4.0 RADIOLOGICAL ENVIRONMENTAL MONITORING PROGRAM

The radiological environmental monitoring stations are listed in Table B.4-1. The locations of the stations with respect to the Seabrook Station are shown on the maps in Figures B.4-1 to B.4-6.

Direct radiation measurements are analyzed at the station. All other radiological analyses for environmental samples are performed at a contractor laboratory. The contractor laboratory participates in an Interlaboratory Comparison Program for all relevant species in an aqueous (water) matrix. An independent vendor (Analytics) supplies the remaining cross check samples. These samples are presented on an air filter and in milk and water matrices.

Pursuant to Part A Surveillance S.9.2.1, the land use census will be conducted "during the growing season" at least once per 12 months. The growing season is defined, for the purposes of the land use census, as the period from June 1 to October 1. The method to be used for conducting the census will consist of one or more of the following, as appropriate: door-to-door survey, visual inspection from roadside, aerial survey, or consulting with local agricultural authorities.

Technical Specification 6.8.1.3 and Part A, Section 10.1 of the ODCM require that the results of the Radiological Environmental Monitoring Program be summarized in the Annual Radiological Environmental Operating Report "in the format of the table in the Radiological Assessment Branch Technical Position, Revision 1, 1979." The general table format will be used with one exception and one clarification, as follows. The mean and range values will be based not upon detectable measurements only, as specified in the NRC Branch Technical Position, but upon all measurements. This will prevent the positive bias associated with the calculation of the mean and range based upon detectable measurements only. Secondly, the Lower Limit of Detection column will specify the LLD required by ODCM Table A.9.1-2 for that radionuclide and sample medium.

TABLE B.4-1

RADIOLOGICAL ENVIRONMENTAL MONITORING STATIONS[a]

Exposure Pathway and/or Sample		Sample Location and Designated Code		Distance From Unit 1 Containment (km)	Direction From the Plant
1.	AIRBORNE (Particulate and Radioiodine)				
		AP/CF-01	PSNH Barge Landing Area	2.6	ESE
		AP/CF-02	Harbor Road	2.5	E
		AP/CF-03	SW Boundary	1.0	SW
		AP/CF-04	W. Boundary	1.2	W
		AP/CF-05	Winnacunnet H.S.[b]	4.0	NNE
		AP/CF-06	Georgetown Substation (Control)	22.6	SSW
		AP/CF-07	(PSNH Substation)	5.7	NNW
		AP/CF-08	E&H Substation[b]	3.4	SSE
2.	WATERBORNE				
	a. Surface	WS-01	Hampton-Discharge Area	5.3	E
		WS-51	Ipswich Bay (Control)	16.9	SSE
	b. Sediment	SE-02	Hampton-Discharge Area[b]	5.3	E
		SE-07	Hampton Beach[b]	3.1	E
		SE-08	Seabrook Beach	3.2	ESE
		SE-52	Ipswich Bay (Control)[b]	16.9	SSE
		SE-57	Plum Island Beach (Control)[b]	15.9	SSE
3.	INGESTION				
	a. Milk	TM-04	Salisbury, MA	5.3	SW
		TM-09	Hampton, NH	5.3	NNW
		TM-15	Hampton Falls, NH	6.9	NW
		TM-16	Kensington, NH[b]	7.6	WNW
		TM-20	Rowley, MA (Control)	17.0	S
		TM-21	North Andover, MA[b]	20.8	S
		TM-23	Newbury, MA[b]	12.0	S
	b. Fish and Invertebrates[c]				
		FH-03	Hampton - Discharge Area	4.5	ESE
		FH-53	Ipswich Bay (Control)	16.4	SSE
		HA-04	Hampton - Discharge Area	5.5	E
		HA-54	Ipswich Bay (Control)	17.2	SSE
		MU-06	Hampton - Discharge Area	5.2	E
		MU-09	Hampton Harbor[b]	2.6	E
		MU-56	Ipswich Bay (Control)	17.4	SSE
		MU-59	Plum Island[b]	15.8	SSE

TABLE B.4-1

RADIOLOGICAL ENVIRONMENTAL MONITORING STATIONS[a]

(Continued)

Exposure Pathway and/or Sample	Sample Location and Designated Code	Distance From Unit 1 Containment (km)	Direction From the Plant
4. DIRECT RADIATION			
TL-1	Brimmer's Lane, Hampton Falls	.97	N
TL-2	Landing Rd., Hampton	3.0	NNE
TL-3	Glade Path, Hampton Beach	2.9	NE
TL-4	Island Path, Hampton Beach	2.3	ENE
TL-5	Harbor Rd., Hampton Beach	2.6	E
TL-6	PSNH Barge Landing Area	2.7	ESE
TL-7	Cross Rd., Seabrook Beach	2.6	SE
TL-8	Farm Lane, Seabrook	1.3	SSE
TL-9	Farm Lane, Seabrook	1.3	S
TL-10	Site Boundary Fence	1.2	SSW
TL-11	Site Boundary Fence	1.0	SW
TL-12	Site Boundary Fence	1.2	WSW
TL-13	Inside Site Boundary	1.2	W
TL-14	Trailer Park, Seabrook	1.3	WNW
TL-15	Brimmer's Lane, Hampton Falls	1.4	NW
TL-16	Brimmer's Lane, Hampton Falls	1.2	NNW
TL-17	South Rd., N. Hampton	7.8	N
TL-18	Mill Rd., N. Hampton	7.6	NNE
TL-19	Appledore Ave., N. Hampton	7.7	NE
TL-20	Ashworth Ave., Hampton Beach	3.2	ENE
TL-21	Route 1A, Seabrook Beach	3.7	SE
TL-22	Cable Ave., Salisbury Beach	7.6	SSE
TL-23	Ferry Rd., Salisbury	8.1	S
TL-24	Ferry Lots Lane, Salisbury	7.2	SSW
TL-25	Elm St., Amesbury	7.6	SW
TL-26	Route 107A, Amesbury	8.1	WSW

TABLE B.4-1
RADIOLOGICAL ENVIRONMENTAL MONITORING STATIONS[a]
(Continued)

Exposure Pathway and/or Sample	Sample Location and Designated Code		Distance From Unit 1 Containment (km)	Direction From the Plant
	TL-27	Highland St., S. Hampton	7.5	W
	TL-28	Route 150, Kensington	7.5	WNW
	TL-29	Frying Pan Lane, Hampton Falls	7.2	NW
	TL-30	Route 27, Hampton	7.6	NNW
	TL-31	Alumni Drive, Hampton	3.8	NNE
	TL-32	Seabrook Elementary School	2.0	S
	TL-33	Dock Area, Newburyport	9.8	S
	TL-34	Bow St., Exeter	12.0	NW
	TL-35	Lincoln Ackerman School	2.3	NNW
	TL-36	Route 97, Georgetown (Control)	22.6	SSW
	TL-37	Plaistow, NH (Control)	21.5	WSW
	TL-38	Hampstead, NH (Control)	27.7	W
	TL-39	Fremont, NH (Control)	27.0	WNW
	TL-40	Newmarket, NH (Control)	21.6	NNW
	TL-41	Portsmouth, NH, (Control)[b]	21.0	NNE
	TL-42	Ipswich, MA (Control)[b]	22.8	SSE

(a) Sample locations are shown on Figures B.4-1 to B.4-6.

(b) This sample location is not required by monitoring program defined in Part A of ODCM; program requirements specified in Part A do not apply to samples taken at this location.

(c) Samples will be collected pursuant to ODCM Table A.9.1-1. Samples are not required from all stations listed during any sampling interval (FH = Fish; HA = Lobsters; MU = Mussels). Table A.9.1-1 specifies that "one sample of three commercially and recreationally important species" be collected in the vicinity of the plant discharge area, with similar species being collected at a control location. (This wording is consistent with the NRC Final Environmental Statement for Seabrook Station.) Since the discharge area is off-shore, there is a great number of fish species that could be considered commercially or recreationally important. Some are migratory (such as striped bass), making them less desirable as an indicator of plant-related radioactivity. Some pelagic species (such as herring and mackerel) tend to school and wander throughout a large area, sometimes making catches of significant size difficult to obtain. Since the collection of all species would be difficult or impossible, and would provide unnecessary redundancy in terms of monitoring important pathways to man, three fish and invertebrate species have been specified as a minimum requirement. Samples may include marine fauna such as lobsters, clams, mussels, and bottom-dwelling fish, such as flounder or hake. Several similar species may be grouped together into one sample if sufficient sample mass for a single species is not available after a reasonable effort has been made (e.g., yellowtail flounder and winter flounder).

FIGURE B.4-1
RADIOLOGICAL ENVIRONMENTAL MONITORING LOCATIONS
WITHIN 4 KILOMETERS OF SEABROOK STATION

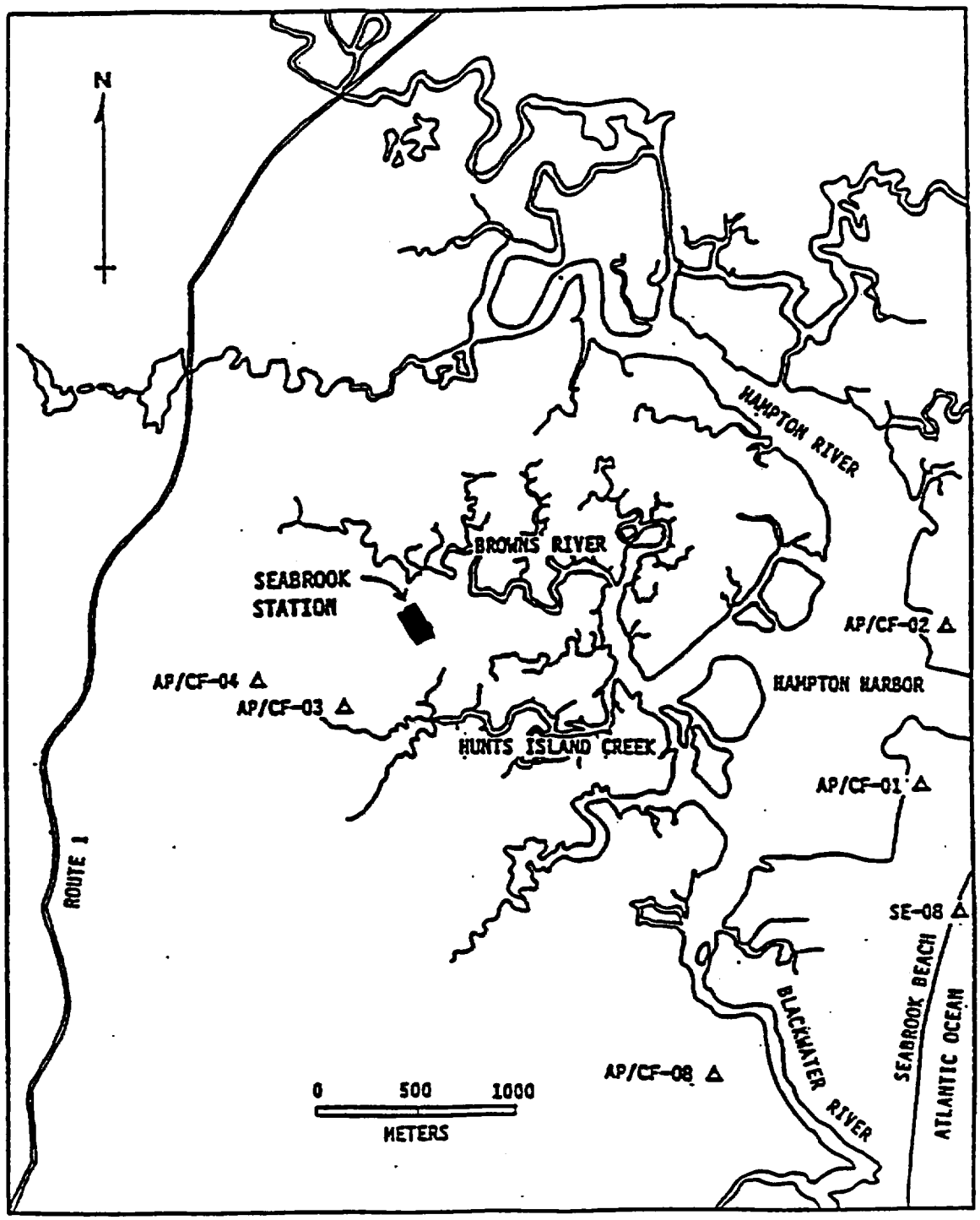


FIGURE B.4-2
RADIOLOGICAL ENVIRONMENTAL MONITORING LOCATIONS
BETWEEN 4 KILOMETERS AND 12 KILOMETERS FROM SEABROOK STATION

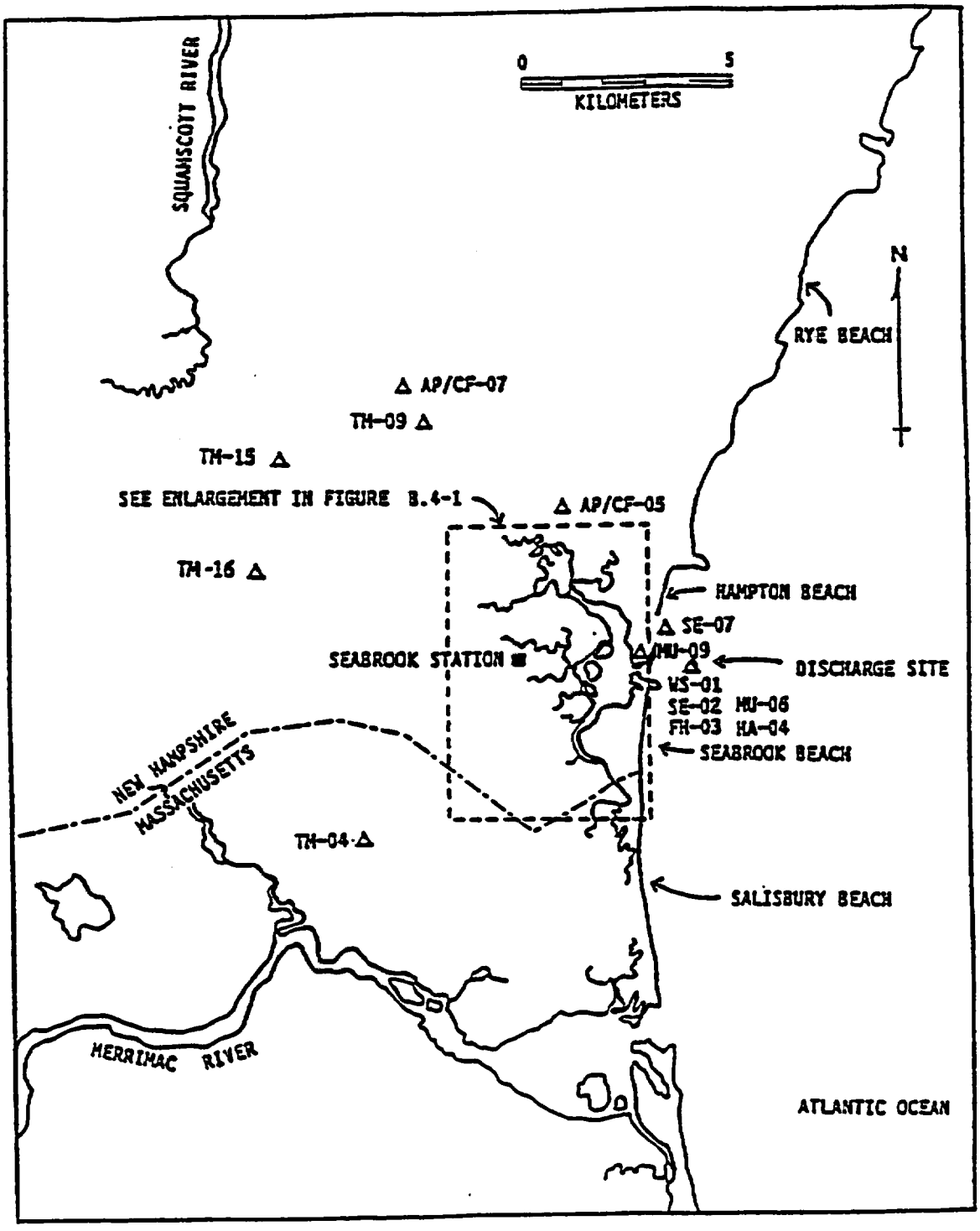


FIGURE B.4-3
RADIOLOGICAL ENVIRONMENTAL MONITORING LOCATIONS
OUTSIDE 12 KILOMETERS OF SEABROOK STATION

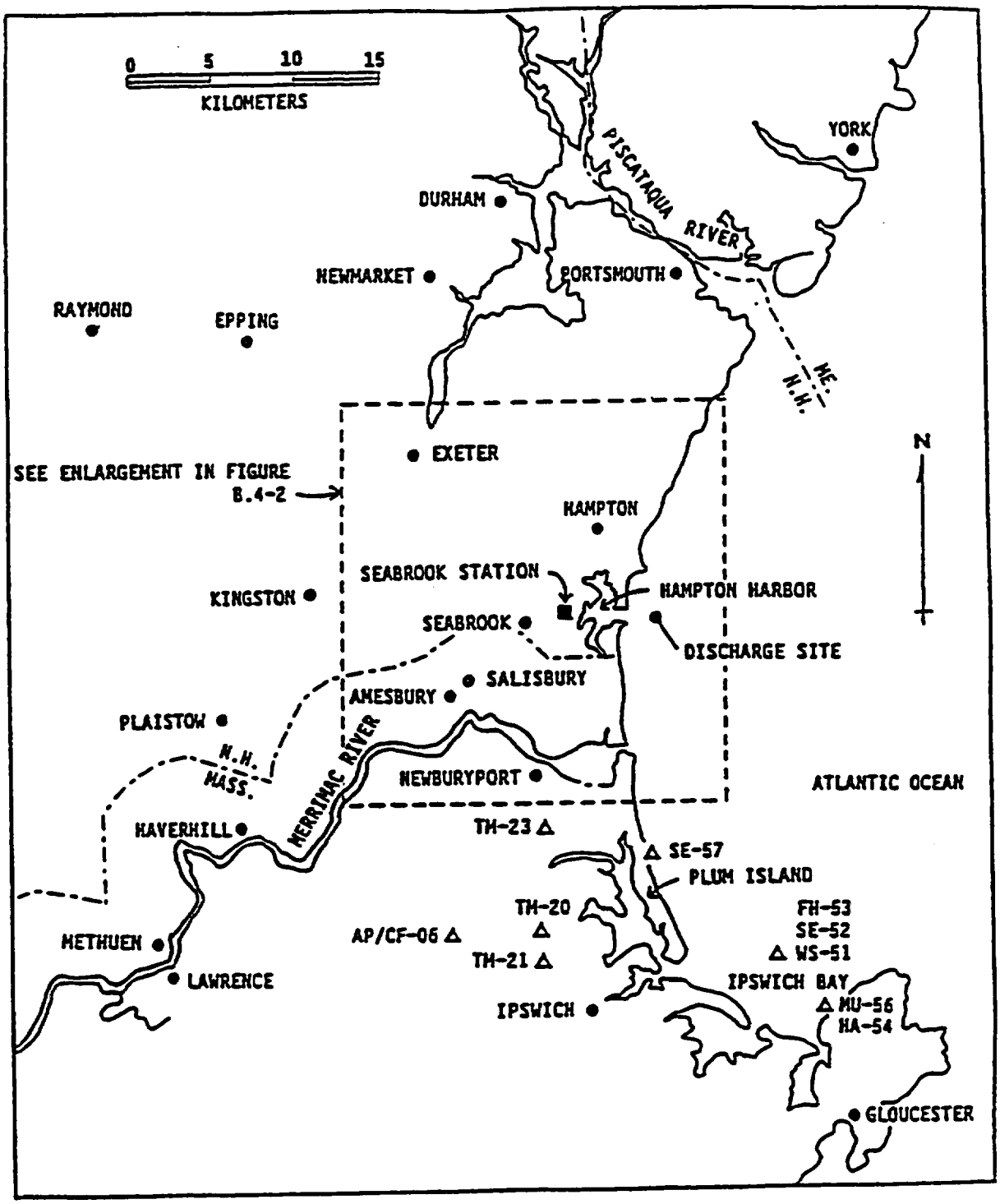


FIGURE B.4-4
DIRECT RADIATION MONITORING LOCATIONS WITHIN
4 KILOMETERS OF SEABROOK STATION

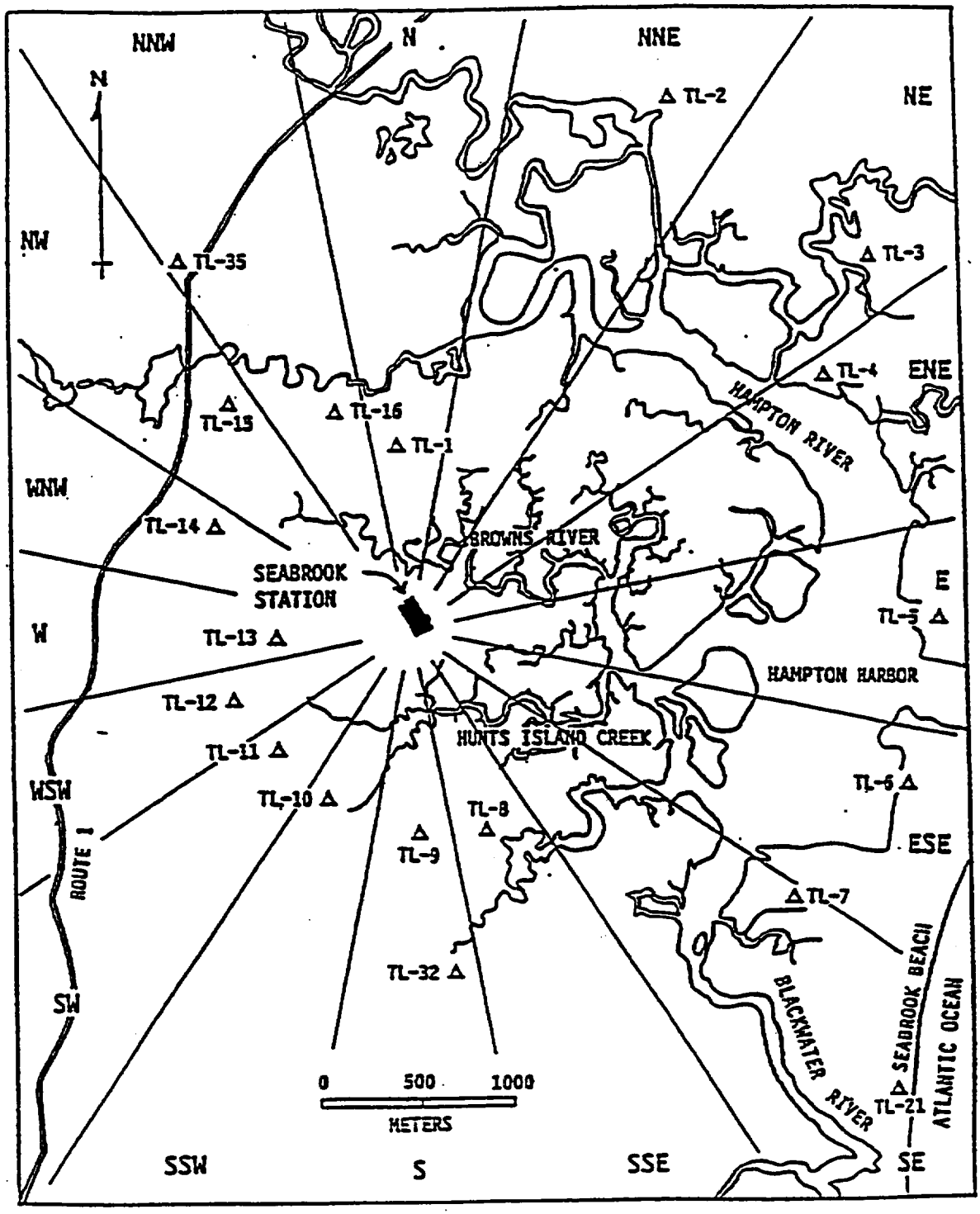


FIGURE B.4-5

DIRECT RADIATION MONITORING LOCATIONS BETWEEN
4 KILOMETERS AND 12 KILOMETERS FROM SEABROOK STATION

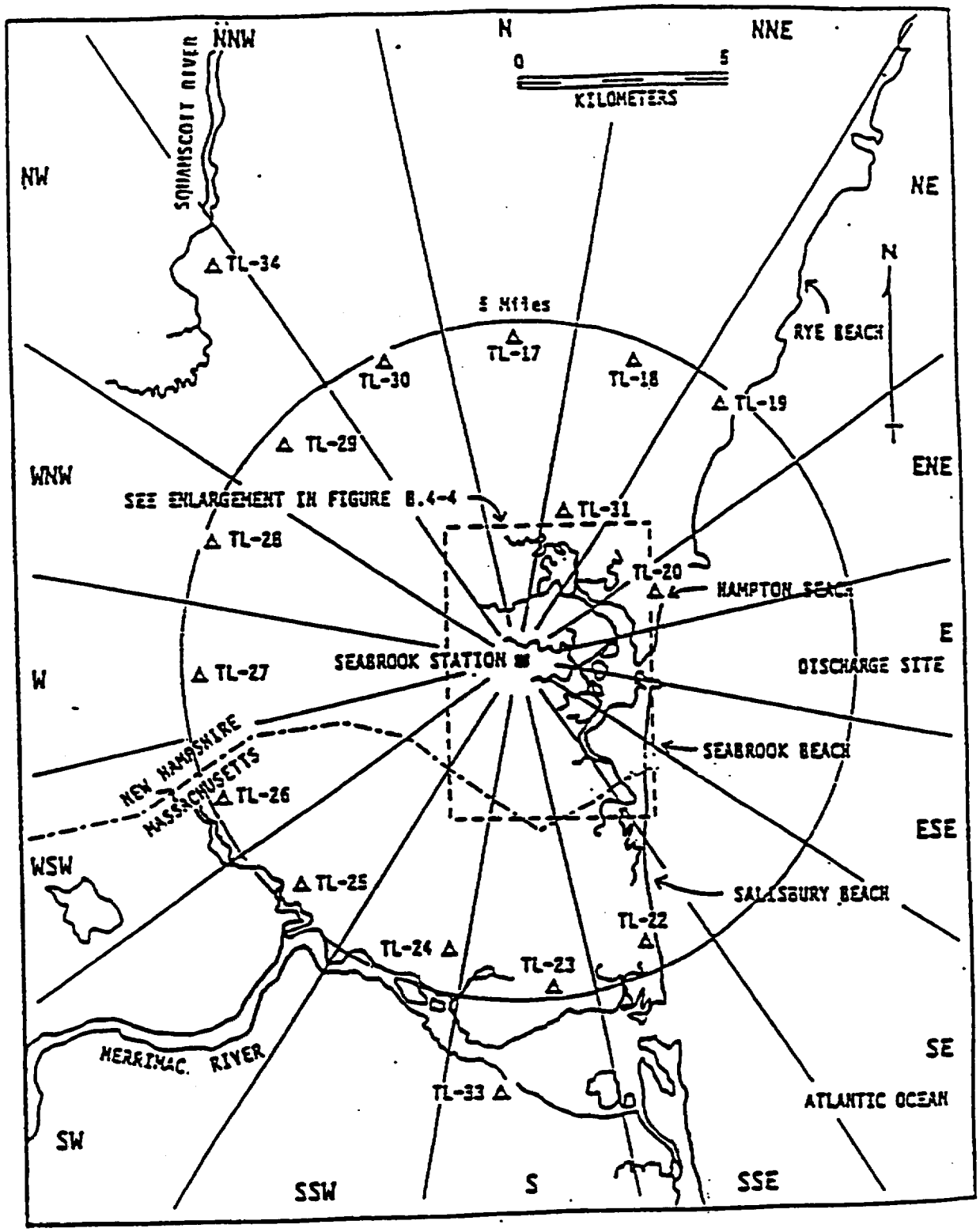
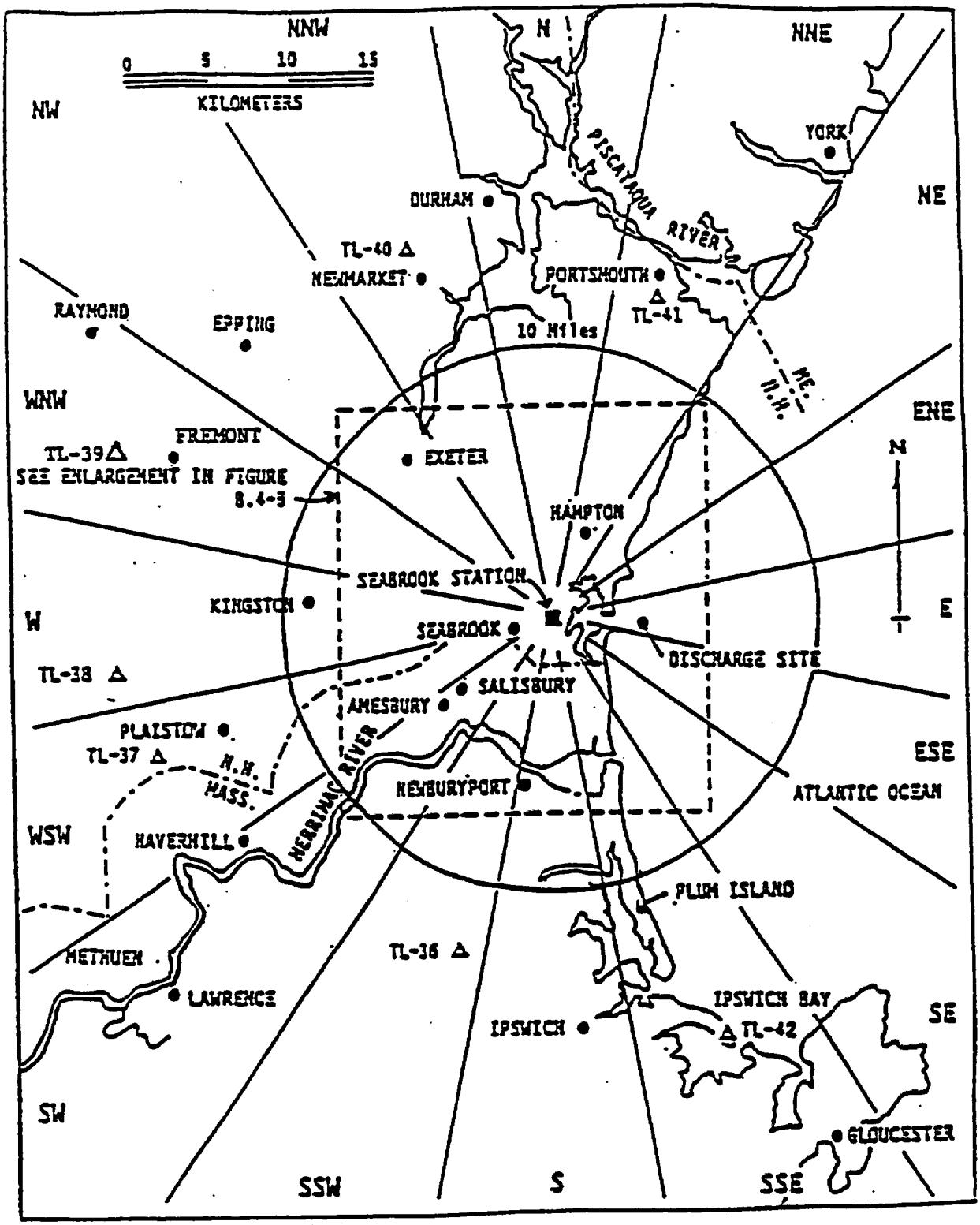


FIGURE B.4-6
DIRECT RADIATION MONITORING LOCATIONS OUTSIDE
12 KILOMETERS OF SEABROOK STATION



5.0 SETPOINT DETERMINATIONS

Chapter 5 contains the methodology for the calculation of effluent monitor setpoints to implement the requirements of the radioactive effluent monitoring systems Part A Controls C.5.1 and C.5.2 for liquids gases, respectively.

