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1. PURPOSE

The purpose of this calculation is to provide control room infiltration rates that produce thyroid inhalation doses equal to the regulatory limits for a variety of control room models. Whole body and beta skin doses from airborne activity within the control room are also checked against regulatory limits.

2. ASSUMPTIONS AND DATA

2.1 Assumptions

The assumptions of Reference 7 (Section 2.4) and of Reference 8 (Subsection 2.1.2) are used.

The sprayed volume of the containment is 85% of the free volume.

Various values for control room recirculation filter efficiency and control room infiltration rate are assumed.

For wall deposition purposes, the wetted area is assumed to be 410,000 ft^2; see Section 4.5 for discussion.

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2.2 Data

Primary Containment Data

Description	Value	Reference
Containment Free Volume, ft^3	2.736+6	Ref. 9, Table 14.3.2-5 (1)
Fraction of Containment Vol. Sprayed	.85	Assumed
Containment Leak Rate, %/day		
0 - 24 hr	0.1	Ref. 10, p. 212
24 - 720 hr	0.05	Ref. 1, p. 1.4-1
Iodine Species Fractions		
Elemental	.91	Ref. 1, p. 1.4-1
Particulate	.05	
Organic	.04	
Spray Flow Rate, gpm		
One pump	2615.	Calculated from two pumps
two pumps	5230.	Ref. 11, p. 6A-9
Spray Drop Fall Height, ft.	147.	Ref. 11, Table 6A-1
Sump Water Volume	—	See Section 4.4
Iodine Partition Coefficient	10,000.	See Subsection 4.2.1
Spray Nozzle Type	SPRAYCO #1713	Ref. 11, p. 6.4-4
Spray Nozzle Types #1713 and #1713A Have Same Characteristics	—	Ref. 12
Spray Nozzle #1713A Data	—	Ref. 13

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Atmospheric Dilution Data

Description	Value	Reference
Containment Projected Area Normal to Wind Direction, ft^2	26436.	Ref. 14, p. 18
m^2	2456.	Ref. 14, p. 18
Plan View Separation Distance, ft, (Containment surface to Control Room Air Inlet)	91.76	Ref. 14, p. 13
Circuitous Path Separation Distance, m.	80.	Ref. 15, p. 2-26
ft.	262.5	(calculated from 80 m.)
Containment Outside Diameter, ft.	147	Ref. 14, p. 12

Control Room Data

Description	Value	Reference
Free Volume, ft^3	1.19122+5	Ref. 16
Make-up Air Flow Rate, cfm	2000. ± 10%	Ref. 10, p. 284
Conservative Value*, cfm	1800.	Calculated*
Recirculation Air Flow Rate, cfm	11500.	Ref. 16
Make-up Air Filter Efficiency (Iodine)	99%	Ref. 11, Q9.8-1 & Q9.3-1

* Conservative value = 2000. − .10 * 2000. = 1800. This smaller value gives less dilution by filtered air, thus higher thyroid doses (conservative).

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3. METHODS

NRC guidance found in References 1 through 5 is used.

Spray removal rates, plateout rate, and decontamination factors formulations and data are taken from Reference 2, pages 6.5.2-10 through 6.5.2-12. Parameters for the elemental iodine spray removal rate are obtained from computer runs using program SPIRT, S & L Program Number SPI 09810010 0 (Reference 6). Effective spray times are hand calculated using the algorithms of Reference 7, pages 9, 10, and 27; these describe a two compartment model (unsprayed and sprayed) for spray removal as inferred by Reference 2, p. 6.5.2-7.

Control room (χ/Q') methodology is obtained from Reference 4 and the resulting windspeeds are converted to POSTDBA windspeeds by the methods in Reference 7.

Control room finite cloud correction factors for whole body dose are obtained from a computer run using program POSTDBA, S&L Program Number POS 09808511 0 (Reference 8).

Control room doses are obtained from computer runs using program POSTDBA, S&L Program Number POS 09808511 0 (Reference 8). Thyroid doses are supplemented with values using the Iodine Protection Factor (IPF) methodology of Reference 4.

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4. SPRAY REMOVAL ANALYSES

4.1 Spray Description

The operation of the containment spray is described in the Zion FSAR. According to Reference 11, Appendix A, pages 6A-8 and 6A-9, two spray pumps operate at a total of 5230 gpm for 15 minutes during the injection phase. This leaves 100,000 gal. in the RWST. At this point the changeover to the recirculation phase is manually started. But the spray injection phase continues another 19 minutes depleting the last 100,000 gal. from the RWST. This implies that two spray pumps are still operating during this last 19 minutes.

However, Reference 11, page 6.2-9 says that only one spray pump operates to empty the RWST. One spray pump operating at 5230 gpm/2 = 2615 gpm on 100,000 gal. would take 100,000 gal/2615 gpm = 38.24 minutes to empty the RWST. As will be seen in Subsections 4.7.1 and 4.7.2, the smaller spray rate results in a smaller removal rate for particulate iodine. Thus, it will take longer to reach a DF of 50 (Subsection 4.7.3); this would lead to conservatively larger thyroid doses. Thus, after the first 15 minutes of operation by two spray pumps, one spray pump will be considered as operating for an additional 38 minutes (conservatively rounded).

In summary, the spray will operate at 5230 gpm for the time period 0-15 minutes. Then, it will operate at 2615 gpm for the time period 15-53 minutes.

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4.2 SPIRT Calculations

4.2.1 Data and Preliminary Calculations

The SPIRT options used and most of the SPIRT data are taken from Reference 17. Exceptions are now given.

Containment Free Volume = 2.736+6 ft^3, Ref. 9, Table 14.3-2-5 (1)
(SPIRT acronym CNTVOL)

Fraction of containment free volume sprayed = .85, assumed
(SPIRT acronym FRCVS).

Spray flow rate = 5230 gpm for two pumps } See Section 4.1
= 2615 gpm for one pump }
(SPIRT acronym FLOW)

Partition Coefficient = 10,000, Ref. 18, Figure 33, page 44, for pH = 7 (conservative). A conservatively small H is picked at a time much less than 1000 sec; note that spray is on longer than 1000 sec (Section 4.1).
(SPIRT acronym H)

Plateout surface area = 410,000 ft^2 See Section 4.5.
From Reference 17, page 8, this gives

SPIRT acronym AWALLR = $410{,}000 * \frac{10}{147}$ = 2.789+4 ft^2

and SPIRT acronym AWALTR = 410,000 − 2.789+4 = 3.8211+5 ft^2

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4.2.2 SPIRT Input

The SPIRT input instructions are in Reference 6. The input listings for both cases (5230 gpm and 2615 gpm spray flow rates) are found on the attached microfiche (Microfiche A):

ZI-5-91 RU SR NSLD 4C4-A1 SYS CR CNTRL RM INFILT STDY(SPIRT)
S&L 03/11/91 10:15:52 WG=212 ID=DRSH
ORIG=05 DUPS=01 PRJ=ZIO780511 PGM=SPI098100100/

The input description for each case is as follows.

Card No. 1 Format (20A4)
(TITLE(I), I=1, 20) Literal title (see listing, Microfiche A)

Card No. 2 Format (6I3)

NGRP = 50	Rev. 0	Ref. 17
NTYPE = 1	Rev. 0	
NSTEPS = 147	Rev. 0	
NREAC = 1	Rev. 1	
NDATA = 0	Rev. 0	

Card No. 3 Format (8E10.8)

CNTVOL = 2.736+6		Subsection 4.2.1
FRCVS = .85		Subsection 4.2.1
FLOW = 5230.0	for case 1	Subsection 4.2.1
= 2615.0	for case 2	
ZMAX = 147.0		Ref. 17, Rev. 0
EFC = 1.0		
H = 10000.0		Subsection 4.2.1

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Card No. 4 Format (8E10.3)

TNORM = 70.0 Rev. 0
TEMPF = 267.0 Rev. 0
DMEANG = .0282 Rev. 0
SIGMAG = 2.018 Rev. 0
RK = 7.7-8 Rev. 1
HR = 5.0 Rev. 1
DMAX = 0.4 Rev. 0

Reference 17 and
Reference 11, Subsection 6.4.2,
page 6.4-1.

Card No. 5 Format (8E10.3)

AWALLR = 2.789+4
AWALTR = 3.8211+5

Subsection 4.2.1

WALLFR = .05 Rev. 0
WALLDT = 1.0 Rev. 0
CNTDIA = 140.0 Rev. 0
WALLSP = 6.465+4 Rev. 0

Reference 17

Cards 6 and 7 are omitted because NTYPE=1.

4.2.3 SPIRT Output

The SPIRT output for both SPIRT cases can be found in the attached Microfiche A.

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4.3 Elemental Iodine Spray Removal Rate

4.3.1 Spray Flow Rate of 5230 GPM (Two Pumps)

The following table presents the calculation of the elemental iodine spray removal rate, λ_s, for two spray pumps operating (accident time 0 to 15 minutes). Note that the volume mean diameter from the final SPIRT temporal distribution is used because it is larger than that from the final spatial distribution; thus, the calculated λ_s is smaller (conservative).

	Case 1 SPIRT Results* at Drop Diameters (D) of		Linearly Interpolated
Variable	D=.1715 cm	D=.1918 cm	for D=.1829 cm**
h (input)	147. ft.	147. ft.	—
v (calculated)	417.6 cm/sec	441.5 cm/sec	—
$T = h/v$	.35201 ft·sec/cm	.33296 ft·sec/cm	.34131 ft·sec/cm
K_g (calculated)	5.544 cm/sec	5.354 cm/sec	5.437 cm/sec
V (input)	2.736+6 ft^3	2.736+6 ft^3	2.736+6 ft^3
F (input)	5230. gpm	5230. gpm	5230. gpm
C ***	244.4	244.4	244.4
$\lambda_s = C \frac{6 K_g T F}{V D}$ †	31.90 hr^{-1}	26.05 hr^{-1}	28.44 hr^{-1} ††

---

* see attached microfiche A

** Mass mean diameter (volume) from final SPIRT temporal distribution; see microfiche A.

*** Units conversion factor, $cm \cdot ft^2 \cdot min/(gal \cdot hr)$ from (30.48 cm/ft)(.13365 ft^3/gal)(60. min/hr).

† From Ref. 2, page 6.5.2-10 (except units conversion factor C).

†† Calculated using linearly interpolated values and D=.1829 cm.

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4.3.2 Spray Flow Rate of 2615 GPM (One Pump)

The following table presents the calculation of the elemental iodine spray removal rate, λ_s, for one spray pump operating (accident time 15 to 53 minutes).

	Case 2 SPIRT Results * at Drop Diameters (D) of		Linearly Interpolated
Variable	D= .1382 cm	D= .1539 cm	for D= .1405 cm **
h (input)	147. ft.	147. ft.	——
v (calculated)	374.8 cm/sec	395.5 cm/sec	——
$T = h/v$	.39221 ft·sec/cm	.37168 ft·sec/cm	.38920 ft·sec/cm
k_g (calculated)	5.944 cm/sec	5.740 cm/sec	5.914 cm/sec
V (input)	$2.736+6$ ft^3	$2.736+6$ ft^3	$2.736+6$ ft^3
F (input)	2615. gpm	2615. gpm	2615. gpm
C ***	244.4	244.4	244.4
$\lambda_s = C\dfrac{6k_g TF}{VD}$ †	23.64 hr^{-1}	19.43 hr^{-1}	22.96 hr^{-1} ††

---

* see attached microfiche A.

** Mass mean diameter (volume) from final SPIRT temporal distribution; see microfiche A.

*** Units conversion factor, $cm \cdot ft^2 \cdot min/(gal \cdot hr)$ from
(30.48 cm/ft)(.13365 ft^3/gal)(60. min/hr).

† From Ref. 2, page 6.5.2-10 (except units conversion factor C).

†† Calculated using linearly interpolated values and D= .1405 cm.

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4.3.3 Elemental Iodine Spray Removal Summary

The SPIRT calculated parameters are now summarized for each flow rate.

Variable		Two Spray Pumps, 5230. gpm	One Spray Pump, 2615. gpm
Mass mean drop size diameter,	D	.1829 cm. or 1829 μ	.1405 cm. or 1405 μ
Drop fall time,	T	10.403 sec. or .1734 min.	11.863 sec. or .1977 min.
Mass transfer coefficient,	K_g	5.437 cm/sec or 10.70 ft/min.	5.914 cm/sec or 11.64 ft/min.

The following table presents the elemental iodine spray removal rates that were obtained.

TABLE 1

Elemental Iodine Spray Removal Rates

Spray Flow Rate	Calculated Rate	To Be Used Rate
5230 gpm (two pumps) ; $0 \le t \le 15$ minutes†	28.44 hr^{-1}	20. hr^{-1} *
2615 gpm (one pump) ; $15 < t \le 53$ minutes†	22.96 hr^{-1}	20. hr^{-1} *

---

* Spray removal rate for elemental iodine is limited to 20. hr^{-1} by Reference 2, p. 6.5.2-11.

† subject to the DF = 200. constraint (Section 4.4)

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4.4 Elemental Iodine Spray Decontamination Factor

The elemental iodine spray decontamination factor is given by

$$(DF) = 1 + HV_s/(V - V_s) \qquad \text{(Ref. 2, p. 6.5.2-12)}$$

where H = partition coefficient = 10,000 (Subsection 4.2.1)
V = containment free volume = 2.736+6 ft^3 (Section 2.2)
V_s = water volume in sump

V_s is comprised of:

RWST tank minimum volume = 350,000 gal. Ref. 11, Table 6.2-4
Accumulators volume = 25,436 gal. Ref. 11, Table 6.2-2
Boron Injection Tank Volume = 900 gal. Ref. 11, Table 6.2-3
Reactor coolant Volume = 95,000 gal. Ref. 11, p. 14A.8-1*
Spray additive Tank Volume = 2,500 gal. Ref. 11, p. 6.4-2

Total Sump Volume V_s = 473,936 gal

V_s = 63342 ft^3

$$(DF) = 1 + 10000 * 63342/(2.736+6 - 63342)$$

$$(DF) = 238.0$$

But Ref 2, p. 6.5.2-12 limits the (DF) to 200; therefore

$$(DF) = 200.$$

---

* Reference gives 12,760. ft^3 which is 95,470. gal. then rounded to 95,000 gal.

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4.5 Elemental Iodine Wall Deposition Rate

The elemental iodine wall deposition rate is given as

$$\lambda_w = K_w A_w / V$$, Reference 2, p. 6.5.2-10

where

A_w = wetted surface area, ft^2

V = containment free volume = 2.736+6 ft^3

Ref. 9, Table 14.3.2-5(1)

and K_w = 4.9 m/hr , Reference 2, p. 6.5.2-10.

(a units conversion factor is also required.)

Reference 9, Tables 14.3.2-5(1), 14.3.2-5(2), and 14.3.4-8 provide structural heat sink areas in the primary primary containment. These tables are attached as the next three pages of this calculation. When the individual areas, omitting the 15500 ft^2 floor area which is assumed flooded, are added, the total area is found to be 449211. ft^2. All of this area may not be wetted. There is no way to determine the amount of dry area (if any). Any smaller area than this total area would give a conservatively smaller λ_w (less wall deposition implies more leakage to invironment and higher doses). This calculation will arbitrarily assume an A_w = 410,000 ft^2. Then,

$$\lambda_w = \left[4.9 \frac{m}{hr} * (410{,}000\ ft^2) / (2.736 \times 10^6\ ft^3)\right] / .3048 \frac{m}{ft}$$

$$\lambda_w = 2.41\ hr^{-1}$$

The accuracy of λ_w is not important because it is always added to λ_s (20 hr^{-1}) (Section 4.3) and $\lambda_s + \lambda_w$ is effective only until a DF of 200 is reached (Section 4.4 & 4.6) no matter how small λ_w is.

