{sec}}$$

$$P = \frac{2.21}{2.22} \times 10^{-3} Q_0 \frac{\mu C}{\text{sec}}$$

Assuming 58% of Activity released by a fuel element failure is due to the noble gases, the particulate fission product emission rate from the stack would be

$$Q_0 = Q_{\text{FALLOUT}} = 0.42 Q_{\text{FP}} = 0.42 (171 \text{ Ci}) = 72 \text{ Ci} \frac{\mu C}{\text{sec}}$$

Assuming no filtration, fractional release of activity $Q_1 = 1$ $\therefore Q_0 = 72 \mu C/\text{sec}$

$$\text{Inversion } P = 4.33 \times 10^{-3} (72 \frac{\mu C}{\text{sec}}) = 0.312 \frac{\mu C}{\text{sec}}$$

$$P = 0.312 \frac{\mu C}{\text{sec}}$$

$$\text{Lapse } P = \frac{2.21}{2.22} \times 10^{-3} (72 \frac{\mu C}{\text{sec}}) = \frac{0.159}{0.160} \frac{\mu C}{\text{sec}}$$

$$P = \frac{0.159}{0.160} \frac{\mu C}{\text{sec}}$$

Operational Stack Release
WASHOUT INTO LAKE

313

App. D

SIMILAR TO

DR'N JCL	CH'D	APP'D	SCALE = 12	SHEET 36 OF 37	ISSUE
ALLIS-CHALMERS MFG. CO. DEPT.				1-63	

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

The flow rate in the lake is $150 \frac{\text{m}^3}{\text{sec}}$ or $1.5 \times 10^8 \frac{\text{cm}^3}{\text{sec}}$. The concentration in the lake would be:

$$\frac{P \frac{\mu\text{C}}{\text{sec}}}{1.5 \times 10^8 \frac{\text{cm}^3}{\text{sec}}} = 6.67 \times 10^{-9} P \frac{\mu\text{C}}{\text{cm}^3}$$

For Inversion Conditions

$$\text{concentration} = 6.67 \times 10^{-9} (0.312 \frac{\mu\text{C}}{\text{sec}}) = 2.08 \times 10^{-9} \frac{\mu\text{C}}{\text{cm}^3}$$

The (MPC)_w for an unknown mixture of fission products is $10^{-7} \mu\text{C}/\text{ml} = 10^{-7} \mu\text{C}/\text{cm}^3$ (from NBS Handbook 69, page 93). Therefore, the concentration for inversion conditions is below the (MPC)_w by a factor of

$$\frac{2.08 \times 10^{-9} \frac{\mu\text{C}}{\text{cm}^3}}{10^{-7} \frac{\mu\text{C}}{\text{cm}^3}} = 2.08 \times 10^{-2}$$

For Lapse Conditions

$$\text{concentration} = 6.67 \times 10^{-9} (\frac{0.159}{60} \frac{\mu\text{C}}{\text{sec}}) = 1.06 \times 10^{-9} \frac{\mu\text{C}}{\text{cm}^3}$$

The concentration for lapse conditions is below the (MPC)_w by a factor of

$$\frac{1.06 \times 10^{-9} \frac{\mu\text{C}}{\text{cm}^3}}{10^{-7} \frac{\mu\text{C}}{\text{cm}^3}} = 1.06 \times 10^{-2}$$

It is seen that the operational stack release does not raise the concentration of fission products in Melton Hill Lake above the (MPC)_w for the assumed Meteorological conditions.

It should be noted that the combination of rain and inversion conditions is relatively uncommon.
[WASH 740 p 53]

Operational Stack Release
WASHOUT INTO LAKE

313

App. D

SIMILAR TO

DR'N DCE

CH'D J.L.

APP'D

SCALE

= 12

SHEET

37 OF 37

ISSUE

ALLIS-CHALMERS MFG. CO.

DEPT.

1-63

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

Thyroid Doses Due To STEAM SYSTEM FAILURE

Results summarized from IV-334 Approved Issue dated 9-7-62 Appendix D page 4B of 4B

The Activity is released from a 61 meter high stack

Meteorological Condition	Connected to TVA Network		Disconnected from TVA Network	
	LAPSE	INVERSION	LAPSE	INVERSION
Dist. of Max. Ground Conc.	401 m	9090 m	401 m	9090 m
Maximum Thyroid Dose	0.0306 Rem	0.005 Rem	1.33 Rem	0.224 Rem
Minimum Thyroid Dose	negligible	negligible	0.24 Rem	0.040 Rem

(Thyroid dose given is at point of maximum ground concentration)

Electromatic Relief Valves release Activity

Thyroid Dose due to Steam
System FAILURE
(Electromatic Relief Valve Release)

Source: IV 334

313

App. E

DR'N ADA	CH'D <i>alx</i>	APP'D	SCALE = 12	SIMILAR TO	SHEET / OF /	ISSUE
ALLIS-CHALMERS MFG. CO. DEPT.						

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3