Example setpoint calculations are provided for each of the required effluent monitors.

5.1 Liquid Effluent Instrumentation Setpoints

Part A Control C.5.1 requires that the radioactive liquid effluent instrumentation in Table A.5.1-1 of Part A have alarm setpoints in order to ensure that Part A Control C.6.1.1 is not exceeded. Part A Control C.6.1.1 limits the activity concentration in liquid effluents to the appropriate MPCs in 10CFR20 and a total noble gas MPC.

5.1.1 Liquid Waste Test Tank Monitor (RM-6509)

The liquid waste test tank effluent monitor provides alarm and automatic termination of release prior to exceeding the concentration limits specified in 10CFR20, Appendix B, Table II, Column 2 to the environment. It is also used to monitor discharges from various waste sumps to the environment.

5.1.1.1 Method to Determine the Setpoint of the Liquid Waste Test Tank Monitor (RM-6509)

The alarm setpoint is based on ensuring that radioactive effluents in liquid waste are in compliance with Control limits which are based on the concentration limits in Appendix B to 10CFR20. The alarm point depends on available dilution flow through the discharge tunnel, radwaste discharge flow rate from the test tanks, the isotopic composition of the liquid waste, and the monitor response efficiency and background count rate applicable at the time of the discharge. The alarm/trip setpoint is determined prior to each batch release taking into account current values for each variable parameter. The following steps are used in determining the monitor setpoint:

First, the minimum required dilution factor is determined by evaluating the isotopic analysis of each test tank to be released along with MPC requirements for each radionuclide. The most recent analysis data for tritium and other beta emitters that are analyzed only monthly or quarterly on composite samples can be used as an estimate of activity concentration in the tank to be released. For noble gases, the Control limit (C.6.1.1) is defined as 2E-04 μCi/ml total for all dissolved and entrained gases. Therefore,

$$DF_{min} = \Sigma \frac{C_i}{MPC_i} \quad \text{or} \quad \Sigma \frac{C_{NG}}{2E-04}, \text{ whichever is larger.} \qquad (5\text{-}3)$$

Where:

DF_{min} = Minimum required dilution factor necessary to ensure that the sum of the ratios for each nuclide concentration divided by its MPC value is not greater than 1 (dimensionless).

C_i = Activity concentration of each radionuclide "i" (except noble gases) determined to be in the test tank (μCi/ml). This includes tritium and other non gamma emitting isotopes either measured or estimated from the most recent composite analysis.

C_{ng} = The sum of all dissolved and entrained noble gases identified in each test tank (μCi/ml).

MPC_i = The concentration limit (above background) at point of discharge to the environment for radionuclide "i" taken from 10CFR20, Appendix B, Table II, Column 2 (μCi/ml) for all nuclides other than noble gases.

See ODCM, Appendix B, for a listing. In the event that no activity is expected to be discharged, or can be measured in the system, the liquid monitor setpoint should be based on the most restrictive MPC for an "unidentified" mixture or a mixture known not to contain certain radionuclides as given in 10CFR20, Appendix B, notes.

2E-04 = The total dissolved and entrained noble gas Technical Specification concentration limit in liquid effluents from the plant (μCi/ml).

Next, the available dilution flow through the discharge tunnel (F_d), or a conservative estimate for it, is divided by the minimum dilution factor (DF_{min}) to determine the maximum allowable discharge flow rate (F_{max}) that the test tanks could be released at without exceeding the MPC limits, assuming no additional radioactive flow paths are discharging at the time of release of the test tanks. Therefore,

$$F_{max} = \frac{F_d}{DF_{min}}$$

Where:

F_{max} = The maximum allowable discharge flow rate from the test tank past the monitor which would equate to the Control concentration limit for the radioactivity mixture determined to be in the test tank (gpm).

F_d = The actual or conservative estimate of the flow rate out of the discharge tunnel (gpm).

For Waste Test Tank (WTT) releases, tritium is expected to be the radionuclide with the highest concentration, and therefore requires the highest dilution flow in order to satisfy the discharge MPC limits. Unlike concentrations of other dissolved or suspended radionuclides, tritium concentrations are not expected to vary because they are unaffected by plant cleanup systems used to reduce or control waste radioactivity levels. As such, events that cause sudden increases in the concentrations of other dissolved or suspended radionuclides, such as changes in waste cleanup efficiencies, crud bursts or failed fuel fractions would not change the tritium concentrations. As long as the minimum required dilution factor (DF_{min}) for all radionuclides present in the liquid waste is satisfied, the alarm setpoint for the Waste Test Tank monitor need only consider the potential changes to the concentrations of detectable gamma-emitting radionuclides. Therefore, the required dilution for detectable activity by the WTT monitor can be determined by applying the definition of DF_{min} (given in equation (5-3)) to only the gamma-emitting radionuclides present in the waste.

$$DF_{min\gamma} = \Sigma (C_{i\gamma} / MPC_i) \qquad (5\text{-}3a)$$

Where:

$DF_{min\gamma}$ = Minimum required dilution factor necessary to ensure that the sum of the ratios for the concentration of each gamma-emitting radionuclide to the respective MPC value is not greater than 1 (dimensionless).

$C_{i\gamma}$ = Activity concentration of each detectable gamma-emitting radionuclide "i" in the mixture (μCi/ml).

MPC_i = As defined previously.

As in the determination of F_{max} for the total radioactivity mixture, the maximum allowable discharge flow rate that the waste from the test tanks could be released at without exceeding the MPC limit for gamma-emitters, $F_{max\gamma}$, is obtained by dividing the discharge tunnel flow, F_d, by $DF_{min\gamma}$. This determination is based on the assumption that there are no additional discharges of liquid waste at the time of release from the test tanks. Therefore,

$$F_{max\gamma} = F_d / DF_{min\gamma}$$

Where:

$F_{max\gamma}$ = The maximum allowable discharge flow rate from the test tank past the monitor which would equate to the control concentration limit for the gamma radioactivity mixture determined to be in the test tank (gpm).

F_d = The actual or conservative estimate of the flow rate out of the discharge tunnel (gpm).

The selection of the actual discharge flow rate (F_m) from the test tanks compared to the maximum allowable discharge rate based on all radionuclides that are present (F_{max}) and the maximum allowable discharge rate based on only gamma-emitting radionuclides that are present ($F_{max\gamma}$) must satisfy the following:

$$F_m \leq F_{max} * f_{tt} \leq F_{max\gamma} * f_{tt}$$

Where the f_{tt} represents an administrative fraction of the maximum allowable discharge flow from the test tanks. This fraction provides additional margin in meeting MPC limits for non-gamma emitters (such as tritium) at the discharge point to the ocean when other flow paths may contribute to the total site release at the time of tank discharges and minimum dilution flow conditions exist.

With the above conditions on discharge and dilution flow rates satisfied, the alarm/trip setpoint for the monitor which corresponds to the maximum allowable concentration at the point of discharge is determined as follows:

$$R_{setpoint} = f_1 \times \frac{F_d}{F_m \times DF_{minv}} \times \sum C_i \qquad (5\text{-}1)$$

Where:

$R_{setpoint}$ = The maximum allowable alarm/trip setpoint for an instrument response (μCi/ml) that ensures the limiting concentration at the point of discharge is not exceeded.

f_1 = The fraction of the total contribution of MPC at the discharge point to be associated with the test tank effluent pathway, where f_2, f_3, and f_4 are the fractions for the Turbine Building Sump, Steam Generator Blowdown, and Primary Component Cooling pathways contributions to the total, respectively ($f_1+f_2+f_3+f_4 \leq 1$). Each of the fractions may be conservatively set administratively such that the sum of the fractions is less than 1. This additional margin can be used to account for the uncertainty in setpoint parameters such as estimated concentration of non gamma emitters that are based on previous composite analyses of the waste stream.

5.1.1.2 Liquid Waste Test Tank Monitor Setpoint Example

The radioactivity concentration of each radionuclide, C_i, in the waste test tank is determined by analysis of a representative grab sample obtained at the radwaste sample sink, and analyzed prior to release for gamma emitters, or as part of a composite analysis for non gamma emitters. This setpoint example is based on the following data:

i	C_i (μCi/ml)	MPC_i (μCi/ml)
Cs-134	2.15E-05	9E-06
Cs-137	7.48E-05	2E-05
Co-60	2.56E-05	3E-05
H-3	1.50E-01	3E-03

The minimum required dilution factor for this mix of radionuclides (including beta-emitters) is:

$$DF_{min} = \Sigma \frac{C_i}{MPC_i} = \frac{2.15E-05}{9E-06} + \frac{7.48E-05}{2E-05} + \frac{2.56E-05}{3E-05} + \frac{1.50E-01}{3E-03} = 57$$

The release flow rate (F_m) from the waste test tanks can be set between 10 and 150 gpm. The cooling water tunnel discharge dilution flow rate (F_d) can typically vary from approximately 8,800 to 412,000 gpm depending on the operating status of the plant. In this example, if the dilution flow (F_d) is taken as 412,000 gpm, the maximum allowable discharge rate (F_{max}) is:

$$F_{max} = \frac{F_d}{DF_{min}}$$
$$= \frac{412,000}{57} \text{gpm}$$
$$= 7228 \text{ gpm}$$

Next, the required dilution factor for only gamma emitters in the mix is:

$$DF_{min\gamma} = \Sigma (C_{i\gamma}/MPC_i) = \frac{2.15E-05}{9E-06} + \frac{7.48E-05}{2E-05} + \frac{2.56E-05}{3E-05} = 7.0$$

The maximum allowable discharge flow rate ($F_{max\gamma}$) considering only gamma emitters is given as:

$$F_{max\gamma} = \frac{F_d}{DF_{min\gamma}} = \frac{412,000}{7} \text{gpm} = 58,857 \text{ gpm}$$

With the selected release rate from the test tank set at 150 gpm, and the administrative flow fraction (f_{ft}) assumed in this example to be 0.7, the condition for the control concentration limits is met since:

F_m (equal to 150) < F_{max} (equal to 7228 gpm) x f_{ft} (set at 0.7)
< $F_{max\gamma}$ (equal to 58857 gpm x F_{ft} (set at 0.7)

$$150 < 5060 < 41200$$

and the monitor response due to the mix of the gamma emitters is:

i	$C\gamma_i$ (μCi/ml)
Cs-134	2.15E-05
Cs-137	7.48E-05
Co-60	2.56E-05
	$\Sigma C_{\gamma i}$ = 1.22E-04 μCi/ml

Under these conditions, the alarm/trip setpoint for the liquid radwaste discharge monitor is:

$$R_{setpoint} = f_1 \times \frac{F_d}{F_m \times DF_{min\gamma}} \times \Sigma C\gamma i \qquad (5\text{-}1)$$

μCi/ml ( ) ( ) μCi/ml

$$R_{setpoint} = 0.4 \times \frac{412{,}000}{150 \times 7} \times 1.22E-04$$

$$= 1.92E-02\ \mu Ci/ml$$

In this example, the alarm/trip setpoint of the liquid radwaste discharge monitor can be put at 1.92E-02 μCi/ml above background. For the example, it is assumed that the test tank release pathway will be limited to only 40% of the total site discharge allowable concentration.

5.1.2 Turbine Building Drains Liquid Effluent Monitor (RM-6521)

The Turbine Building drains liquid effluent monitor continuously monitors the Turbine Building sump effluent line. The only sources to the Sump Effluent System are from the secondary steam system. Activity is expected in the Turbine Building Sump Effluent System only if a significant primary-to-secondary leak is present. If a primary-to-secondary leak is present, the activity in the sump effluent system would be comprised of only those radionuclides found in the secondary system, with reduced activity from decay and dilution.

The Turbine Building drains liquid effluent monitor provides alarm and automatic termination of release prior to exceeding the concentration limits specified in 10CFR20, Appendix B, Table II, Column 2 to the environment. The alarm setpoint for this monitor will be determined using the same method as that of the liquid waste test tank monitor if the total sump activity is greater than 10 percent of MPC, as determined by the most recent grab sample isotopic analysis. If the total activity is less than 10 percent of MPC, the setpoints of RM-6521 are calculated as follows:

$$\text{High Trip Monitor Setpoint } (\mu Ci/ml) = f_2\,(DF')\,(\text{"unidentified mix MPC"}\ (\mu Ci/ml)) \qquad (5\text{-}21)$$

where:

$$DF' = \frac{\text{Circulating water flow rate (gpm)}}{\text{Flow rate pass-monitor (gpm)}}$$

unidentified mix MPC = most restrictive MPC value (μCi/ml) for an unidentified mixture or a mixture known not to contain certain radionuclides as given in 10CFR20, Appendix B, Notes.

f_2 = $1 - (f_1 + f_3 + f_4)$; where the f values are described above.

In addition, a warning alarm setpoint can be determined by multiplying the high trip alarm point by an administratively selected fraction (as an example, 0.25).

$$\begin{pmatrix}\text{Warning Alarm}\\ \text{Monitor Setpoint}\\ (\mu\text{Ci/ml})\end{pmatrix} = \begin{pmatrix}\text{High Trip}\\ \text{Monitor Sepoint}\end{pmatrix} (0.25)$$

5.1.3 Steam Generator Blowdown Liquid Sample Monitor (RM-6519)

The steam generator blowdown liquid sample monitor is used to detect abnormal activity concentrations in the steam generator blowdown flash tank liquid discharge.

The alarm setpoint for the steam generator blowdown liquid sample monitor, when liquid is to be discharged from the site, will be determined using the same approach as the Turbine Building drains liquid effluent monitor.

For any liquid monitor, in the event that no activity is expected to be discharged, or can be measured in the system, the liquid monitor setpoint should be based on the most restrictive MPC for an "unidentified" mixture or a mixture known not to contain certain radionuclides given in 10CFR20, Appendix B notes.

5.1.4 PCCW Head Tank Rate-of-Change Alarm Setpoint

A rate-of-change alarm on the liquid level in the Primary Component Cooling Water (PCCW) head tank will work in conjunction with the PCCW radiation monitor to alert the operator in the Main Control Room of a leak to the Service Water System from the PCCW System. For the rate-of-change alarm, a setpoint is selected based on detection of an activity level equivalent to 10^{-8} µCi/ml in the discharge of the Service Water System. The activity in the PCCW is determined in accordance with the liquid sampling and analysis program described in Part A, Table A.6 1-1 of the ODCM and is used to determine the setpoint.

The rate-of-change alarm setpoint is calculated from:

$$RC_{set} = 1x10^{-8} \bullet SWF \bullet \frac{1}{PCC} \qquad (5\text{-}23)$$

$$\left(\frac{gal}{hr}\right) = \left(\frac{\mu Ci}{ml}\right)\left(\frac{gal}{hr}\right)\left(\frac{ml}{\mu Ci}\right)$$

where:

RC_{set} = The setpoint for the PCCW head tank rate-of-change alarm (in gallons per hour).

$1x10^{-8}$ = The minimum detectable activity level in the Service Water System due to a PCCW to SWS leak (µCi/ml).

SWF = Service Water System flow rate (in gallons per hour).

PCC = Primary Component Cooling Water measured (decay corrected) gross radioactivity level (µCi/ml).

As an example, assume a PCCW activity concentration of $1x10^{-5}$ μCi/ml with a service water flow rate of only 80 percent of the normal flow of 21,000 gpm. The rate-of-change setpoint is then:

$$RC_{set} = 1x10^{-8}\ \frac{\mu Ci}{ml} \bullet 1.0x10^{6}\ gph\ (1/1x10^{-5}\ \frac{\mu Ci}{ml})$$

$$RC_{set} = 1000\ gph$$

As a result, for other PCCW activities, the RC_{set} which would also relate to a detection of a minimum service water concentration of $1x10^{-8}$ μCi/ml can be found from:

$$RC_{set} = \frac{1x10^{-5}\ x\ \mu Ci/ml\ x\ 1000\ gph}{PCC} \qquad (5\text{-}24)$$

5.1.5 PCCW Radiation Monitor

The PCCW radiation monitor will alert the operator in the Main Control Room of a leak to the PCCW System from a radioactively contaminated system.

The PCCW radiation monitor alarm is based on a trend of radiation levels in the PCCW System. The background radiation of the PCCW is determined by evaluating the radiation levels over a finite time period. The alert alarm setpoint is set at 1.5 x background, and the high alarm setpoint is set at 2 x background, per Technical Specification Table 3.3-6.

5.2 Gaseous Effluent Instrumentation Setpoints

Part A Control C.5.2 requires that the radioactive gaseous effluent instrumentation in Table A.5.2-1 of Part A have their alarm setpoints set to insure that Part A Control C.7.1.1 is not exceeded.

5.2.1 Plant Vent Wide-Range Gas Monitors (RM-6528-1,2 and 3)

The plant vent wide-range gas monitors are shown on Figure B.6-2.

5.2.1.1 Method to Determine the Setpoint of the Plant Vent Wide Range Gas Monitors (RM-6528-1,2 and 3)

The maximum allowable setpoint for the plant vent wide-range gas monitor (readout response in μCi/sec) is set by limiting the off-site noble gas dose rate to the total body or to the skin, and denoted $R_{setpoint}$. $R_{setpoint}$ is the lesser of:

$$R_{tb} = 588 \frac{1}{DFB_c} f_v \qquad (5\text{-}5)$$

$$\mu Ci/sec = \left(\frac{mrem\text{-}\mu Ci\text{-}m^3}{yr\text{-}pCi\text{-}sec}\right)\left(\frac{pCi\text{-}yr}{mrem\text{-}m^3}\right)$$

and:

$$R_{skin} = 3{,}000 \frac{1}{DF'_e} f_v \qquad (5\text{-}6)$$

$$\mu Ci/sec = \left(\frac{mrem}{yr}\right)\left(\frac{\mu Ci\text{-}yr}{mrem\text{-}sec}\right)$$

where:

R_{tb} = Response of the monitor at the limiting total body dose rate (μCi/sec)

588 = $\frac{500}{(1E+06)\ (8.5E-07)}\left(\frac{mrem\text{-}\mu Ci\text{-}m^3}{yr\text{-}pCi\text{-}sec}\right)$

500 = The offsite limiting total body dose rate (mrem/yr) from all release points

1E+06 = Number of pCi per μCi (pCi/μCi)

8.5E-07 = $[X/Q]_\gamma$, maximum off-site long-term average gamma atmospheric dispersion factor for primary vent stack releases (sec/m^3)

DFB_c = Composite total body dose factor (mrem-m^3/pCi-yr)

$$= \frac{\Sigma \dot{Q}_i DFB_i}{\Sigma \dot{Q}_i} \quad (5\text{-}7)$$

f_v = The fraction of the offsite limiting total body dose rate to be administratively assigned to the plant vent ($f_v \leq 1 - f_g$, where f_g is the fraction of the limiting dose rate to be assigned to monitored ground level releases)

$\dot{Q}_i$ = The relative release rate of noble gas "i" in the mixture, for each noble gas identified or postulated to be in the off-gas (µCi/sec)

DFB_i = Total body dose factor (see Table B.1-10) (mrem-m^3/pCi-yr)

R_{skin} = Response of the monitor at the limiting skin dose rate (µCi/sec)

3,000 = The offsite limiting skin dose rate (mrem/yr)

DF'_c = Composite skin dose factor (mrem-sec/µCi-yr)

$$= \frac{\Sigma \dot{Q}_i DF'_{i(e)}}{\Sigma \dot{Q}_i} \quad (5\text{-}8)$$

$DF'_{i(e)}$ = Combined skin dose factor for elevated release point (see Table B.1-10) (mrem-sec/µCi-yr)

5.2.1.2 Plant Vent Wide Range Gas Monitor Setpoint Example for Limiting Case

The following setpoint example for the plant vent wide range gas monitors demonstrates the use of equations 5-5 and 5-6 for determining setpoints. Evaluations of potential releases rates associated with the limiting offsite dose rates (Control C.7.1.1.a) have been made considering different noble gas mixes related to normal operations, observed periods with fuel defects, and potential UFSAR accident conditions. The bounding noble gas mix case for setpoint alarm indications was found to be related to projected fuel gap activity at the time of shutdown from power operations (UFSAR Table 15.7-20). By setting the maximum alarm setpoint in accordance with this assumed mix, other potential or realistic release conditions will not create an effluent discharge at or above the limiting offsite dose rates without the monitor going into alarm.

This limiting setpoint example is based on the following data (see Table B.1-10 for $DFB_{i(e)}$ and $DF'_{i(e)}$):

i	$\dot{Q}_i$ $(\frac{\mu Ci}{sec})$	DFB_i $(\frac{mrem\text{-}m^3}{pCi\text{-}yr})$	$DF'_{i(e)}$ $(\frac{mrem\text{-}sec}{\mu Ci\text{-}yr})$
Xe-138	2.52E+02	8.83E-03	1.20E-02
Kr-87	7.90E+01	5.92E-03	1.38E-02
Kr-88	1.15E+02	1.47E-02	1.62E-02
Kr-85m	4.49E+01	1.17E-03	2.35E-03
Xe-135	6.82E+01	1.81E-03	3.33E-03
Xe-133	3.23E+02	2.94E-04	5.83E-04
Kr-85	4.13E+00	1.61E-05	1.11E-03
Xe-131m	1.15E+00	9.15E-05	5.37E-04
Xe-133m	4.67E+01	2.51E-04	1.12E-03
Xe-135m	6.64E+01	3.12E-03	3.74E-03

$$DFB_c = \frac{\Sigma\ \dot{Q}_i\, DFB_i}{\Sigma\ \dot{Q}_i} \qquad (5\text{-}7)$$

$$\Sigma\ \dot{Q}_i\, DFB_i = (2.52E{+}02)(8.83E{-}03) + (7.90E{+}01)(5.92E{-}03) + (1.15E{+}02)\ (1.47E{-}02)$$

$$+ (4.49E{+}01)(1.17E{-}03) + (6.82E{+}01)(1.81E{-}03) + (3.23E{+}02)\ (2.94E{-}04)$$

$$+ (4.13E{+}00)(1.61E{-}05) + (1.15E{+}00)(9.15E{-}05) + (4.67E{+}01)\ (2.51E{-}04)$$

$$+ (6.64E{+}01)\ (3.12E{-}03)$$

$$= 4.86E{+}00\ (\mu Ci\text{-}mrem\text{-}m^3/sec\text{-}pCi\text{-}yr)$$

$$\Sigma\ \dot{Q}_i = 2.52E{+}02 + 7.90E{+}01 + 1.15E{+}02 + 4.49E{+}01 + 6.82E{+}01$$

$$+ 3.23E{+}02 + 4.14E{+}00 + 1.16E{+}00 + 4.67E{+}01 + 6.64E{+}01$$

$$= 1.00E{+}03\ \mu Ci/sec$$

$$DFB_c = \frac{4.86E{+}00}{1.00E{+}03}$$

$$= 4.86E{-}03\ (mrem\text{-}m^3/pCi\text{-}yr)$$

and therefore:

$$R_{tb} = 588\ \frac{1}{DFB_c}\ f_v \qquad (5\text{-}5)$$

$$= (588)\ \frac{1}{(4.86E{-}03)}\ 0.7$$

$$= 8.47E{+}04\ \mu Ci/sec$$

and next;

$$DF_c' = \frac{\Sigma\ \dot{Q}_i\, DF_i'}{\Sigma\ \dot{Q}_i} \qquad (5\text{-}8)$$

$$\Sigma\ \dot{Q}_i\, DF_i' = (2.52E{+}02)(1.20E{-}02) + (7.90E{+}01)(1.38E{-}02) + (1.15E{+}02)\ (1.62E{-}02)$$

$$+ \ (4.49E{+}01)(2.35E{-}03) + (6.82E{+}01)(3.33E{-}03) + (3.23E{+}02)\ (5.83E{-}04)$$

$$+ \ (4.13E{+}00)(1.11E{-}03) + (1.15E{+}00)(5.37E{-}04) + (4.67E{+}01)\ (1.12E{-}03)$$

$$+ \ (6.64E{+}01)\ (3.74E{-}03)$$

$$= 6.80E{+}00\ (\mu Ci\text{-}mrem\text{-}sec/sec\text{-}\mu Ci\text{-}yr)$$

$$DF'_c = \frac{6.80E+00}{1.00E+03}$$

$$= 6.80E-03 \quad (mrem-sec/\mu Ci-yr)$$

and therefore:

$$R_{skin} = 3{,}000\,\frac{1}{DF_c'}\ f_v \qquad (5\text{-}6)$$

$$= (3{,}000) \quad \left(\frac{1}{6.80E-03}\right)\ 0.7$$

$$= 3.09E{+}05\ \mu Ci/sec$$

The setpoint, $R_{setpoint}$, is the lesser of R_{tb} and R_{skin}. For the limiting noble gas mixture, R_{tb} is less than R_{skin}, indicating that the total body dose rate is more restrictive. Therefore, the plant vent wide-range gas monitor should be set at no more than 8.47E+04 µCi/sec above background, or at some administrative fraction of the above value.

5.2.2 Waste Gas System Monitors (RM-6504 and RM-6503)

Process radiation monitors in the waste gas system provide operational information on the performance of the system before its discharge is combined and diluted with other gas flows routed to the plant vent for release to the environment.