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TABLE 14.3.2-5(1)

CONTAINMENT DATA

NET FREE VOLUME	2.736×10^6 ft^3
INITIAL CONDITIONS	
Pressure	14.7 psia
Temperature	90°F
RWST Temperature	62°F
Service Water Temperature	33°F
Outside Temperature	-10°F
SPRAY SYSTEM	
Number of Pumps Operating	3
Runout Flow Rate	3600 gpm/each
Actuation Time	45.0 seconds
SAFEGUARDS FAN COOLERS	
Number of Fan Coolers	5
Fastest Post-Accident Initiation of Fan Coolers	38 sec

STRUCTURAL HEAT SINKS

Structure Thickness (in)	Area (ft^2)
Painted Containment Cylinder .25 steel, 12 concrete; .004 paint	54447
Painted Containment Dome .25 steel, 12 concrete; .004 paint	15026
Containment Floor 18 concrete	15500
Reactor Cavity .25 steel, 12 concrete	2000
Crane Wall, Operating Deck 12 concrete	36000
Shield Walls 9 concrete	7000

TABLE 14.3.2-5 (2)

CONTAINMENT DATA

Thickness (in.)	Area (Ft^2)
Refueling Canal .25 steel, 12 concrete	16000
Misc. Steel Structures .25 steel	54860
Misc. Painted Steel .375 steel; .004 paint	89300
Misc. Stiffeners 0.6249 steel	1060
5.25 steel, 12 concrete	1147
.64 steel, 12 concrete	1400
10.51 steel, 12 concrete	186
24.51 steel, 12 concrete	54
.75 steel, 12 concrete	440
7.287 steel, 12 concrete	603.94
12.0308 steel, 12 concrete	180.93
Unpainted Containment Cylinder 0.25 steel, 12 concrete	14862.
Unpainted Containment Dome 0.25 steel, 12 concrete	3712
Unpainted Misc. Steel 0.375 steel	32000

TABLE 14.3.4-8

ADDITIONAL STRUCTURAL HEAT SINKS

	Exposed Surface (ft^2)	Thickness (inches)
Accumulator Tanks	576	2-3/4
	404	3/8
	260	1-13/32
Ducts	7300	1/4
Fan Coolers	11,760	3/8
Polar Crane	40,000	3/8*
Duct	2050	1/4
CRDM Missile Shield Support Beams	1,913	3/8*
Cable Pan Structural Framing	2,279	3/8*
Steam Generator and Reactor Coolant Pump Supports	14,794	3/8*
Galleries	37,596	3/8*

*Both sides exposed

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4.6 Calculation of Elemental Iodine Spray Time (Effective)

The following is a calculation of the spray time for which the elemental iodine spray removal rate is effective. The removal rate should be the sum of λ_s (spray removal rate, see Subsection 4.3.3) and λ_w (wall deposition rate, see Section 4.5). This idea is obtained by the following considerations.

- if λ_w is omitted the spray time will be too long (nonconservative) because the (DF) will not be reached at proper time (removal from the air is too small).
- if λ_w is included the spray time will be too short (conservative) because the (DF) will be reached before the proper time (removal by λ_w was to the wall and not to the water).
- Radiodecay should not be included because that rate occurs both in the air and in the water and, thus, does not affect the concentration ratio.
- Leakage from the primary containment can be ignored because it is (comparitively) negligible.

Thus, to be conservative the removal rate λ_R to be used in the calculation of the elemental iodine spray time is

$$\lambda_R = \lambda_s + \lambda_w$$

$\lambda_R = 20. + 2.41 = 22.41\ hr^{-1}$ (two spray pumps)
$\lambda_R = 20. + 2.41 = 22.41\ hr^{-1}$ (one spray pump).

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As in Reference 7, the primary containment is described by a two compartment model - an unsprayed volume and a sprayed volume. The sprayed volume is assumed to be 85% of the total volume.

Primary Containment total volume = 2.736+6 ft^3 (Ref. 9, Table 14.3.2.5(1))
Unsprayed volume, $V_1 = .15 \times 2.736{+}6 = 4.104{+}5\ ft^3$
Sprayed Volume, $V_2 = .85 \times 2.736{+}6 = 2.3256{+}6\ ft^3$

The Reactor Containment Fan Coolers provide mixing between the two volumes. The flow rate for each fan is 66,000 cfm (Reference 19). During accident conditions three of the five fans must operate (Reference 19). Therefore, the flow rate for containment mixing is

$$3 \times 66,000 = 198,000 \text{ cfm}.$$

Subsections 6.1.4 and 6.1.7 of Reference 19 contain the referenced information.

The methodology for calculating the spray time is given in Reference 7, pp. 9, 10, and 27.

Assumption: the initial activity release is into the unsprayed volume (conservative); thus, $a_2(0) = 0.0$

Data: $Q_{12} = Q_{21} = 1.98+5$ cfm
$S = \lambda_R = 22.41$ hr^{-1}
$V_1 = .15*(2.736+6) = 4.104+5$ ft^3 (unsprayed)
$V_2 = .85*(2.736+6) = 2.3256+6$ ft^3 (sprayed)
$l_1 = (Q_{12}/V_1)*60 \frac{min}{hr} = 28.94736842$ hr^{-1}
$m_1 = \lambda + L + P + l_1 = 28.94736842$ hr^{-1}
(λ, L, and P $\equiv 0.0$)
$l_2 = (Q_{21}/V_2)*60 \frac{min}{hr} = 5.108359133$ hr^{-1}
$m_2 = \lambda + L + P + S + l_2 = 27.51835913$ hr^{-1}

$$\mu_a = \frac{1}{2}\left[-(m_1+m_2)+\sqrt{(m_1+m_2)^2-4(m_1m_2-l_1l_2)}\right] = -16.05156373$$

$$\mu_b = \frac{1}{2}\left[-(m_1+m_2)-\sqrt{(m_1+m_2)^2-4(m_1m_2-l_1l_2)}\right] = -40.41416382$$

Since the fraction of the activity remaining airborne is independent of the initial activity, set

$a_1(0) = 1.0$ (initial activity release in unsprayed volume)

Then,

$C_a = -(\mu_b + m_1)/(\mu_a - \mu_b) = .4706720694$
$C_b = (\mu_a + m_1)/(\mu_a - \mu_b) = .5293279306$

$C_{a1} = C_a(\mu_a + m_1)/l_2 = 1.188188794$
$C_{b1} = C_b(\mu_b + m_1)/l_2 = -1.188188794$

Therefore,

$$a_1(t) = .4706720694\, e^{-16.05156373\, t} + .5293279306\, e^{-40.41416382\, t}$$

$$a_2(t) = 1.188188794\, e^{-16.05156373\, t} - 1.188188794\, e^{-40.41416382\, t}$$

The fraction remaining airborne is just

$$F_R(t) = a_1(t) + a_2(t) \quad ,$$

and the decontamination factor is

$$DF(t) = 1.0 / F_R(t) \ .$$

The above equations (this page) must be solved for t_c (spray effectiveness cutoff time) at which $DF(t_c) = 200$ (see Section 4.4). The procedure is illustrated in the following table.

Estimated Time, t					
Minutes	Hours	$a_1(t)$	$a_2(t)$	$F_R(t)$	$DF(t)$
15	.25	8.531912210-3	2.143506148-2	2.996697369-2	33.37007
20	.3333333333	2.234404222-3	5.637083632-2	7.871487854-3	127.04079
21.697	.3616166667	1.418807125-3	3.580574193-3	4.999381319-3	200.02475
21.69654	.3616090000	1.418977985-3	3.581005175-3	4.999983160-3	200.000

Therefore, the spray effectiveness cutoff time is

$t_c = .361609$ hr for elemental iodine. (less than the 53 minute spray operating time).

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4.7 Particulate Iodine Spray Removal Rate

4.7.1 Spray Flow Rate of 5230 GPM (Two Pumps)

The particulate iodine spray removal rate, λ_p, is given by

$$\lambda_p = \frac{3hF}{2V}\left(\frac{E}{D}\right) \qquad (\text{Ref. } 2,\ \text{p. } 6.5.2-11)$$

where

h = spray drop fall height = 44.8 m. (147 ft)

F = spray flow rate = 5230 gpm.

$\left(\frac{E}{D}\right) = 10.\ m^{-1}$ until a decontamination factor of 50 is reached (Ref. 2, p. 6.5.2-12)

and V = containment free volume = 2.736+6 ft^3

Then,

$$\lambda_p = \frac{3 * 44.8\,(m) * 5230.\left(\frac{gal.}{min.}\right) * 10.\left(\frac{1}{m}\right) * .13365\left(\frac{ft^3}{gal.}\right) * 60.\left(\frac{min.}{hr}\right)}{2 * 2.736{+}6\,(ft^3)}$$

$\lambda_p = 10.3\ hr^{-1}$ until a decontamination factor of 50 is reached or until the spray flow rate is changed or until spray injection stops, whichever is first.

4.7.2 Spray Flow Rate of 2615 GPM (One Pump)

As in the previous Subsection, the particulate iodine spray removal rate can be calculated for a spray flow rate, $F = 2615$ gpm; thus,

$$\lambda_p = \frac{3 * 44.8\,(m) * 2615.\left(\frac{gal}{min}\right) * 10.\left(\frac{1}{m}\right) * .13365\left(\frac{ft^3}{gal}\right) * 60.\left(\frac{min.}{hr}\right)}{2 * 2.736{+}6\;(ft^3)}$$

$\lambda_p = 5.15\ hr^{-1}$ until a decontamination factor of 50 is reached or until spray injection stops, whichever is first.

4.7.3 Particulate Iodine Spray Removal Summary

The following table presents the particulate iodine spray removal rates that were obtained

TABLE 2

Particulate Iodine Spray Removal Rates

Spray Flow Rate		To Be Used Rate
5230. gpm (two pumps);	$0 \le t \le 15$ minutes *	10.3 hr^{-1}
2615. gpm (one pump);	$15 < t \le 53$ minutes *	5.15 hr^{-1}

---

* subject to the DF = 50 constraint (Ref. 2, p. 6.5.2-12).

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4.7.4 Calculation of Particulate Iodine Spray Time (Effective)

The following is a calculation of the spray time for which the particulate iodine spray removal is effective. The spray removal rates for two time intervals should be the values given in Table 2 (Subsection 4.7.3). Radiodecay should not be included because the particulate iodine spray removal theory is based on aerosol mechanics which are not affected by radiodecay (radiodecay does not remove particles). Leakage from the primary containment can be ignored because it is (comparitively) negligible.

The methodology for calculating the spray time is given in Reference 7, pp. 9, 10, and 27.

Assumption: the initial activity release is into the unsprayed volume (conservative); thus, $a_2(0) = 0.0$

Data:

$Q_{12} = Q_{21} =$ 1.98+5 cfm Section 4.6

$S = \lambda_p =$ 10.3 hr^{-1} $(0 \le t \le 15 \text{ minutes})$

$S = \lambda_p =$ 5.15 hr^{-1} $(15 < t \le 53 \text{ minutes})$

$V_1 = .15 * (2.736+6) =$ 4.104+5 ft^3

$V_2 = .85 * (2.736+6) =$ 2.3256+6 ft^3

$l_1 = (Q_{12}/V_1) * 60 \frac{min.}{hr} =$ 28.94736842 hr^{-1}

$m_1 = \lambda + L + P + l_1 =$ 28.94736842 hr^{-1}

(λ, L, and $P \equiv 0.0$)

$l_2 = (Q_{21}/V_2) * 60 \frac{min}{hr} =$ 5.108359133 hr^{-1}

$m_2 = \lambda + L + P + S + l_2 =$ 15.40835913 hr^{-1} $(0 \le t \le 15 \text{ min})$

$m_2 = \lambda + L + P + S + l_2 =$ 10.25835913 hr^{-1} $(15 < t \le 53 \text{ min.})$

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Variable	Calculated Values	
	$0 \le t \le 15$ min.	$15 < t \le 53$ min.
$\mu_a = \frac{1}{2}\left[-(m_1+m_2) + \sqrt{(m_1+m_2)^2 - 4(m_1 m_2 - l_1 l_2)}\right]$	$-8.260258129\ hr^{-1}$	$-4.266849924\ hr^{-1}$
$\mu_b = \frac{1}{2}\left[-(m_1+m_2) - \sqrt{(m_1+m_2)^2 - 4(m_1 m_2 - l_1 l_2)}\right]$	$-36.09546943\ hr^{-1}$	$-34.93887763\ hr^{-1}$
t_1 (beginning of time period)	0	.25 hr.
$a_1(t_1)$ (initial condition)	1.0	3.265447579-2 *
$a_2(t_1)$ (initial condition)	0.0	1.317514968-1 *
$C_a = \left[l_2 a_2(t_1) - (\mu_b + m_1) a_1(t_1)\right] / \left[\mu_a - \mu_b\right]$	.2568006734	2.832168654-2
$C_b = \left[(\mu_a + m_1) a_1(t_1) - l_2 a_2(t_1)\right] / \left[\mu_a - \mu_b\right]$	.7431993266	4.332789253-3
$C_{a1} = C_a(\mu_a + m_1)/l_2$	1.039955045	.1368333530
$C_{b1} = C_b(\mu_b + m_1)/l_2$	-1.039955045	-5.081856234-3

---

* obtained from the equations for $a_1(t)$ and $a_2(t)$ (see next page) evaluated at 0.25 hr (15 minutes) using the data in the $0 \le t \le 15$ min column.

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For $0 \leq t \leq .25$ hr (15 minutes):

$$a_1(t) = .2568006734\, e^{-8.260258129t} + .7431993266\, e^{-36.09546943t}$$

$$a_2(t) = 1.039955045\, e^{-8.260258129t} - 1.039955045\, e^{-36.09546943t}$$

For $.25 < t \leq .8833$ hr (53 minutes):

$$a_1(t) = (2.832168654-2)\, e^{-4.266849924(t-.25)} + (4.332789253-3)\, e^{-34.93887763(t-.25)}$$

$$a_2(t) = .1368333530\, e^{-4.266849924(t-.24)} - (5.081856234-3)\, e^{-34.93887763(t-.25)}$$

The fraction remaining airborne is just $F_R(t) = a_1(t) + a_2(t)$, and the decontamination factor is $DF(t) = 1.0 / F_R(t)$.
The above equations (this page) must be solved for t_c (spray effectiveness cutoff time) at which $DF(t_c) = 50$. (Ref. 2, p. 6.5.2-12). Thus,

Estimated Time, t					
Minutes	Hours	$a_1(t)$	$a_2(t)$	$F_R(t)$	$DF(t)$
15	.25	3.265447579-2	1.317514968-1	1.644059725-1	6.0825
40	.6666666667	4.786378713-3	2.312489040-2	2.791126912-2	35.82782
44.687	.7447833333	3.429661715-3	1.657006155-2	1.999972326-2	50.00069
44.6868	.7447800000	3.429710494-3	1.657029722-2	2.000000772-2	49.99998

Therefore, the spray effectiveness cutoff time is

$t_c = .74478$ hr for particulate iodine (less than the 53 minute spray operating time).

4.7.5 POSTDBA Effective Spray Removal Rate for Particulate Iodine

Program POSTDBA (References 7 and 8) can accomodate only one spray removal rate for each iodine species. Since the particulate iodine spray removal rate changes at 15 minutes into the accident, POSTDBA cannot model the conditions. However, if a spray removal rate can be found which achieves a DF of 50 at the spray effectiveness cutoff time ($t_c = .74478$ hr, see Subsection 4.7.4), that removal rate would be conservative because at all times between 0 and .74478 hr, the airborne activity (particulate) would be higher than that using the correct model. At and after .74478 hr, the airborne activity (particulate) would be the same as that using the correct model.

Such a removal rate can be found by evaluating the equations given in Subsection 4.7.4 with

$t_1 = 0.0$

$t = .74478$ hr

$a_1(t_1) = 1.0$

$a_2(t_1) = 0.0$

and iterating on the spray removal rate, S, (instead of on the time) until a DF = 50 is reached.