The setpoints for the waste gas system monitors are administratively set as small multiples of the expected activity concentration to provide operational control over unexpected changes in gas discharges from the system. Typically, the alert alarm setpoint for both monitors is placed at 1.5 times the expected activity concentration passing the monitor, with the high alarm trip set at 2.0 times the expected concentration flow.

Under all conditions, the maximum allowable alarm trip shall not exceed a concentration equivalent to 62.5 $\mu Ci/cm^3$. This concentration limit, based on system design flow of 1.2 cfm, assures that any release from the waste gas system to the plant vent will not exceed the site boundary dose rate limits of Part A Control C.7.1.1.a.

5.2.3 Main Condenser Air Evacuation Monitor (RM-6505)

The process radiation monitor on the main condenser air evacuation system provides operational information about the air being discharged. The discharge typically occurs either directly from the turbine building during start up (hogging mode) or through the plant vent during normal operations. During maintenance activities or other temporary operational conditions, discharges to the turbine roof may also occur. This process monitor is also used as an indicator of potential releases from the Turbine Gland Seal Condenser exhaust. Early indications of a potential release (i.e., monitor count rate at twice the normal background) should be evaluated by collecting a grab sample of the exhausts from both the main condenser and the Turbine Gland Seal Condenser.

The operational setpoints for the air evacuation monitor are administratively set as small multiples of the expected background response of the detector to provide operational control over unexpected changes in the activity discharged from the system. Typically, the alert setpoint is 1.5 times background, with the high alarm set at 2 times background.

Maximum allowable setpoint determinations assure that the site boundary dose rate limits of Part A Control C.7.1.1.a will not be exceeded. For the air evacuation detector an efficiency of 1.87E + 08 $cpm\text{-}cm^3/\mu Ci$, (the AR – 41 response value determined by HPSTID 00-021), flow rates of 10 to 50 cfm and 10,000 cfm for the normal and hogging modes of operation, respectively, and assuming that all the response is due to the most restrictive noble gas mixture associated with fuel gap activity inventory at the end of power operations (same mixture as used for the limiting mixture for the plant vent Wide Range Gas Monitor setpoint given in section 5.2.1.2), the following examples illustrate the calculation of the limiting setpoint for different operational conditions.

Case 1: For start-up operations (i.e., 10,000 cfm hogging flow to the Turbine Building roof), the maximum allowable alarm setpoint is calculated as:

$$R_{AE} = 147 \frac{1}{DFB_c} f_g f_{gland}$$

where :

R_{AE} = Release rate equivalent to the assigned fraction of the limiting offsite total body dose rate (uCi/sec)

$$147 = \frac{500}{(1E+06)(3.4E-06)} \left(\frac{mrem - uCi - m^3}{yr - pCi - sec}\right)$$

500 = The site boundary limiting total body dose rate (mrem/yr) from all release points

1E+06 = Number of pCi per uCi (pCi/uCi)

3.4E-06 = Maximum off-site long-term average gamma atmospheric dispersion factor for ground level releases (sec/m^2)

DFB_c = Composite total body dose factor (defined for the WRGM in Section 5.2.1.2 to be equal to 4.86E-03 [mrem-m^3 /pCi-yr] for the limiting fuel gap activity mix)

f_g = The fraction of the site boundary total body dose rate limit to be administratively assigned to monitored ground level releases (for this illustration = 0.3) such that the combination of the plant vent fraction (f_v) and ground fraction (f_g) is less than or equal to 1 ($f_g \leq 1 - f_v$).

f_{gland} = Release reduction factor to be administratively assigned to account for potential unmonitored contributions from the Turbine Gland Seal Condenser exhaust (for this illustration = 0.7).

$$R_{AE} = 147 \frac{1}{4.86E-03} (0.3)(0.7)$$

= 6.36E+03 uCi/sec release rate limit

and for the 10,000 cfm (4.72E+06 cm^3/sec) exhaust flow, the count rate response of the air evacuation monitor would be:

$$\text{Monitor Response} = \frac{R_{AE}}{4.72E+06 cm^3/sec} 1.87E+08 \text{ cpm-cm3/uCi}$$

$$= (6.36E+03)(1.87E+08) / (4.72E+06)$$

$$= 2.520E+05 \text{ cpm}$$

Case 2: As an extension of Case 1 which assumed the full startup hogging flow was released to the Turbine Building roof, maintenance requirements could direct normal operating main condenser offgas flow (assume 50 cfm or equivalent 2.36E+04 cm3/sec) to the Turbine Building Roof (ground level release point) instead of the elevated main plant vent. In this situation, the same release rate limit as calculated above (i.e., 6.36E+03 uCi/sec) would apply. However, the reduced gas flow from 10,000 cfm down to 50 cfm would permit a higher alarm setpoint to be used.

$$\text{Monitor Response} = \frac{R_{AE}}{2.36E+04 \text{cm}^3/\text{sec}} \quad 1.87E+08 \text{ cpm-cm}^3/\text{uCi}$$

$$= (6.36E+03)\,(1.87E+08) / (2.36E+04)$$

$$= 5.04E+07 \text{ cpm}$$

Case 3: For normal operations which direct main condenser offgas flow (assume 50 cfm or equivalent 2.36E+04 cm3/sec) to be released to the atmosphere via the main plant vent, the maximum allowable alarm setpoint would be:

$$R_{AE} = 588 \quad \frac{1}{DFB_c} \quad f_v \quad f_{gland}$$

where :

R_{AE} = Release rate equivalent to the assigned fraction of the limiting offsite total body dose rate (uCi/sec)

$$588 = \frac{500}{(1E+06)\,(8.5E-07)} \quad \left(\frac{\text{mrem - uCi - m}^3}{\text{yr - pCi - sec}}\right)$$

5.8E-07 = Maximum off-site long-term average gamma atmospheric dispersion factor for elevated (mixed mode) releases (sec/m2)

DFBc = Composite total body dose factor (defined for the WRGM in Section 5.2.1.2 to be equal to 4.86E-03 [mrem-m3 /pCi-yr] for the limiting fuel gap activity mix)

f_{gland} = Same as listed above (i.e., 0.7)

f_v = The fraction of the site boundary total body dose rate limit to be administratively assigned to plant vent releases such that the combination of the plant vent fraction (f_v) and ground fraction (f_g) is less than or equal to 1 ($f_v \leq 1 - f_g$). For the case that main condenser offgas is discharged to the main plant vent, there is no ground release fraction to be assigned (i.e., $f_g = 0$), and f_v maybe set at 1.

$$R_{AE} = 588 \frac{1}{4.86E - 03} 0.7$$

= 8.47E+04 uCi/sec release rate limit

and for the 50 cfm (2.36E+06 cm3/sec) Main Condenser offgas exhaust flow, the count rate response of the air evacuation monitor would be:

$$\text{Monitor Response} = \frac{R_{AE}}{2.36E+06 \text{cm}^3/\text{sec}} \; 1.87E+08 \text{ cpm-cm}^3/\text{uCi}$$

$$= (8.47E+04)\,(1.87E+08) / (2.36E+04)$$

$$= 6.71E+08 \text{ cpm}$$

The operation of the Main Condenser Evacuation System assumes 670 lbs./hour of steam flow through the Turbine Gland Seal Condenser exhaust (very small fraction of total steam flow), 1.5E+07 lbs./hour steam flow to the main condenser, and that the Turbine Gland Seal Condenser exhaust mostly air at a flow rate of 1,800 cfm which goes directly to the Turbine Building Vents (does not pass RM-6505). The main condenser offgas which goes past the Air Evacuation monitor during power operations is combined with other plant ventilation and process gas streams before being monitored by the WRGM and discharged to the atmosphere via the Plant Vent as a single release point.

The maximum allowable setpoints during startup and normal power operations may be recalculated based on identified changes in detector efficiency, discharge flow rate, radionuclide mix distribution, or administrative apportionment of potential contributions from the plant vent and ground level release points following the methods identified in Part-B, Section 8.5.

6.0 LIQUID AND GASEOUS EFFLUENT STREAMS, RADIATION MONITORS AND RADWASTE TREATMENT SYSTEMS

Figure B.6-1 shows the liquid effluent streams, radiation monitors and the appropriate Liquid Radwaste Treatment System. Figure B.6-2 shows the gaseous effluent streams, radiation monitors and the appropriate Gaseous Radwaste Treatment System.

For more detailed information concerning the above, refer to the Seabrook Station Final Safety Analysis Report, Sections 11.2 (Liquid Waste System), 11.3 (Gaseous Waste System) and 11.5 (Process and Effluent Radiological Monitoring and Sampling System).

The turbine gland seal condenser exhaust iodine and particulate gaseous releases will be determined by continuously sampling the turbine gland seal condenser exhaust. The noble gas releases will be determined by periodic noble gas grab samples. A ratio of main condenser air evacuation exhaust and turbine gland seal condenser exhaust noble gas will be determined periodically.

Figure B.6-1
Liquid Effluent Streams, Radiation Monitors, and Radwaste Treatment System at Seabrook Station

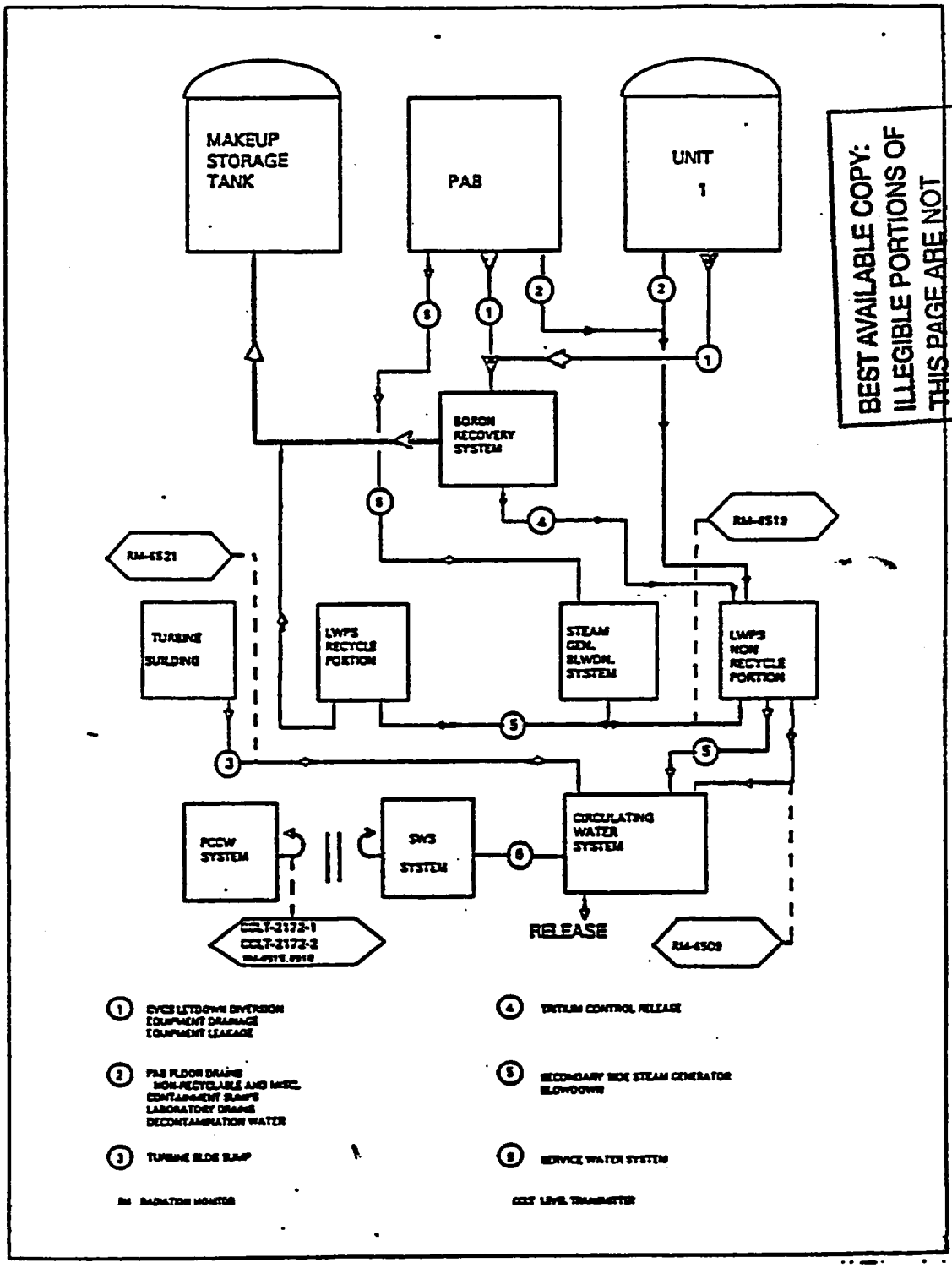
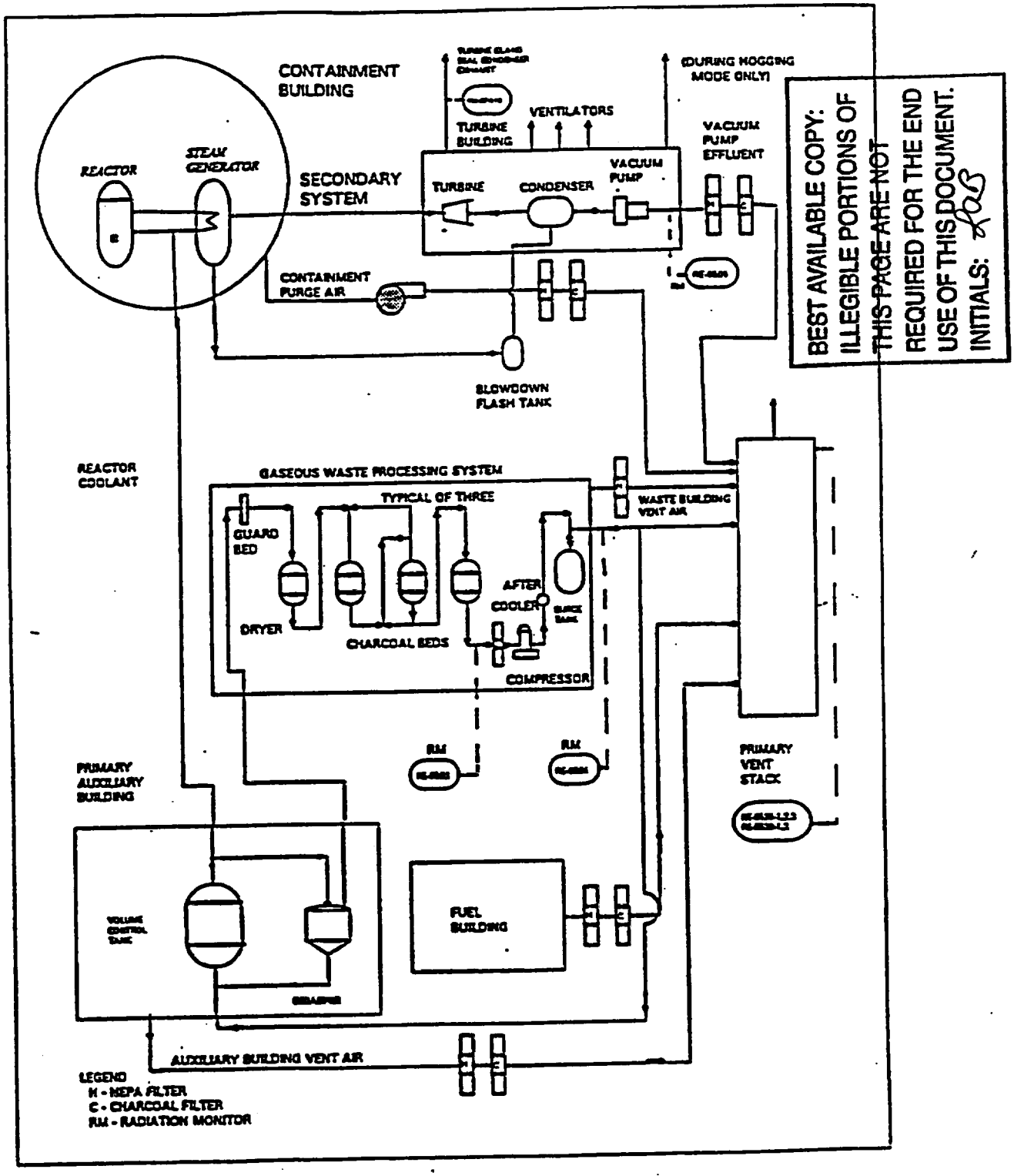


Figure B.6-2
Gaseous Effluent Streams, Radiation Monitors, and Radwaste Treatment System at Seabrook Station



7.0 BASES FOR DOSE CALCULATION METHODS

7.1 Liquid Release Dose Calculations

This section serves: (1) to document the development and conservative nature of Method I equations to provide background information to Method I users, and (2) to identify the general equations, parameters and approaches to Method II-type dose assessments. Appendix C provides the bases for the EMS software which is used to implement the dose and dose rate calculations indicated as Method IA.

Method I may be used to show that the Part A RECP which limit off-site total body dose from liquids (C.6.2.1 and C.6.3.1) have been met for releases over the appropriate periods. The quarterly and annual dose limits in Part A Control C.6.2.1 are based on the ALARA design objectives in 10CFR50, Appendix I Subsection II A. The minimum dose values noted in Part A Control C.6.3.1 are "appropriate fractions," as determined by the NRC, of the design objective to ensure that radwaste equipment is used as required to keep off-site doses ALARA.

Method I was developed such that "the actual exposure of an individual ... is unlikely to be substantially underestimated" (10CFR50, Appendix I). The definition, below, of a single "critical receptor" (a hypothetical or real individual whose behavior results in a maximum potential dose) provides part of the conservative margin to the calculation of total body dose in Method I. Method II allows that actual individuals, associated with identifiable exposure pathways, be taken into account for any given release. In fact, Method I was based on a Method II analysis for a critical receptor assuming all principal pathways present instead of any real individual. That analysis was called the "base case;" it was then reduced to form Method I. The general equations used in the base case analysis are also used as the starting point in Method II evaluations. The base case, the method of reduction, and the assumptions and data used are presented below.

The steps performed in the Method I derivation follow. First, the dose impact to the critical receptor [in the form of dose factors DFL_{itb} (mrem/μCi)] for a unit activity release of each radioisotope in liquid effluents was derived. The base case analysis uses the general equations, methods, data and assumptions in Regulatory Guide 1.109 (Equations A-3 and A-7, Reference A). The liquid pathways contributing to an individual dose are due to consumption of fish and invertebrates, shoreline activities, and swimming and boating near the discharge point. A nominal operating plant discharge flow rate of 918 ft^3/sec was used with a mixing ratio of 0.10. The mixing ratio of 0.10 corresponds to the minimum expected prompt dilution or near-field mixing zone created at the ocean surface directly above the multiport diffusers. (Credit for additional dilution to the outer edge of the prompt mixing zone which corresponds to the 10F surface isotherm (mixing ratio .025) can be applied in the Method II calculation for shoreline exposures only since the edge of this isotherm typically does not reach the shoreline receptor points during the tidal cycle. The mixing ratio for aquatic food pathways in Method II assessments shall be limited to the same value (0.10) as applied in Method I for near-field mixing, or prompt dilution only.

The requirements for the determination of radiological impacts resulting from releases in liquid effluents is derived from 10CFR50, Appendix I. Section III.A.2 of Appendix I indicates that in making the assessment of doses to hypothetical receptors, "The Applicant may take account of any real phenomenon or factors actually affecting the estimate of radiation exposure, including the characteristics of the plant, modes of discharge of radioactive materials, physical processes tending to attenuate the quantity of radioactive material to which an individual would be exposed, and the effects of averaging exposures over time during which determining factors may fluctuate." In accessing the liquid exposure pathways that characterize Seabrook Station, the design and physical location of the Circulating Water Discharge System needs to be considered within the scope of Appendix I.

Seabrook utilizes an offshore submerged multiport diffuser discharger for rapid dissipation and mixing of thermal effluents in the ocean environment. The 22-port diffuser section of the Discharge System is located in approximately 50 to 60 feet of water with each nozzle 7 to 10 feet above the sea floor. Water is discharged in a generally eastward direction away from the shoreline through the multiport diffuser, beginning at a location over one mile due east of Hampton Harbor inlet. This arrangement effectively prevents the discharge plume (at least to the 1 degree or 40 to 1 dilution isopleth) from impacting the shoreline over the tidal cycle.

Eleven riser shafts with two diffuser nozzles each form the diffuser and are spaced about 100 feet apart over a distance of about 1,000 feet. The diffusers are designed to maintain a high exit velocity of about 7.5 feet per second during power operations. Each nozzle is angled approximately 20 degrees up from the horizontal plane to prevent bottom scour. These high velocity jets passively entrain about ten volumes of fresh ocean water into the near field jet mixing region before the plume reaches the water surface. This factor of 10 mixing occurs in a very narrow zone of less than 300 feet from the diffuser by the time the thermally buoyant plume reaches the ocean surface. This high rate of dilution occurs within about 70 seconds of discharge from the diffuser nozzles.

The design of the multiport diffuser to achieve a 10 to 1 dilution in the near field jet plume, and a 40 to 1 dilution in the near mixing zone associated with the 1 degree isotherm, has been verified by physical model tests (reference "Hydrothermal Studies of Bifurcated Diffuser Nozzles and Thermal Backwashing - Seabrook Station," Alden Research Laboratories, July 1977).

During shutdown periods, when the plant only requires service water cooling flow, the high velocity jet mixing created by the normal circulating water flow at the diffuser nozzles is reduced. However, mixing within the discharge tunnel water volume is significantly increased (factor of about 5) due to the long transit time (approximately 50 hours) for batch waste discharged from the plant to travel the three miles through the 19-foot diameter tunnels to the diffuser nozzles. Additional mixing of the thermally buoyant effluent in the near field mixing zone assures that an equivalent overall 10 to 1 dilution occurs by the time the plume reaches the ocean surface.

The dose assessment models utilized in the ODCM are taken from NRC Regulatory Guide 1.109. The liquid pathway equations include a parameter (M_p) to account for the mixing ratio (reciprocal of the dilution factor) of effluents in the environment at the point of exposure. Table 1, in Regulatory Guide 1.109, defines the point of exposure to be the location that is anticipated to be occupied during plant lifetime, or have potential land and water usage and food pathways as could actually exist during the term of plant operation. For Seabrook, the potable water and land irrigation pathways do not exist since saltwater is used as the receiving water body for the circulating water discharge. The three pathways that have been factored into the assessment models are shoreline exposures, ingestion of invertebrates, and fish ingestion.

With respect to shoreline exposures, both the mixing ratios of 0.1 and 0.025 are extremely conservative since the effluent plume which is discharged over one mile offshore never reaches the beach where this type of exposure could occur. Similarly, bottom dwelling invertebrates, either taken from mud flats near the shoreline or from the area of diffuser, are not exposed to the undiluted effluent plume. The shore area is beyond the reach of the surface plume of the discharge, and the design of the upward directed discharge nozzles along with the thermal buoyancy of the effluent, force the plume to quickly rise to the surface without affecting bottom organisms.

Consequentially, the only assumed exposure pathway which might be impacted by the near field plume of the circulating water discharge is finfish. However, the mixing ratio of 0.1 is very conservative because fish will avoid both the high exit velocity provided by the discharge nozzles and the high thermal temperature difference between the water discharged from the diffuser and the ambient water temperature in the near field. In addition, the dilution factor of 10 is achieved within 70 seconds of discharge and confined to a very small area, thus prohibiting any significant quantity of fish from reaching equilibrium conditions with radioactivity concentrations created in the water environment.

The mixing ratio of 0.025, which corresponds to the 1 degree thermal near field mixing zone, is a more realistic assessment of the dilution to which finfish might be exposed. However, even this dilution credit is conservative since it neglects the plant's operational design which discharges radioactivity by batch mode. Batch discharges are on the order of only a few hours in duration several times per week and, thus, the maximum discharge concentrations are not maintained in the environment long enough to allow fish to reach equilibrium uptake concentrations as assumed in the dose assessment modeling. Not withstanding the above expected dilution credit afforded at the 1 degree isotherm, all Method II aquatic food pathway dose calculations shall conservatively assume credit for prompt dilution only with an $M_p = 0.10$. When dose impacts from the fish and invertebrate pathways are then added to the conservative dose impacts derived for shoreline exposures, the total calculated dose is very unlikely to have underestimated the exposure to any real individual.

The recommended value for dilution of 1.0 given in NUREG-0133 is a simplistic assumption provided so that a single model could be used with any plant design and physical discharge arrangement. For plants that utilize a surface canal-type discharge structure where little entrainment mixing in the environment occurs, a dilution factor of 1.0 is a reasonable assumption. However, in keeping with the guidance provided in Appendix I to 10CFR50, Seabrook has determine site-specific mixing ratios which factor in its plant design.

The transit time used for the aquatic food pathway was 24 hours, and for shoreline activity 0.0 hours. Table B.7-1 outlines the human consumption and use factors used in the analysis. The resulting, site-specific, total body dose factors appear in Table B.1-11. Appendix A provides an example of the development of a Method I liquid dose conversion factor for site-specific conditions at Seabrook.

7.1.1 Dose to the Total Body

For any liquid release, during any period, the increment in total body dose from radionuclide "i" is:

$$\Delta D_{tb} = k Q_i DFL_{itb}$$

$$(\text{mrem})\ ()\ (\mu\text{Ci})\left(\frac{\text{mrem}}{\mu\text{Ci}}\right) \qquad (7\text{-}1)$$

where:

DFL_{itb} = Site-specific total body dose factor (mrem/μCi) for a liquid release. It is the highest of the four age groups. See Table B.1-11.

Q_i = Total activity (μCi) released for radionuclide "i".

k = $918/F_d$ (dimensionless); where F_d is the average dilution flow of the Circulating Water System at the point of discharge from the multiport diffuser (in ft^3/sec).

Method I is more conservative than Method II in the region of the Part A dose limits because the dose factors DFL_{itb} used in Method I were chosen for the base case to be the highest of the four age groups (adult, teen, child and infant) for that radionuclide. In effect each radionuclide is conservatively represented by its own critical age group.

7.1.2 Dose to the Critical Organ

The methods to calculate maximum organ dose parallel to the total body dose methods (see Part B, Section 7.1.1).

For each radionuclide, a dose factor (mrem/μCi) was determined for each of seven organs and four age groups. The largest of these was chosen to be the maximum organ dose factor (DFL_{imo}) for that radionuclide. DFL_{imo} also includes the external dose contribution to the critical organ.

For any liquid release, during any period, the increment in dose from radionuclide "i" to the maximum organ is:

$$\Delta D_{mo} = k Q_i DFL_{imo}$$

$$(\text{mrem})\ ()\ (\mu\text{Ci})\left(\frac{\text{mrem}}{\mu\text{Ci}}\right) \qquad (7\text{-}2)$$

where:

DFL_{imo} = Site-specific maximum organ dose factor (mrem/μCi) for a liquid release. See Table B.1-11.

Q_i = Total activity (μCi) released for radionuclide "i".

k = $918/F_d$ (dimensionless); where F_d is the average dilution flow of the Circulating Water System at the point of discharge from the multiport diffuser (in ft^3/sec).

Table B.7-1
Usage Factors for Various Liquid Pathways at Seabrook Station

(From Reference A, Table E-5*, except as noted. Zero where no pathway exists)

AGE	VEG.	LEAFY VEG.	MILK	MEAT	FISH	INVERT.	POTABLE WATER	SHORELINE	SWIMMING**	BOATING**
	(KG/YR)	(KG/YR)	(LITER/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(LITER/YR)	(HR/YR)	(HR/YR)	(HR/YR)
Adult	0.00	0.00	0.00	0.00	21.00	5.00	0.00	334.00***	8.00	52.00
Teen	0.00	0.00	0.00	0.00	16.00	3.80	0.00	67.00	45.00	52.00
Child	0.00	0.00	0.00	0.00	6.90	1.70	0.00	14.00	28.00	29.00
Infant	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

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* Regulatory Guide 1.109.

** HERMES; "A Digital Computer Code for Estimating Regional Radiological Effects from Nuclear Power Industry," HEDL, December 1971. Note, for Method II analyses, these pathways need not be evaluated since they represent only a small fraction of the total dose contribution associated with the other pathways.

*** Regional shoreline use associated with mudflats - Maine Yankee Atomic Power Station Environmental Report.

7.2 Gaseous Release Dose Calculations

7.2.1 Total Body Dose Rate From Noble Gases

This section serves: (1) to document the development of the Method I equation, (2) to provide background information to Method I users, and (3) to identify the general equations, parameters and approaches to Method II-type dose rate assessments.

Method I may be used to show that the Part A Controls which limit total body dose rate from noble gases released to the atmosphere (Part A Control C.7.1.1) has been met for the peak noble gas release rate.

Method I was derived from general equation B-8 in Regulatory Guide 1.109 as follows:

$$\dot{D}_{tb} = 1E+06[X/Q]^{\gamma} \sum_i \dot{Q}_i DFB_i \qquad (7\text{-}3)$$

$$\left(\frac{mrem}{yr}\right) = \left(\frac{pCi}{\mu Ci}\right)\left(\frac{sec}{m^3}\right)\left(\frac{\mu Ci}{sec}\right)\left(\frac{mrem\text{-}m^3}{pCi\text{-}yr}\right)$$

where:

$[X/Q]^{\gamma}$ = Maximum off-site receptor location long-term average gamma atmospheric dispersion factor.

$\dot{Q}_i$ = Release rate to the environment of noble gas "i" (μCi/sec).

DFB_i = Gamma total body dose factor, $\left(\frac{mrem\text{-}m^3}{pCi\text{-}yr}\right)$. See Table B.1-10. (Regulatory Guide 1.109, Table B-1).

Elevated and ground level gaseous effluent release points are addressed separately through the use of specific $[X/Q]^{\gamma}$ For an elevated gaseous effluent release point and off-site receptor, Equation 7-3 takes the form:

$$\dot{D}_{tb(e)} = (1E+06) * (8.5E-07) * \sum_i (\dot{Q}_i * DFB_i)$$

$$\left(\frac{mrem}{yr}\right) = \left(\frac{pCi}{\mu Ci}\right) * \left(\frac{sec}{m^3}\right) * \Sigma\left(\frac{\mu Ci}{sec} * \frac{mrem - m^3}{pCi - yr}\right)$$

which reduces to:

$$\dot{D}_{tb(e)} = 0.85 * \sum_i (\dot{Q}_i * DFB_i) \qquad (3\text{-}3a)$$

$$\left(\frac{\text{mrem}}{\text{yr}}\right) = \left(\frac{\text{pCi} - \text{sec}}{\mu\text{Ci} - \text{m}^3}\right) \Sigma \left(\frac{\mu\text{Ci}}{\text{sec}}\right) * \left(\frac{\text{mrem} - \text{m}^3}{\text{pCi} - \text{yr}}\right)$$

For a ground level gaseous effluent release point and off-site receptor, Equation 7-3 takes the form:

$$\dot{D}_{tb(g)} = (1E+06) * (3.4E-06) * \sum_i (\dot{Q}_i * DFB_i)$$

which reduces to:

$$\dot{D}_{tb(g)} = 3.4 * \sum_i (\dot{Q}_i * DFB_i) \qquad (3\text{-}3b)$$

$$\left(\frac{\text{mrem}}{\text{yr}}\right) = \left(\frac{\text{pCi} - \text{sec}}{\mu\text{Ci} - \text{m}^3}\right) \Sigma \left(\frac{\mu\text{Ci}}{\text{sec}}\right) * \left(\frac{\text{mrem} - \text{m}^3}{\text{pCi} - \text{yr}}\right)$$

The selection of critical receptor, outlined in Part B, Section 7.3 is inherent in the derived Method I, since the maximum expected off-site long-term average atmospheric dispersion factor is used. The sum of doses from both plant vent stack and ground level releases must be considered for determination of Technical Specification compliance. All noble gases in Table B.1-10 should be considered.

A Method II analysis could include the use of actual concurrent meteorology to assess the dose rates as the result of a specific release.

7.2.2 Skin Dose Rate from Noble Gases

This section serves: (1) to document the development of the Method I equation, (2) to provide background information to Method I users, and (3) to identify the general equations parameters and approaches to Method II-type dose rate assessments. The methods to calculate skin dose rate parallel the total body dose rate methods in Part B, Section 7.2.1. Only the differences are presented here.

Method I may be used to show that the Part A Controls which limit skin dose rate from noble gases released to the atmosphere (Part A Control C.7.1.1) has been met for the peak noble gas release rate.

The annual skin dose limit is 3,000 mrem (from NBS Handbook 69, Reference D, pages 5 and 6, is 30 rem/10). The factor of 10 reduction is to account for nonoccupational dose limits.

It is the skin dose commitment to the critical, or most limiting, off-site receptor assuming long-term site average meteorology and that the release rate reading remains constant over the entire year.

Method I was derived from the general equation B-9 in Regulatory Guide 1.109 as follows:

$$D^S = 1.11\, D^{\gamma}_{air} + 3.17E{+}04 \sum_i \dot{Q}_i [X/Q]\, DFS_i \qquad (7\text{-}4)$$

$$\left(\frac{\text{mrem}}{\text{yr}}\right) = \left(\frac{\text{mrem}}{\text{mrad}}\right)\left(\frac{\text{mrad}}{\text{yr}}\right)\left(\frac{\text{pCi-yr}}{\text{Ci-sec}}\right)\frac{\text{Ci}}{\text{yr}}\left(\frac{\text{sec}}{\text{m}^3}\right)\left(\frac{\text{mrem-m}^3}{\text{pCi-yr}}\right)$$

where:

1.11 = Average ratio of tissue to air absorption coefficients (will convert mrad in air to mrem in tissue).

DFS_i = Beta skin dose factor for a semi-infinite cloud of radionuclide "i" which includes the attenuation by the outer "dead" layer of the skin.

$$D^{\gamma}_{air} = 3.17E{+}04 \sum_i \dot{Q}_i [X/Q]\, DF^{\gamma}_i \qquad (7\text{-}5)$$

$$\left(\frac{\text{mrad}}{\text{yr}}\right) = \left(\frac{\text{pCi-yr}}{\text{Ci-sec}}\right)\left(\frac{\text{Ci}}{\text{yr}}\right)\left(\frac{\text{sec}}{\text{m}^3}\right)\left(\frac{\text{mrad-m}^3}{\text{pCi-yr}}\right)$$

DF^{γ}_i = Gamma air dose factor for a uniform semi-infinite cloud of radionuclide "i".

Now it is assumed for the definition of (X/Q^{γ}) from Reference 8 that:

$$D^{\gamma}_{finite} = D^{\gamma}_{air} [X/Q]^{\gamma} / [X/Q] \qquad (7\text{-}6)$$

$$\left(\frac{\text{mrad}}{\text{yr}}\right) = \left(\frac{\text{mrad}}{\text{yr}}\right)\left(\frac{\text{sec}}{\text{m}^3}\right)\left(\frac{\text{m}^3}{\text{sec}}\right)$$

and

$$Q_i = 31.54\, \dot{Q}_i \qquad (7\text{-}7)$$

$$\left(\frac{\text{Ci}}{\text{yr}}\right) = \left(\frac{\text{Ci-sec}}{\mu\text{Ci-yr}}\right)\left(\frac{\mu\text{Ci}}{\text{sec}}\right)$$

so:

$$\dot{D}_{skin} = 1.11\ 1E+06 \left[\frac{X}{Q}\right]^{\gamma} \sum_i \dot{Q}_i * DF_i^{\gamma} \qquad (7\text{-}8)$$

$$\left(\frac{mrem}{yr}\right) = \left(\frac{mrem}{mrad}\right)\left(\frac{pCi}{\mu Ci}\right)\left(\frac{sec}{m^3}\right)\left(\frac{\mu Ci}{sec}\right)\left(\frac{mrad - m^3}{pCi - yr}\right)$$

$$+1E+06\ X/Q \sum_i \dot{Q}_i DFS_i$$

$$\left(\frac{pCi}{\mu Ci}\right)\left(\frac{sec}{m^3}\right)\left(\frac{\mu Ci}{sec}\right)\left(\frac{mrem - m^3}{pCi - yr}\right)$$

Substituting atmospheric dispersion factors for an elevated gaseous effluent release point, Equation 7-8 takes the following form:

$$\dot{D}_{skin(e)} = [1.11 * 1E+06 * 8.5E-07 * \sum_i (\dot{Q}_i * DF_i^{\gamma})] + [1E+06 * 8.2E-07 * \sum_i (\dot{Q}_i * DFS_i)]$$

which yields:

$$\dot{D}_{skin(e)} = [0.94 \sum_i (\dot{Q}_i * DF_i^{\gamma})] + [0.82 \sum_i (\dot{Q}_i * DFS_i)]$$

$$\left(\frac{mrem}{yr}\right) = \left(\frac{pCi - sec - mrem}{\mu Ci - m^3 - mrad}\right) \Sigma \left(\frac{\mu Ci}{sec} * \frac{mrem - m^3}{pCi - yr}\right) + \frac{pCi - sec}{\mu Ci - m^3} \Sigma \left(\frac{\mu Ci}{sec} * \frac{mrem - m^3}{pCi - yr}\right) \qquad (7\text{-}9a)$$

defining:

$$DF'_{i(e)} = 0.94\, DF_i^{\gamma} + 0.82\, DFS_i \qquad (7\text{-}10a)$$

Then the off-site skin dose rate equation for an elevated gaseous effluent release point is:

$$\dot{D}_{skin(e)} = \sum_i \dot{Q}_i * DF'_{i(e)} \qquad (3\text{-}4a)$$

$$\left(\frac{mrem}{yr}\right) = \Sigma \left(\frac{\mu Ci}{sec} * \frac{mrem - sec}{\mu Ci - yr}\right)$$

For an off-site receptor and a ground level gaseous effluent release point, Equation 7-8 becomes:

$$\dot{D}_{skin(g)} = [1.11 * 1E+06 * 3.4E-06 * \Sigma(\dot{Q}_i * DF_i^{\gamma})] + [1E+06 * 1.0E-05 * \sum_i (\dot{Q}_i * DFS_i)]$$

which yields:

$$\dot{D}_{skin(g)} = [3.8 \sum_i (\dot{Q}_i * DF_i^{\gamma})] + [10 \sum_i (\dot{Q}_{ii} * DFS_i)] \quad (7\text{-}9b)$$

$$= \sum_i \dot{Q}_i [3.8\, DF_i^{\gamma} + 10\, DFS_i]$$

defining:

$$DF'_{i(g)} = 3.8\, DF_i^{\gamma} + 10\, DFS_i \quad (7\text{-}10b)$$

Then the off-site skin dose rate equation for ground level gaseous effluent release points is:

$$\dot{D}_{skin(g)} = \sum_i \dot{Q}_i * DF'_{i(g)} \quad (3\text{-}4b)$$

The selection of critical receptor, outlined in Part B, Section 7.3, is inherent in the derived Method I, as it is based on the determined maximum expected off-site atmospheric dispersion factors. All noble gases in Table B.1-10 must be considered.

7.2.3 Critical Organ Dose Rate from Iodines, Tritium and Particulates With Half-Lives Greater Than Eight Days

This section serves: (1) to document the development of the Method I equation, (2) to provide background information to Method I users, and (3) to identify the general equation's parameters and approached to Method II type dose rate assessments. The methods to calculate skin dose rate parallel the total body dose rate methods in Part B, Section 7.2.1.

Method I may be used to show that the Part A Controls which limit organ dose rate from iodines, tritium and radionuclides in particulate form with half lives greater than 8 days released to the atmosphere (Part A Control C.7.1.1) has been met for the peak above-mentioned release rates. The annual organ dose limit is 1500 mrem (from NBS Handbook 69, Reference D, pages 5 and 6). It is evaluated by looking at the critical organ dose commitment to the most limiting off-site receptor assuming long-term site average meteorology.

The equation for $\dot{D}_{co}$ is derived from a form of Equation 3-8 in Part B, Section 3.9 by applying the conversion factor, 3.154E+07 (sec/yr) and converting Q to $\dot{Q}$ µCi/sec:

$$\dot{D}_{co} = 3.15\,E{+}07 * \sum_i (\dot{Q}_i * DFG_{ico}) \quad (7\text{-}12)$$

$$\left(\frac{mrem}{yr}\right) = \left(\frac{sec}{yr}\right) \Sigma \left(\frac{\mu Ci}{sec}\right) * \left(\frac{mrem}{\mu Ci}\right)$$

Equation 7-12 is rewritten in the form:

$$\dot{D}_{co} = \sum_i (\dot{Q}_i * DFG'_{ico})$$

$$\left(\frac{\text{mrem}}{\text{yr}}\right) = \Sigma\left(\frac{\mu\text{Ci}}{\text{sec}}\right) * \left(\frac{\text{mrem-sec}}{\mu\text{Ci-yr}}\right) \qquad \text{(7-12a)}$$

where:

$$DFG'_{ico} = 3.154\text{E+}07 * DFG_{ico} \qquad \text{(7-13)}$$

$$\left(\frac{\text{mrem-sec}}{\mu\text{Ci-yr}}\right) = \left(\frac{\text{sec}}{\text{yr}}\right) * \left(\frac{\text{mrem}}{\mu\text{Ci}}\right)$$

The dose conversion factor, DFG_{ico}, has been developed for both elevated gaseous effluent release points and ground level gaseous effluent release points ($DFG_{ico(e)}$ and $DFG_{ico(g)}$), respectively. These dose factors are used to determine accumulated doses over extended periods and have been calculated with the Shielding Factor (SF) for ground plane exposure set equal to 0.7, as referenced in Regulatory Guide 1.109. In the case of the dose rate conversion factors ($DFG'_{ico(e)}$ and $DFG'_{ico(g)}$), the dose conversion factors from which they were derived were calculated with the Shielding Factor (SF) for ground plane exposure set equal to 1.0.

For an off-site receptor and elevated effluent release point, the critical organ dose rate equation is:

$$\dot{D}_{co(e)} = \sum_i (\dot{Q}_i * DFG'_{ico(e)}) \qquad \text{(3-5a)}$$

$$\left(\frac{\text{mrem}}{\text{yr}}\right) = \Sigma\left(\frac{\mu\text{Ci}}{\text{sec}} * \frac{\text{mrem-sec}}{\mu\text{Ci-yr}}\right)$$

For an off-site receptor and ground level effluent release point, the critical organ dose rate equation is:

$$\dot{D}_{co(g)} = \sum_i (\dot{Q}_i * DFG'_{ico(g)}) \qquad \text{(3-5b)}$$

$$\left(\frac{\text{mrem}}{\text{yr}}\right) = \Sigma\left(\frac{\mu\text{Ci}}{\text{sec}} * \frac{\text{mrem-sec}}{\mu\text{Ci-yr}}\right)$$

The selection of critical receptor, outlined in Part B, Section 7.3 is inherent in Method I, as are the expected atmospheric dispersion factors.

In accordance with the Basis Statement 3/4.11.2.1 in NUREG-0472, and the base's section for the organ dose rate limit given for Part A Control C.7.1.1 a Method II dose rate calculation, for compliance purposes, can be based on restricting the inhalation pathway to a child's thyroid to less than or equal to 1,500 mrem/yr. Concurrent meteorology with time of release may also be used to assess compliance for a Method II calculation.

7.2.4 Gamma Dose to Air from Noble Gases

This section serves: (1) to document the development and conservative nature of Method I equations to provide background information to Method I users, and (2) to identify the general equations, parameters and approaches to Method II-type dose assessments.

Method I may be used to show that the Part A Control C.7.2.1 which limits off-site gamma air dose from gaseous effluents has been met for releases over appropriate periods. This Part A Control is based on the objective in 10CFR50, Appendix I, Subsection B.1, which limits the estimated gamma air dose in off-site unrestricted areas.

NUREG/CR-2919 presents a methodology for determining atmospheric dispersion factors (CHI/Q values) for intermittent releases at user specified receptor locations (intermittent releases being defined as releases with durations between 1 and 8,760 hours). The CHI/Q values for intermittent releases are determined by linearly interpolating (on a log-log basis) between an hourly 15-percentile CHI/Q value and an annual average CHI/Q value as a function of release duration. This methodology has been adopted to produce a set of time-dependent atmospheric dispersion factors for Method I calculations.

For any noble gas release, in any period, the increment in dose is taken from Equations B-4 and B-5 of Regulatory Guide 1.109 with the added assumption that $D^{\gamma}_{finite} = D^{\gamma}\,[X/Q]^{\gamma}/[X/Q]$:

$$\Delta D^{\gamma}_{air(e)} = 3.17E+4\,[X/Q]^{\gamma} \sum_i Q_i DF^{\gamma}_i$$

$$(\text{mrad}) = \left(\frac{\text{pCi - yr}}{\text{Ci - sec}}\right)\left(\frac{\text{sec}}{\text{m}^3}\right)(\text{Ci})\left(\frac{\text{mrad - m}^3}{\text{pCi - yr}}\right) \qquad (7\text{-}14)$$

where:

3.17E+04= Number of pCi per Ci divided by the number of seconds per year.

$[X/Q]^{\gamma}$ = Annual average gamma atmospheric dispersion factor for the receptor location of interest.

Q_i = Number of curies of noble gas "i" released.

DF^{γ}_i = Gamma air dose factor for a uniform semi-infinite cloud of radionuclide "i".

Incorporating a unitless release duration adjustment term t^{-a} (where "a" is a constant and "t" is the total release duration in hours), and the conversion factor for Ci to μCi (to accommodate the use of a release rate Q in μCi), and substituting the 1-hour gamma atmospheric dispersion factor in place of the annual average gamma atmospheric dispersion factor in Equation 7-14 leads to:

$$D^{\gamma}_{air} = 3.17E-02 * [X/Q]^{\gamma}_{hr} * t^{-a} * \sum_i \left(Q_i * DF_i^{\gamma}\right)$$

$$(\text{mrad}) = \left(\frac{\text{pCi-yr}}{\mu\text{Ci}-\text{sec}}\right) * \left(\frac{\text{sec}}{\text{m}^3}\right) * \sum \left(\mu\text{Ci} * \frac{\text{mrad-m}^3}{\text{pCi-yr}}\right) \quad (3\text{-}6)$$

For an elevated release, the equation used for an off-site receptor is:

$$D^{\gamma}_{air(e)} = 3.17E-02 * [1.0E-05] * t^{-0.275} * \sum_i \left(Q_i * DF_i^{\gamma}\right)$$

which leads to:

$$D^{\gamma}_{air(e)} = 3.2E-07 * t^{-0.275} * \sum_i \left(Q_i * DF_i^{\gamma}\right) \quad (3\text{-}6a)$$

$$(\text{mrad}) = \left(\frac{\text{pCi-yr}}{\mu\text{Ci}-\text{m}^3}\right) * \sum \left(\mu\text{Ci} * \frac{\text{mrad-m}^3}{\text{pCi-yr}}\right)$$

For a ground-level release, the equation used for an off-site receptor is:

$$D^{\gamma}_{air(g)} = 3.17E-02 * [4.9E-05] * t^{-0.293} * \sum_i \left(Q_i * DF_i^{\gamma}\right)$$

which leads to:

$$D^{\gamma}_{air(g)} = 1.6E-06 * t^{-0.293} * \sum_i \left(Q_i * DF_i^{\gamma}\right) \quad (3\text{-}6b)$$

$$(\text{mrad}) = \left(\frac{\text{pCi-yr}}{\mu\text{Ci}-\text{m}^3}\right) * \sum \left(\mu\text{Ci} * \frac{\text{mrad-m}^3}{\text{pCi-yr}}\right)$$

The major difference between Method I and Method II is that Method II would use actual or concurrent meteorology with a specific noble gas release spectrum to determine $[X/Q]^{\gamma}$ rather than use the site's long-term average meteorological dispersion values.

7.2.5 Beta Dose to Air from Noble Gases

This section serves: (1) to document the development and conservative nature of Method I equations to provide background information to Method I users, and (2) to identify the general equations, parameters and approaches to Method II-type dose assessments.

Method I may be used to show that Part A Control C.7.2.1, which limits off-site beta air dose from gaseous effluents, has been met for releases over appropriate periods. This Part A Control is based on the objective in 10CFR50, Appendix I, Subsection B.1, which limits the estimated beta air dose in off-site unrestricted area locations.

For any noble gas release, in any period, the increment in dose is taken from Equations B-4 and B-5 of Regulatory Guide 1.109:

$$\Delta D^{\beta}_{air} = 3.17E-02 * X/Q \sum_i \left(Q_i * DF_i^{\beta}\right) \quad (7\text{-}15)$$

$$(\text{mrad}) = \left(\frac{\text{pCi-yr}}{\mu\text{Ci}-\text{sec}}\right) * \left(\frac{\text{sec}}{\text{m}^3}\right) (\mu\text{Ci}) \left(\frac{\text{mrad-m}^3}{\text{pCi-yr}}\right)$$

where:

DF_i^β = Beta air dose factors for a uniform semi-infinite cloud of radionuclide "i".

Incorporating the term t^{-a} into Equation 7-15 leads to:

$$D_{air}^\beta = 3.17E-02 * X/Q_{1hr} * t^{-a} * \sum_i (Q_i * DF_i^\beta) \quad (3\text{-}7)$$

$$(\text{mrad}) = \left(\frac{\text{pCi - yr}}{\mu\text{Ci - sec}}\right) * \left(\frac{\text{sec}}{\text{m}^3}\right) * ( ) * \Sigma \left(\mu\text{Ci} * \frac{\text{mrad - m}^3}{\text{pCi - yr}}\right)$$

Where X/Q_{1hr} = average 1-hour undepleted atmospheric dispersion factor.

For an elevated release, the equation used for an off-site receptor is:

$$D_{air(e)}^\beta = 3.17E-02 * 1.3E-05 * t^{-0.3} * \sum_i (Q_i * DF_i^\beta)$$

$$(\text{mrad}) = \left(\frac{\text{pCi - yr}}{\mu\text{Ci - sec}}\right) * \left(\frac{\text{sec}}{\text{m}^3}\right) * ( ) * \Sigma \left(\mu\text{Ci} * \frac{\text{mrad - m}^3}{\text{pCi - yr}}\right)$$

which leads to:

$$D_{air(e)}^\beta = 4.1E-07 * t^{-0.3} * \sum_i (Q_i * DF_i^\beta) \quad (3\text{-}7a)$$

$$(\text{mrad}) = \left(\frac{\text{pCi - yr}}{\mu\text{Ci - m}^3}\right) * ( ) * \Sigma \left(\mu\text{Ci} * \frac{\text{mrad - m}^3}{\text{pCi - yr}}\right)$$

For a ground-level release, the equation used for an off-site receptor is:

$$D_{air(g)}^\beta = 3.17E-02 * 1.9E-04 * t^{-0.319} * \sum_i (Q_i * DF_i^\beta)$$

$$(\text{mrad}) = \left(\frac{\text{pCi - yr}}{\mu\text{Ci - sec}}\right) * \left(\frac{\text{sec}}{\text{m}^3}\right) * ( ) * \Sigma \left(\mu\text{Ci} * \frac{\text{mrad - m}^3}{\text{pCi - yr}}\right)$$

which leads to:

$$D^{\beta}_{air(g)} = 6.0E-06 * t^{-0.319} * \sum_i \left(Q_i * DF_i^{\beta}\right) \qquad (3\text{-}7b)$$

$$(\text{mrad}) = \left(\frac{\text{pCi - yr}}{\mu\text{Ci} - \text{m}^3}\right) * (\,) * \Sigma \left(\mu\text{Ci} * \frac{\text{mrad - m}^3}{\text{pCi - yr}}\right)$$

7.2.6 Dose to Critical Organ from Iodines, Tritium and Particulates with Half-Lives Greater Than Eight Days

This section serves: (1) to document the development and conservative nature of Method I equations to provide background information to Method I users, and (2) to identify the general equations, parameters and approaches to Method II-type dose assessments.

Method I may be used to show that the Part A Controls which limit off-site organ dose from gases (C.7.3.1 and C.8.1.1) have been met for releases over the appropriate periods. Part A Control C.7.3.1 is based on the ALARA objectives in 10CFR50, Appendix I, Subsection II C. Part A Control C.8.1.1 is based on Environmental Standards for Uranium Fuel Cycle in 40CFR190, which applies to direct radiation as well as liquid and gaseous effluents. These methods apply only to iodine, tritium, and particulates in gaseous effluent contribution.

Method I was developed such that "the actual exposure of an individual ... is unlikely to be substantially underestimated" (10CFR50, Appendix I). The use below of a single "critical receptor" provides part of the conservative margin to the calculation of critical organ dose in Method I. Method II allows that actual individuals, associated with identifiable exposure pathways, be taken into account for any given release. In fact, Method I was based on a Method II analysis of a critical receptor assuming all pathways present. That analysis was called the "base case"; it was then reduced to form Method I. The base case, the method of reduction, and the assumptions and data used are presented below.

The steps performed in the Method I derivation follow. First, the dose impact to the critical receptor [in the form of dose factors DFG_{ico} (mrem/μCi)] for a unit activity release of each iodine, tritium, and particulate radionuclide with half lives greater than eight days to gaseous effluents was derived. Six exposure pathways (ground plane, inhalation, stored vegetables, leafy vegetables, milk, and meat ingestion) were assumed to exist at the site boundary (not over water or marsh areas) which exhibited the highest long-term X/Q. Doses were then calculated to six organs (bone, liver, kidney, lung, GI-LLI, and thyroid), as well as for the whole body and skin for four age groups (adult, teenager, child, and infant) due to the seven combined exposure pathways. For each radionuclide, the highest dose per unit activity release for any organ (or whole body) and age group was then selected to become the Method I site-specific dose factors. The base case, or Method I analysis, uses the general equations methods, data, and assumptions in Regulatory Guide 1.109 (Equation C-2 for doses resulting from direct exposure to contaminated ground plane; Equation C-4 for doses associated with inhalation of all radionuclides to different organs of individuals of different age groups; and Equation C-13 for doses to organs of individuals in different age groups resulting from ingestion of radionuclides in produce, milk, meat, and leafy vegetables in Reference A). Tables B.7-2 and B.7-3 outline human consumption and environmental parameters used in the analysis. It is conservatively assumed that the critical receptor lives at the "maximum off-site atmospheric dispersion factor location" as defined in Section 7.3.

The resulting site-specific dose factors are for the maximum organ which combine the limiting age group with the highest dose factor for any organ with each nuclide. These critical organ, critical age dose factors are given in Table B.1-12. Appendix A provides an example of the development of Method I gaseous dose conversion factor for site-specific conditions at Seabrook.

For any iodine, tritium, and particulate gas release, during any period, the increment in dose from radionuclide "i" is:

$$\Delta D_{ico} = Q_i DFG_{ico} \qquad (7\text{-}16)$$

where DFG_{ico} is the critical dose factor for radionuclide "i" and Q_i is the activity of radionuclide "i" released in microcuries.

Applying this information, it follows that the general form for the critical organ dose equation is:

$$D_{co} = (X/Q)^{depl}_{1\,hr} / (X/Q)^{depl}_{an} * t^{-a} * \sum_i (Q_i * DFG_{ico}) \qquad (3\text{-}8)$$

$$\text{mrem} = \left(\frac{\text{sec}}{\text{m}^3}\right) / \left(\frac{\text{sec}}{\text{m}^3}\right) * ( ) * \Sigma \left(\mu\text{Ci} * \frac{\text{mrem}}{\mu\text{Ci}}\right)$$

Substituting specific values associated with the maximum off-site receptor location and elevated release condition yields:

$$D_{co(e)} = (1.12\text{E-}05)/(7.55\text{E-}07) * t^{-0.297} * \sum_i (Q_i * DFG_{ico(e)})$$

which reduces to:

$$D_{co(e)} = 14.8 * t^{-0.297} * \sum_i (Q_i * DFG_{ico(e)}) \qquad (3\text{-}8a)$$

For the maximum off-site receptor location and ground-level release conditions, the equation is:

$$D_{co(g)} = (1.71E-04)/(9.64E-06) * t^{-0.316} * \sum_i (Q_i * DFG_{ico(g)})$$

which reduces to:

$$D_{co(g)} = 17.7 * t^{-0.316} * \sum_i (Q_i * DFG_{ico(g)}) \quad (3\text{-}8b)$$

7.2.7 Special Receptor Gaseous Release Dose Calculations

Part A Section 10.2 requires that the doses to individuals involved in recreational activities within the site boundary are to be determined and reported in the Annual Radioactive Effluent Release Report.

The gaseous dose calculations for the special receptors parallel the bases of the gaseous dose rates and doses in Part B, Sections 7.2.1 through 7.2.5. Only the differences are presented here. The special receptor XQs are given in Table B.7-5.