The data from Subsection 4.7.4 can be used:

$l_1 = 28.94736842 \text{ hr}^{-1}$

$m_1 = 28.94736842 \text{ hr}^{-1}$

$l_2 = 5.108359133 \text{ hr}^{-1}$

But

$m_2 = S + 5.108359133 \text{ hr}^{-1}$

$a_1(t) = C_a e^{u_a t} + C_b e^{u_b t}$

$a_2(t) = C_{a1} e^{u_a t} + C_{b1} e^{u_b t}$

Iteration Index	S, hr^{-1}	μ_a	$\mu_a t$	$e^{\mu_a t}$
1	6.6	-5.422515269	-4.038580922	1.762246233-2
2	6.67	-5.477727774	-4.079702092	1.691250328-2
3	6.672	-5.479304468	-4.080876382	1.689265475-2
4	6.6721	-5.479383302	-4.080935096	1.689166294-2
5	6.67217	-5.479438485	-4.080976195	1.689096873-2

Iteration Index	μ_b	$\mu_b t$	$e^{\mu_b t}$	C_a
1	-35.23321229	-26.24099185	4.014967556-12	.2108586680
2	-35.24799978	-26.25200528	3.970991612-12	.2116417128
3	-35.24842309	-26.25232055	3.969739864-12	.2116641324
4	-35.24844425	-26.25233631	3.969677303-12	.2116652535
5	-35.24845907	-26.25234735	3.969633487-12	.2116660382

Iteration Index	C_b	C_{a1}	C_{b1}	$a_1(t)$
1	.7891413320	.9710396374	-.9710396374	3.715848937-3
2	.7883582872	.9723582107	-.9723582107	3.579391166-3
3	.7883358676	.9723958842	-.9723958842	3.575569115-3
4	.7883347465	.9723977679	-.9723977679	3.575378123-3
5	.7883339618	.9723990864	-.9723990864	3.575244435-3

Iteration Index	$a_2(t)$	$F_R(t)$	$DF(t)$
1	1.711210943-2	2.082795837-2	48.01238712
2	1.644501143-2	2.002440259-2	49.93906786
3	1.642634795-2	2.000191706-2	49.99520780
4	1.642541534-2	2.000079347-2	49.99801641
5	1.642476255-2	2.000000699-2	49.99998253

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From the foregoing, a POSTDBA effective spray removal rate of

$$S = 6.67217\ hr^{-1}$$

will achieve a DF of 50 at the spray effectiveness cutoff time of .74478 hr.

5. CONTROL ROOM FINITE CLOUD CORRECTION FACTORS

The control room finite cloud correction factors for whole body dose that are required in Section 6 are calculated in a separate POSTDBA run.

5.1 Data

The control room dimensions are 47 ft 9 in wide by 106 ft long by 24 ft 3 in high (Reference 16). The dose point is conservatively selected at 6 feet above the center of the floor. The center of the floor is at

$\frac{1}{2} \times 106 = 53$ ft in the long dimension
$\frac{1}{2} \times 47.75 = 23.875$ ft in the wide dimension

Calculations were performed for each nuclide used in Section 6.

Discrete gamma energies and frequencies for the radiodecay of each nuclide are from Reference 20; values are discussed in the next section (Section 5.2).

5.2 POSTDBA Input

POSTDBA input instructions are in Reference 8. The input listing is found on the attached microfiche (Microfiche B):

```
ZI-5-91 R0 SR NSLD 4C4-A1 SYS CR CNTRL RM INFILT STDY (CLOUD)
S&L 03/11/91 10:26:56 WG=212 ID=DRSH
ORIG=05 DUPS=01 PRJ=ZI0780511 PGM=POS098085110/
```

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The input description is as follows.

Line 1 Format (9I5, 3A6) (POSTDBA Card 1)

IP = 0
ISPRAY = 3
MURF = 1
ICONT = 1
IC1 = 0
} not used in the calculation

IC2 = 2 Calculate finite cloud correction factors for control room and quit (no dose calculations).

IC3 = 0 not used in the calculation

MET = 0 read nuclide discrete gamma energies (and frequencies)

INL = 0 not used in the calculation

(ISTAT(I), I = 1, 3) = ZION 7805-11 literal station name and charge number.

Lines 2 through 133 (POSTDBA Cards 23 through 26 repeated as a group for each nuclide)
Nuclide discrete gamma energy data

Line 134 FORMAT (3A6) (POSTDBA Card 23)
(TI (I), I = 1, 3) = blank (no nuclide name)

Line 135 FORMAT (I10) (POSTDBA Card 24)
NI = 0 signals end of nuclide data.

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Line 136 Format(I10) (POSTDBA Card 27)

IREC = 1 use a rectangular parallelepiped room

Line 137 Format (6E10.2) (POSTDBA Card 28 for IREC = 1)

XL1 = 53.0 center of floor in length dimension
XL = 106.0 room (floor) length
W1 = 23.875 center of floor in width dimension
W = 47.75 room (floor) width
H(1) = 6.0 dose point height above floor
H(2) = 18.25 dose point distance below ceiling:
Room height 24.25 — 6.0 above floor

ft.

Line 138 Format (4I10) (POSTDBA Card 29)

NORDA = 6
NHA = 4
NORDG = 6
NHG = 2

Reference 8, p. 40, recommended values.

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5.3 POSTDBA Output

The POSTDBA output for the finite cloud correction factors calculation can be found in the attached microfiche B. The results are given in the following table.

TABLE 3

Control Room Finite Cloud Correction Factors (Dose Ratios)

Nuclide	Infinite to Finite Gamma Cloud Dose Ratio
I-131	16.65
I-132	18.10
I-133	17.46
I-134	18.55
I-135	20.04
XE-133M	6.701
XE-133	7.976
XE-135M	16.55
XE-135	16.49
KR-85M	15.08
KR-85	17.07
KR-87	20.85
KR-88	21.86

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6. CONTROL ROOM DOSE CALCULATIONS

6.1 Preliminary Calculations

6.1.1 Calculation of POSTDBA Effective Windspeeds

The POSTDBA effective windspeeds and, thus, the control room (χ/Q')'s are based on the default parameters and diffuse source-point receptor (χ/Q') equation given in Reference 4. The default parameters are given as (χ/Q') reduction factors for four time periods (Ref. 4, Table 1). Reference 4, also, suggests a wind speed of 1.0 m/sec for the five percentile case (0 to 8 hours). Thus, since (χ/Q') is inversely proportional to windspeed, the reciprocal of the overall reduction factor can be thought of as a windspeed including wind direction and occupancy. Then, from Reference 4,

Time Period, Hours	Overall Reduction Factor, R	Wind Speed, m/sec, $u = 1/R$
0 – 8	1.0	1.0
8 – 24	.59	1.695
24 – 96	.225 *	4.444
96 – 720	.066	15.15

---

* In Ref. 4, Table 1, the product of the individual reduction factors gives .225 which will not be rounded to .22.

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From Reference 4, for only one inlet,

$$\left(\chi/Q'\right) = \frac{(k+2)}{uA}, \quad (\sigma_y \text{ and } \sigma_z \text{ are negligible for Class F})$$

where A = projected area, m^2, of containment building

$$K = 3/\left[(s/d)^{1.4}\right]$$

s = distance between containment surface and inlet
d = diameter of containment (outside diameter)

From Reference 7,

$$\left(\chi/Q'\right) = \frac{2}{\overline{u}_{eff}\, A}$$

where $\overline{u}_{eff}$ = an effective windspeed to give the correct (χ/Q').

Then,

$$\frac{2}{\overline{u}_{eff}\, A} = \frac{k+2}{uA}$$

$$\overline{u}_{eff} = 2u/(k+2), \quad (\text{POSTDBA effective wind speed})$$

$\overline{u}_{eff}$ for each time period must be input to POSTDBA so that that program can calculate the correct (χ/Q'). These input data are dependent on the separation distance, s.

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6.1.1.1 Plan View Separation Distance

The plan view separation distance was given as [illegible] = 91.76 ft. (Ref. 14, p. 13)
The containment outside diameter was given as d = 147. ft (Ref. 14, p. 12)
Then,

$$K = 3/\left[(91.76/147.)^{1.4}\right] = 5.8030$$

$$\bar{u}_{eff} = 2u/(5.8030 + 2.)$$

$$\bar{u}_{eff} = .25631u$$ (see Subsection 6.1.1 for u)

The evaluation of $\bar{u}_{eff}$ for various time periods according to Reference 4 is presented in the following table.

TABLE 4

POSTDBA Effective Windspeeds for Plan View Separation Distance

Ref. 4 Time Period, Hours	Ref. 4 Wind Speed, u, m/sec *	POSTDBA $\bar{u}_{eff} = .25631u$, m/sec	Occupancy Ref. 4, Occ.	Full Occupancy Control Room (χ/Q'), sec/m³ **
0 – 8	1.0	.2563	1.0	3.177×10^{-3}
8 – 24	1.695	.4344	1.0	1.875×10^{-3}
24 – 96	4.444	1.139	.60	1.192×10^{-3}
96 – 720	15.15	3.883	.40	5.243×10^{-4}

---

* including speed, direction, and occupancy (see Subsection 6.1.1).

** $(\chi/Q')^{o} = 2/[O_{cc.} * \bar{u}_{eff} * A]$ where $A = 2456.\ m^2$ (Ref. 14, p. 18) (division by Occ. to remove Occ. from $\bar{u}_{eff}$). This (χ/Q') is given for information only.

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6.1.1.2 Circuitous Path Separation Distance

The circuitous path separation distance was given as $s = \overbrace{80.\ m}^{\text{(Ref. 15, p. 2-26)}} = 262.5$ ft.
The containment outside diameter was given as $d = 147.$ ft. (Ref. 14, p. 12)
Then,

$$K = 3/\left[(262.5/147.)^{1.4}\right] = 1.3322$$

$$\overline{u}_{eff} = 2u/(1.3322 + 2)$$

$$\overline{u}_{eff} = .60020\,u \quad \text{(see Subsection 6.1.1 for } u\text{)}$$

The evaluation of $\overline{u}_{eff}$ for various time periods according to Reference 4 is presented in the following table.

TABLE 5

POSTDBA Effective Windspeeds for Circuitous Path Separation Distance

Ref. 4 Time Period, Hours	Ref. 4 Wind Speed, U, m/sec *	POSTDBA $\overline{u}_{eff} = .60020\,u$, m/sec	Ref. 4 Occupancy, Occ.	Full Occupancy Control Room (χ/Q'), sec/m³ **
0 – 8	1.0	.6002	1.0	1.357×10^{-3}
8 – 24	1.695	1.0173	1.0	8.005×10^{-4}
24 – 96	4.444	2.667	.60	5.089×10^{-4}
96 – 720	15.15	9.093	.40	2.239×10^{-4}

---

* including speed, direction, and occupancy (see Subsection 6.1.1).

** $(\chi/Q') = 2/[\text{Occ.} * \overline{u}_{eff} * A]$ where $A = 2456.\ m^2$, (Ref. 14, p. 18) (division by Occ. to remove Occ. from $\overline{u}_{eff}$). This (χ/Q') is given for information only.

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6.1.2 ECCS Leakage

6.1.2.1 ECCS Leak Rate (POSTDBA Purge Rate)

The ECCS leak rate is 1770 cc/hr (Ref. 11, Table 6.2.3-4). Two times this leak rate should be used in the calculations (Ref. 5, p. 15.6.5-17). Hence, the leak rate is 3540 cc/hr. Since ESF atmosphere filtration is provided (Ref. 11, p. 9.10-3), potential leakage from a gross failure of passive components need not be considered (Ref. 5, p. 15.6.5-17). Then,

$$3540 \frac{cm^3}{hr} \times \frac{1\ m^3}{10^6\ cm^3} \times 264.2 \frac{gal.}{m^3} = .9353\ gal/hr.$$

The sump water volume in which the iodine activity resides is 473,936 gal. (see Section 4.4). Thus, the ECCS Leak rate is

$$.9353 \frac{gal.}{hr} / 473936\ gal. = 1.97347 \times 10^{-6}\ hr^{-1}$$

$$1.97347 \times 10^{-6}\ hr^{-1} \times \frac{1\ hr}{60\ min.} = 3.2891 \times 10^{-8}\ min.^{-1}$$

In POSTDBA this ECCS leakage can be modelled by a containment purge in which the purge rate P is given by

$P = 3.2891 \times 10^{-8}\ min.^{-1}\ V\ ft^3$ where V = free volume of containment.

But $V = 2.736 \times 10^6\ ft^3$; therefore,

$$P = .08999\ cfm.$$

However, the injection phase of the ECCS lasts 15 minutes (see Section 4.1). Thus, the ECCS leak rate is zero for the first 15 minutes (P=0.0). It will be conservatively assumed that the recirculation phase starts at 15 minutes (P=.08999 cfm) and lasts for 30 days. (The containment leak rate in POSTDBA must be set to zero.)

6.1.2.2 Effective POSTDBA Purge Filter Efficiency

Since the sump water is less than 212 °F *, 10% of the iodine in the ECCS leakage becomes airborne (Ref 5, page 15.6.5-17). This is the conservative maximum amount. The airborne iodine is instantaneously exhausted (conservative) to the atmosphere through a 90% efficient filter (Ref. 11, Vol. VIII, Q 9.8, page 3). These iodine reduction capabilities can be effected in POSTDBA by setting the POSTBA purge filter fractional efficiency E_p so that

$$(1 - E_p) = (1 - E) F_p$$

where E = actual filter efficiency (fractional) = .90
F_p = iodine fraction airborne = .10

Then,

$$E_p = 1 - F_p + F_p E$$

$$E_p = 1 - .10 + .10 \times .90$$

$$E_p = .99$$

---

* Reference 9, Subsection 14.3.5.6.3, page 14.3-46 gives a sump water temperature of 200°F.

6.1.3 Nuclide Data

6.1.3.1 Initial Airborne Activity in Primary Containment

Table 6 presents the calculation of initial airborne activity in the primary containment for releases based on both core and gap inventory.

6.1.3.2 Nuclide Data Adjustments

Thyroid inhalation doses based on adult thyroid dose conversion factors from both Reference 21, page 1.109-45, and Reference 22*, Table 2.1, page 136 were desired. However, the thyroid inhalation dose conversion factors are built-in to program POSTDBA and cannot be changed. Since for each iodine nuclide the thyroid dose is proportional to this factor and proportional to the initial airborne activity in the containment, the initial airborne activity can be multiplied by the ratio of the desired dose conversion factor to the POSTDBA dose conversion factor. When using this resulting activity for each iodine nuclide, the thyroid inhalation dose as calculated by POSTDBA would be based on the desired dose conversion factor.

But in order to obtain the correct whole body and beta skin doses for each iodine nuclide, both the average gamma energy and the average beta energy for that nuclide must be multiplied by the reciprical of the ratio that was applied to the activity.

These calculations for Reference 21 dose conversion factors are performed in Table 7. These calculations for Reference 22 dose conversion factors are performed in Table 8.

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* The Reference 22 dose conversion factors come from ICRP-30, Supplement to Part 1, Volume 3, No. 1-4, 1979.

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TABLE 6

Calculation of Initial Airborne Activity In Primary Containment

Nuclide	Ref. 9, Table 14.3.5-5,* Activity, Curies	LOCA Airborne Activity,** Curies	Ref. 11, Table A.2-1 Percent of Core Inventory Activity in Gap	Calculated Gap Activity,*** Curies
I-131	9.34 +7	2.335 +7	2.3	2.148 +6
I-132	1.38 +8	3.450 +7	.26	3.588 +5
I-133	1.76 +8	4.400 +7	.79	1.390 +6
I-134	2.19 +8	5.475 +7	.16	3.504 +5
I-135	1.78 +8	4.450 +7	.43	7.654 +5
Kr-85m	2.70 +7	2.70 +7	.29	7.830 +4
Kr-85	9.40 +5	9.40 +5	21.57	2.028 +5
Kr-87	5.08 +7	5.08 +7	.20	1.016 +5
Kr-88	7.70 +7	7.70 +7	.29	2.233 +5
Xe-133m	4.94 +6	4.94 +6	1.27	6.274 +4
Xe-133	1.88 +8	1.88 +8	1.85	3.478 +6
Xe-135m	5.20 +7	5.20 +7	.086	4.472 +4
Xe-135	5.42 +7	5.42 +7	.54	2.927 +5

---

* End of Life Core Inventory for 3391 Mwt (~104% Full Power).