7.2.7.1 Total Body Dose Rate from Noble Gases

Method I was derived from Regulatory Guide 1.109 as follows:

$$\dot{D}_{tb} = 1E+06[X/Q]^{r} \sum_i \dot{Q}_i DFB_i \quad (7\text{-}3)$$

General Equation (7-3) is then multiplied by an Occupancy Factor (OF) to account for the time an individual will be at the on-site receptor locations during the year. There are two special receptor locations on-site. The "Rocks" is a boat landing area which provides access to Browns River and Hampton Harbor. The Seabrook Station UFSAR, Chapter 2.1, indicates little boating activity in either Browns River or nearby Hunts Island Creek has been observed upon which to determine maximum or conservative usage factors for this on-site shoreline location. As a result, a default value for shoreline activity as provided in Regulatory Guide 1.109, Table E-5, for maximum individuals was utilized for determining the "Rocks" occupancy factor. The 67 hours/year corresponds to the usage factor for a teenager involved in shoreline recreation. This is the highest usage factor of all four age groups listed in Regulatory Guide 1.109, and has been used in the ODCM to reflect the maximum usage level irrespective of age.

Regulatory Guide 1.109 does not provide a maximum individual usage factor for activities similar to those which would be associated with the Seabrook Station Science & Nature Center. Therefore, the usage factor used in the ODCM for the Science & Nature Center reflects the observed usage patterns of visitors to the facility. Individuals in the public who walk in to look at the exhibits on display and pick up available information stay approximately 1.5 hours each. Tour groups who schedule visits to the facility stay approximately 2.5 hours. For conservatism, it was assumed that an individual in a tour group would return five times in a year, and stay 2.5 hours on each visit. These assumptions, when multiplied together, provide the occupancy factor of 12.5 hours/year used in the ODCM for public activities associated with the Science & Nature Center.

For the Science & Nature Center, and the "Rocks", the occupancy factors (OFs) are:

$$\text{Science \& Nature Center} - \frac{12.5\,\text{hrs/yr}^{(1)}}{8760\,\text{hrs/yr}} = 0.0014$$

$$\text{The "Rocks"} - \frac{67\,\text{hrs/yr}^{(1)}}{8760\,\text{hrs/yr}} = 0.0076$$

substituting in the annual average gamma X/Qs:

$[X/Q]_{\gamma} = 1.1E\text{-}06$ sec/m^3 (Science & Nature Center) for primary vent stack releases.

$= 5.3E\text{-}06$ sec/m^3 (Science & Nature Center) for ground level releases.

$= 5.0E\text{-}06$ sec/m^3 (The "Rocks") for primary vent stack releases.

$= 2.6E\text{-}05$ sec/m^3 (The "Rocks") for ground level releases.

and multiplying by:

OF = 0.0014 (Science & Nature Center)

= 0.0076 (The "Rocks")

gives:

$$\dot{D}_{tbE(e)} = 0.0015 * \sum_i (\dot{Q}_i * DFB_i) \qquad \text{(mrem/yr)} \qquad \text{(3-3c)}$$

$$\dot{D}_{tbE(g)} = 0.0074 * \sum_i (\dot{Q}_i * DFB_i) \qquad \text{(mrem/yr)} \qquad \text{(3-3d)}$$

$$\dot{D}_{tbR(e)} = 0.038 * \sum_i (\dot{Q}_i * DFB_i) \qquad \text{(mrem/yr)} \qquad \text{(3-3e)}$$

$$\dot{D}_{tbR(g)} = 0.2 * \sum_i (\dot{Q}_i * DFB_i) \qquad \text{(mrem/yr)} \qquad \text{(3-3f)}$$

where:

$\dot{D}_{tbE(e)}, \dot{D}_{tbE(g)}, \dot{D}_{tbR(e)}$, and $\dot{D}_{tbR(g)}$ = total body dose rates to an individual at the Science & Nature Center and the "Rocks" (recreational site), respectively, due to noble gases in an elevated (e) and ground level (g) release,

(1) Taken from Seabrook Station Technical Specifications (Figure 5.1-1).

$\dot{Q}$ and DFB_i are as defined previously.

7.2.7.2 Skin Dose Rate from Noble Gases

Method I was derived from Equation (7-8):

$$\dot{D}_{skin} = 1.111E+06\ [X/Q]^{\gamma} \sum_i \dot{Q}_i\, DF_i^{\gamma} + \qquad (7\text{-}8)$$

$$1E+06\ X/Q \sum_i \dot{Q}_i DFS_i$$

substituting in the annual average gamma X/Qs:

$[X/Q]^{\gamma}$ = 1.1E-06 sec/m^3 (Science & Nature Center) for primary vent stack releases.

= 5.3E-06 sec/m^3 (Science & Nature Center) for ground level release points.

= 5.0E-06 sec/m^3 (The "Rocks") for primary vent stack releases.

= 2.6E-05 sec/m^3 (The "Rocks") for ground level release points.

and the annual average undepleted X/Qs:

X/Q = 1.6E-06 sec/m^3 (Science & Nature Center) for primary vent stack releases.

= 2.3E-05 sec/m^3 (Science & Nature Center) for ground level release points.

= 1.7E-05 sec/m^3 (The "Rocks") for primary vent stack releases.

= 1.6E-04 sec/m^3 (The "Rocks") for ground level release points.

and multiplying by:

OF = 0.0014 (Science & Nature Center)

= 0.0076 (The "Rocks")

gives:

$$\dot{D}_{skinE(e)} = 0.0014 \sum_i \dot{Q}_i [1.22\, DF_i^{\gamma} + 1.60\, DFS_i] \text{ for an elevated release point.}$$

$$\dot{D}_{skinE(g)} = 0.0014 \sum_i \dot{Q}_i [5.88\, DF_i^{\gamma} + 23\, DFS_i] \text{ for a ground level release point.}$$

$$\dot{D}_{skinR(e)} = 0.0076 \sum_i \dot{Q}_i [5.55\, DF_i^{\gamma} + 17.0\, DFS_i] \text{ for an elevated release point.}$$

$$\dot{D}_{skinR(g)} = 0.0076 \sum_i \dot{Q}_i [28.9\, DF_i^{\gamma} + 160\, DFS_i] \text{ for a ground level release point.}$$

and the equations can be written:

$$\dot{D}_{skinE(e)} = 0.0014 * \sum_i (\dot{Q}_i * DF'_{iE(e)}) \quad (3\text{-}4c)$$

$$\dot{D}_{skinE(g)} = 0.0014 * \sum_i (\dot{Q}_i * DF'_{iE(g)}) \quad (3\text{-}4d)$$

$$\dot{D}_{skinR(e)} = 0.0076 * \sum_i (\dot{Q}_i * DF'_{iR(e)}) \quad (3\text{-}4e)$$

$$\dot{D}_{skinR(g)} = 0.0076 * \sum_i (\dot{Q}_i * DF'_{iR(g)}) \quad (3\text{-}4f)$$

where:

$\dot{D}_{skinE(e)}, \dot{D}_{skinE(g)}, \dot{D}_{skinR(e)}$, and $\dot{D}_{skinR(g)}$ = the skin dose rate (mrem/yr) to an individual at the Science & Nature Center and the "Rocks", respectively, due to noble gases in an elevated (e) and ground level (g) release,

$\dot{Q}_i$ = defined previously, and

$DF'_{iE(e)}, DF'_{iE(g)}, DF'_{iR(e)}$, and $DF'_{iR(e)}$ = the combined skin dose factors for radionuclide "i" for the Science & Nature Center and the "Rocks", respectively, for elevated (e) and ground level (g) release points (see Table B.1-13).

7.2.7.3 Critical Organ Dose Rate from Iodines, Tritium and Particulates with Half-Lives Greater Than Eight Days

The equations for $\dot{D}_{co}$ are derived in the same manner as in Part B, Section 7.2.2, except that the occupancy factors are also included. Therefore:

$\dot{D}_{CoE(e)} = 0.0014 * \sum_i (\dot{Q}_i * DFG'_{icoE(e)})$ for an elevated release. (3-5c)

$\dot{D}_{coE(g)} = 0.0014 * \sum_i (\dot{Q}_i * DFG'_{icoE(g)})$ for a ground level release. (3-5d)

$\dot{D}_{coR(e)} = 0.0076 * \sum_i (\dot{Q}_i * DFG'_{icoR(e)})$ for an elevated release. (3-5e)

$\dot{D}_{coR(g)} = 0.0076 * \sum_i (\dot{Q}_i * DFG'_{icoR(g)})$ for a ground level release. (3-5f)

where:

$\dot{D}_{coE(e)}, \dot{D}_{coE(g)}, \dot{D}_{coR(e)}$, and $\dot{D}_{coR(g)}$ = the critical organ dose rates (mrem/yr) to an individual at the Science & Nature Center and the "Rocks", respectively, due to iodine, tritium, and particulates in elevated (e) and ground level (g) releases,

$\dot{Q}_i$ = as defined previously, and

$DFG'_{icoE(e)}, DFG'_{icoE(g)}, DFG'_{icoR(e)}$, and $DFG'_{icoR(g)}$ = the critical organ dose rate factors for radionuclide "i" for the Science & Nature Center and the "Rocks", respectively, for elevated (e) and ground level (g) release points (see Tables B.1-14 and B.1-15).

7.2.7.4 Gamma Dose to Air from Noble Gases

Method I was derived from Equation (3-6):

$$D^{\gamma}_{air} = 3.17E\text{-}02 * [X/Q]^{\gamma}_{hr} * t^{-a} * \sum_i (\dot{Q}_i * DF^{\gamma}_i) \qquad (3\text{-}6)$$

where all terms of the equation are as defined previously.

Incorporating the specific OF and the atmospheric dispersion factor, the gamma air dose equation for the Science & Nature Center for elevated releases:

$$D^{\gamma}_{airE(e)} = 3.17E\text{-}02 * 1.1E\text{-}05\, t^{-0.252} * 0.0014 * \sum_i (Q_i * DF^{\gamma}_i)$$

which reduces to:

$$D^{\gamma}_{airE(e)} = 4.9E\text{-}10 * t^{-0.252} * \sum_i (Q_i * DF^{\gamma}_i) \qquad (3\text{-}6c)$$

$$(\text{mrad}) = \left(\frac{\text{pCi-yr}}{\mu\text{Ci-m}^3}\right) * (\,) * \Sigma\left(\mu\text{Ci} * \frac{\text{mrad-m}^3}{\text{pCi-yr}}\right)$$

For ground-level releases, the gamma air dose equation for the Science & Nature Center becomes:

$$D^{\gamma}_{air(E(g)} = 3.17E\text{-}02 * 1.0E\text{-}04\, t^{-0.321} * 0.0014 * \sum_i (Q_i * DF^{\gamma}_i)$$

which reduces to:

$$D^{\gamma}_{airE(g)} = 4.4E\text{-}09 * t^{-0.321} * \sum_i (Q_i * DF^{\gamma}_i) \qquad (3\text{-}6d)$$

$$(\text{mrad}) = \left(\frac{\text{pCi-yr}}{\mu\text{Ci-m}^3}\right) * (\,) * \Sigma\left(\mu\text{Ci} * \frac{\text{mrad-m}^3}{\text{pCi-yr}}\right)$$

Incorporating the specific OF and atmospheric dispersion factors for the "Rocks" yields the gamma air dose equation for elevated releases:

$$D^{\gamma}_{airR(e)} = 3.17E\text{-}02 * 2.1E\text{-}05 * t^{-0.155} * 0.0076 * \sum_i (Q_i * DF^{\gamma}_i)$$

which reduces to:

$$D^{\gamma}_{airR(e)} = 5.1E\text{-}09 * t^{-0.155} * \sum_i (Q_i * DF^{\gamma}_i) \qquad (3\text{-}6e)$$

$$(\text{mrad}) = \left(\frac{\text{pCi-yr}}{\mu\text{Ci-m}^3}\right) * (\,) * \Sigma\left(\mu\text{Ci} * \frac{\text{mrad-m}^3}{\text{pCi-yr}}\right)$$

For ground-level releases, the gamma air dose equation for the "Rocks" becomes:

$$D^{\gamma}_{airR(g)} = 3.17E\text{-}02 * 1.7E\text{-}04\, t^{-0.204} * 0.0076 * \sum_i (Q_i * DF^{\gamma}_i)$$

which reduces to:

$$D^{\gamma}_{airR(g)} = 4.1E\text{-}08 * t^{-0.204} * \sum_i (Q_i * DF^{\gamma}_i) \qquad (3\text{-}6f)$$

$$(\text{mrad}) = \left(\frac{\text{pCi-yr}}{\mu\text{Ci-m}^3}\right) * (\,) * \Sigma\left(\mu\text{Ci} * \frac{\text{mrad-m}^3}{\text{pCi-yr}}\right)$$

7.2.7.5 Beta Dose to Air from Noble Gases

Method I was derived as described in Part B, Section 7.2.5. The general form of the dose equation is:

$$D^{\beta}_{air} = 3.17E\text{-}02 * X/Q^{undepl}_{1\text{-}hr} * t^{-a} * \sum_i (Q_i * DF^{\beta}_i) \qquad (3\text{-}7)$$

where all terms in the equation are as defined in Part B, Section 7.2.5.

Incorporating the specific OF and atmospheric dispersion factor for elevated releases into Equation 3-7 yields the following beta dose equation for the Science & Nature Center:

$$D^{\beta}_{airE(e)} = 3.17E\text{-}02 * 4.0E\text{-}05 * t^{-0.35} * 0.0014 * \sum_i (Q_i * DF_i^{\beta})$$

which reduces to:

$$D^{\beta}_{airE(e)} = 1.8E\text{-}09 * t^{-0.35} * \sum_i (Q_i * DF_i^{\beta}) \qquad (3\text{-}7c)$$

$$(\text{mrad}) = \left(\frac{\text{pCi-yr}}{\mu\text{Ci-m}^3}\right) * (\ ) * \Sigma\left(\mu\text{Ci} * \frac{\text{mrad-m}^3}{\text{pCi-yr}}\right)$$

For ground-level releases, the beta air dose equation for the Science & Nature Center becomes:

$$D^{\beta}_{airE(g)} = 3.17E\text{-}02 * 5.5E\text{-}04 * t^{-0.347} * 0.0014 * \sum_i (Q_i * DF_i^{\beta})$$

which reduces to:

$$D^{\beta}_{airE(g)} = 2.4E\text{-}08 * t^{-0.347} * \sum_i (Q_i * DF_i^{\beta}) \qquad (3\text{-}7d)$$

$$(\text{mrad}) = \left(\frac{\text{pCi-yr}}{\mu\text{Ci-m}^3}\right) * (\ ) * \Sigma\left(\mu\text{Ci} * \frac{\text{mrad-m}^3}{\text{pCi-yr}}\right)$$

Incorporating the specific OF and atmospheric dispersion factors for the "Rocks" yields the beta air dose equation for elevated releases:

$$D^{\beta}_{airR(e)} = 3.17E\text{-}02 * 1.6E\text{-}04 * t^{-0.249} * 0.0076 * \sum_i (Q_i * DF_i^{\beta})$$

which reduces to:

$$D^{\beta}_{airR(e)} = 3.9E\text{-}08 * t^{-0.249} * \sum_i (Q_i * DF_i^{\beta}) \qquad (3\text{-}7e)$$

$$(\text{mrad}) = \left(\frac{\text{pCi-yr}}{\mu\text{Ci-m}^3}\right) * (\ ) * \Sigma\left(\mu\text{Ci} * \frac{\text{mrad-m}^3}{\text{pCi-yr}}\right)$$

For ground-level releases, the beta air dose equation for the "Rocks" becomes:

$$D^{\beta}_{airR(g)} = 3.17E\text{-}02 * 1.9E\text{-}03 * t^{-0.267} * 0.0076 * \sum_i (Q_i * DF_i^{\beta})$$

which reduces to:

$$D^{\beta}_{airR(g)} = 4.6E\text{-}07 * t^{-0.267} * \sum_i (Q_i * DF_i^{\beta}) \qquad (3\text{-}7f)$$

$$(\text{mrad}) = \left(\frac{\text{pCi-yr}}{\mu\text{Ci-m}^3}\right) * (\ ) * \Sigma\left(\mu\text{Ci} * \frac{\text{mrad-m}^3}{\text{pCi-yr}}\right)$$

7.2.7.6 Critical Organ Dose from Iodines, Tritium and Particulates With Half-Lives Greater Than Eight Days

Method I was derived as described in Part B, Section 7.2.3. The Critical Organ Dose equations for receptors at the Science & Nature Center and the "Rocks" were derived from Equation 3-8. The following general equation incorporates (i) a ratio of the average 1-hour depleted atmospheric dispersion factor to the average annual depleted atmospheric dispersion factor, (ii) the unitless t^{-a} term, and (iii) the OF:

$$D_{co} = (X/Q)^{depl}_{1\text{-}hr} / (X/Q)^{depl}_{an} * t^{-a} * OF * \sum_i (Q_i * DFG_{ico})$$

$$(\text{mrem}) = \left(\frac{\text{sec}}{\text{m}^3}\right) / \left(\frac{\text{sec}}{\text{m}^3}\right) * (\ ) * (\ ) * \Sigma\left(\mu\text{Ci} * \frac{\text{mrem}}{\mu\text{Ci}}\right)$$

Applying the Science & Nature Center-specific factors for elevated release conditions produces the equation:

$$D_{coE(e)} = (3.72E\text{-}05)/(1.56E\text{-}06) * t^{-0.349} * 0.0014 * \sum_i (Q_i * DFG_{ico\,E(e)})$$

which reduces to:

$$D_{coE(e)} = 3.3E\text{-}02 * t^{-0.349} * \sum_i (Q_i * DFG_{ico\,E(e)}) \qquad (3\text{-}8c)$$

$$(\text{mrem}) = (\ ) * (\ ) * \Sigma\left(\mu\text{Ci} * \frac{\text{mrem}}{\mu\text{Ci}}\right)$$

For a ground-level release, the equation for a receptor at the Science & Nature Center is:

$$D_{coE(g)} = (5.21E\text{-}04)/(2.23E\text{-}05) * t^{-0.347} * 0.0014 * \sum_i (Q_i * DFG_{ico\,E(g)})$$

which reduces to:

$$D_{coE(g)} = 3.3E\text{-}02 * t^{-0.347} * \sum_i (Q_i * DFG_{ico\,E(g)}) \qquad (3\text{-}8d)$$

$$(\text{mrem}) = (\ ) * (\ ) * \Sigma\left(\mu\text{Ci} * \frac{\text{mrem}}{\mu\text{Ci}}\right)$$

The specific Critical Organ Dose equation for a receptor at the "Rocks" under elevated release conditions is:

$$D_{coR(e)} = (1.54E-04)/(1.61E-05) * t^{-0.248} * 0.0076 * \sum_i (Q_i * DFG_{icoR(e)})$$

which reduces to:

$$D_{coR(e)} = 7.3E-02 * t^{-0.248} * \sum_i (Q_i * DFG_{icoR(e)}) \qquad (3\text{-}8e)$$

$$(\text{mrem}) = (\ ) * (\ ) * \Sigma\left(\mu\text{Ci} * \frac{\text{mrem}}{\mu\text{Ci}}\right)$$

For a ground-level release, the equation for a receptor at the "Rocks" is:

$$D_{coR(g)} = (1.80E-03)/(1.59E-04) * t^{-0.267} * 0.0076 * \sum_i (Q_i * DFG_{icoR(g)})$$

which reduces to:

$$D_{coR(g)} = 8.6E-02 * t^{-0.267} * \sum_i (Q_i * DFG_{icoR(g)}) \qquad (3\text{-}8f)$$

$$(\text{mrem}) = (\ ) * (\ ) * \Sigma\left(\mu\text{Ci} * \frac{\text{mrem}}{\mu\text{Ci}}\right)$$

The special receptor equations can be applied under the following conditions (otherwise, justify Method I or consider Method II):

1. Normal operations (nonemergency event).

2. Applicable radionuclide releases via the station vents to the atmosphere.

If Method I cannot be applied, or if the Method I dose exceeds this limit, or if a more refined calculation is required, then Method II may be applied.

Table B.7-2

Environmental Parameters for Gaseous Effluents at Seabrook Station

(Derived from Reference A)*

Variable			Vegetables		Cow Milk		Goat Milk		Meat	
			Stored	Leafy	Pasture	Stored	Pasture	Stored	Pasture	Stored
YV	Agricultural Productivity	(Kg/M^2)	2.	2.	0.70	2.	0.70	2.	0.70	2
P	Soil Surface Density	(Kg/M^2)	240.	240.	240.	240.	240.	240.	240.	240
T	Transport Time to User	(HRS)			48.	48.	48.	48.	480.	480
TB	Soil Exposure Time [1]	(HRS)	131400.	131400.	131400.	131400.	131400.	131400.	131400.	131400.
TE	Crop Exposure Time to Plume	(HRS)	1440.	1440.	720.	1440.	720.	1440.	720.	1440
TH	Holdup After Harvest	(HRS)	1440.	24.	0.	2160.	0.	2160.	0.	2160
QF	Animals Daily Feed	(Kg/DAY)			50.	50.	6.	6.	50.	50
FP	Fraction of Year on Pasture[2]				0.50		0.50		0.50	
FS	Fraction Pasture when on Pasture[3]				1.		1.		1.	
FG	Fraction of Stored Veg. Grown in Garden		0.76							
FL	Fraction of Leafy Veg. Grown in Garden			1.0						
FI	Fraction Elemental Iodine = 0.5									
H	Absolute Humidity = 5.60[4]	(gm/m^3)								

* Regulatory Guide 1.109, Rev. 1

Table B.7-2

Environmental Parameters for Gaseous Effluents at Seabrook Station

Notes:

(1) For Method II dose/dose rate analyses of identified radioactivity releases of less than one year, the soil exposure time for that release may be set at 8760 hours (1 year) for all pathways.

(2) For Method II dose/dose rate analyses performed for releases occurring during the first or fourth calendar quarters, the fraction of time animals are assumed to be on pasture is zero (nongrowing season). For the second and third calendar quarters, the fraction of time on pasture (FP) will be set at 1.0. FP may also be adjusted for specific farm locations if this information is so identified and reported as part of the land use census.

(3) For Method II analyses, the fraction of pasture feed while on pasture may be set to less than 1.0 for specific farm locations if this information is so identified and reported as part of the land use census.

(4) For all Method II analyses, an absolute humidity value equal to 5.6 (gm/m^3) shall be used to reflect conditions in the Northeast (Reference Health Physics Journal, Vol. 39 (August), 1980; Page 318-320, Pergammon Press).

Table B.7-3

Usage Factors for Various Gaseous Pathways at Seabrook Station

(from Reference A, Table E-5)*

Maximum Receptor:

Age Group	Vegetables (kg/yr)	Leafy Vegetables (kg/yr)	Milk (1/yr)	Meat (kg/yr)	Inhalation (m^3/yr)
Adult	520.00	64.00	310.00	110.00	8000.00
Teen	630.00	42.00	400.00	65.00	8000.00
Child	520.00	26.00	330.00	41.00	3700.00
Infant	0.00	0.00	330.00	0.00	1400.00

The "Rocks" and Science & Nature Center:

Age Group	Vegetables (kg/yr)	Leafy Vegetables (kg/yr)	Milk (1/yr)	Meat (kg/yr)	Inhalation (m^3/yr)
Adult	0.00	0.00	0.00	0.00	8000.00
Teen	0.00	0.00	0.00	0.00	8000.00
Child	0.00	0.00	0.00	0.00	3700.00
Infant	0.00	0.00	0.00	0.00	1400.00

* Regulatory Guide 1.109

7.3 Receptor Points and Average Atmospheric Dispersion Factors for Important Exposure Pathways

The gaseous effluent dose equations (Method I) have been simplified by assuming an individual whose behavior and living habits inevitably lead to a higher dose than anyone else. The following exposure pathways to gaseous effluents listed in Regulatory Guide 1.109 (Reference A) have been considered:

1. Direct exposure to contaminated air;
2. Direct exposure to contaminated ground;
3. Inhalation of air;
4. Ingestion of vegetables;
5. Ingestion of goat's milk; and
6. Ingestion of meat.

Part B, Section 7.3.1 details the selection of important off-site and on-site locations and receptors. Part B, Section 7.3.2 describes the atmospheric model used to convert meteorological data into atmospheric dispersion factors. Part B, Section 7.3.3 presents the maximum atmospheric dispersion factors calculated at each of the off-site receptor locations.

7.3.1 Receptor Locations

The most limiting site boundary location in which individuals are, or likely to be located as a place of residence was assumed to be the receptor for all the gaseous pathways considered. This provides a conservative estimate of the dose to an individual from existing and potential gaseous pathways for the Method I analysis.

This point is the west sector, 974 meters from the center of the reactor units for undepleted, depleted, and gamma X/Q calculations, and the northwest section, 914 meters for calculations with D/Q the dispersion parameter.

The site boundary in the NNE through SE sectors is located over tidal marsh (e.g., over water), and consequently are not used as locations for determining maximum off-site receptors (Reference NUREG 0133).

Two other locations (on-site) were analyzed for direct ground plane exposure and inhalation only. They are the "Rocks" (recreational site) and the Education Center shown on Figure 5.1-1 of the Technical Specifications.

7.3.2 Seabrook Station Atmospheric Dispersion Model

The time average atmospheric dispersion factors for use in both Method I and Method II are computed for routine releases using the AEOLUS-2 Computer Code (Reference B).

AEOLUS-2 produces the following average atmospheric dispersion factors for each location:

1. Undepleted X/Q dispersion factors for evaluating ground level concentrations of noble gases;

2. Depleted X/Q dispersion factors for evaluating ground level concentrations of iodines and particulates;

3. Gamma X/Q dispersion factors for evaluating gamma dose rates from a sector averaged finite noble gas cloud (multiple energy undepleted source); and

4. D/Q deposition factors for evaluating dry deposition of elemental radioiodines and other particulates.

Gamma dose rate is calculated throughout this ODCM using the finite cloud model presented in "Meteorology and Atomic Energy - 1968" (Reference E, Section 7-5.2.5). That model is implemented through the definition of an effective gamma atmospheric dispersion factor, [X/Q^{γ}] (Reference B, Section 6), and the replacement of X/Q in infinite cloud dose equations by the [X/Q^{γ}].

7.3.3 Average Atmospheric Dispersion Factors for Receptors

The calculation of Method I and Method II atmospheric diffusion factors (undepleted CHI/Q, depleted CHI/Q, D/Q, and gamma CHI/Q values) utilize a methodology generally consistent with US NRC Regulatory Guide 1.111 (Revision 1) criteria and the methodology for calculating routine release diffusion factors as represented by the XOQDOQ computer code (NUREG/CR-2919). The primary vent stack is treated as a "mixed-mode" release, as defined in Regulatory Guide 1.111. Effluents are considered to be part-time ground level/part-time elevated releases depending on the ratio of the primary vent stack effluent exit velocity relative to the speed of the prevailing wind. All other release points (e.g., Turbine Building and Chemistry lab hoods) are considered ground-level releases.

In addition, Regulatory Guide 1.111 discusses the concept that constant mean wind direction models like AEOLUS-2 do not describe spatial and temporal variations in airflow such as the recirculation of airflow which can occur during prolonged periods of atmospheric stagnation. For sites near large bodies of water like Seabrook, the onset and decay of sea breezes can also result in airflow reversals and curved trajectories. Consequently, Regulatory Guide 1.111 states that adjustments to constant mean wind direction model outputs may be necessary to account for such spatial and temporal variations in air flow trajectories. Recirculation correction factors have been applied to the diffusion factors. The recirculation correction factors used are compatible to the "default open terrain" recirculation correction factors used by the XOQDOQ computer code.

The relative deposition rates, D/Q values, were derived using the relative deposition rate curves presented in Regulatory Guide 1.111 (Revision 1). These curves provide estimates of deposition rates as a function of plume height, stability class, and plume travel distance.

Receptor Locations

For ground-level releases, the downwind location of "The Rocks" (244m NE/ENE) and the Science & Nature Center (406m SW) were taken as the distance from the nearest point on the Unit 1 Administrative Building/Turbine Building complex. For the site boundary, the minimum distances from the nearest point on the Administration Building/Turbine Building complex to the site boundary within a 45-degree sector centered on the compass direction of interest as measured from UFSAR Figure 2.1-4A were used (with the exception that the NE-NE-ENE-E-ESE-SE site boundary sectors were not evaluated because of their over-water locations).

For primary vent stack releases, the distances from the Unit 1 primary vent stack to "The Rocks" (244m NE) and the Science & Nature Center (488m SW) as measured from a recent site aerial photograph were used. For the site boundary, the minimum distances from the Unit 1 primary vent stack to the site boundary within a 45-degree sector centered on the compass direction of interest as measured from UFSAR Figure 2.1-4A were used (with the exception that the NNE-NE-ENE-E-ESE-SE site boundary sectors were not evaluated because of their over-water locations).