** 25% core inventory of iodines; 100% core inventory of nobles; Ref. 1.

*** 100% is assumed airborne after LOCA when using the Gap Source.

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TABLE 7 : Nuclide Data Adjustments For Reference 21 Thyroid Dose Conversion Factors

	Thyroid Dose Conversion Factor, Rem/Ci		Airborne Activity, Curies, (Based on 25% Core Inventory)		Airborne Activity, Curies, (Based on 100% Gap Activity)	
	POSTDBA *	Ref. 21 **	Actual ***	Adjusted †	Actual ***	Adjusted †
Nuclide	A	B	C	D	E	F
I-131	1.49+6	1.49+6	2.335+7	2.335+7	2.148+6	2.148+6
I-132	5.48+4	1.43+4	3.450+7	9.003+6	3.588+5	9.363+4
I-133	3.66+5	2.69+5	4.400+7	3.234+7	1.390+6	1.022+6
I-134	2.87+4	3.73+3	5.475+7	7.116+6	3.504+5	4.554+4
I-135	1.17+5	5.60+4	4.450+7	2.130+7	7.654+5	3.663+5

	Average Gamma Energy, Mev/dis.		Average Beta Energy, Mev/dis.	
	POSTDBA *	Adjusted †	POSTDBA *	Adjusted †
Nuclide	G	H	I	J
I-131	.381	.381	.191	.191
I-132	2.26	8.661	.490	1.878
I-133	.608	.8272	.411	.5592
I-134	2.601	20.01	.621	4.778
I-135	1.557	3.253	.368	.7689

---

* Reference 7, page 30.

** page 1.109-45, Adult thyroid values were multiplied by 10^9 to convert units.

† (Column D) = (Column C)(Column B)/(Column A); (Column F) = (Column E)(Column B)/(Column A)
(Column H) = (Column G)(Column A)/(Column B); (Column J) = (Column I)(Column A)/(Column B)

*** Table 6

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TABLE 8 : Nuclide Data Adjustments For Reference 22 Thyroid Dose Conversion Factors

	Thyroid Dose Conversion Factor, Rem/Ci		Airborne Activity, Curies, (Based on 25% Core Inventory)		Airborne Activity, Curies (Based on 100% Gap Activity)	
	POSTDBA*	Ref. 22 **	Actual***	Adjusted †	Actual***	Adjusted †
Nuclide	A	B	C	D	E	F
I-131	1.49+6	1.08+6	2.335+7	1.692+7	2.148+6	1.557+6
I-132	5.48+4	6.4 +3	3.450+7	4.029+6	3.588+5	4.190+4
I-133	3.66+5	1.80+5	4.400+7	2.164+7	1.390+6	6.836+5
I-134	2.87+4	1.07+3	5.475+7	2.041+6	3.504+5	1.306+4
I-135	1.17+5	3.13+4	4.450+7	1.190+7	7.654+5	2.048+5

	Average Gamma Energy, Mev/dis.		Average Beta Energy, Mev/dis.	
	POSTDBA *	Adjusted †	POSTDBA *	Adjusted †
Nuclide	G	H	I	J
I-131	.381	.5256	.191	.2635
I-132	2.26	19.35	.490	4.196
I-133	.608	1.236	.411	.8357
I-134	2.601	69.77	.621	16.66
I-135	1.557	5.820	.368	1.376

---

* Reference 7, page 30.

** Reference 22, Table 2.1.

† (Column D) = (Column C)(Column B)/(Column A); (Column F) = (Column E)(Column B)/(Column A)
(Column H) = (Column G)(Column A)/(Column B); (Column J) = (Column I)(Column A)/(Column B)

*** Table 6

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6.2 POSTDBA Calculations

6.2.1 Description

In POSTDBA the spray effectiveness cutoff time can be calculated only for a decontamination factor of 100. Hence, this option could not be used in this calculation. Spray effectiveness cutoff times were hand calculated in Section 4.6 and Subsection 4.7.4. There were two different spray effectiveness cutoff times, one for elemental iodine and one for particulate iodine. However, POSTDBA can accept only one spray effectiveness cutoff time. Thus, whenever control room doses due to containment leakage are desired, two POSTDBA cases must be run, one for elemental iodine and noble gas, and one for particulate and organic iodine. These cases are designated by the suffixes A and B respectively. Since these cases involve containment leakage the case designations will contain a C; cases involving ECCS leakage will have an E in the case designation but no A or B suffix.

POSTDBA results were desired for all combinations of initial airborne activity (based on core inventory or gap inventory), (χ/Q) model (plan view or circuitous path), and thyroid dose conversion factors (Ref. 21 or Ref. 22). These eight possible combinations were given case numbers 1 through 8. Each of these cases were run three times, once for 0.0 cfm control room infiltration, once for 1000.0 cfm infiltration, and once for 2000.0 cfm infiltration which were thought to bracket any possible measured value. The case designation will contain a 0, 1, or 2 after the C or E to denote the infiltration (0, 1000, and 2000 cfm respectively). Thus, a total of 72 POSTDBA cases were required. Table 9 relates the case designations to the parameters used in each case.

TABLE 9

POSTDBA Cases

POSTDBA Case Designation	Activity Inventory Source	(χ/Q') Model	Thyroid Dose Conversion Factors	Leakage (C)ontainment (E)CCS	Control Room Infiltration, cfm	Nuclides (E)lemental Iodine (P)articulate Iodine (O)rganic Iodine (N)oble Gas
1C0-A	Core	Plan View	Ref. 21	C	0	E & N
1C0-B				C	0	P & O
1E0				E	0	E, P, & O
1C1-A				C	1000	E & N
1C1-B				C	1000	P & O
1E1				E	1000	E, P, & O
1C2-A				C	2000	E & N
1C2-B				C	2000	P & O
1E2				E	2000	E, P, & O
2C0-A		Circuitous Path		C	0	E & N
2C0-B				C	0	P & O
2E0				E	0	E, P, & O
2C1-A				C	1000	E & N
2C1-B				C	1000	P & O
2E1				E	1000	E, P, & O
2C2-A				C	2000	E & N
2C2-B				C	2000	P & O
2E2				E	2000	E, P, & O

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TABLE 9 , Cont'd

POSTDBA Cases

POSTDBA Case Designation	Activity Inventory Source	(χ/Q') Model	Thyroid Dose Conversion Factors	Leakage (C)ontainment (E)CCS	Control Room Infiltration, cfm	Nuclides (E)lemental Iodine (P)articulate Iodine (O)rganic Iodine (N)oble Gas
3C0-A	Gap	Plan View	Ref. 21	C	0	E & N
3C0-B				C	0	P & O
3E0				E	0	E, P, & O
3C1-A				C	1000	E & N
3C1-B				C	1000	P & O
3E1				E	1000	E, P, & O
3C2-A				C	2000	E & N
3C2-B				C	2000	P & O
3E2				E	2000	E, P, & O
4C0-A		Circuitous Path		C	0	E & N
4C0-B				C	0	P & O
4E0				E	0	E, P, & O
4C1-A				C	1000	E & N
4C1-B				C	1000	P & O
4E1				E	1000	E, P, & O
4C2-A				C	2000	E & N
4C2-B				C	2000	P & O
4E2				E	2000	E, P, & O

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TABLE 9 , Cont'd

POSTDBA Cases

POSTDBA Case Designation	Activity Inventory Source	(X/Q') Model	Thyroid Dose Conversion Factors	Leakage (C)ontainment (E)CCS	Control Room Infiltration, cfm	Nuclides (E)lemental Iodine (P)articulate Iodine (O)rganic Iodine (N)oble Gas
5C0-A	Core	Plan View	Ref. 22	C	0	E & N
5C0-B				C	0	P & O
5E0				E	0	E, P, & O
5C1-A				C	1000	E & N
5C1-B				C	1000	P & O
5E1				E	1000	E, P, & O
5C2-A				C	2000	E & N
5C2-B				C	2000	P & O
5E2				E	2000	E, P, & O
6C0-A		Circuitous Path		C	0	E & N
6C0-B				C	0	P & O
6E0				E	0	E, P, & O
6C1-A				C	1000	E & N
6C1-B				C	1000	P & O
6E1				E	1000	E, P, & O
6C2-A				C	2000	E & N
6C2-B				C	2000	P & O
6E2				E	2000	E, P, & O

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TABLE 9 , Cont'd

POSTDBA Cases

POSTDBA Case Designation	Activity Inventory Source	(X/Q') Model	Thyroid Dose Conversion Factors	Leakage (C)ontainment (E)CCS	Control Room Infiltration, cfm	Nuclides (E)lemental Iodine (P)articulate Iodine (O)rganic Iodine (N)oble Gas
7C0-A	Gap	Plan View	Ref. 22	C	0	E & N
7C0-B				C	0	P & O
7E0				E	0	E, P, & O
7C1-A				C	1000	E & N
7C1-B				C	1000	P & O
7E1				E	1000	E, P, & O
7C2-A				C	2000	E & N
7C2-B				C	2000	P & O
7E2				E	2000	E, P, & O
8C0-A		Circuitous Path		C	0	E & N
8C0-B				C	0	P & O
8E0				E	0	E, P, & O
8C1-A				C	1000	E & N
8C1-B				C	1000	P & O
8E1				E	1000	E, P, & O
8C2-A				C	2000	E & N
8C2-B				C	2000	P & O
8E2				E	2000	E, P, & O

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6.2.2 POSTDBA Input

The POSTDBA input instructions are in Reference 8. The input listing for case designations 1CO-A through 4E2 (all cases using Reference 21 thyroid dose conversion factors) is found on the attached microfiche (Microfiche C):

ZI-5-91 RO SR NSLD 4C4-A1 SYS CR CNTRL RM INFILT STDY(DOSE1)
S&L 03/11/91 10:26:56 WG=212 ID=DRSH
ORIG=05 DUPS=01 PRJ=ZI078051l PGM=POS098085110/

The input listings for case designations 5CO-A through 8E2 (all cases using Reference 22 thyroid dose conversion factors) is found on the attached microfiche (Microfiche D):

ZI-5-91 RO SR NSLD 4C4-A1 SYS CR CNTRL RM INFILT STDY(DOSE2)
S&L 03/11/91 10:26:56 WG=212 ID=DRSH
ORIG=05 DUPS=01 PRJ=ZI0780511 PGM=POS0980851l0/

The input description for each case is as follows.

<u>POSTDBA Card Type 1; Format (9I5, 3A6)</u>

IP = 0 for all cases except those with an E in the case designation; for those (ECCS Leakage) IP = 4, number of entries in purge table.
ISPRAY = 3 } not used
MURF = 2 }
ICONT = 1 use HVAC System I
IC1 = 0 }
IC2 = 0 }
IC3 = 0 } not used
MET = 0 }
INL = 0 Input POSTDBA $\bar{u}_{aff}$ on Card Type 14 (and 16 for ECCS cases)
(ISTAT(I), I=1,3) = ZION 7805-11 literal station name and charge number.

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POSTDBA Card Type 2 ; Format (12A6)

(JITLE(I), I=1, 12) Literal case title provides information of the type given in Table 9 .

POSTDBA Card Type 3 ; Format (7D10.2)

DLEAK(1) = 4.167-5 * when C is in case designation.
= 0.0 when E is in case designation (Purge will be used).
DLEAK(2) = 2.083-5 ** when C is in case designation.
= 0.0 when E is in case designation (Purge will be used)
Q12 = 1.98+5 Section 4.6
Q21 = 1.98 +5 Section 4.6
V1 = 4.1040+5 Section 4.6
V2 = 2.32560+6 Section 4.6
TSPRAY = .361609 Section 4.6 when suffix A is in case designation.
= .74478 Subsection 4.7.4 when suffix B is in case designation.

POSTDBA Card Type 4 ; Format (7D10.2)

SPRAY(1) = 22.41 Section 4.6 when suffix A is in case designation.
= 0.0 all other cases
SPRAY(2) = 6.67217 Subsection 4.7.5 when suffix B is in case designation.
= 0.0 all other cases
SPRAY(3) = 0.0 Organic iodine spray removal conservatively omitted.
FPP = 0.0 Pipe penetration room not used.
PPFILT(1) = 0.0
PPFILT(2) = 0.0
PPFILT(3) = 0.0
} Pipe penetration room not used.

---

* Ref. 10, p. 212 gives 0.1%/day which is 4.167×10^{-5} hr^{-1}.
** Ref. 1, p. 1.4-1 implies 0.05%/day which is 2.083×10^{-5} hr^{-1}

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POSTDBA Card Type 5; Format (7D10.2)

AREA = 26436. Ref. 14, p. 18
FI(1) = 0.0 when suffix B is in case designation.
= .91 all other cases. Ref. 1, p. 1.4-1
FI(2) = 0.0 when suffix A is in case designation.
= .05 all other cases. Ref. 1, p. 1.4-1
FI(3) = 0.0 when suffix A is in case designation.
= .04 all other cases. Ref. 1, p. 1.4-1
PFILT(1) = .99 when E is in case designation (purge will be used)*
= 0.0 all other cases.
PFILT(2) = .99 when E is in case designation (purge will be used).*
= 0.0 all other cases.
PFILT(3) = .99 when E is in case designation (purge will be used).*
= 0.0 all other cases.

POSTDBA Card Type 6; Format (6D10.2)

This card type is omitted for all cases containing a C in the case designation; for cases containing an E in the case designation, this card type contains:

TP(1) = .25 beginning time of recirculation phase
P(1) = 0.0 purge is zero until TP(1) Subsection 6.1.2.1
TP(2) = 2.0
P(2) = .08999
TP(3) = 8.0
P(3) = .08999

$\left\}\begin{array}{l}\text{Purge rate is .08999 cfm}\\ \text{from .25 hr to 720.0 hr.}\\ \text{Subsection 6.1.2.1}\end{array}\right.$

TP(4) = 720.0 ending time

---

* Subsection 6.1.2.2

POSTDBA Card Type 7; Format (7D10.2)

All entries are zero because EAB and LPZ doses are not required.

POSTDBA Card Type 8; Format (3D10.2)

All entries are zero because off site doses are not required.

POSTDBA Card Types 9 through 13

These card types are omitted because INL = 0 on card type 1.

POSTDBA Card Type 14; Format (5D10.2)

DMURF(1) = .2563
DMURF(2) = .2563
DMURF(3) = .4344
DMURF(4) = 1.139
DMURF(5) = 3.883

} Table 4 } for case designations beginning with 1, 3, 5, and 7.

but

DMURF(1) = .6002
DMURF(2) = .6002
DMURF(3) = 1.0173
DMURF(4) = 2.667
DMURF(5) = 9.093

} Table 5 } for case designations beginning with 2, 4, 6, and 8.

POSTDBA Card Type 15; Format (7D10.2)

All entries are zero for case designations containing an E because EAB and LPZ doses are not required.
This card type is omitted for all other cases because IP = 0 on card type 1.

POSTDBA Card Type 16 ; Format (5D10.2)

DMURFG(1) = .6002
DMURFG(2) = .6002
DMURFG(3) = 1.0173
DMURFG(4) = 2.667
DMURFG(5) = 9.093

Table 5 — for case designations containing an E

This card type is omitted for all other cases because IP=0 on card type 1.

POSTDBA Card Type 17 ; Format (6D10.2)

RI = 1800. Section 2.2 Conservative Make-up Air Flow Rate (Control Room)
RIFILT(1) = .99
RIFILT(2) = .99
RIFILT(3) = .99

Ref. 11 , Q9.8-1 & Q.9.3-1

VC = 1.19122+5 Ref. 16
RF = 0.0 for case designations with 0 following the C or E
= 1000.0 for case designations with 1 following the C or E
= 2000.0 for case designations with 2 following the C or E

POSTDBA Card Type 18 ; Format (7D10.2)

RC = 0.0
RCFILT(1) = 0.0
RCFILT(2) = 0.0
RCFILT(3) = 0.0

recirculation not used.

CBRTH(1) = 3.47-4
CBRTH(2) = 3.47-4
CBRTH(3) = 3.47-4

Ref. 4

POSTDBA Card Type 19 ; Format (3D10.2)

This card type is omitted because ICONT=1 on card type 1.

POSTDBA Card Type 20 ; Format (I5)

IRPT = 0 Nuclide data are to be read on card type 21.

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POSTDBA Card Type 21; Format (A6, I4, D10.2, 3F6.2, 2X, 3D10.2, 2F5.4)

For case designations beginning with 1 or 2, and for case designations containing a C. There is one record (card) for each nuclide (ISO). <u>However</u>, case designations with the suffix B omit the noble gas records.

Note: Noble gas AAO is from Table 6, LOCA Airborne Activity.

ISO	IPRN	Table 7 Col. D (Iodine) AAO	FINA	Table 3 FINC	FINS & DLAM	Table 7 Col. H EG	Table 7 Col. J EB	BOD & SKN
I-131	1	2.335+7	blank	16.65	blank	.3810	.1910	blank
I-132	1	9.003+6		18.10		8.661	1.878	
I-133	1	3.234+7		17.46		.8272	.5592	
I-134	1	7.116+6		18.55		20.01	4.778	
I-135	1	2.130+7		20.04		3.253	.7689	
XE-33M	0	4.940+6		6,701		blank	blank	
XE-133	0	1.880+8		7.976				
XE-35M	0	5.200+7		16.55				
XE-135	0	5.420+7		16.49				
KR-85M	0	2.700+7		15.08				
KR-85	0	9.400+5		17.09				
KR-87	0	5.080+7		20.85				
KR-88	0	7.700+7		21.86				

POSTDBA Card Type 22; Format (A3)

ISO = END This card type follows the last record (card) in the above table.

POSTDBA Card Type 21; Format (A6, I4, D10.2, 3F6.2, 2X, 3D10.2, 2F5.4)

For case designations beginning with 1 or 2, and for case designations containing an E. There is one record (card) for each nuclide (ISO).

		(see note below)		Table 3	FINS &	Table 7 Col. H	Table 7 Col. J	BOD &
ISO	IPRN	AAO	FINA	FINC	DLAM	EG	EB	SKN
I-131	1	4.670+7	blank	16.65	blank	.3810	.1910	blank
I-132	1	1.801+7		18.10		8.661	1.878	
I-133	1	6.468+7		17.46		.8272	.5592	
I-134	1	1.423+7		18.55		20.01	4.778	
I-135	1	4.260+7		20.04		3.253	.7689	

Note: These values of AAO are two times the values in Table 7, Col. D, because 50% of the core inventory is supposed to be in the sump water.

POSTDBA Card Type 22; Format (A3)

ISO = END This card type follows the last record (card) in the above table.

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POSTDBA Card Type 21; Format (A6, I4, D10.2, 3F6.2, 2X, 3D10.2, 2F5.4)

For case designations beginning with 3 or 4, and for case designations containing a C. There is one record (card) for each nuclide (ISO). However, case designations with the suffix B omit the noble gas records.

Note: Noble gas AAO is from Table 6, Calculated Gap Activity.

		Table 7			FINS	Table 7	Table 7	BOD
		Col. F (iodine)		Table 3	&	Col. H	Col. J	&
ISO	IPRN	AAO	FINA	FINC	DLAM	EG	EB	SKN
I-131	1	2.148+6	blank	16.65	blank	.3810	.1910	blank
I-132	1	9.363 +4		18.10		8.661	1.878	
I-133	1	1.022+6		17.46		.8272	.5592	
I-134	1	4.554 +4		18.55		20.01	4.778	
I-135	1	3.663 +5		20.04		3.253	.7689	
XE-33M	0	6.274+4		6.701		blank	blank	
XE-133	0	3.478 +6		7.976				
XE-35M	0	4.472 +4		16.55				
XE-135	0	2.927+5		16.49				
KR-85M	0	7.830+4		15.08				
KR-85	0	2.028+5		17.09				
KR-87	0	1.016+5		20.85				
KR-88	0	2.233+5		21.86				

POSTDBA Card Type 22; Format (A3)

ISO = END This card type follows the last record (card) in the above table.

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POSTDBA Card Type 21; Format (A6, I4, D10.2, 3F6.2, 2X, 3D10.2, 2F5.4)

For case designations beginning with 3 or 4, and for case designations containing an E. There is one record (card) for each nuclide (ISO).

		Table 7 Col. F		Table 3	FINS &	Table 7 Col. H	Table 7 Col. J	BOD &
ISO	IPRN	AAO	FINA	FINC	DLAM	EG	EB	SKN
I-131	1	2.148+6	blank	16.65	blank	.3810	.1910	blank
I-132	1	9.363+4		18.10		8.661	1.878	
I-133	1	1.022+6		17.46		.8272	.5592	
I-134	1	4.554+4		18.55		20.01	4.778	
I-135	1	3.663+5		20.04		3.253	.7689	

POSTDBA Card Type 22; Format (A3)

ISO = END This card type follows the last record (card) in the above table.

POSTDBA Card Type 21; Format (A6, I4, D10.2, 3F6.2, 2X, 3D10.2, 2F5.4)

For case designations beginning with 5 or 6, and for case designations containing a C. There is one record (card) for each nuclide (ISO). <u>However</u>, case designations with the suffix B omit the noble gas records.

Note: Noblegas AA0 is from Table 6, LOCA Airborne Activity.

ISO	IPRN	Table 8 Col. D (iodine) AA0	FINA	Table 3 FINC	FINS & DLAM	Table 8 Col. H EG	Table 8 Col. J EB	BOD & SKN
I-131	1	1.692+7	blank	16.65	blank	.5256	.2635	blank
I-132	1	4.029+6		18.10		19.35	4.196	
I-133	1	2.164+7		17.46		1.236	.8357	
I-134	1	2.041+6		18.55		69.77	16.66	
I-135	1	1.190+7		20.04		5.820	1.376	
XE-33M	0	4.940+6		6.701		blank	blank	
XE-133	0	1.880+8		7.976				
XE-35M	0	5.200+7		16.55				
XE-135	0	5.420+7		16.49				
KR-85M	0	2.700+7		15.08				
KR-85	0	9.400+5		17.09				
KR-87	0	5.080+7		20.85				
KR-88	0	7.700+7	↓	21.86	↓	↓	↓	↓

POSTDBA Card Type 22; Format (A3)

ISO = END This card type follows the last record (card) in the above table.

POSTDBA Card Type 21; Format (A6, I4, D10.2, 3F6.2, 2X, 3D10.2, 2F5.4)

For case designations beginning with 5 or 6, and for case designations containing an E. There is one record (card) for each nuclide (ISO).

ISO	IPRN	(see note below) AAO	FINA	Table 3 FINC	FINS & DLAM	Table 8 Col. H EG	Table 8 Col. J EB	BOD & SKN
I-131	1	3.384+7	blank	16.65	blank	.5256	.2635	blank
I-132	1	8.058+6		18.10		19.35	4.196	
I-133	1	4.328+7		17.46		1.236	.8357	
I-134	1	4.082+6		18.55		69.77	16.66	
I-135	1	2.380+7		20.04		5.820	1.376	

Note: These values of AAO are two times the values in Table 8, Col. D, because 50% of the core inventory is supposed to be in the sump water.

POSTDBA Card Type 22; Format (A3)

ISO = END This card type follows the last record (card) in the above table.

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POSTDBA Card Type 21; Format (A6, I4, D10.2, 3F6.2, 2X, 3D10.2, 2F5.4)

For case designations beginning with 7 or 8, and for case designations containing a C. There is one record (card) for each nuclide (ISO). However, case designations with the suffix B omit the noble gas records.

Note: Noble gas AAO is from Table 6, Calculated Gap Activity.

		Table 8 Col. F (iodine)		Table 3	FINS &	Table 8 Col. H	Table 8 Col. J	BOD &
ISO	IPRN	AAO	FINA	FINC	DLAM	EG	EB	SKN
I-131	1	1.557+6	blank	16.65	blank	.5256	.2635	blank
I-132	1	4.190+4		18.10		19.35	4.196	
I-133	1	6.836+5		17.46		1.236	.8357	
I-134	1	1.306+4		18.55		69.77	16.66	
I-135	1	2.048+5		20.04		5.820	1.376	
XE-33M	0	6.274+4		6.701		blank	blank	
XE-133	0	3.478+6		7.976				
XE-35M	0	4.472+4		16.55				
XE-135	0	2.927+5		16.49				
KR-85M	0	7.830+4		15.08				
KR-85	0	2.028+5		17.09				
KR-87	0	1.016+5		20.85				
KR-88	0	2.233+5		21.86				

POSTDBA Card Type 22; Format (A3)

ISO = END This card type follows the last record (card) in the above table.

POSTDBA Card Type 21; Format (A6, I4, D10.2, 3F6.2, 2X, 3D10.2, 2F5.4)

For case designations beginning with 7 or 8, and for case designations containing an E. There is one record (card) for each nuclide (ISO).

ISO	IPRN	Table 8 Col. F AA0	FINA	Table 3 FINC	FINS & DLAM	Table 8 Col. H EG	Table 8 Col. J EB	BOD & SKN
I-131	1	1.557+6	blank	16.65	blank	.5256	.2635	blank
I-132	1	4.190+4		18.10		19.35	4.196	
I-133	1	6.836+5		17.46		1.236	.8357	
I-134	1	1.306+4		18.55		69.77	16.66	
I-135	1	2.048+5		20.04		5.820	1.376	

POSTDBA Card Type 22; Format (A3)

ISO = END This card type follows the last record (card) in the above table.

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6.2.3 POSTDBA Output

The POSTDBA output for the control room dose calculations that used Reference 21 thyroid dose conversion factors can be found in the attached microfiche C.

The POSTDBA output for the control room dose calculations that used Reference 22 thyroid dose conversion factors can be found in the attached microfiche D.

Note that the total dose for any specific set of parameters must be hand calculated as the sum of
the containment leakage dose in case designation with suffix A
plus the containment leakage dose in case designation with suffix B
plus the ECCS leakage dose in case designation containing an E.

Although this calculation does not use the "Cumulative Activity Output to Environment" found on the individual iodine nuclide output pages, it should be pointed out that these POSTDBA output values are in error because the initial iodine activities were adjusted to give correct thyroid doses based on different thyroid dose conversion factors.

7. IODINE PROTECTION FACTOR METHODOLOGY

Reference 4 presents an Iodine Protection Factor (IPF) equation; IPF is the ratio of the iodine activite outside of the control room to that inside the control room. The IPF is a function of control room parameters only. If the thyroid dose D_1 is known for one set of control room parameters $(IPF)_1$, then the thyroid dose D_2 can be found for any other set of parameters $(IPF)_2$ because

$$D_1 (IPF)_1 = D_2 (IPF)_2$$

The Reference 4 equation for IPF is

$$IPF = \frac{F_1 + \eta F_2 + F_3}{(1-\eta) F_1 + F}$$

if make-up and recirculation filters are identical.

Reference 4 then explains that if the make-up and recirculation filters are different,

$$IPF = \frac{F_1 + \eta_2 F_2 + F_3}{(1-\eta_1) F_1 + F_3}$$

where

F_1 = make-up air flow rate

η_1 = make-up air filter fractional efficiency for iodine

F_2 = recirculation air flow rate

η_2 = recirculation air filter fractional efficiency for iodine

F_3 = infiltration air flow rate

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For this calculation, $F_1 = 1800$ cfm See Section 2.2
$F_2 = 11500$ cfm Ref. 16
$\eta_1 = .99$ Ref. 11, Q 9.8-1 & Q 9.3-1

Then,

$$IPF = \frac{(1800 + 11500\eta_2 + F_3)}{[(1-.99)1800 + F_3]} = \frac{(F_3 + 11500\eta_2 + 1800)}{(F_3 + 18)}$$

Let the dose D_{1000} be known from a POSTDBA calculation
for $F_3 = 1000$ cfm
and $\eta_2 = 0.0$

Then the $(IPF)_{1000}$ for the known dose D_{1000} is

$$(IPF)_{1000} = \frac{(1000 + 1800)}{(1000 + 18)} = 2.750491159$$

Now the dose D for any other combination of F_3 and η_2 is

$$D = D_{1000}\,(IPF)_{1000}\,/\,IPF$$

Thus,

$$\boxed{D = \frac{D_{1000} * 2.750491159\,(F_3 + 18)}{(F_3 + 11500\eta_2 + 1800)}}$$

Solving for F_3,

$$\boxed{F_3 = \left[11500\eta_2 + 1800 - 49.50884086\left(\frac{D_{1000}}{D}\right)\right] \Big/ \left[2.750491159\left(\frac{D_{1000}}{D}\right) - 1\right]}$$

where D will be any target 30 day thyroid dose; e.g.,

D=30 Rem (Refs. 23 & 4; single inlet; no iodine blockers)
D=120 Rem (manually operated dual inlets - (1/2) reduced by factor of 4 from Ref. 3; no iodine blockers)
D=50 Rem (Ref. 24; single inlet; no iodine blockers)
D=200 Rem (manually operated dual inlets; no iodine blockers)

These values can be multiplied by 10 if iodine blockers are used (Ref. 25, p. 2, states, "90% effective if taken immediately prior to or concurrent with exposure to radioactive iodine.").

8. CONTROL ROOM DOSE RESULTS

Tables 10 through 13 summarize the 30 Day Control Room Doses when using Regulatory Guide 1.109 (Ref. 21) thyroid dose conversion factors. These POSTDBA calculated doses are found on the attached microfiche C. These tables also give the total doses as defined in Subsection 6.2.3 (paragraph 3).

Tables 14 through 17 summarize the 30 Day Control Room Doses when using ICRP-30 (Ref. 22) thyroid dose conversion factors. These POSTDBA calculated doses are found on the attached microfiche D. These tables also give the total doses as defined in Subsection 6.2.3 (paragraph 3).

Tables 18 and 19 summarize the total doses at 0, 1000, and 2000 cfm and define a Model designation (A, B, C, and D) for the different combinations of Initial source and (χ/Q'). Table 18 is for the use of Ref. 21 thyroid dose conversion factors, and Table 19 is for the use of Ref. 22 thyroid dose conversion factors. In addition thyroid doses at intermediate infiltration rates are calculated using the dose equation of Section 7 with $\eta_2 = 0.0$ (no recirculation). These calculated doses are based on the POSTDBA dose at 1000 cfm infiltration. Calculated values at 0 cfm and 2000 cfm are in parantheses and can be compared to the POSTDBA values showing the accuracy of the IPF methodology. Tables 18 and 19 also summarize the whole body and beta skin doses and provide comparisons with regulatory limits (Ref. 23) for all doses.