Meteorological Data Bases

For "The Rocks" and Science & Nature Center receptors, the diffusion factors represent six-year averages during the time period January 1980 through December 1983 and January 1987 through December 1988 (with the exception that, because of low data recovery, April 1979 and May 1979 were substituted for April 1980 and May 1980). For the site boundary receptors, both six-year average growing season (April through September) and year-round (January through December) diffusion factors were generated, with the higher of the two chosen to represent the site boundary.

The meteorological diffusion factor used in the development of the ODCM Method I dose models are summarized on Tables B.7-4 through B.7-6.

Table B.7-4

Seabrook Station Long-Term Average Dispersion Factors*

Primary Vent Stack

	Dose Rate to Individual			Dose to Air		Dose to Critical Organ
	Total Body	Skin	Critical Organ	Gamma	Beta	Thyroid
X/Q depleted $\left(\frac{sec}{m^3}\right)$	-	-	7.5E-07	-	-	7.5E-07
X/Q undepleted $\left(\frac{sec}{m^3}\right)$	-	8.2E-07	-	-	8.2E-07	-
D/Q $\left(\frac{1}{m^2}\right)$	-	-	1.5E-08**	-	-	1.5E-08
X/Q^{γ} $\left(\frac{sec}{m^3}\right)$	8.5E-07	8.5E-07	-	8.5E-07	-	-

* West site boundary, 974 meters from Containment Building

** Northwest site boundary, 914 meters from Containment Building

Table B.7-5

Seabrook Station Long-Term Average Dispersion Factors for Special (On-Site) Receptors Primary Vent Stack

	Dose Rate to Individual			Dose to Air		Dose to Critical Organ
	Total Body	Skin	Critical Organ	Gamma	Beta	Thyroid
Education Center: (SW - 488 meters)						
X/Q depleted $\left(\frac{sec}{m^3}\right)$	-	-	1.5E-06	-	-	1.5E-06
X/Q undepleted $\left(\frac{sec}{m^3}\right)$	-	1.6E-06	-	-	1.6E-06	-
D/Q $\left(\frac{1}{m^2}\right)$	-	-	2.7E-08	-	-	-
X/Q^{γ} $\left(\frac{sec}{m^3}\right)$	1.1E-06	1.1E-06	-	1.1E-06	-	-
The "Rocks": (ENE - 244 meters)						
X/Q depleted $\left(\frac{sec}{m^3}\right)$	-	-	1.6E-05	-	-	1.6E-05
X/Q undepleted $\left(\frac{sec}{m^3}\right)$	-	1.7E-05	-	-	1.7E-05	-
D/Q $\left(\frac{1}{m^2}\right)$	-	-	1.1E-07	-	-	-
$X/Q^{\gamma}\left(\frac{sec}{m^3}\right)$	5.0E-06	5.0E-06	-	5.0E-06	-	-

Table B.7-6

Seabrook Station

Long-Term Atmospheric Diffusion and Deposition Factors

Ground-Level Release Pathway

Diffusion Factor	RECEPTOR[a]		
	The Rocks	Science & Nature Center	Off-Site
Undepleted CHI/Q, sec/m^3	1.6×10^{-4} (244m ENE)	2.3×10^{-5} (406m SW)	1.0×10^{-5} (823m W)
Depleted CHI/Q, sec/m^3	1.5×10^{-4} (244m ENE)	2.1×10^{-5} (406m SW)	9.6×10^{-6} (823m W)
D/Q, m^{-2}	5.1×10^{-7} (244m ENE)	1.0×10^{-7} (406m SW)	5.1×10^{-8} (823m W)
Gamma CHI/Q, sec/m^3	2.6×10^{-5} (244m ENE)	5.3×10^{-6} (406m SW)	3.4×10^{-6} (823m W)

(a) The highest site boundary diffusion and deposition factors occurred during the April through September growing season. Note that for the primary vent stack release pathway, none of the off-site receptor diffusion and deposition factors (located at 0.25-mile increments beyond the site boundary) exceeded the site boundary diffusion and deposition factors.

8.0 BASES FOR LIQUID AND GASEOUS MONITOR SETPOINTS

8.1 Basis for the Liquid Waste Test Tank Monitor Setpoint

The liquid waste test tank monitor setpoint must ensure that the limits of Part A Control C.5.1 are not exceeded in combination with any other site discharge pathways. The liquid waste test tank monitor is placed upstream of the major source of dilution flow.

The derivation of Equation 5-1 begins with the general equation for the response of a radiation monitor:

$$R = \Sigma \; C_{\gamma i} \; S_{li} \qquad (8\text{-}1)$$

$$(cps) = \left(\frac{\mu Ci}{ml}\right)\left(\frac{cps - ml}{\mu Ci}\right)$$

where:

R = Response of the monitor to radioactivity (cps).

S_{li} = Detector counting efficiency for radionuclide "i" (cps/(μCi/ml)).

$C_{\gamma i}$ = Activity concentration of each gamma emitting radionuclide "i" in the mixture that the monitor has a response efficiency sufficient to detect (μCi/ml).

The detector calibration procedure for the liquid waste test tank monitor at Seabrook Station establishes counting efficiency by use of a known calibration source standard and a linearity response check. Therefore, in Equation 8-1 one may substitute S_l for S_{li}, where S_l is the detector counting efficiency determined from the calibration procedure. Therefore, Equation 8-1 becomes:

$$R = S_i \; \Sigma \; C_\gamma \qquad (8\text{-}2)$$

$$(cps) = \left(\frac{cps - ml}{\mu Ci}\right)\left(\frac{\mu Ci}{ml}\right)$$

The MPC for a given radionuclide must not be exceeded at the point of discharge to the environment. When a mixture of radionuclides is present, 10CFR20 specifies that the concentration (excluding dissolved and entrained noble gases) at the point of discharge shall be limited as follows:

$$\sum \frac{Cd_i}{MPC_i} \leq 1 \qquad (8\text{-}3)$$

where:

C_{di} = Activity concentration of radionuclide "i" determined to be present in the mixture at the point of discharge to the environment (μCi/ml).

MPC_i = The maximum permissible concentration (μCi/ml) for radionuclide "i" from 10CFR20, Appendix B, Table II, Column 2 for all radionuclides except noble gases. The limit for the sum of all noble gases in the waste discharge is 2E-04 μCi/ml (See ODCM Appendix B for listing).

The activity concentration of radionuclide "i" at the point of discharge is related to the activity concentration of each radionuclide at the monitor as follows:

$$C_{di} = \frac{F_m}{F_d}(C\gamma_i + C\beta_i)$$

$$\left(\frac{\mu Ci}{ml}\right) = \left(\frac{gpm}{gpm}\right)\left(\frac{\mu Ci}{ml}\right)$$

and with equivalence of $C_i = (C\gamma_i + C\beta_i)$, Equation 8-4 can be written as

$$C_{di} = \frac{F_m}{F_d} C_i$$

where:

F_m = Flow rate past monitor (gpm)

F_d = Flow rate out of discharge tunnel (gpm)

$C\beta_i$ = Activity concentration of non gamma emitting radionuclide "i" in the mixture at the monitor for which the monitor response is inefficient to detect (μCi/ml).

C_i = The activity concentration of each radionuclide "i" in the waste stream. This includes both gamma and non gamma emitters, such as tritium.

Substituting the right half of Equation 8-4 for C_{di} in Equation 8-3, and solving for F_d/F_m yields the dilution factor needed to complete Equation 8-3:

$$DF_{min} \leq \frac{F_d}{F_m} \geq \sum_i \frac{C_i}{MPC_i} \qquad (8\text{-}5)$$

$$\left(\frac{gpm}{gpm}\right) \left(\frac{\mu Ci - ml}{ml - \mu Ci}\right)$$

where:

MPC_i = The maximum permissible concentration (μCi/ml) for radionuclide "i" from 10CFR20, Appendix B, Table II, Column 2 for radionuclides, except dissolved and entrained noble gases. For noble gases, a value of 2E-04 μCi/ml is used for the limit of the sum of noble gases in the waste stream.

If F_d/F_m is less than DF_{min}, then the tank may not be discharged until either F_d or F_m or both are adjusted such that:

$$DF_{min} \leq \frac{F_d}{F_m} \qquad (8\text{-}5)$$

The maximum allowable discharge flow rate past the monitor can be found by setting F_m to F_{max} and its equivalents, i.e:

$$F_{max} = \frac{F_d}{DF_{min}}$$

Usually F_d/F_m is greater than DF_{min} (i.e., there is more dilution than necessary to comply with Equation 8-3), but must be satisfied since the monitor can only detect the gamma emitting portion of the waste stream. The response of the liquid waste test tank monitor at the setpoint is therefore:

$$R_{setpoint} = f_1 \times \frac{F_d}{F_m \times DF_{min}} \times S_i \Sigma C\gamma_i$$

$$(cps)\ (\ )\qquad (\ )\ \left(\frac{cps - ml}{\mu Ci}\right)\left(\frac{\mu Ci}{ml}\right) \qquad (8\text{-}6)$$

or with F_{max} substituted into Equation 8-6 for the maximum allowable discharge flow rate $\left(\frac{F_d}{DF_{min}}\right)$, the setpoint equation can be stated also as:

$$R_{setpoint} = f_1 \times \frac{F_{max}}{F_m} \times S_i \Sigma C\gamma_i$$

where f_1 is equal to the fraction of the total concentration of MPC at the discharge point to the environment to be associated with the test tank effluent pathway, such that the sum of the fractions of the four liquid discharge pathways is equal to or less than one ($f_1 + f_2 + f_3 + f_4 \leq 1$).

The monitoring system is designed to incorporate the detector efficiency, S_1, into its software. This results in an automatic readout in μCi/ml or μCi/cc for the monitor response. Since the conversion for changing cps to μCi/ml is inherently done by the system software, the monitor response setpoint can be calculated in terms of the total waste test tank activity concentration in μCi/ml determined by the laboratory analysis. Therefore, the setpoint calculation for the liquid waste test tank is:

$$R_{setpoint} = f_1 \times \frac{F_d}{F_m \times DF_{min}} \times \Sigma \; C\gamma_i \qquad (5\text{-}1)$$

$$\left(\frac{\mu Ci}{ml}\right) \quad ( ) \quad ( ) \quad \left(\frac{\mu Ci}{ml}\right)$$

8.2 Basis for the Plant Vent Wide Range Gas Monitor Setpoints

The setpoints of the plant vent wide range gas monitors must ensure that Part A Control C.7.1.1.a is not exceeded. Part B, Sections 3.4 and 3.5 show that Equations 3-3 and 3-4 are acceptable methods for determining compliance with that Part A Control. Which equation (i.e., dose to total body or skin) is more limiting depends on the noble gas mixture. For the limiting setpoint case, the gas mixture associated with the fuel gap activity at time of shutdown (UFSAR Table 15.7-20) indicates that the total body dose rate to the maximum offsite receptor is the limiting dose rate type. The derivations of Equations 5-5 and 5-6 begin with the general equation for the response R of a radiation monitor:

$$R = \sum_i S_{gi} \; C_{mi} \qquad (8\text{-}7)$$

$$(\text{cpm}) = \left(\frac{\text{cpm} - \text{cm}^3}{\mu\text{Ci}}\right)\left(\frac{\mu\text{Ci}}{\text{cm}^3}\right)$$

where:

R = Response of the instrument (cpm)

S_{gi} = Detector counting efficiency for noble gas "i" (cpm/(μCi/cm^3))

C_{mi} = Activity concentration of noble gas "i" in the mixture at the noble gas activity monitor (μCi/cm^3)

C_{mi}, the activity concentration of noble gas "i" at the noble gas activity monitor, may be expressed in terms of $\dot{Q}_i$ by dividing by F, the appropriate flow rate. In the case of the plant vent noble gas activity monitors the appropriate flow rate is the plant vent flow rate.

$$C_{mi} = \dot{Q}_i \; \frac{1}{F} \qquad (8\text{-}8)$$

$$\left(\frac{\mu\text{Ci}}{\text{cm}^3}\right) = \left(\frac{\mu\text{Ci}}{\text{sec}}\right)\left(\frac{\text{sec}}{\text{cm}^3}\right)$$

where:

$\dot{Q}_i$ = The relative release rate of noble gas "i" identified or postulated to be in the mixture.

F = Appropriate flow rate (cm^3/sec)

Substituting the right half of Equation 8-8 into Equation 8-7 for C_{mi} yields:

$$R = \sum_i S_{gi} \; \dot{Q}_i \; \frac{1}{F} \qquad (8\text{-}9)$$

$$(\text{cpm}) = \left(\frac{\text{cpm} - \text{cm}^3}{\mu\text{Ci}}\right)\left(\frac{\mu\text{Ci}}{\text{sec}}\right)\left(\frac{\text{sec}}{\text{cm}^3}\right)$$

As in the case before, for the liquid waste test tank monitor, the plant vent wide range gas monitor establishes the detector counting efficiency by use of a calibration source. Therefore, S_g can be substituted for S_{gi} in Equation 8-9, where S_g is the detector counting efficiency determined from the calibration procedure. Therefore, Equation 8-9 becomes:

$$R = S_g \quad \frac{1}{F} \sum_i \dot{Q}_i \qquad (8\text{-}10)$$

$$(cpm) = \left(\frac{cpm - cm^3}{\mu Ci}\right)\left(\frac{sec}{cm^3}\right)\left(\frac{\mu Ci}{sec}\right)$$

The total body dose rate due to noble gases is determined with Equation 3-3a:

$$\dot{D}_{tb(e)} = 0.85 * \sum_i (\dot{Q}_i * DFB_i) \qquad (3\text{-}3a)$$

$$\left(\frac{mrem}{yr}\right) = \left(\frac{pCi - sec}{\mu Ci - m^3}\right) \quad \left(\frac{\mu Ci}{sec}\right) \quad \left(\frac{mrem - m^3}{pCi - yr}\right)$$

where:

$\dot{D}_{tb(e)}$ = Total body dose rate (mrem/yr)

0.85 = (1.0E+06) x (8.5E-07) (pCi-sec/μCi-m^3)

1E+06 = Number of pCi per μCi (pCi/μCi)

8.5E-07 = $[X/Q]^\gamma$, maximum off-site average gamma atmospheric dispersion factor (sec/m^3) for primary vent stack releases

$\dot{Q}_i$ = The relative release rate of noble gas "i" identified or postulated to be in the gas mix (μCi/sec).

DFB_i = Total body dose factor (see Table B.1-10) (mrem-m^3/pCi-yr)

A composite total body gamma dose factor, DFB_c, may be defined such that:

$$DFB_c \sum_i \dot{Q}_i = \sum_i \dot{Q}_i \; DFB_i \tag{8-11}$$

$$\frac{mrem - m^3}{pCi - yr} \left(\frac{\mu Ci}{sec}\right) = \left(\frac{\mu Ci}{sec}\right) \left(\frac{mrem - m^3}{pCi - yr}\right)$$

Solving Equation 8-11 for DFB_c yields:

$$DFB_c = \frac{\sum_i \dot{Q}_i DFB_i}{\sum_i \dot{Q}_i} \tag{5-7}$$

Part A Control C.7.1.1.a limits the dose rate to the total body from noble gases at any location at or beyond the site boundary to 500 mrem/yr. By setting $\dot{D}_{tb}$ equal to 500 mrem/yr and substituting DFB_c for DFB_i in Equation 3-3, one may solve for $\sum_i \dot{Q}_i$ at the limiting whole body noble gas dose rate:

$$\sum_i \dot{Q}_i = 588 \; \frac{1}{DFB_c} \tag{8-12}$$

$$\left(\frac{\mu Ci}{sec}\right) = \left(\frac{mrem - \mu Ci - m^3}{yr - pCi - sec}\right) \left(\frac{pCi - yr}{mrem - m^3}\right)$$

Substituting this result for $\sum_i \dot{Q}_i$ in Equation 8-10 yields R_{tb}, the response of the monitor at the limiting noble gas total body dose rate:

$$R_{tb} = 588 \; S_g \; \frac{1}{F} \; \frac{1}{DFB_c} \tag{8-13}$$

$$(cpm) = \left(\frac{mrem - \mu Ci - m^3}{yr - pCi - sec}\right) \left(\frac{cpm - cm^3}{\mu Ci}\right) \left(\frac{sec}{cm^3}\right) \left(\frac{pCi - yr}{mrem - m^3}\right)$$

The skin dose rate due to noble gases is determined with Equation 3-4a:

$$\dot{D}_{skin(e)} = \sum_i (\dot{Q}_i * DF'_{i(e)}) \qquad (3\text{-}4a)$$

$$\frac{\text{mrem}}{\text{yr}} = \sum \left(\frac{\mu\text{Ci}}{\text{sec}}\right) \left(\frac{\text{mrem - sec}}{\mu\text{Ci - yr}}\right)$$

where:

$\dot{D}_{skin(e)}$ = Skin dose rate (mrem/yr)

$\dot{Q}_i$ = As defined above.

$DF'_{i(e)}$ = Combined skin dose factor (see Table B.1-10) (mrem-sec/μCi-yr)

A composite combined skin dose factor, DF'_c, may be defined such that:

$$DF'_c * \sum_i \dot{Q}_i = \sum_i (\dot{Q}_i * DF'_{i(e)}) \qquad (8\text{-}14)$$

$$\left(\frac{\text{mrem - sec}}{\mu\text{Ci - yr}}\right)\left(\frac{\mu\text{Ci}}{\text{sec}}\right) = \left(\frac{\mu\text{Ci}}{\text{sec}}\right)\left(\frac{\text{mrem - sec}}{\mu\text{Ci - yr}}\right)$$

Solving Equation 8-14 for DF'_c yields:

$$DF'_c = \frac{\sum_i \dot{Q}_i DF'_{i(e)}}{\sum_i \dot{Q}_i} \qquad (5\text{-}8)$$

Part A Control C.7.1.1.a limits the dose rate to the skin from noble gases at any location at or beyond the site boundary to 3,000 mrem/yr. By setting $\dot{D}_{skin}$ equal to 3,000 mrem/yr and substituting DF'_c for DF'_i in Equation 3-4 one may solve for $\sum_i \dot{Q}_i$ at the limiting skin noble gas dose rate:

$$\sum_i \dot{Q}_i = 3{,}000 \ \frac{1}{DF'_c} \qquad (8\text{-}15)$$

$$\left(\frac{\mu Ci}{sec}\right) \quad \left(\frac{mrem}{yr}\right)\left(\frac{\mu Ci - yr}{mrem - sec}\right)$$

Substituting this result for $\sum_i \dot{Q}_i$ 0in Equation 8-10 yields R_{skin}, the response of the monitor at the limiting noble gas skin dose rate:

$$R_{skin} = 3{,}000 \quad S_g \quad \frac{1}{F} \quad \frac{1}{DF'_c}$$

$$(cpm) \quad \left(\frac{mrem}{yr}\right)\left(\frac{cpm - cm^3}{\mu Ci}\right)\left(\frac{sec}{cm^3}\right)\left(\frac{\mu Ci - yr}{mrem - sec}\right) \qquad (8\text{-}16)$$

As with the liquid monitoring system, the gaseous monitoring system is also designed to incorporate the detector efficiency, S_g, into its software. The monitor also converts the response output to a release rate (µCi/sec) by using a real time stack flow rate measurement input. Therefore, multiplying by the main plant vent flow rate measurement (F), the Equations 8-13 and 8-16 become:

$$R_{tb(e)} = 588 \ \frac{1}{DFB_c} \qquad (5\text{-}5)$$

$$\left(\frac{\mu Ci}{sec}\right) = \left(\frac{mrem - \mu Ci - m^3}{yr - pCi - sec}\right)\left(\frac{pCi - yr}{mrem - m^3}\right)$$

$$R_{skin(e)} = 3{,}000 \ \frac{1}{DF'_c} \qquad (5\text{-}6)$$

$$\left(\frac{\mu Ci}{sec}\right) = \left(\frac{mrem}{yr}\right)\left(\frac{\mu Ci - yr}{mrem - sec}\right)$$

These equations assume that the main plant vent is the only release point contributing to the determination of limiting offsite dose rate. The Control dose rate limits (500 mrem/yr and 3000 mrem/yr for total body and skin, respectively) apply to combination of all release points to the limiting offsite receptor. Administrative fractions (f) should be applied to main plant vent setpoint calculation as a multiplier, and any other release points, such that the summation of all fractions is less than or equal to 1. This provides for the combined impact of all release points to ensure that selected setpoints alarm at or before the site dose rate limits is exceeded.0

8.3 Basis for PCCW Head Tank Rate-of-Change Alarm Setpoint

The PCCW head tank rate-of-change alarm will work in conjunction with the PCCW radiation monitor to alert the operator in the Main Control Room of a leak to the Service Water System from the PCCW System. For the rate-of-change alarm, a setpoint based on detection of an activity level of 10^{-8} μCi/cc in the discharge of the Service Water System has been selected. This activity level was chosen because it is the minimum detectable level of a service water monitor if such a monitor were installed. The use of rate-of-change alarm with information obtained from the liquid sampling and analysis commitments described in Table A.6.1-1 of Part A ensure that potential releases from the Service Water System are known. Sampling and analysis requirements for the Service Water System extend over various operating ranges with increased sampling and analysis at times when leakage from the PCCW to the service water is occurring and/or the activity level in the PCCW is high.

8.4 Basis for Waste Gas Processing System Monitors (RM-6504 and RM-6503)

The maximum allowable setpoint for the waste gas system monitors (response in uCi/cm^3) can be determined by equating the limiting off-site noble gas dose rate from the plant vent to the total body or skin dose rate limits of Part A Control C.7.1.1.a, assuming that all the activity detected by the vent wide-range gas monitors is due to waste gas system discharges.

By evaluating the noble gas radionuclide with the most limiting dose factor as given on Table B.1-10, a conservative activity release rate from the plant vent for both whole body and skin dose rate conditions can be calculated. From Table B.1-10, Kr-89 is seen to be the most restrictive individual noble gas if it were present in the effluent discharge. Applying plant vent setpoint equation 5-5 for the whole body, and equation 5-6 for the skin, the maximum allowable plant vent stack release rate can be calculated as follows:

$$R_{tb} = 588\ 1/DFB_c \qquad (5\text{-}5)$$

where:

R_{tb} = plant vent maximum release rate (μCi/sec) based on the whole body does rate limit of 500 mrem/yr

DFB_c = 1.66E-02 (mrem-m^3/pCi-yr), whole body dose factor for Kr-89

588 = conversion factor (mrem-μCi-m^3/yr-pCi-sec)

Therefore:

R_{tb} = 588 1/1.66E-02

= 35,421 μCi/sec maximum release rate at plant vent

Next, the skin dose rate limit is evaluated from equation 5-6 in a similar fashion as follows:

$$R_{skin} = 3000\ 1/DF'_c \qquad (5\text{-}6)$$

where:

R_{skin} = plant vent maximum release rate (uCi/sec) based on skin dose rate limit of 3000 mrem/yr.

DF'_c = 2.45E-02 mrem-sec/μCi-yr skin dose factor for Kr-89

3000 = Site boundary skin dose rate limit (mrem/yr)

therefore:

R_{skin} = 3000 (mrem/yr) 1/2.45E-02(mrem-sec/μCi-yr)

= 122,449 μCi/sec from the plant vent

Comparing the release rate limit for the whole body to that for the skin (i.e., 35,421 μCi/sec vs 122,449 μCi/sec, respectively) it is determined that the release rate for the whole body is limiting.

Next, to get the maximum plant vent release rate from the waste gas system discharge, equate the plant vent maximum release rate limit for the whole body equal to the waste gas system activity concentration times its flow rate to the plant vent, i.e.:

R_{tb} = 35,421(μCi/sec) = R_{wg}(μCi/cm^3) F_{wg}(cm^3/sec)

or solving for R_{wg}:

R_{wg}(μCi/cm^3) = 35,421(μCi/sec) / F_{wg}(cm^3/sec)

where:

R_{wg} = maximum concentration (setpoint limit) at the waste gas system monitors

F_{wg} = waste gas design flow of 566.4 cm^3/sec (1.2 cfm)

therefore:

R_{wg}(μCi/cm^3) = 35,421(μCi/sec) / 566.4(cm^3/sec)

= 62.5 μCi/cm^3

This represents the maximum waste gas discharge concentration which would equal the site boundary whole body dose rate limit for plant vent releases. Administrative controls may set alert alarm and high alarm (waste gas isolation) setpoints on the waste gas monitors as some multiple of expected activity concentration, such as 1.5 and 2 times, respectively, as long as the maximum setpoint does not exceed 62.5 μCi/cm^3. This provides operational controls to be exercised before any waste gas discharges could equate to the Part A Control C.7.1.1.a.

The primary process monitor noted in Part A Control C.5.2 is RM-6504, which is downstream of the waste gas discharge compressor at the end of the process system. Monitor RM-6503 is on the inlet side of the compressor downstream of the charcoal delay beds, and is considered as an alternate monitor if RM-6504 is inoperable. For the purpose of setting the maximum discharge setpoint, RM-6503 is treated the same as RM-6504, which assumes no additional source reduction before discharge to the plant vent.

8.5 Basis for the Main Condenser Air Evacuation Monitor Setpoint (RM-6505)

The maximum allowable setpoint for the main condenser air evacuation monitor must be evaluated for two modes of operation. For normal operations the monitor is responding to a low flow rate that is typically released through the plant vent stack. During start-up (hogging mode), the monitor response must be related to a high flow rate that is being released from the turbine building which is considered a ground level release. In both instances, the setpoint can be determined by equating the limiting off-site noble gas dose rate from the release point to the total body or skin dose rates of Part A Control C.7.1.1.a. The most restrictive noble gas mixture has been found to be represented by the noble gases associated with the fuel gap activity at the time of plant shutdown. This mixture is listed on UFSAR Table 15.7-20, and provides a limiting setpoint calculation that bounds other potential or observed offgas mix conditions.

In addition to monitoring the main condenser air, the air evacuation monitor response is also used as an indicator for Turbine Gland Seal Condenser exhaust. Since this is a potential release pathway during both the normal and the hogging modes of operation, the impact is considered in the setpoint calculations.

8.5.1 Limiting Example for the Air Evacuation Monitor Setpoint During Normal Operations

During normal power operation the maximum allowable setpoint for the air evacuation monitor is determined by applying plant vent setpoint equation 8-13 for the total body, and equation 8-16 for the skin. Therefore, the maximum allowable stack release rate can be calculated as follows:

$$R_{tb(e)} = (588)\,(S_g)\,(1/F)\,(1/DFB_c) \qquad (8\text{-}13)$$

$$(\text{cpm}) = (\text{mrem-}\mu\text{Ci-m}^3\text{/yr-pCi-sec})\,(\text{cpm-cm}^3/\mu\text{Ci})\,(\text{sec/cm}^3)(\text{pCi-yr/mrem-m}^3)$$

where:

$R_{tb(e)}$ = count rate (cpm) for the plant vent maximum release rate based on the total body dose rate limit of 500 mrem/yr

588 = conversion factor (mrem-μCi-m^3/yr-pCi-sec)

S_g = the detector response efficiency (cpm-cm^3/μCi) as determined from monitor calibration. For the air evacuation monitor, a typical value is 1.87E+08 cpm-cm^3/μCi.

F = release flow rate. During normal operations, a typical flow value ranges from 10 to 50 cfm (2.36E+04 cc/sec maximum) for the air evacuation pathway.

DFB_c = the composite total body dose factor, (mrem-m^3/pCi-yr). For different gas mixes, the composite can be found from:

$$DFB_c = \sum_i \dot{Q}_i\, DFB_i\, 0 \,/\, \sum_i \dot{Q}_i \qquad (5\text{-}7)$$

DFB_c for the limiting gas mixture is 4.86E-03 mrem-m^3/pCi-yr (See Section 5.2.1.2)

Therefore,

$R_{tb(e)}$ = 588 1.87E+08 (1/2.36E+04) (1/4.86E-03)

= 9.59E+08 cpm detector count rate for a maximum release rate at the plant vent based on the total body dose rate.

Next, the off-site skin dose rate limit is evaluated from equation 8-16 in a similar fashion as follows:

$R_{skin(e)} = 3000\ S_g\ (1/F)\ (1/DF'_c)$ (8-16)

(cpm) = (mrem/yr) (cpm-cm^3/Ci) (sec/cm^3) (μCi-yr/mrem-sec)

where:

$R_{skin(e)}$ = count rate (cpm) for a plant vent maximum release rate based on the skin dose rate limit of 3000 mrem/yr

DF'_c = the elevated release skin dose factor for the limiting noble gas mix associated with fuel gap activity at shutdown is calculated in the example provided in Section 5.2.1.2, and is equal to 6.80E-03 (mrem-sec/μCi-yr).