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TABLE 10

POSTDBA 30 Day Control Room Doses Using Core Inventory; Plan View (X/Q); R.G. 1.109 Thyroid Dose Conversion Factors

Case No.	Infiltration, cfm	Leakage	Iodine Species*	Nobles	30 Day Thyroid, Rem	30 Day Whole Body, Rem	30 Day Beta Skin, Rem
1C0-A	0.0	Containment	E	Yes	4.21	1.81	15.2
1C0-B	0.0	Containment	P & O	No	22.6	.001	.005
1E0	0.0	ECCS	all	—	.71	0	.0001
Totals	0.0	—	all	Yes	27.52	1.811	15.21
1C1-A	1000.0	Containment	E	Yes	154.	1.90	15.9
1C1-B	1000.0	Containment	P & O	No	823.	.041	.21
1E1	1000.0	ECCS	all	—	25.7	.001	.01
Totals	1000.0	—	all	Yes	1002.7	1.942	16.12
1C2-A	2000.0	Containment	E	Yes	225.	1.95	16.3
1C2-B	2000.0	Containment	P & O	No	1200.	.061	.31
1E2	2000.0	ECCS	all	—	37.6	.001	.01
Totals	2000.0	—	all	Yes	1462.6	2.012	16.62

* E = elemental ; P = particulate ; O = organic

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TABLE 11

POSTDBA 30 Day Control Room Doses Using Core Inventory; Circuitous Path (1/6); R.G. 1.109 Thyroid Dose Conversion Factors

Case No.	Infiltration, cfm	Leakage	Iodine Species*	Nobles	30 Day Thyroid, Rem	30 Day Whole Body, Rem	30 Day Beta Skin, Rem
2C0-A	0.0	Containment	E	Yes	1.80	.771	6.47
2C0-B	0.0	Containment	P & O	No	9.64	.0005	.002
2E0	0.0	ECCS	all	—	.301	0	0
Totals	0.0	—	all	Yes	11.741	.7715	6.472
2C1-A	1000.0	Containment	E	Yes	65.7	.811	6.79
2C1-B	1000.0	Containment	P & O	No	352.	.0173	.088
2E1	1000.0	ECCS	all	—	11.0	.0004	.002
Totals	1000.0	—	all	Yes	428.7	.8287	6.880
2C2-A	2000.0	Containment	E	Yes	96.2	.833	6.96
2C2-B	2000.0	Containment	P & O	No	515.0	.0258	.130
2E2	2000.0	ECCS	all	—	16.1	.0006	.003
Totals	2000.0	—	all	Yes	627.3	.8594	7.093

* E = elemental ; P = particulate ; O = organic

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TABLE 12

POSTDBA 30 Day Control Room Doses Using Gap Inventory; Circuitous Path (X/Q); R.G. 1.109 Thyroid Dose Conversion Factors

Case No.	Infiltration, cfm.	Leakage	Iodine Species*	Nobles	30 Day Thyroid, Rem	30 Day Whole Body, Rem	30 Day Beta Skin, Rem
4C0-A	0.0	Containment	E	Yes	.142	.00783	.0844
4C0-B	0.0	Containment	P & O	No	.796	.000016	.00009
4E0	0.0	ECCS	all	—	.0128	0	.000001
Totals	0.0	—	all	Yes	.9508	.007846	.08449
4C1-A	1000.0	Containment	E	Yes	5.18	.00808	.0861
4C1-B	1000.0	Containment	P & O	No	29.0	.000578	.00317
4E1	1000.0	ECCS	all	—	.465	.000008	.00004
Totals	1000.0	—	all	Yes	34.645	.008666	.08831
4C2-A	2000.0	Containment	E	Yes	7.57	.00821	.0869
4C2-B	2000.0	Containment	P & O	No	42.4	.000852	.00466
4E2	2000.0	ECCS	all	—	.68	.000012	.00006
Totals	2000.0	—	all	Yes	50.65	.009074	.09162

* E = elemental ; P = particulate ; O = organic

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TABLE 13

POSTDBA 30 Day Control Room Doses Using Gap Inventory; Plan View (1/2'); R.G. 1.109 Thyroid Dose Conversion Factors

Case No.	Infiltration, Cfm	Leakage	Iodine Species*	Nobles	30 Day Thyroid, Rem	30 Day Whole Body, Rem	30 Day Beta Skin, Rem
3C0-A	0.0	Containment	E	Yes	.333	.0183	.198
3C0-B	0.0	Containment	P&O	No	1.86	.00004	.0002
3E0	0.0	ECCS	all	—	.030	0	0
Totals	0.0	—	all	Yes	2.223	.01834	.1982
3C1-A	1000.0	Containment	E	Yes	12.1	.0189	.202
3C1-B	1000.0	Containment	P & O	No	67.9	.00135	.0074
3E1	1000.0	ECCS	all	—	1.09	.00002	.0001
Totals	1000.0	—	all	Yes	81.09	.02027	.2095
3C2-A	2000.0	Containment	E	Yes	17.7	.0192	.204
3C2-B	2000.0	Containment	P & O	No	99.3	.00199	.0109
3E2	2000.0	ECCS	all	—	1.59	.00003	.0002
Totals	2000.0	—	all	Yes	118.59	.02122	.2151

* E = elemental ; P = particulate ; O = organic

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TABLE 14

POSTDBA 30 Day Control Room Doses Using Core Inventory; Plan View (X/Q); ICRP-30 Thyroid Dose Conversion Factors

Case No.	Infiltration, Cfm	Leakage	Iodine Species*	Nobles	30 Day Thyroid, Rem	30 Day Whole Body, Rem	30 Day Beta Skin, Rem
5C0-A	0.0	Containment	E	Yes	2.99	1.81	15.2
5C0-B	0.0	Containment	P & O	No	16.1	.001	.01
5E0	0.0	ECCS	all	—	.506	0	0
Totals	0.0	—	all	Yes	19.596	1.811	15.21
5C1-A	1000.0	Containment	E	Yes	109.	1.90	15.9
5C1-B	1000.0	Containment	P & O	No	588.	.040	.20
5E1	1000.0	ECCS	all	—	18.4	.001	.01
Totals	1000.0	—	all	Yes	715.4	1.941	16.11
5C2-A	2000.0	Containment	E	Yes	160.	1.95	16.3
5C2-B	2000.0	Containment	P & O	No	860.	.060	.30
5E2	2000.0	ECCS	all	—	27.0	.001	.01
Totals	2000.0	—	all	Yes	1047.0	2.011	16.61

* E = elemental ; P = particulate ; O = organic

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TABLE 15

POSTDBA 30 Day Control Room Doses Using Core Inventory; Circuitous Path (χ/Q); ICRP-30 Thyroid Dose Conversion Factors

Case No.	Infiltration, Cfm	Leakage	Iodine Species*	Nobles	30 Day Thyroid, Rem	30 Day Whole Body, Rem	30 Day Beta Skin, Rem
6C0-A	0.0	Containment	E	Yes	1.27	.771	6.47
6C0-B	0.0	Containment	P & O	No	6.88	.0005	.002
6E0	0.0	ECCS	all	—	.216	0	0
Totals	0.0	—	all	Yes	8.366	.7715	6.472
6C1-A	1000.0	Containment	E	Yes	46.5	.811	6.79
6C1-B	1000.0	Containment	P & O	No	251.	.0173	.088
6E1	1000.0	ECCS	all	—	7.87	.0004	.002
Totals	1000.0	—	all	Yes	305.37	.8287	6.880
6C2-A	2000.0	Containment	E	Yes	68.1	.833	6.96
6C2-B	2000.0	Containment	P & O	No	367.	.0258	.130
6E2	2000.0	ECCS	all	—	11.5	.0006	.003
Totals	2000.0	—	all	Yes	446.6	.8594	7.093

* E = elemental ; P = particulate ; O = organic

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TABLE 16

POSTDBA 30Day Control Room Doses Using Gap Inventory; Circuitous Path (½); ICRP-30 Thyroid Dose Conversion Factors

Case No.	Infiltration, cfm	Leakage	Iodine Species*	Nobles	30 Day Thyroid, Rem	30 Day Whole Body, Rem	30 Day Beta Skin, Rem
8C0-A	0.0	Containment	E	Yes	.102	.00783	.0844
8C0-B	0.0	Containment	P&O	No	.574	.000016	.00009
8E0	0.0	ECCS	all	—	.0092	0	0
Totals	0.0	—	all	Yes	.6852	.007846	.08449
8C1-A	1000.0	Containment	E	Yes	3.73	.00808	.0861
8C1-B	1000.0	Containment	P & O	No	20.9	.000578	.00317
8E1	1000.0	ECCS	all	—	.336	.000008	.00004
Totals	1000.0	—	all	Yes	24.966	.008666	.08931
8C2-A	2000.0	Containment	E	Yes	5.45	.00821	.0869
8C2-B	2000.0	Containment	P & O	No	30.6	.000852	.00466
8E2	2000.0	ECCS	all	—	.491	.000012	.00006
Totals	2000.0	—	all	Yes	36.541	.009074	.09162

* E = elemental ; P = particulate ; O = organic

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TABLE 17

POSTDBA 30 Day Control Room Doses Using Gap Inventory; Plan View (1/2); ICRP-30 Thyroid Dose Conversion Factors

Case No.	Infiltration, Cfm	Leakage	Iodine Species*	Nobles	30 Day Thyroid, Rem	30 Day Whole Body, Rem	30 Day Beta Skin, Rem
7C0-A	0.0	Containment	E	Yes	.239	.0183	.198
7C0-B	0.0	Containment	P & O	No	1.34	.00004	.0002
7E0	0.0	ECCS	all	—	.0216	0	0
Totals	0.0	—	all	Yes	1.6006	.01834	.1982
7C1-A	1000.0	Containment	E	Yes	8.72	.0189	.202
7C1-B	1000.0	Containment	P & O	No	49.0	.00135	.0074
7E1	1000.0	ECCS	all	—	.786	.00002	.0001
Totals	1000.0	—	all	Yes	58.506	.02027	.2095
7C2-A	2000.0	Containment	E	Yes	12.8	.0192	.204
7C2-B	2000.0	Containment	P & O	No	71.6	.00199	.0109
7E2	2000.0	ECCS	all	—	1.15	.00003	.0002
Totals	2000.0	—	all	Yes	85.55	.02122	.2151

* E = elemental ; P = particulate ; O = organic

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TABLE 18: Control Room Dose Summary Using Ref. 21 Thyroid Dose Conversion Factors

Control Room 30 Day Thyroid Dose, Rem for No Recirculation Filtration and Single Inlet

Infiltration Rate, Cfm	Model A Core Inventory Plan View (X/Q) R.G. 1.109 Thyroid Dose Conv.		Model B Core Inventory Circuitous Path (X/Q) R.G. 1.109 Thyroid Dose Conv.		Model C Gap Inventory Circuitous Path (X/Q) R.G. 1.109 Thyroid Dose Conv.		Model D Gap Inventory Plan View (X/Q) R.G. 1.109 Thyroid Dose Conv.	
0	27.52	(27.58)	11.741	(11.79)	.9508	(.9529)	2.223	(2.230)
200	300.6		128.5		10.39		24.31	
400	524.0		224.0		18.11		42.38	
500	621.1		265.6		21.46		50.23	
600	710.2		303.6		24.54		57.43	
1000	1002.7		428.7		34.645		81.09	
1500	1269.		542.4		43.83		102.6	
2000	1462.6	(1465.)	627.3	(626.2)	50.65	(50.60)	118.59	(118.4)
Refs. 23 & 4 Limits	30.		30.		30.		30.	

Infiltration Rate, Cfm	Control Room 30 Day Whole Body Dose, Rem, for No Recirculation Filtration and Single Inlet				Control Room 30 Day Beta Skin Dose, Rem for No Recirculation Filtration and Single Inlet			
	Model A	Model B	Model C	Model D	Model A	Model B	Model C	Model D
0	1.811	.7715	.007846	.01834	15.21	6.472	.08449	.1982
200								
400								
500								
600								
1000	1.942	.8287	.008666	.02027	16.12	6.880	.08931	.2095
1500								
2000	2.012	.8594	.009074	.02122	16.62	7.093	.09162	.2151
Ref. 23 Limits	5.	5.	5.	5.	30.	30.	30.	30.

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TABLE 19 : Control Room Dose Summary Using Ref. 22 Thyroid Dose Conversion Factors

Control Room 30 Day Thyroid Dose, Rem for No Recirculation Filtration and Single Inlet

Infiltration Rate, cfm	Model A Core Inventory Plan View (χ/Q) ICRP-30 Thyroid Dose Conv.		Model B Core Inventory Circuitous Path (χ/Q') ICRP-30 Thyroid Dose Conv.		Model C Gap Inventory Circuitous Path (χ/Q') ICRP-30 Thyroid Dose Conv.		Model D Gap Inventory Plan View (χ/Q') ICRP-30 Thyroid Dose Conv.	
0	19.596	(19.68)	8.366	(8.399)	.6852	(.6867)	1.6006	(1.609)
200	214.5		91.55		7.485		17.54	
400	373.9		159.6		13.05		30.57	
500	443.2		189.2		15.47		36.24	
600	506.7		216.3		17.68		41.44	
1000	715.4		305.37		24.966		58.506	
1500	905.1		386.4		31.59		74.02	
2000	1047.0	(1045.)	446.6	(446.0)	36.541	(36.47)	85.55	(85.46)
Refs. 23 & 4 Limits	30.		30.		30.		30.	

Infiltration Rate, cfm	Control Room 30 Day Whole Body Dose, Rem, for No Recirculating Filtration and Single Inlet				Control Room 30 Day Beta Skin Dose, Rem for No Recirculation Filtration and Single Inlet			
	Model A	Model B	Model C	Model D	Model A	Model B	Model C	Model D
0	1.811	.7715	.007846	.01834	15.21	6.472	.08449	.1982
200								
400								
500								
600								
1000	1.941	.8287	.008666	.02027	16.11	6.880	.08931	.2095
1500								
2000	2.011	.8594	.009074	.02122	16.61	7.093	.09162	.2151
Ref. 23 Limits	5.	5.	5.	5.	30.	30.	30.	30.

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Table 20 provides a calculation of infiltration rates that should produce a 30 day control room thyroid dose of 30 Rem* when using Reference 21 thyroid dose conversion factors for the various models, for various combinations of inlet configuration and iodine blockers use, and for various control room recirculation filter fractional efficiencies. This table was produced by evaluating the F_3 equation given in Section 7. The D_{1000} (dose for 1000 cfm infiltration) for each model came from Table 18. Values of η_2 were 0.0, 0.7, 0.9, and 0.99. The target dose D was obtained as follows.

Inlet			Blockers			D,
Inlet Configuration	Protection † Factor Ⓐ		Iodine Blockers	Protection Factor Ⓑ		Target Dose, Rem (30 Rem)*Ⓐ*Ⓑ
Single	1.0		No	1.0		30.0
Single	1.0		Yes	10.0	Ref. 25	300.0
Dual (manually operated)	4.0	Ref. 3, page 6.4-11	No	1.0		120.0
Dual (manually operated)	4.0	Ref. 3, page 6.4-11	Yes	10.0	Ref. 25	1200.0

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* 30 Rem limit from Reference 23 and Reference 4.

† Protection comes from a reduction in (χ/Q').

TABLE 20

Infiltration Rates to Obtain a 30 Day Control Room Thyroid Dose of 30 Rem (R.G. 1.109)

Using: SRP Occupancy; 11500 cfm Recirculation Rate; IPF Methodology Based on 1000 cfm Infiltration and Zero Recirculation Filter Fractional Efficiency; Infiltration Rates Not Rounded Up

Model	Activity Inventory Source	(χ/Q) Model	Thyroid Conversion Factors	Inlet Configuration	Iodine Blocked	Infiltration Rate, cfm, for the Indicated Recirculation Filter Fractional Efficiencies			
						0.0	0.7	0.9	0.99
A	Core	Plan View	R.G. 1.109 (Ref. 21)	Single	No	1.597	90.12	115.4	126.8
				Single	Yes	199.5	1182.	1462.	1589.
				Dual	No	63.06	429.2	533.8	580.9
				Dual	Yes	1354.	7555.	9326.	10120.
B	Core	Circuitous	R.G. 1.109 (Ref. 21)	Single	No	28.52	238.6	298.7	325.7
				Single	Yes	590.0	333.7	4121.	4475.
				Dual	No	183.9	1095.	1356.	1473.
				Dual	Yes	∞	∞	∞	∞
C	Gap	Circuitous	R.G. 1.109 (Ref. 21)	Single	No	800.7	4499.	5556.	6032.
				Single	Yes	∞	∞	∞	∞
				Dual	No	∞	∞	∞	∞
				Dual	Yes	∞	∞	∞	∞
D	Gap	Plan View	R.G. 1.109 (Ref. 21)	Single	No	258.9	1509.	1867.	2028.
				Single	Yes	∞	∞	∞	∞
				Dual	No	2057.	11430.	14110	15310.
				Dual	Yes	∞	∞	∞	∞

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Table 21 provides a calculation of infiltration rates that should produce a 30 day control room thyroid dose of 30 Rem* when using Reference 22 thyroid dose conversion factors for the various models, for various combinations of inlet configuration and iodine blocker use, and for various control room recirculation filter fractional efficiencies. This table was produced by evaluating the F_3 equation given in Section 7. The D_{1000} (dose for 1000 cfm infiltration) for each model came from Table 19. Values of η_2 were 0.0, 0.7, 0.9, and 0.99. The target dose D was obtained in the manner given on page 81.