Therefore,

$R_{skin(e)}$ = 3000 1.87E+08 (1/2.36E+04) (1/6.80E-03)

= 3.50E+09 cpm detector count rate for a maximum release rate at the plant vent based on the skin dose rate.

Comparing the release rate limit for the total body to that of the skin (i.e., 9.59E+08 cpm versus 3.50E+09 cpm, respectively) it is determined that the release rate for the total body is limiting in this case.

Since during normal operations the Turbine Gland Seal Condenser exhaust has the potential to be a minor additional contribution to the total site release, the effective contribution from the main condenser exhaust must be limited to some fraction of the calculated value. The contribution from the Turbine Gland Seal Condenser exhaust is expected to be minor because this system handles only 670 lbs/hour of steam which is a very small fraction of the 1.5E+07 lbs/hour of secondary side steam that the main condenser handles. Therefore, the maximum alarm is set at 6.71E+08 cpm, which is 70% of the calculated value, to ensure that the contribution of the two does not exceed the dose rate limit of Part A Control C.7.1.1.a. During normal operations, this would represent the maximum allowable count rate on the air evacuation monitor that would equate to the site boundary total body dose rate limit or less.

8.5.2 Example for the Air Evacuation Monitor Setpoint During Startup (Hogging Mode)

During startup (hogging mode), the determination of the air evacuation setpoint must take into account a larger air flow rate that is also released as a ground level effluent. The flow rate must also include the contribution from the Turbine Gland Seal Condenser exhaust, which is a potential release pathway which the air evacuation monitor response must also take into account. For ground releases, the general equation 8-10 is used to represent the monitor count rate.

$$R = (S_g)(1/F) \sum_i \dot{Q}_i \quad (8\text{-}10)$$

$$(\text{cpm}) = (\text{cpm-cm}^3/\mu\text{Ci})\ (\text{sec/cm}^3)\ (\mu\text{Ci/sec})$$

where:

R = detector count rate (cpm)

S_g = the detector efficiency (cpm-cm^3/μCi)

F = release flow rate (cm^3/sec)

$\dot{Q}_i$ = the release rate of noble gas "i" in the mixture, for each noble gas listed in Table B.1-10.

For a ground release, the off-site total body dose rate is based on:

$$\dot{D}_{tb(g)} = 3.4 \sum_i (\dot{Q}_i DFB_i) \quad (3\text{-}3b)$$

A composite total body dose factor, DFB_c can be defined such that:

$$DFB_c \sum_i \dot{Q}_i = \sum_i (\dot{Q}_i DFB_i) \quad (8\text{-}11)$$

By substituting 8-11 into 3-3b and rearranging to solve for $\sum_i \dot{Q}_i$ the following equation is obtained:

$$\sum_i \dot{Q}_i = (\dot{D}_{(tb(g))} / 3.4)\ (1/DFB_c)$$

By inserting a limiting value of 500 mrem/yr as $\dot{D}_{tb(g)}$ this simplifies to:

$$\sum_i \dot{Q}_i = 147\ (1/DFB_c)$$

Insertion of this equation into equation 8-10 yields:

$$R_{tb(g)} = 147\ S_{(g)}\ (1/F)\ (1/DFB_c)$$

$$(cpm) = (mrem\text{-}\mu Ci\text{-}m^3/yr\text{-}pCi\text{-}sec)\ (cpm\text{-}cm^3/\mu Ci)\ (sec/cm^3)\ (pCi\text{-}yr/mrem\text{-}m^3)$$

where:

$R_{tb(g)}$ = count rate (cpm) for the maximum ground release rate based on the total body dose rate limit of 500 mrem/yr.

147 = conversion factor (mrem-μCi-m^3/yr-pCi-sec)

S_g = the detector response efficiency for the air evacuation monitor (a typical value of 1.87E+08 cpm-cm^3/μCi is applied in this example).

F = release flow rate. During the hogging mode of operation, a value of 4.72E+06 cm^3/sec (10,000 cfm) is assumed. This represents the hogging flow that is discharged to the Turbine Building roof via the air evacuation monitor. An additional 1800 cfm is discharged from the Gland Seal Condenser exhaust directly to the Turbine Building roof without passing via the air evacuation monitor. To account for this unmonitored flow, an administrative fraction (f_{gland}) is applied to the setpoint calculation to ensure that the monitor would alarm before the dose rate limit for the combined release would be exceeded. One approach for determining a conservative fraction is to assume that the radioactivity concentration in the gland seal exhaust is equal to the main condenser offgas, even though the steam flow to the gland seal system is a very small fraction of the steam flow to the main condenser. Then the ratio of the Gland Seal Condenser exhaust flow to the total flow of hogging discharge and gland seal condenser provides for the relative flow of both sources. For the stated conditions, the unmonitored flow is about 15 % of the total (as additional conservatism, this could be doubled to 30% for the relative proportion assumed to be contributed by the unmonitored pathway). Therefore, f_{gland} = 1-0.3, or 0.7 as the fraction applied to the air evacuation monitor setpoint. An additional fraction (f_g) is also applied to account for the potential offsite dose rate contribution from this total ground source vs the plant main vent ($f_g \leq 1 - f_v$). The split for this illustration is set at 0.3 for ground sources and 0.7 for the plant vent.

DFBc = Composite total body dose factor which weights the combination of total body dose factors (from ODCM Table B.1-10) of each radionuclide assumed to be in the gas mix in accordance with the fraction that it makes up of the total release. For the limiting noble gas mix associated with fuel gap activity at shutdown (see example calculation provided in Section 5.2.1.2), the value is equal to 4.86E-03 (mrem-m^3/pCi-yr).

In addition, two administrative fractions are applied to the general calculation to account for other release contributions to the site dose that do not go by the air evacuation monitor. The first (f_g) is the fraction of the site boundary total body dose rate limit to be administratively assigned to monitored ground level releases (for this illustration = 0.3) such that the combination of the plant vent fraction (f_v) and ground fraction (f_g) is less than or equal to 1 ($f_g \leq 1 - f_v$). The second release reduction factor (f_{gland}) is administratively assigned to account for potential unmonitored contributions from the Turbine Gland Seal Condenser exhaust (for this illustration = 0.7) which discharges to the Turbine Building roof without going past the air evacuation monitor

Therefore:

$R_{tb(g)}$ = (147) (1.87E+08) (1/4.72E+06) (1/4.86E-03) (0.3) (0.7)

= 2.52E+05 cpm detector count rate for a maximum ground release rate based on the total body dose rate.

Next, the off-site skin dose rate limit for a ground release is evaluated from equation 3-4b in a similar fashion as follows:

$$\dot{D}_{skin(g)} = \sum_i \left(\dot{Q}_i DF_{i(g)}\right) \qquad (3\text{-}4b)$$

A composite skin dose factor, $DF'_{c(g)}$ can be defined such that:

$$DF'_{c(g)} \sum_i \dot{Q}_i = \sum_i \left(\dot{Q}_i DF_{i(g)} \right) \quad (8\text{-}17)$$

By substituting 8-17 into 3-4b and rearranging to solve for $\sum_i \dot{Q}_i$ the following equation is obtained:

$$\sum_i \dot{Q}_i = \dot{D}_{skin(g)} \left(1/DF'_{c(g)}\right)$$

By inserting a limiting value of 3000 mrem/yr as $\dot{D}_{skin(g)}$ this simplifies to:

$$\sum_i \dot{Q}_i = 3000 \, (1/DF'_{c(g)})$$

Insertion of this equation into equation 8-10 yields:

$$R_{skin(g)} = 3000 \, S_g \, (1/F) \, (1/DF'_{c(g)})$$

$$(cpm) = (mrem/yr) \, (cpm\text{-}cm^3/\mu Ci) \, (sec/cm^3) \, (\mu Ci\text{-}yr/mrem\text{-}sec)$$

where:

$R_{skin(g)}$ = Count rate (cpm) for the maximum ground release rate based on the skin dose rate limit of 3000 mrem/yr.

$DF'_{c(g)}$ = The composite ground release skin dose factors which weights the combination of the combined skin dose factors (from ODCM Table B.1-10) of each radionuclide assumed to be in the gas mix in accordance with the fraction that it makes up of the total release. For the limiting noble gas mix associated with fuel gap activity at shutdown (see example calculation provided in Section 5.2.1.2), the value is equal to 6.80E-03 (mrem-sec/uCi-yr).

As with the whole body dose rate above, the same two administrative fractions, f_g and f_{gland} are also applied to the skin dose rate response.

Therefore:

$R_{skin(g)}$ = (3000) (1.87E+08) (1/4.72E+06) (1/6.80E-03) (0.3) (0.7)

= 3.67E+06 cpm detector count rate for a maximum ground release rate based on the skin dose rate.

Comparing the release rate limit for the total body to that of the skin (i.e., 2.52E+05 cpm versus 3.67E+06 cpm, respectively) it is determined that the release rate for the total body is limiting in this case.

REFERENCES

A. Regulatory Guide 1.109, "Calculation of Annual Doses to Man From Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10CFR50, Appendix I", U.S. Nuclear Regulatory Commission, Revision 1, October 1977.

B. Hamawi, J. N., "AEOLUS-2 - A Computer Code for the Determination of Continuous and Intermittent-Release Atmospheric Dispersion and Deposition of Nuclear Power Plant Effluents in Open-Terrain Sites, Coastal Sites, and Deep-River Valleys for Assessment of Ensuing Doses and Finite-Cloud Gamma Radiation Exposures," Entech Engineering, Inc., March 1988.

C. Regulatory Guide 1.111, "Methods for Estimating Atmospheric Transport and Dispersion of Gaseous Effluents in Routine Releases From Light-Water Cooled Reactors", U.S. Nuclear Regulatory Commission, March 1976.

D. National Bureau of Standards, "Maximum Permissible Body Burdens and Maximum Permissible Concentrations of Radionuclides in Air and in Water for Occupational Exposure", Handbook 69, June 5, 1959.

E. Slade, D. H., "Meteorology and Atomic Energy - 1968", USAEC, July 1968.

F. Seabrook Station Technical Specifications.

APPENDIX A

DOSE CONVERSION FACTORS

APPENDIX A
METHOD I DOSE CONVERSION FACTORS

I. LIQUID PATHWAYS - SEABROOK SITE SPECIFIC DCF'S

The models used to assess doses resulting from effluents into liquids is derived from Appendix A of Reg. Guide 1.109. Since Seabrook is a salt water site, the assumed pathways of exposure taken from Reg Guide 1.109 are Aquatic foods - fish; Aquatic foods -invertebrates; and dose from shoreline deposits (direct dose). No drinking water or irrigation pathways exist because of the salt water environment. In addition, exposures resulting from boating and swimming activities have been included for key radionuclides even though Reg. Guide 1.109 identifies these pathways as not contributing any significant contribution to the total dose, and therefore does not provide dose equations for them. For completeness, the swimming and boating pathways have been included using the dose models from the HERMES code (HEDL-TME-71-168, Dec. 1971) section G, Water Immersion.

The Method I dose conversion factors are derived by calculating the dose impact to individuals via the site specific pathways for a unit activity release (1 curie per nuclide). For each pathway, doses by radionuclide are calculated for each of the 7 organs (including whole body) for each of the four age groups (adult, teen, child, and infant). The Method I dose factor for each nuclide is then selected by taking the highest factor for any organ in any of the age groups for all the exposure pathways combined. The list of dose factors in the ODCM then represents a combination of different limiting organs and age groups which, when used to calculate a dose impact from a mix of radionuclides released in liquid effluents, gives a conservative dose since it combines the exposure to different organs and age groups as if there was a single critical organ-age group.

As an example of how the liquid dose conversion factors are developed, the following calculation for Co-60 is shown. The critical organ/age group is selected based on the full assessment of all organs and age groups.

Factor for fish Ingestion:

The general equation for ingestion doses in RG 1.109 is eq. A-3.

$$1119.7 * \frac{U_{ap} * M_p}{F} * \sum_i Q_i * B_{ip} * D_{aipj} * e^{-\lambda * t_p}$$

The full assessment for the ODCM dose factors indicated that for i = Co-60, the maximum dose (mrem/yr) is to the GI-LLI of an adult as the target organ and age group, therefore:

U_{ap} := 21 kg/yr adult usage factor for fish

M_p	:=	0.1	mixing ratio for near field dilution provided by submerged multiport diffuser.
F	:=	918	cu. ft./sec effluent flow rate for circulating water system
Q_i	:=	1.0	curies/year released of Co-60 assumed
B_{ip}	:=	100	equilibrium bioaccumulation factor for Co-60 in salt water fish, in liters/kg
D_{aipj}	:=	$4.02 * 10^{-5}$	mrem/pCi. adult GI-LLI ingestion dose factor from RG-1.109, table E-11.
λ	:=	$1.501 * 10^{-5}$	decay constant for Co-60 in 1/hrs.
t_p	:=	24	time between release and ingestion, in hrs.
1119.7			is the factor to convert from Ci/yr per ft^3/sec to pCi/liter. Note that RG 1.109 uses 1100 as a rounded approximation.

Therefore the dose from fish to adult GI-LLI is (mrem/yr):

$$1119.7 * \frac{U_{ap} * M_p}{F} * Q_i * B_{ip} * D_{aipj} * e^{-\lambda * t_p} = 0.0103$$

Factor for invertebrate ingestion:

Next, the dose from invertebrates to the adult GI-LLI is given by the same general equation but with the following variables changed:

U_{ap}	:=	5	kg/yr usage factor
B_{ip}	:=	1000	1/kg bioaccumulation factor

all other variables the same as above

therefore the dose from invertebrates is (mrem/yr):

$$1119.7 * \frac{U_{ap} * M_p}{F} * Q_i * B_{ip} * D_{aipj} * e^{-\lambda * t_p} = 0.0245$$

Factor for shoreline direct dose:

The general equation for direct dose from shoreline deposits is taken from equation A-7 in RG-1.109 as (mrem/yr):

$$111970 * \frac{U_{ap} * M_p * W}{F} * \sum_i Q_i * T * D_{aipj} * e^{-\lambda * t_p} * \left[1 - e^{-\lambda * t_b}\right]$$

It is assumed that all internal organ doses also receive exposure from direct external sources, therefore each organ dose due to ingestion must have an external component added. For the above equation, the site specific variables for an adult exposure to a 1 curie per year release of Co-60 are:

U_{ap}	:=	334	hrs/year usage factor used for assumed shoreline activities at Seabrook.
M_p	:=	0.1	mixing ratio for near field dilution provided by the submerged multiport diffuser and assume to be extended to the beach continuously.
W	:=	0.5	shorewidth factor for ocean sites, dimensionless
T	:=	$1.923*10^3$	radioactive half life in days for Co-60
D_{aipj}	:=	$1.70*10^{-8}$	dose factor for Co-60 due to deposits in sediments, units of (mrem/hr)/(pCi/m^2)
t_p	:=	0.0	transit time to point of exposure, hrs
t_b	:=	131400	period that sediment is assumed to be exposed to water contamination for long term buildup, set at 15 years for Method I DCF's
Q_i	:=	1.0	curies per year, Co-60 assumed
111970			conversion factor to convert (Ci/yr)/(ft^3/sec) to pCi/liter and account for the proportionality constant used in sediment model

Therefore the dose to the whole body and each organ due to direct exposure to the shoreline (mrem/yr) is:

$$111970 * \frac{U_{ap} * M_p * W}{F} * Q_i * T * D_{aipj} * e^{-\lambda * t_p} * \left[1 - e^{-\lambda * t_b}\right] = 0.0573$$

Direct dose due to Swimming:

The dose due to immersion in water (swimming) is taken from the HERMES computer code. The original ODCM calculation was based on some preliminary dilution assumptions which gave a near field prompt dilution factor for the multiport diffuser of 8. For single unit operation with both service water and circulating water flow (412,000 gpm), a value of 10 is more realistic. This surface area of the plume is restricted to a small area over the diffuser and does not touch the shoreline approx. 1 mile away. Since the over all impact from swimming is small when compared to the other exposure pathways, the original conservatism on dilution are kept here.

The dose from swimming is given by the following equation:

$$1.0*10^{12}*\frac{U_p}{F_a}*\sum_i Q_i*DF_{im} \qquad \text{(mrem/yr)}$$

Where:

U_p	:=	45	hrs/yr, usage factor for swimming for maximum age group (teen) from HERMES.
F_a	:=	$6.56*10^{11}$	liters/yr, estimated annual dilution effluent flow in multiport diffuser
Q_i	:=	1.0	Curies/yr, assumed release rate of nuclide i.
DF_{im}	:=	$4.6*10^{-6}$	mrem-liters per hrs-pCi, dose factor for Co-60 for water immersion taken from HERMES.
$1.0*10^{12}$			constant for pCi/Ci

Therefore the swimming dose for a 1 curie release of Co-60 is (mrem/yr):

$$1.0*10^{12}*U_p*\frac{M_p}{F_a}*Q_i*DF_{im} = 3.155*10^{-5}$$

As can be seen, the contribution of the swimming dose is only about one 30000ths of the total of the RG 1.109 pathways, and can be ignored in the case of Co-60. Similarly, the boating dose as given in HERMES is taken as half of the swimming dose, (and corrected for change in usage assumptions). The resulting dose is found to be less than the swimming dose and can also therefore be discounted in this case.

Total liquid Pathway dose:

The sum of the above liquid pathway doses can now be added to give the total maximum individual dose to the critical organ (adult-GI-LLI) for Co-60. This gives:

$$0.0103 + 0.0245 + 0.0573 = 0.0921 \text{ mrem/yr}$$

Since the internal doses given by the RG-1.109 methods actually are 50 yr dose commitments resulting from one year exposure to the quantity of activity assumed to be released into the water, and the direct dose represents the dose received for the period assumed to be exposed to the pathway, and the activity release was taken as a unit quantity (i.e. Q = 1 Ci), the above total liquid pathway dose can be stated as site specific committed dose factor in mrem/Ci released. For Method I in the ODCM, the critical organ dose factor is seen to be 0.0921 mrem/Ci, as shown above. The value reported on Table B.1-11 (9.22 E-08 mrem/μCi) was generated by a computational routine which gives rise to the round-off difference between it and the above example. The whole body site specific dose factor for the ODCM was calculated in the same way treating the whole body as a separate organ.

II. GASEOUS PATHWAYS - SEABROOK SITE SPECIFIC DCF'S

The models used to assess doses resulting from gaseous effluents in the form of iodines, tritium, and particulates are derived from Appendix C of Reg. Guide 1.109. For Seabrook, it is assumed that at the off site location which exhibits minimum atmospheric dilution for plant releases the following exposure pathways exist: inhalation, ground plane, ingestion of goats milk, meat, stored vegetables, and leafy vegetables.

The Method I dose and dose rate factors are derived by calculating the dose impact to all age group individuals via the site specific pathways for a unit activity release (1 curie per nuclide). For each pathway, doses by nuclide are calculated for each of 7 organs (including the whole body) for each of the 4 age groups. The Method I dose factor for each nuclide is then selected by taking the highest factor for any organ in any of the age groups for all exposure pathways combined. The list of dose factors in the ODCM then represents a combination of different limiting organs and age groups which, when used to calculate the dose impact from a mix of radionuclides released into the atmosphere, gives a conservative dose since it combines the exposure to different organs and age groups as if they were for all the same critical organ-age group.

As an example of how the gaseous particulate dose factors are developed, the following calculation for Mn-54 is shown. The critical organ/age group for Mn-54 was selected based on a full assessment of all organ and age group combinations. For elevated releases from the plant vent stack to the maximum site boundary (max. dose point due to meteorology), the critical organ and age group for Mn-54 was determined to be the GI-LLI for the adult.

PART A: INHALATION DOSE CONTRIBUTION

The general equations for inhalation doses in RG 1.109 are eq. C-3, and C-4 which together give:

$$3.17*10^{4}*R_a*\left[\frac{X}{Q}\right]*\sum_i Q_i*DFA_{ija}=D_{ja}$$

Where for the case of Mn-54 releases, the variables above are defined as:

$3.17*10^{4}$			is the number of pCi/Ci divided by the number of second per year
R_a	:=	8000	the breathing rate for age group a (adults) in m^3 /yr.
$\frac{X}{Q}$	:=	$7.5 * 10^{-7}$	the long term average depleted atmospheric dispersion factor, in sec/m^3, at the maximum exposure point off site (S.B.)
Q_i	:=	1	the release rate of nuclide i to the atmosphere in Ci/yr

$DFA_{ija} := 9.67*10^{-6}$ the inhalation dose factor for nuclide i (Mn-54), organ j (GI-LLI), and age group a (adult) taken from RG 1.109, table E-7, in mrem/pCi inhaled.

Therefore, the inhalation dose to the maximum potential off site individual is given as:

$$3.17*10^{4}*R_a*\left[\frac{X}{Q}\right]*Q_i*DFA_{ija} = 0.00184 \text{ mrem/yr per Ci}$$

PART B: GROUND PLANE DIRECT DOSE CONTRIBUTION

The general equations for ground plane external direct dose in RG 1.109 are equations C-1 and C-2 which together give the dose DG as:

$$8760*1.0*10^{12}*S_F*\left[\frac{D}{Q}\right]*\sum_i Q_i*\frac{1-e^{-\lambda_i*t_b}}{\lambda_i}*DFG_{ij}$$

Where for the case of Mn-54 releases, the variables in the above equation are defined as:

$1.0*10^{12}$ is the number of pCi per Ci

$S_F := 0.7$ the shielding factor provided by residential structures (dimensionless) for use in calculation accumulated doses over time. Note that for determination of dose rate factors (i.e. instantaneous dose rates) the shielding factor is set equal to 1.0, or in effect no credit for dose reduction is taken for determination of dose rates at points in time.

$\frac{D}{Q} := 1.5*10^{-8}$ the long term average relative deposition factor at the maximum site boundary location, in $1/m^2$

$\lambda_i := 0.8105$ is the radiological decay constant for Mn-54 (nuclide i in this case) in 1/yr.

$t_b := 15$ is the time in years over which accumulation is evaluated (approx. midpoint of plant operating life)

$DFG_{ij} := 5.80*10^{-9}$ external dose factor to the whole body, or any internal organ j, for standing on contaminated ground from Mn-54 (RG 1.109 Table E-6) in mrem/hr per pCi/m^2

$Q_i := 1.0$ is the unit release quantity assumed for each nuclide i, in Ci/yr.

8760 is the number of hours in a year

Therefore, the contribution to the total dose made by exposure to the ground plane at the maximum off site exposure location for Mn-54 is given as:

$$8760 * 1.0 * 10^{12} * S_F * \left[\frac{D}{Q}\right] * Q_i * \frac{1-e^{-\lambda_i * t_b}}{\lambda_i} * DFG_{ij} = 0.658 \quad \text{mrem per yr per Ci}$$

PART C: INGESTION DOSE CONTRIBUTION:

As an initial step to determining the dose contribution from ingestion of milk, meat, stored vegetables, and leafy vegetables, we must first calculate the radionuclide concentration in forage, produce, and leafy vegetables resulting from atmospheric tranfers of the activity to the surface of the vegetation and onto the soil for root uptake. For all radioiodines and particulate nuclides (except tritium and C-14), the concentration of nuclide i in and on the vegetation at a point of interest can be calculated using R.G. 1.109 equations C-5 and C-6, which combined gives:

$$1.14*10^{8}*\left[\frac{D}{Q}\right]*Q_i*\left[r*\frac{1-e^{-\lambda_{Ei}*t_e}}{Y_v*\lambda_{Ei}}+B_{iv}*\frac{1-e^{-\lambda_i*t_b}}{P*\lambda_i}\right]*e^{-\lambda_i*t_h}$$

PART C.1: Concentration in Produce (stored vegetables)

For the case of Mn-54 released in air emissions to the maximum site boundary, the concentration of Mn in produce grown in the hypothetical garden at that location can be calculated from the above equation where the variables are defined as:

$1.14*10^{8}$ is the number of pCi per Ci divided by the number of hours in a year (8760).

$\frac{D}{Q}=1.5*10^{-8}$ is the relative deposition factor, in $1/m^2$, at the maximum exposure point off site (S. B.)

$Q_i := 1$ the release rate of nuclide i to the atmosphere in Ci/yr

$r := 0.2$ fraction of deposited activity retained on crops, leafy vegetables, or pasture grass (1.0 for iodines)

$\lambda_{Ei} := 0.00219$ effective removal rate constant for Mn-54 from crops due to decay and weathering, in hr-1

$t_b := 131400$ soil exposure time to deposition, in (equal to 15 yrs, or mid plant life)

$Y_v := 2.0$ agricultural productivity (yield) for produce, in kg/m-2

$B_{iv} := 2.9*10^{-2}$ concentration factor for uptake of Mn-54 from soil by edible parts of crops in pCi/kg (wet weight) per pCi/kg dry soil

λ_i	:=	$9.252*10^{-5}$	radioactive decay constant for Mn-54, in hrs-1
P	:=	240	effective surface density of soil, in kg/m^2
t_h	:=	1440	crop holdup time after harvest and before ingestion, in hrs
t_e	:=	1440	crop exposure time to plume, in hrs

Therefore, the concentration of Mn-54 in stored vegetables produced at the location of maximum deposition for a unit activity release is given as:

$$1.14*10^{8}*\left[\frac{D}{Q}\right]*Q_i*\left[r*\frac{1-e^{-\lambda_{Ei}*t_e}}{Y_v*\lambda_{Ei}}+B_{iv}*\frac{1-e^{-\lambda_i*t_h}}{P*\lambda_i}\right]*e^{-\lambda_i*t_h}=67.379 \quad \text{pCi/kg}$$

PART C.2: Leafy Vegetable Concentration

For leafy vegetables, the above equation is repeated with the value for t_h, crop holdup time after harvest is changed from 1440 hrs to 24 hrs, i.e.:

t_h	:=	24	crop holdup time after harvest, in hrs.

Therefore the concentration of Mn-54 in leafy vegetables at the maximum deposition point due to a unit activity release is given as:

$$1.14*10^{8}*\left[\frac{D}{Q}\right]*Q_i*\left[r*\frac{1-e^{-\lambda_{Ei}*t_e}}{Y_v*\lambda_{Ei}}+B_{iv}*\frac{1-e^{-\lambda_i*t_h}}{P*\lambda_i}\right]*e^{-\lambda_i*t_h}=76.811 \quad \text{pCi/kg}$$

PART C.3.a: Animal Feed concentration (pasture): C_p

Next, we can repeat the above calculation to determine the concentration of Mn-54 in pasture grass used as animal feed. This will allow for the determination of dose contribution from milk and meat.

For pasture grass, all the above variables remain the same except for:

Y_v	:=	0.70	for agricultural productivity of pasture grasses, kg/m^2
t_e	:=	720	for grass exposure time to plume, hrs
t_h	:=	0.0	for holdup time after harvest

Using these variables in the above equation gives the concentration in pasture grass as:

$$1.14*10^{8}*\left[\frac{D}{Q}\right]*Q_i*\left[r*\frac{1-e^{-\lambda_{Ei}*t_e}}{Y_v*\lambda_{Ei}}+B_{iv}*\frac{1-e^{-\lambda_i*t_h}}{P*\lambda_i}\right]*e^{-\lambda_i*t_h}=179.227 \quad \text{pCi/kg}$$

PART C.3.b: Animal Feed Concentration (stored feed): C_s

For stored feed that would be given to goats, or meat animals, the average concentration would be calculated by changing the following variables in the above calculation to:

Y_v	:=	2.0	agricultural productivity for stored feed
t_e	:=	1440	feed crop exposure time to plume in hrs
t_h	:=	2160	feed crop holdup time after harvest, hrs

Putting these values back into the above equation gives the concentration in stored animal feed (goat and meat animal) of Mn-54 for a unit activity release to the maximum exposure point.

$$1.14*10^{8}*\left[\frac{D}{Q}\right]*Q_i*\left[r*\frac{1-e^{-\lambda_{Ei}*t_e}}{Y_v*\lambda_{Ei}}+B_{iv}*\frac{1-e^{-\lambda_i*t_h}}{P*\lambda_i}\right]*e^{-\lambda_i*t_h}=63.037 \quad \text{pCi/kg}$$

PART C.3.c.: Concentration in Goat's Milk: C_m

The Mn-54 concentration in milk is dependent on the amount and contamination level of the feed consumed by the animal. The radionuclide concentration in milk is estimated from RG 1.109 general equation C-10 as:

$$F_m*C_v*Q_F*e^{-\lambda_i*t_f} = \text{conc. in milk, pCi/liter}$$

where the variables are defined as:

F_m	:=	$2.5*10^{-4}$	average fraction of animal's daily intake of Mn-54 which appears in each liter of milk, in days/liter
Q_F	:=	6.0	amount of feed consumed by a goat per day, in kg/day (50 kg/d for meat)
t_f	:=	2.0	average transport time of activity from feed into milk and to receptor, in days.