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* 30 Rem limit from Reference 23 and Reference 4.

TABLE 21

Infiltration Rates to Obtain a 30 Day Control Room Thyroid Dose of 30 Rem (ICRP-30)

Using: SRP Occupancy; 11500 cfm Recirculation Rate; IPF Methodology Based on 1000 cfm Infiltration and Zero Recirculation Filter Fractional Efficiency; Infiltration Rates *Not* Rounded Up

Model	Activity Inventory Source	(χ/Q) Model	Thyroid Conversion Factors	Inlet Configuration	Iodine Blocked	Infiltration Rate, cfm, for the Indicated Recirculation Filter Fractional Efficiencies 0.0	0.7	0.9	0.99
A	Core	Plan View	ICRP-30 *	Single	No	9.589	134.2	169.8	185.8
				Single	Yes	302.5	1750.	2164.	2350.
				Dual	No	97.73	620.5	769.9	837.1
				Dual	Yes	2767.	15350.	18940.	20560.
B	Core	Circuitous	ICRP-30	Single	No	48.00	346.1	431.3	469.7
				Single	Yes	972.1	5445.	6723.	7298.
				Dual	No	279.0	1620.	2004.	2176.
				Dual	Yes	∞	∞	∞	∞
C	Gap	Circuitous	ICRP-30	Single	No	1364.	7609.	9394.	10190.
				Single	Yes	∞	∞	∞	∞
				Dual	No	∞	∞	∞	∞
				Dual	Yes	∞	∞	∞	∞
D	Gap	Plan View	ICRP-30	Single	No	390.3	2234.	2762.	2999.
				Single	Yes	∞	∞	∞	∞
				Dual	No	5207.	28810.	35550.	38590.
				Dual	Yes	∞	∞	∞	∞

---

* As reported in Reference 22, Table 2.1

Table 22 provides a calculation of infiltration rates that should produce a 30 day control room thyroid dose of 50 Rem[*] when using Reference 22 thyroid dose conversion factors for the various models, for various combinations of inlet configuration and iodine blockers use, and for various control room recirculation filter fractional efficiencies. This table was produced by evaluating the F_3 equation given in Section 7. The D_{1000} (dose for 1000 cfm infiltration) for each model came from Table 19. Values of η_2 were 0.0, 0.7, 0.9, and 0.99. The target dose D was obtained as follows.

Inlet		Blockers		D,
Inlet Configuration	Protection[†] Factor Ⓐ	Iodine Blockers	Protection Factor Ⓑ	Target Dose, Rem (50 Rem) * Ⓐ * Ⓑ
Single	1.0	No	1.0	50.0
Single	1.0	Yes	10.0 Ref. 25	500.0
Dual (manually operated)	4.0 Ref. 3, page 6.4-11	No	1.0	200.0
Dual (manually operated)	4.0 Ref. 3, page 6.4-11	Yes	10.0 Ref. 25	2000.0

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[*] 50 Rem limit from Reference 24.

[†] Protection comes from a reduction in (χ/Q').

TABLE 22

Infiltration Rates to Obtain a 30 Day Control Room Thyroid Dose of 50 Rem (ICRP-30)

Using: SRP Occupancy; 11500 cfm Recirculation Rate; IPF Methodology Based on 1000 cfm Infiltration and Zero Recirculation Filter Fractional Efficiency; Infiltration Rates **Not** Rounded Up

Model	Activity Inventory Source	(χ/Q) Model	Thyroid Conversion Factors	Intake Configuration	Iodine Blocked	Infiltration Rate, cfm, for the Indicated Recirculation Filter Fractional Efficiencies 0.0	0.7	0.9	0.99
A	Core	Plan View	ICRP-30 *	Single	No	28.46	238.3	298.3	325.3
				Single	Yes	589.0	3331.	4114.	4467.
				Dual	No	183.6	1094.	1354.	1471.
				Dual	Yes	∞	∞	∞	∞
B	Core	Circuitous	ICRP-30	Single	No	94.79	604.3	749.9	815.4
				Single	Yes	2603.	14440.	17820.	19340.
				Dual	No	538.9	3054.	3773.	4097.
				Dual	Yes	∞	∞	∞	∞
C	Gap	Circuitous	ICRP-30	Single	No	4754.	26310.	32470.	35240.
				Single	Yes	∞	∞	∞	∞
				Dual	No	∞	∞	∞	∞
				Dual	Yes	∞	∞	∞	∞
D	Gap	Plan View	ICRP-30	Single	No	785.2	4414.	5450.	5917.
				Single	Yes	∞	∞	∞	∞
				Dual	No	∞	∞	∞	∞
				Dual	Yes	∞	∞	∞	∞

* As reported in Reference 22, Table 2.1

9. SUMMARY

Control Room infiltration rates that produce thyroid inhalation doses equal to the regulatory limits for a variety of control room models were found. The results were summarized in Tables 20, 21, and 22.

Whole body and beta skin doses from airborne activity within the control room were also found. The results were summarized in Tables 18 and 19. These doses were less than the regulatory limits as indicated in these tables.

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17. J. S. Brtis, "Calculation of Post-LOCA Iodine Spray Removal Rate," Sargent & Lundy Calc. No. ZI-3-86, Rev. 0, for Commonwealth Edison Company, January 8, 1987, and
W. J. Johnson, Rev. 1 to that calculation, March 23, 1987.

18. J. T. Bell, M.H. Lietzke, and D. A. Palmer, "Predicted Rates of Formation of Iodine Hydrolysis Species at pH Levels, Concentrations, and Temperatures Anticipated in LWR Accidents," ORNL-5876, NUREG/CR-2900, October 1982.

19. Reactor Containment Ventilation Systems Functional Description, FD-RV-01, Rev. B, January 28, 1987.

20. M. J. Martin, Editor, "Nuclear Decay Data for Selected Radionuclides," Oak Ridge National Laboratory, ORNL-5114, March 1976.

21. U.S. Nuclear Regulatory Commission, "Calculation of Annual Doses to Man From Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance With 10 CFR Part 50, Appendix I," U.S.N.R.C. Regulatory Guide 1.109, Revision 1, October 1977.

22. Federal Guidance Report No. 11, "Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion," EPA-520/1-88-020, September 1988.

23. 10CFR 50, Appendix A, Criterion 19 of Group II - Control Room.

24. 10CFR 20.201, "Occupational Dose Limits for Adults," Effective January 1, 1993; SECY-90-387, "Transmittal of Revised Part 20", Nov. 26, 1990.

25. GSEP Environs Group Emergency Plan Implementing Procedure, Commonwealth Edison Company, "Use of Potassium Iodide Tablets by Emergency Workers," (Formerly EG-5), CEPIP 3005-1, Rev. 5, April, 1990, (Approved December 20, 1990).

11. ATTACHMENTS

11.1 Microfiche A

ZI-5-91 RO SR NSLD 4C4-A1 SYS CR CNTRL RM INFILT STDY (SPIRT)
S&L 03/11/91 10:15:52 WG=212 ID=DRSH
ORIG=05 DUPS=01 PRJ=ZI0780511 PGM=SPI098100100/

SLIT THIS END

11.2 <u>Microfiche B</u>

ZI-5-91 R0 SR NSLD 4C4-A1 SYS CR CNTRL RM INFILT STDY(CLOUD)
S&L 03/11/91 10:26:56 WG=212 ID=DRSH
ORIG=05 DUPS=01 PRJ=ZI0780511 PGM=POS098085110/

SLIT THIS END

SARGENT & LUNDY
ENGINEERS

Calcs. For		Calc. No. ZI-5-91
☒ Safety-Related	☐ Non-Safety-Related	Rev. 0 Date
		Page 94 of

Client	Prepared by	Date
Project	Reviewed by	Date
Proj. No. 7805-11 Equip. No.	Approved by	Date

11.3 Microfiche C

ZI-5-91 R0 SR NSLD 4C4-A1 SYS CR CNTRL RM INFILT STDY (DOSE1)
S&L 03/11/91 10:26:56 WG=212 ID=DRSH
ORIG=05 DUPS=01 PRJ=ZI0 780511 PGM=P0S098085110/

SLIT THIS END

11.4 Microfiche D

ZI-5-91 R0 SR NSLD 4C4-A1 SYS CR CNTRL Rm INFILT STDY (DOSE2)
S&L 03/11/91 10:26:56 WG=212 ID=DRSH
ORIG=05 DUPS=01 PRJ=ZI0780511 PGM=POS098085110 /

SLIT THIS END

LECHLER

FAX CORRESPONDENCE

Lechler Inc, 445 Kautz Rd, St. Charles, IL 60174
Phone 708-377-6611 Fax 708-377-6657

Send to Fax No. (312) 269-3680

Attention: BARRY SCHWARTZ Company: ~~B~~ SARGENT & LUNDY

From: BILL MEYER Total Pages: 5 Date: 3-27-91

THE FOLLOWING PAGES OF THIS FAX SHOW FLOW RATE & DROPLET SIZE DATA FOR THE 1713 & 1713 A NOZZLES. AS YOU CAN SEE, THE PERFORMANCE IS ESSENTIALLY IDENTICAL.

THE MAIN DIFFERENCE BETWEEN THE 2 IS THAT THE 1713 WAS MANUFACTURED TO STANDARD COMMERCIAL SPECIFICATIONS & TOLERANCES WHILE THE 1713A IS MANUFACTURED TO THE MUCH TIGHTER NUCLEAR SPECIFICATIONS.

I HOPE THIS HELPS.

BEST REGARDS,

Bill Meyer

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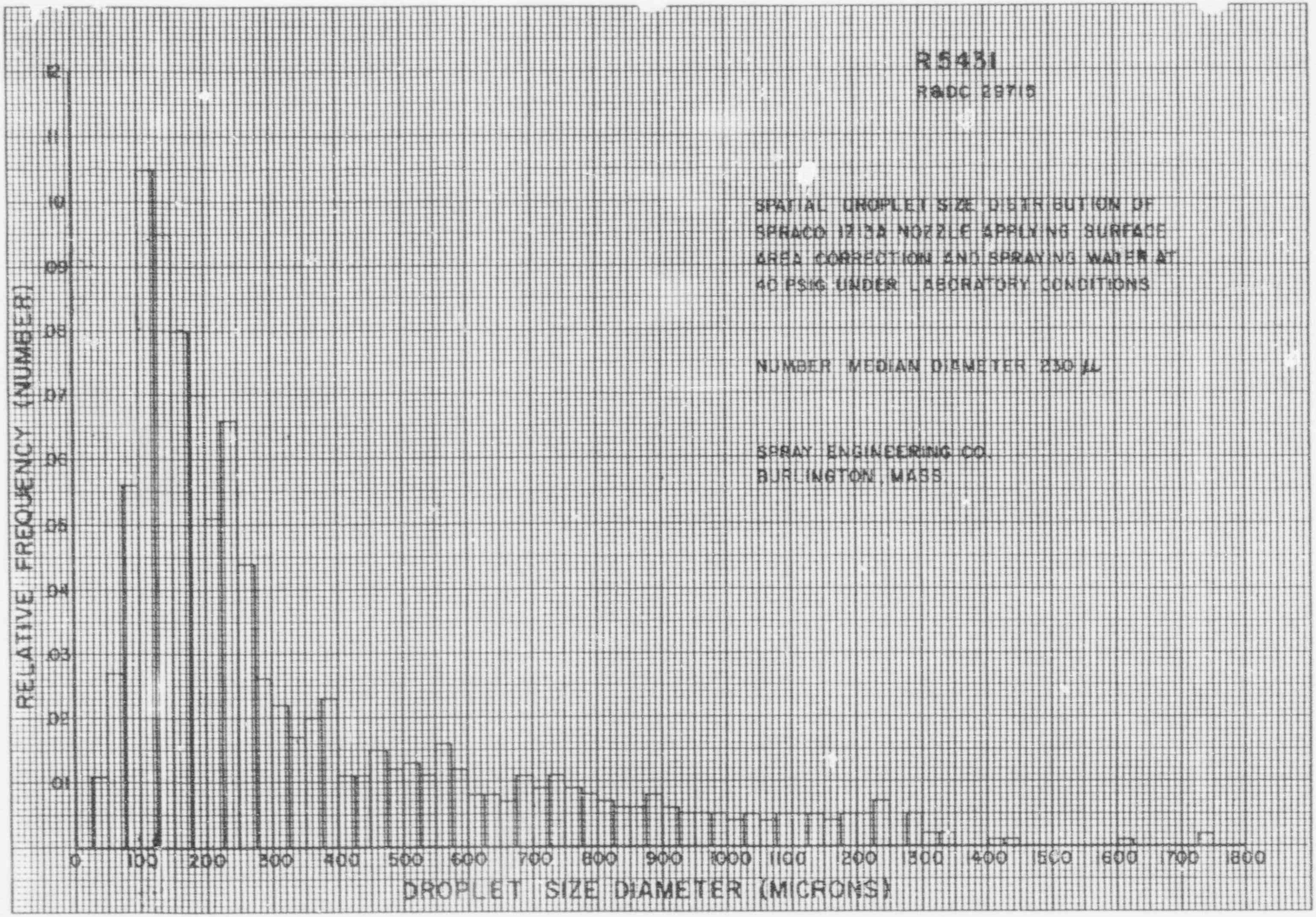
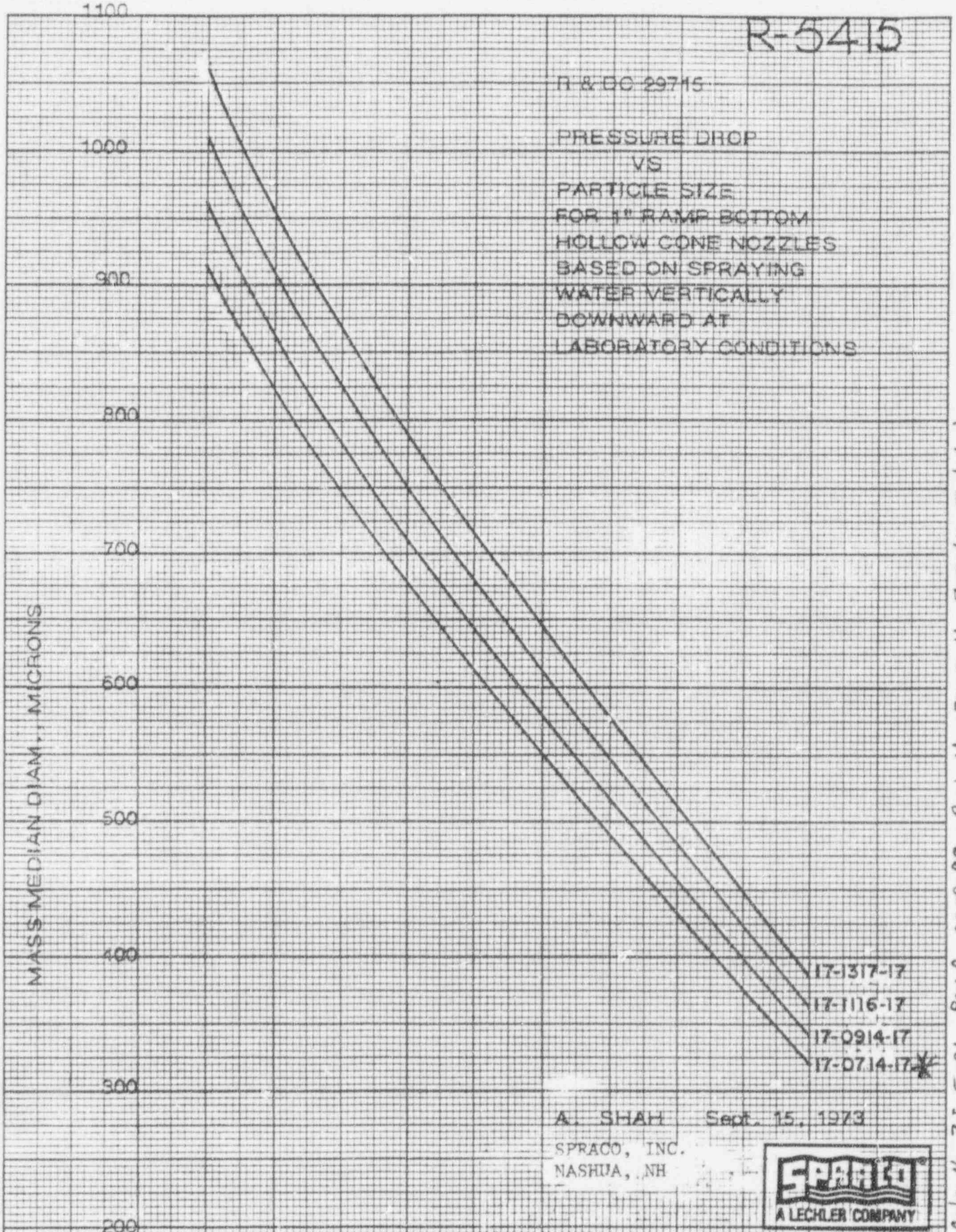
Safety-Related



Calc. No. ZI-5-91 Rev. 0 Page 97 Proj. No. 7805-11 Safety-Related

1713A



R & DC 29715

PRESSURE DROP
VS
PARTICLE SIZE
FOR 1" RAMP BOTTOM
HOLLOW CONE NOZZLES
BASED ON SPRAYING
WATER VERTICALLY
DOWNWARD AT
LABORATORY CONDITIONS

A. SHAH Sept. 15, 1973

SPRACO, INC.
NASHUA, NH

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* 373084.XX.BN (1713)

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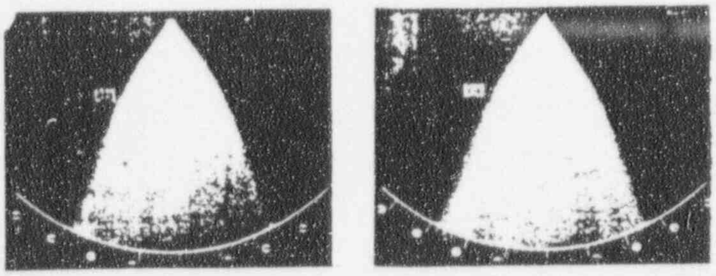
Nozzle-model 1713A

Test media-Water



Nozzle serial number — T-53
Spray angle — 60°

Nozzle serial number — T-54
Spray angle — 60°

Fig. 1

FLOW RATE DATA SHEET

Test Media — Water

Water Temperature 59°F

Nozzle — Mdl 1713A

Nozzle Serial #T-54

TEST PRESSURE (PAIG)	ACTUAL GA. PRESSURE (PAIG)	FLOW UP (MM)	FLOW UP (GPM)	FLOW DOWN (MM)	FLOW DOWN (GPM)	AVERAGE FLOW (GPM)
10	9-5/8	72	7.61	72	7.61	7.61
20	19-3/4	101	10.82	99	10.60	10.71
30	29-3/4	123	13.42	121	13.20	13.31
40	40	140	15.30	138	15.10	15.20
50	50	156	17.06	156	17.06	17.06

j. 2

TESTING PERFORMED EXCLUSIVELY FOR NUCLEAR INDUSTRY

The following tests were run on the 1713A in SPRACO's laboratory with qualified Nuclear Engineers in attendance.

From a quantity of 325 nozzles, 65 nozzles were randomly selected for testing.

The spray angle was measured by photographic record at the design pressure of PSIG to determine agreement with the predicted angle of 62°. (see figure 1 for typical spray angle chart)

Each nozzle was flow tested at a range of inlet pressures from 10 to 50 PSIG to determine that the actual flow at 40 PSIG was in accordance with the predicted value of 15.2 GPM. (see figure 2 for typical flow rate)

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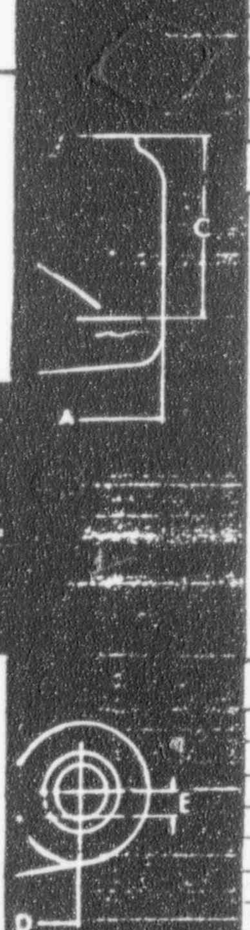

Wt. in Lbs.
.035
.035
.035
.035

MEDIUM ANGLE

NOZZLE NO.	Female Conn. (Inches)	Orifice	FLOW RATE IN GALLONS PER MINUTE at POUNDS PER SQUARE INCH PRESSURES											Effective Angle at 2' Distance			WT. IN LBS.	DIMENSIONS (Inches)				
			5	7	10	15	20	25	30	40	50	75	100	5	15	50		A	B (Max)	C	D	E
1706	3/8	5/32	2.7	3.3	4.0	4.9	5.7	6.4	7.0	8.0	8.8	10.7	12.5	53°	67°	74°	.6	2 1/8	1 5/16	1 1/8	1 1/8	5/16
1708	3/8	13/64	3.8	4.3	5.2	6.3	7.3	8.1	9.0	10.4	11.7	14.2	16.5	64°	71°	74°	.6	2 1/8	1 5/16	1 1/8	1 1/8	5/16
1710	3/8	15/64	4.4	5.2	6.2	7.7	8.9	10.0	10.9	12.5	13.9	16.9	19.5	69°	77°	74°	.6	2 1/8	1 5/16	1 1/8	1 1/8	5/16
1713	1	1/4	5.4	6.6	7.7	9.5	11.0	12.3	13.6	15.2	17.5	21.4	24.6	57°	60°	64°	.7	2 15/16	1 5/8	2 5/16	1 15/16	1/4
1717	1	17/64	6.6	7.6	9.2	11.2	13.1	14.7	16.1	18.6	20.9	25.7	29.7	62°	69°	67°	.7	2 15/16	1 5/8	2 5/16	1 15/16	1/4
1721	1	19/64	8.0	9.6	11.2	13.7	16.0	17.7	19.5	22.5	25.0	30.8	36.0	69°	78°	71°	.7	2 15/16	1 5/8	2 5/16	1 15/16	1/4
1725	1	21/64	9.0	10.8	13.2	16.2	18.5	20.8	22.8	26.5	29.6	36.0	41.5	77°	81°	78°	.7	2 15/16	1 5/8	2 5/16	1 15/16	1/4
1728	1 1/4	11/32	11.0	13.0	15.6	19.2	22.2	24.9	27.4	31.7	35.6	44.2	50.0	67°	74°	77°	1.3	3 5/16	1 5/8	2 5/16	2	5/16
1730	1 1/4	23/64	12.7	15.0	18.0	22.5	26.2	29.5	32.4	37.5	42.0	51.3	59.4	64°	72°	72°	1.3	3 5/16	1 5/8	2 5/16	2	5/16
1732	1 1/4	3/8	13.7	16.2	19.8	24.5	28.7	32.2	35.5	41.1	46.0	56.1	65.0	64°	72°	72°	1.3	3 5/16	1 5/8	2 5/16	2	5/16
1736	1 1/4	7/16	17.7	20.5	24.5	30.3	35.5	40.0	44.2	51.7	57.7	69.0	78.2	78°	81°	81°	1.3	3 5/16	1 5/8	2 5/16	2	5/16
1739	1 1/2	31/64	21.0	24.6	30.0	37.0	43.5	48.5	53.0	60.7	67.1	81.0	93.0	77°	81°	84°	2.0	3 7/8	2 5/16	3 5/16	2 5/16	5/16
1741	1 1/2	1/2	23.0	27.6	33.6	42.3	49.3	55.0	60.0	68.5	76.2	93.0	108	78°	80°	80°	2.0	3 7/8	2 5/16	3 5/16	2 5/16	5/16
1743	1 1/2	9/16	25.0	30.0	38.0	47.5	55.0	61.3	67.0	77.0	85.5	104	121	71°	75°	75°	2.0	3 7/8	2 5/16	3 5/16	2 5/16	5/16
1746	2	5/8	31.5	37.0	44.0	54.0	62.0	69.0	75.0	87.0	97.0	118	135	62°	66°	66°	2.8	4 5/16	2 5/8	3 11/16	2 11/16	1/2
1748	2	1 1/64	36.0	43.0	53.0	64.5	74.0	82.0	89.5	103	115	141	163	71°	74°	74°	2.8	4 5/16	2 5/8	3 11/16	2 11/16	1/2
1751	2	1 9/64	45.0	53.0	63.5	79.0	90.5	101	110	126	141	174	202	77°	80°	82°	2.8	4 5/16	2 5/8	3 11/16	2 11/16	1/2
1753	2	1 7/32	50.0	60.0	72.0	89.0	103	115	125	143	161	193	225	80°	91°	[illegible]	2.8	4 5/16	2 5/8	3 11/16	2 11/16	1/2
1755	2 1/2	1 5/32	63.0	72.0	86.0	104	120	134	148	173	193	237	275	72°	74°	74°	4.5	5 5/16	3 1/4	5 1/2	3 5/8	9/16
1757	2 1/2	1 1/4	65.0	78.0	93.0	114	132	147	160	185	207	252	290	78°	80°	80°	4.5	5 5/16	3 1/4	5 1/2	3 5/8	9/16
1759	2 1/2	1 9/32	75.0	88.0	107	130	150	166	181	208	232	280	320	78°	80°	80°	4.5	5 5/16	3 1/4	5 1/2	3 5/8	9/16
1761	2 1/2	1 3/8	83.0	100	120	145	166	184	200	229	255	312	360	78°	80°	80°	4.5	5 5/16	3 1/4	5 1/2	3 5/8	9/16

MEDIUM ANGLE

NOZZLE NO.	FEMALE CONN. (Inches)	Orifice Diameter	FLOW RATE IN GALLONS PER MINUTE at POUNDS PER SQUARE INCH PRESSURES										Effective Angle at 2' Distance			WT. IN LBS.	DIMENSIONS (Inches)				
			2	3	4	5	7	10	15	20	40	60	3	7	15		A	B	C	D	E
1763	3	1 13/64	44	53	61	68	80	94	114	132	183	220	53°	58°	60°	10.0	6 23/32	4	4 3/4	4 1/4	1 5/16
1764	3	1 3/8	56	67	77	86	100	119	144	165	230	278	60°	64°	65°	10.0	6 23/32	4	4 3/4	4 1/4	1 5/16
1765	3	1 11/16	67	80	93	103	120	143	173	198	277	335	60°	64°	65°	10.0	6 23/32	4	4 3/4	4 1/4	1 5/16
1767	3	2 1/32	78	94	108	120	140	166	202	232	320	388	65°	70°	75°	10.0	6 23/32	4	4 3/4	4 1/4	1 5/16
1768	3	2 3/32	84	101	115	128	150	178	215	246	341	413	68°	74°	75°	10.0	6 23/32	4	4 3/4	4 1/4	1 5/16
1771	4	2 1/8	84	101	115	128	150	178	215	246	341	413	62°	65°	67°	32.3	8 13/16	5	7 1/2	5 3/8	1 3/8
1772	4	2 3/8	98	117	135	150	175	207	250	285	395	480	69°	72°	76°	32.3	8 13/16	5	7 1/2	5 3/8	1 3/8
1774	4	2 1/2	112	135	154	171	200	236	285	328	450	545	74°	78°	80°	32.3	8 13/16	5	7 1/2	5 3/8	1 3/8
1775	4	2 11/16	127	152	174	194	225	266	322	368	508	615	76°	80°	82°	32.3	8 13/16	5	7 1/2	5 3/8	1 3/8
1777	4	2 7/8	137	165	188	208	245	287	348	399	550	662	78°	81°	85°	32.3	8 13/16	5	7 1/2	5 3/8	1 3/8
1778	4	3 11/64	167	201	230	255	300	353	428	490	680	820	80°	83°	87°	32.3	8 13/16	5	7 1/2	5 3/8	1 3/8

NARROW ANGLE

1763N	3	1 13/64	44	53	61	68	80	94	114	132	183	220	43°	45°	46°	11.0	6 23/32	4	6 3/4	4 1/4	1 5/16
1764N	3	1 3/8	56	67	77	86	100	119	144	165	230	278	39°	45°	48°	11.0	6 23/32	4	6 3/4	4 1/4	1 5/16
1765N	3	1 11/16	67	80	93	103	120	143	173	198	277	335	42°	45°	46°	11.0	6 23/32	4	6 3/4	4 1/4	1 5/16
1767N	3	2 1/32	78	94	108	120	140	166	202	232	320	388	39°	45°	48°	11.0	6 23/32	4	6 3/4	4 1/4	1 5/16
1768N	3	2 3/32	84	101	115	128	150	178	215	246	341	413	37°	45°	48°	11.0	6 23/32	4	6 3/4	4 1/4	1 5/16
1771N	4	2 1/8	84	101	115	128	150	178	215	246	341	413	40°	45°	46°	35.6	8 13/16	5	9 1/2	5 5/16	1 3/8
1772N	4	2 3/8	98	117	135	150	175	207	250	285	395	480	39°	45°	50°	35.6	8 13/16	5	9 1/2	5 5/16	1 3/8
1774N	4	2 1/2	112	135	154	171	200	236	285	328	450	545	39°	45°	50°	35.6	8 13/16	5	9 1/2	5 5/16	1 3/8
1775N	4	2 11/16	127	152	174	194	225	266	322	368	508	615	39°	45°	49°	35.6	8 13/16	5	9 1/2	5 5/16	1 3/8
1777N	4	2 7/8	137	165	188	208	245	287	348	399	550	662	39°	45°	48°	35.6	8 13/16	5	9 1/2	5 5/16	1 3/8
1778N	4	3 11/64	167	201	230	255	300	353	428	490	680	820	39°	45°	47°	35.6	8 13/16	5	9 1/2	5 5/16	1 3/8

See following page for spray coverage data

Calc. No. ZI-5-91 Rev. 0 Page 100 Proj. No. 7805-11 Safety-Related

REVIEW METHOD SHEET

Calc. No. ZI-5-91
Revision 0
Page 101, LAST of Rev. 0
Proj. No. 7805-11
Safety-Related

This calculation has been reviewed by me according to the method(s) checked below.

1. Computer Aided Calculations

a X	Review to determine that the computer program(s) has been validated and documented, is suitable to the problem being analyzed, and that the calculation contains all necessary information for reconstruction at a later date.
b	Review to determine that the input data as specified for program execution is consistent with the design input, correctly defines the problem for the computer algorithm and is sufficiently accurate to produce results within any numerical limitations of the program.
c X	Review to verify that the results obtained from the program are correct and within stated assumptions and limitations of the program and are consistent with the input.
d	Review validation documentation for temporary changes to listed, or developmental, or unique single application programs, to assure that methods used adequately validate the program for the intended application.
e X	Review of code input only, since the computer program has sufficient history of use at Sargent & Lundy in similar calculations.
f X	Review arithmetic necessary to prepare code input data.
g	Other:

2. Hand Prepared Design Calculations

a X	Detailed review of the original calculations.
b	Review by an alternate, simplified, or approximate method of calculation.
c	Review of a representative sample of repetitive calculations.
d	Review of the calculation against a similar calculation previously performed.

3. Revisions

a	Editorial changes only.
b	Elimination of unapproved input data without altering calculated results.
c	Other:

4. Other

Reviewer: William

Date: 4/10/91

JAM*FORM.REVIEW-1 02/19/85