λ_i := $2.22*10^{-3}$ decay constant of Mn-54, in days-1

In addition, the C_v term for the concentration of a nuclide in the animal's feed is given from RG 1.109 general equation C-11 as:

$$C_v = f_p * f_s * C_p + [1 - f_p] * C_s + f_p * [1 - f_s] * C_s$$

where the following equals:

f_p	:=	0.5	fraction of the year that animals graze on pasture
f_s	:=	1.0	fraction of daily feed that is pasture grass when the animal grazes on pasture
C_p	:=	179.227	concentration of Mn-54 in pasture grass as calculated from above, pCi/kg
C_s	:=	63.037	concentration of Mn-54 in stored feed as calculated from above, in pCi/kg

Therefore, the concentration in the total animal's feed is estimated to be:

$$f_p * f_s * C_p + [1 - f_p] * C_s + f_p * [1 - f_s] * C_s = 121.132 \text{ pCi/kg}$$

When this value of 121.132 is put back into the above general equation for nuclide concentration in milk, we get:

[C_v := 121.132 pCi/kg]

and

$F_m * C_v * Q_F * e^{-\lambda_i * t_f} = 0.181$ pCi/liter of Mn-54 in goats milk

PART C.3.d.: Concentration in Meat: C_f

Similar to milk, the concentration of the nuclide in animal meat is calculated. RG 1.109 general equation C-12 is given as:

$$C_f = F_f * C_v * Q_F * e^{-\lambda_i * t_s}$$

Here the variables are set as:

F_f	:=	$8.0*10^{-4}$	fraction of animals daily intake of Mn-54 which appears in each kg of flesh, in days/kg
Q_F	:=	50.0	animal's daily feed intake, in kg/day

t_s	:=	20.0	average time from slaughter to consumption, in days
C_v	:=	121.132	concentration on Mn-54 in animal's feed, same as calculated above for goat, in pCi/kg

Therefore, the concentration of Mn-54 in animal meat is calculated to be:

$$F_f * C_v * Q_F * e^{-\lambda * t_s} = 4.635 \quad \text{pCi/kg in meat for Mn-54}$$

PART D: DOSE FROM INGESTION OF FOODS PRODUCED AT MAXIMUM LOCATION

Now that we have calculated the concentration of Mn-54 in milk, meat, leafy vegetables, and stored vegetables produced at a location of maximum air deposition, the resulting dose to any organ j and age group a can be calculated from the following general equation C-13 taken from RG 1.109:

$$\sum_i DFI_{ija} * [U_{va} * f_g * C_v + U_{ma} * C_m + U_{Fa} * C_f + U_{La} * f_l * C_L]$$

For Mn-54 set equal to i, we find that from the evaluation of all organs for all age groups for combination of all exposure pathways, the adults GI-LLI is the critical age group/organ. Therefore, the variables in the above dose equation can be defined as:

DFI_{ija}	:=	$1.40*10^{-5}$	ingestion dose factor for adults/GI-LLI for Mn-54, in mrem/pCi ingested (RG 1.109, Table E-11)
U_{va}	:=	520.0	vegetable ingestion rates for adults, kg/yr
f_g	:=	0.76	fraction of stored vegetables grown in the garden
f_l	:=	1.0	of leafy vegetables grown in the garden
U_{ma}	:=	310.0	milk ingestion rate for adults, liter/yr
U_{Fa}	:=	110.0	meat ingestion rate for adults, kg/yr
U_{La}	:=	64.0	leafy vegetable ingestion rate for adults, kg/yr
C_v	:=	67.379	concentration of Mn-54 in stored vegetables, in pCi/kg (from above)
C_m	:=	0.181	concentration of Mn-54 in milk, in pCi/liter (from above)
C_f	:=	4.635	concentration of Mn-54 in meat, in pCi/kg (from above)

C_L := 76.811 concentration of Mn-54 in leafy vegetables, in pCi/kg (from above)

The dose from the combination of ingestion pathways for this example is calculated by substituting the above listed variables back into the ingestion dose equation:

$$DFI_{ija} * [U_{va} * f_g * C_v + U_{ma} * C_m + U_{Fa} * C_f + U_{La} * f_l * C_L] = 0.4495 \quad \text{mrem-/yr per Ci}$$

By breaking the above dose equation down into the different pathways which combine to give the total ingestion dose, we can see the individual dose contribution made by each exposure pathway.

Therefore, we have:

Dose for ingestion of stored vegetables	$DFI_{ija} * U_{va} * f_g * C_v = 0.373$
Dose for ingestion of goat's milk	$DFI_{ija} * U_{ma} * C_m = 7.855 * 10^{-4}$
Dose for ingestion of meat	$DFI_{ija} * U_{Fa} * C_f = 0.00714$
Dose for ingestion of leafy vegetables	$DFI_{ija} * U_{La} * f_l * C_L = 0.0688$

PART E: TOTAL DOSE FROM ALL EXPOSURE PATHWAYS

The total dose from all exposure pathways assumed to be present at the maximum receptor location can be found by simply adding the individual pathway doses calculated above. Since all the calculations above assumed a unit activity release from the plant vent stack, the combined dose can be stated as dose factor per unit activity released. This then demonstrates the development of the Seabrook ODCM Method I dose factors for gaseous release of particulates from the vent stack.

Inhalation dose (Part A)	0.00184 mrem/yr per Ci
Ground plane dose (Part B)	0.658 mrem/yr per Ci
Ingestion dose total (Part D)	0.449 mrem/yr per Ci

Total dose all pathways	1.11 mrem/yr per Ci
(critical organ is GI-LLI of an adult for Mn-54)	

APPENDIX B

CONCENTRATIONS IN AIR AND WATER ABOVE NATURAL BACKGROUND

TAKEN FROM

10 CFR 20.1-20.602, APPENDIX B

APPENDIX B TO §§ 20.1—20.602—CONCENTRATIONS IN AIR AND WATER ABOVE NATURAL BACKGROUND

[See footnotes at end of Appendix B]

Element (atomic number)	Isotope [1]		Table I		Table II	
			Col. 1—Air (μCi/ml)	Col. 2—Water (μCi/ml)	Col. 1—Air (μCi/ml)	Col. 2—Water (μCi/ml)
Actinium (89)	Ac 227	S	2×10^{-12}	6×10^{-5}	8×10^{-14}	2×10^{-6}
		I	3×10^{-11}	9×10^{-3}	9×10^{-13}	3×10^{-4}
	Ac 228	S	8×10^{-8}	3×10^{-3}	3×10^{-9}	9×10^{-5}
		I	2×10^{-6}	3×10^{-3}	6×10^{-10}	9×10^{-5}
Americium (95)	Am 241	S	6×10^{-12}	1×10^{-4}	2×10^{-13}	4×10^{-6}
		I	1×10^{-10}	8×10^{-4}	4×10^{-12}	3×10^{-5}
	Am 242m	S	6×10^{-12}	1×10^{-4}	2×10^{-13}	4×10^{-6}
		I	3×10^{-10}	3×10^{-3}	9×10^{-12}	9×10^{-5}
	Am 242	S	4×10^{-8}	4×10^{-3}	1×10^{-9}	1×10^{-4}
		I	5×10^{-8}	4×10^{-3}	2×10^{-9}	1×10^{-4}
	Am 243	S	6×10^{-12}	1×10^{-4}	2×10^{-13}	4×10^{-6}
		I	1×10^{-10}	8×10^{-4}	4×10^{-12}	3×10^{-5}
	Am 244	S	4×10^{-8}	1×10^{-3}	1×10^{-9}	5×10^{-5}
		I	2×10^{-8}	1×10^{-3}	8×10^{-9}	5×10^{-5}
Antimony	Sb 122	S	2×10^{-7}	8×10^{-4}	8×10^{-9}	3×10^{-5}
		I	1×10^{-7}	8×10^{-4}	5×10^{-9}	3×10^{-5}
	Sb 124	S	2×10^{-7}	7×10^{-4}	5×10^{-9}	2×10^{-5}
		I	2×10^{-8}	7×10^{-4}	7×10^{-10}	2×10^{-5}
	Sb 125	S	5×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
		I	3×10^{-8}	3×10^{-3}	9×10^{-10}	1×10^{-4}
Argon (18)	A 37	Sub [2]	6×10^{-5}		1×10^{-4}	
	A 41	Sub	2×10^{-6}		4×10^{-8}	
Arsenic (33)	As 73	S	2×10^{-6}	1×10^{-2}	7×10^{-8}	5×10^{-4}
		I	4×10^{-7}	1×10^{-2}	1×10^{-8}	5×10^{-4}
	As 74	S	3×10^{-7}	2×10^{-3}	1×10^{-8}	5×10^{-5}
		I	1×10^{-7}	2×10^{-3}	4×10^{-9}	5×10^{-5}
	As 76	S	1×10^{-7}	6×10^{-4}	4×10^{-9}	2×10^{-5}
		I	1×10^{-7}	6×10^{-4}	3×10^{-9}	2×10^{-5}
	As 77	S	5×10^{-7}	2×10^{-3}	2×10^{-8}	8×10^{-5}
		I	4×10^{-7}	2×10^{-3}	1×10^{-8}	8×10^{-5}
Astatine (85)	At 211	S	7×10^{-9}	5×10^{-5}	2×10^{-10}	2×10^{-6}
		I	3×10^{-8}	2×10^{-3}	1×10^{-9}	7×10^{-5}
Barium (56)	Ba 131	S	1×10^{-6}	5×10^{-3}	4×10^{-8}	2×10^{-4}
		I	4×10^{-7}	5×10^{-3}	1×10^{-8}	2×10^{-4}
	Ba 140	S	1×10^{-7}	8×10^{-4}	4×10^{-9}	3×10^{-5}
		I	4×10^{-8}	7×10^{-4}	1×10^{-9}	2×10^{-5}
Berkelium (97)	Bk 249	S	9×10^{-10}	2×10^{-2}	3×10^{-11}	6×10^{-4}
		I	1×10^{-7}	2×10^{-2}	4×10^{-9}	6×10^{-4}
	Bk 250	S	1×10^{-7}	6×10^{-3}	5×10^{-9}	2×10^{-4}
		I	1×10^{-6}	6×10^{-3}	4×10^{-8}	2×10^{-4}
Beryllium (4)	Be 7	S	6×10^{-6}	5×10^{-2}	2×10^{-7}	2×10^{-3}
		I	1×10^{-6}	5×10^{-2}	4×10^{-8}	2×10^{-3}
Bismuth (83)	Bi 206	S	2×10^{-7}	1×10^{-3}	6×10^{-9}	4×10^{-5}
		I	1×10^{-7}	1×10^{-3}	5×10^{-9}	4×10^{-5}
	Bi 207	S	2×10^{-7}	2×10^{-3}	6×10^{-9}	6×10^{-5}
		I	1×10^{-6}	2×10^{-3}	5×10^{-10}	6×10^{-5}
	Bi 210	S	6×10^{-9}	1×10^{-3}	2×10^{-10}	4×10^{-5}

APPENDIX B TO §§ 20.1—20.602—CONCENTRATIONS IN AIR AND WATER ABOVE NATURAL BACKGROUND—Continued

[See footnotes at end of Appendix B]

Element (atomic number)	Isotope [1]		Table I		Table II	
			Col. 1—Air (μCi/ml)	Col. 2—Water (μCi/ml)	Col. 1—Air (μCi/ml)	Col. 2—Water (μCi/ml)
		I	6×10^{-9}	1×10^{-3}	2×10^{-10}	4×10^{-5}
	Bi 212	S	1×10^{-7}	1×10^{-3}	3×10^{-9}	4×10^{-4}
		I	2×10^{-7}	1×10^{-3}	7×10^{-9}	4×10^{-4}
Bromine (35)	Br 82	S	1×10^{-6}	6×10^{-3}	4×10^{-8}	3×10^{-4}
		I	2×10^{-7}	1×10^{-3}	6×10^{-9}	4×10^{-5}
Cadmium (48)	Cd 109	S	5×10^{-6}	5×10^{-3}	2×10^{-9}	2×10^{-4}
		I	7×10^{-6}	5×10^{-3}	3×10^{-9}	2×10^{-4}
	Cd 115m	S	4×10^{-8}	7×10^{-4}	1×10^{-9}	3×10^{-5}
		I	4×10^{-8}	7×10^{-4}	1×10^{-9}	3×10^{-5}
	Cd 115	S	2×10^{-7}	1×10^{-3}	8×10^{-9}	3×10^{-5}
		I	2×10^{-7}	1×10^{-3}	6×10^{-9}	4×10^{-5}
Calcium (20)	Ca 45	S	3×10^{-8}	3×10^{-4}	1×10^{-9}	9×10^{-6}
		I	1×10^{-7}	5×10^{-3}	4×10^{-9}	2×10^{-4}
	Ca 47	S	2×10^{-7}	1×10^{-3}	6×10^{-9}	5×10^{-5}
		I	2×10^{-7}	1×10^{-3}	6×10^{-9}	3×10^{-5}
Californium (98)	Cf 249	S	2×10^{-12}	1×10^{-4}	5×10^{-14}	4×10^{-6}
		I	1×10^{-10}	7×10^{-4}	3×10^{-12}	2×10^{-5}
	Cf 250	S	5×10^{-12}	4×10^{-4}	2×10^{-13}	1×10^{-5}
		I	1×10^{-10}	7×10^{-4}	3×10^{-12}	3×10^{-5}
	Cf 251	S	2×10^{-12}	1×10^{-4}	6×10^{-14}	4×10^{-6}
		I	1×10^{-10}	8×10^{-4}	3×10^{-12}	3×10^{-5}
	Cf 252	S	6×10^{-12}	2×10^{-4}	2×10^{-13}	7×10^{-6}
		I	3×10^{-11}	2×10^{-4}	1×10^{-12}	7×10^{-6}
	Cf 253	S	8×10^{-10}	4×10^{-3}	3×10^{-11}	1×10^{-4}
		I	8×10^{-10}	4×10^{-3}	3×10^{-11}	1×10^{-4}
	Cf 254	S	5×10^{-12}	4×10^{-6}	2×10^{-13}	1×10^{-7}
		I	5×10^{-12}	4×10^{-6}	2×10^{-13}	1×10^{-7}
Carbon (6)	C 14	S	4×10^{-6}	2×10^{-3}	1×10^{-7}	8×10^{-4}
	(CO_2)	Sub	5×10^{-5}		1×10^{-6}	
Cerium (58)	Ce 141	S	4×10^{-7}	3×10^{-3}	2×10^{-8}	9×10^{-5}
		I	2×10^{-7}	3×10^{-3}	5×10^{-9}	9×10^{-5}
	Ce 143	S	3×10^{-7}	1×10^{-3}	9×10^{-9}	4×10^{-5}
		I	2×10^{-7}	1×10^{-3}	7×10^{-9}	4×10^{-5}
	Ce 144	S	1×10^{-8}	3×10^{-4}	3×10^{-10}	1×10^{-5}
		I	6×10^{-9}	3×10^{-4}	2×10^{-10}	1×10^{-5}
Cesium (55)	Cs 131	S	1×10^{-5}	7×10^{-3}	4×10^{-7}	2×10^{-3}
		I	3×10^{-6}	3×10^{-3}	1×10^{-7}	9×10^{-4}
	Cs 134m	S	4×10^{-5}	2×10^{-1}	1×10^{-6}	6×10^{-3}
		I	6×10^{-6}	3×10^{-2}	2×10^{-7}	1×10^{-3}
	Cs 134	S	4×10^{-8}	3×10^{-4}	1×10^{-9}	9×10^{-6}
		I	1×10^{-8}	1×10^{-3}	4×10^{-10}	4×10^{-5}
	Cs 135	S	5×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
		I	9×10^{-6}	7×10^{-3}	3×10^{-9}	2×10^{-4}
	Cs 136	S	4×10^{-7}	2×10^{-3}	1×10^{-8}	9×10^{-5}
		I	2×10^{-7}	2×10^{-3}	6×10^{-9}	6×10^{-5}
	Cs 137	S	6×10^{-8}	4×10^{-4}	2×10^{-9}	2×10^{-5}
		I	1×10^{-8}	1×10^{-3}	5×10^{-10}	4×10^{-5}
Chlorine (17)	Cl 36	S	4×10^{-7}	2×10^{-3}	1×10^{-8}	8×10^{-5}
		I	2×10^{-6}	2×10^{-3}	6×10^{-10}	6×10^{-5}
	Cl 38	S	3×10^{-6}	1×10^{-2}	9×10^{-8}	4×10^{-4}
		I	2×10^{-6}	1×10^{-2}	7×10^{-8}	4×10^{-4}
Chromium (24)	Cr 51	S	1×10^{-5}	5×10^{-2}	4×10^{-7}	2×10^{-3}
		I	2×10^{-6}	5×10^{-2}	8×10^{-8}	2×10^{-3}
Cobalt (27)	Co 57	S	3×10^{-6}	2×10^{-2}	1×10^{-7}	5×10^{-4}
		I	2×10^{-7}	1×10^{-2}	6×10^{-9}	4×10^{-4}
	Co 58m	S	2×10^{-5}	6×10^{-2}	6×10^{-7}	3×10^{-3}
		I	9×10^{-6}	6×10^{-2}	3×10^{-7}	2×10^{-3}
	Co 58	S	8×10^{-7}	4×10^{-3}	3×10^{-8}	1×10^{-4}
		I	5×10^{-6}	3×10^{-3}	2×10^{-9}	9×10^{-5}
	Co 60	S	3×10^{-7}	1×10^{-3}	1×10^{-8}	5×10^{-5}
		I	9×10^{-9}	1×10^{-3}	3×10^{-10}	3×10^{-5}
Copper (29)	Cu 64	S	2×10^{-6}	1×10^{-2}	7×10^{-8}	3×10^{-4}
		I	1×10^{-6}	6×10^{-3}	4×10^{-8}	2×10^{-4}
Curium (96)	Cm 242	S	1×10^{-10}	7×10^{-4}	4×10^{-12}	2×10^{-5}

APPENDIX B TO §§ 20.1—20.602—CONCENTRATIONS IN AIR AND WATER ABOVE NATURAL BACKGROUND—Continued

[See footnotes at end of Appendix B]

Element (atomic number)	Isotope [1]		Table I		Table II	
			Col. 1—Air (μCi/ml)	Col. 2—Water (μCi/ml)	Col. 1—Air (μCi/ml)	Col. 2—Water (μCi/ml)
		I	2×10^{-10}	7×10^{-4}	6×10^{-12}	2×10^{-5}
	Cm 243	S	6×10^{-12}	1×10^{-4}	2×10^{-13}	5×10^{-6}
		I	1×10^{-10}	7×10^{-4}	3×10^{-12}	2×10^{-5}
	Cm 244	S	9×10^{-12}	2×10^{-4}	3×10^{-13}	7×10^{-6}
		I	1×10^{-10}	8×10^{-4}	3×10^{-12}	3×10^{-5}
	Cm 245	S	5×10^{-12}	1×10^{-4}	2×10^{-13}	4×10^{-6}
		I	1×10^{-10}	8×10^{-4}	4×10^{-12}	3×10^{-5}
	Cm 246	S	5×10^{-12}	1×10^{-4}	2×10^{-13}	4×10^{-6}
		I	1×10^{-10}	8×10^{-4}	4×10^{-12}	3×10^{-5}
	Cm 247	S	5×10^{-12}	1×10^{-4}	2×10^{-13}	4×10^{-6}
		I	1×10^{-10}	6×10^{-4}	4×10^{-12}	2×10^{-5}
	Cm 248	S	6×10^{-12}	1×10^{-5}	2×10^{-14}	4×10^{-7}
		I	1×10^{-11}	4×10^{-5}	4×10^{-13}	1×10^{-6}
	Cm 249	S	1×10^{-6}	6×10^{-2}	4×10^{-7}	2×10^{-3}
		I	1×10^{-6}	6×10^{-2}	4×10^{-7}	2×10^{-3}
Dysprosium (66)	Dy 165	S	3×10^{-6}	1×10^{-3}	9×10^{-8}	4×10^{-4}
		I	2×10^{-6}	1×10^{-2}	7×10^{-8}	4×10^{-4}
	Dy 166	S	2×10^{-7}	1×10^{-3}	8×10^{-9}	4×10^{-5}
		I	2×10^{-7}	1×10^{-3}	7×10^{-9}	4×10^{-5}
Einsteinium (99)	Es 253	S	8×10^{-10}	7×10^{-4}	3×10^{-11}	2×10^{-5}
		I	6×10^{-10}	7×10^{-4}	2×10^{-11}	2×10^{-5}
	Es 254m	S	5×10^{-9}	5×10^{-4}	2×10^{-10}	2×10^{-5}
		I	6×10^{-9}	5×10^{-4}	2×10^{-10}	2×10^{-5}
	Es 254	S	2×10^{-11}	4×10^{-4}	6×10^{-13}	1×10^{-5}
		I	1×10^{-10}	4×10^{-4}	4×10^{-12}	1×10^{-5}
	Es 255	S	5×10^{-10}	8×10^{-4}	2×10^{-11}	3×10^{-5}
		I	4×10^{-10}	8×10^{-4}	1×10^{-11}	3×10^{-5}
Erbium (68)	Er 169	S	6×10^{-7}	3×10^{-3}	2×10^{-8}	9×10^{-5}
		I	4×10^{-7}	3×10^{-3}	1×10^{-8}	9×10^{-5}
	Er 171	S	7×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
		I	6×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
Europium (63)	Eu 152	S	4×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-5}
	(T/2=9.2 hrs)	I	3×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-5}
	Eu 152	S	1×10^{-6}	2×10^{-3}	4×10^{-10}	8×10^{-5}
	(T/2=13 yrs)	I	2×10^{-6}	2×10^{-3}	6×10^{-10}	8×10^{-5}
	Eu 154	S	4×10^{-9}	6×10^{-4}	1×10^{-10}	2×10^{-5}
		I	7×10^{-9}	6×10^{-4}	2×10^{-10}	2×10^{-5}
	Eu 155	S	9×10^{-8}	6×10^{-3}	3×10^{-9}	2×10^{-4}
		I	7×10^{-8}	6×10^{-3}	3×10^{-9}	2×10^{-4}
Fermium (100)	Fm 254	S	6×10^{-8}	4×10^{-3}	2×10^{-9}	1×10^{-4}
		I	7×10^{-8}	4×10^{-3}	2×10^{-9}	1×10^{-4}
	Fm 255	S	2×10^{-8}	1×10^{-3}	6×10^{-10}	3×10^{-5}
		I	1×10^{-8}	1×10^{-3}	4×10^{-10}	3×10^{-5}
	Fm 256	S	3×10^{-9}	3×10^{-5}	1×10^{-10}	9×10^{-7}
		I	2×10^{-9}	3×10^{-5}	8×10^{-11}	9×10^{-7}
Fluorine (9)	F 18	S	5×10^{-6}	2×10^{-2}	2×10^{-7}	8×10^{-4}
		I	3×10^{-6}	1×10^{-2}	9×10^{-8}	5×10^{-4}
Gadolinium (64)	Gd 153	S	2×10^{-7}	6×10^{-3}	8×10^{-9}	2×10^{-4}
		I	9×10^{-8}	6×10^{-3}	3×10^{-9}	2×10^{-4}
	Gd 159	S	5×10^{-7}	2×10^{-3}	2×10^{-8}	8×10^{-5}
		I	4×10^{-7}	2×10^{-3}	1×10^{-8}	8×10^{-5}
Gallium (31)	Ga 72	S	2×10^{-7}	1×10^{-3}	8×10^{-9}	4×10^{-5}
		I	2×10^{-7}	1×10^{-3}	6×10^{-9}	4×10^{-5}
Germanium (32)	Ge 71	S	1×10^{-5}	5×10^{-2}	4×10^{-7}	2×10^{-3}
		I	6×10^{-6}	5×10^{-2}	2×10^{-7}	2×10^{-3}
Gold (79)	Au 196	S	1×10^{-6}	5×10^{-3}	4×10^{-8}	2×10^{-4}
		I	6×10^{-7}	4×10^{-3}	2×10^{-8}	1×10^{-4}
	Au 198	S	3×10^{-7}	2×10^{-3}	1×10^{-8}	5×10^{-5}
		I	2×10^{-7}	1×10^{-3}	8×10^{-9}	5×10^{-5}
	Au 199	S	1×10^{-6}	5×10^{-3}	4×10^{-8}	2×10^{-4}
		I	8×10^{-7}	4×10^{-3}	3×10^{-8}	2×10^{-4}
Hafnium (72)	Hf 181	S	4×10^{-8}	2×10^{-3}	1×10^{-9}	7×10^{-5}
		I	7×10^{-8}	2×10^{-3}	3×10^{-9}	7×10^{-5}
Holmium (67)	Ho 166	S	2×10^{-7}	9×10^{-4}	7×10^{-9}	3×10^{-5}

APPENDIX B TO §§ 20.1—20.602—CONCENTRATIONS IN AIR AND WATER ABOVE NATURAL BACKGROUND—Continued

[See footnotes at end of Appendix B]

Element (atomic number)	Isotope [1]		Table I		Table II	
			Col. 1—Air (μCi/ml)	Col. 2—Water (μCi/ml)	Col. 1—Air (μCi/ml)	Col. 2—Water (μCi/ml)
Hydrogen (1)	H3	I	2×10^{-7}	9×10^{-4}	6×10^{-9}	3×10^{-5}
		S	5×10^{-6}	1×10^{-1}	2×10^{-7}	3×10^{-3}
		I	5×10^{-6}	1×10^{-1}	2×10^{-7}	3×10^{-3}
		Sub	2×10^{-3}		4×10^{-5}	
Indium (49)	In 113m	S	8×10^{-6}	4×10^{-2}	3×10^{-7}	1×10^{-3}
		I	7×10^{-6}	4×10^{-2}	2×10^{-7}	1×10^{-3}
	In 114m	S	1×10^{-7}	5×10^{-4}	4×10^{-9}	2×10^{-5}
		I	2×10^{-6}	5×10^{-4}	7×10^{-10}	2×10^{-5}
	In 115m	S	2×10^{-6}	1×10^{-2}	8×10^{-8}	4×10^{-4}
		I	2×10^{-6}	1×10^{-2}	6×10^{-8}	4×10^{-4}
	In 115	S	2×10^{-7}	3×10^{-3}	9×10^{-9}	9×10^{-5}
		I	3×10^{-6}	3×10^{-3}	1×10^{-8}	9×10^{-5}
Iodine (53)	I 125	S	5×10^{-9}	4×10^{-5}	8×10^{-11}	2×10^{-7}
		I	2×10^{-7}	6×10^{-3}	6×10^{-9}	2×10^{-4}
	I 126	S	8×10^{-9}	5×10^{-5}	9×10^{-11}	3×10^{-7}
		I	3×10^{-7}	3×10^{-3}	1×10^{-8}	9×10^{-5}
	I 129	S	2×10^{-9}	1×10^{-5}	2×10^{-11}	6×10^{-8}
		I	7×10^{-8}	6×10^{-3}	2×10^{-9}	2×10^{-4}
	I 131	S	9×10^{-9}	6×10^{-5}	1×10^{-10}	3×10^{-7}
		I	3×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-5}
	I 132	S	2×10^{-7}	2×10^{-3}	3×10^{-9}	8×10^{-6}
		I	9×10^{-7}	5×10^{-3}	3×10^{-8}	2×10^{-4}
	I 133	S	3×10^{-8}	2×10^{-4}	4×10^{-10}	1×10^{-6}
		I	2×10^{-7}	1×10^{-3}	7×10^{-9}	4×10^{-5}
	I 134	S	5×10^{-7}	4×10^{-3}	6×10^{-8}	2×10^{-5}
		I	3×10^{-6}	2×10^{-2}	1×10^{-7}	6×10^{-4}
	I 135	S	1×10^{-7}	7×10^{-4}	1×10^{-9}	4×10^{-6}
		I	4×10^{-7}	2×10^{-3}	1×10^{-8}	7×10^{-5}
Iridium (77)	Ir 190	S	1×10^{-6}	6×10^{-3}	4×10^{-8}	2×10^{-4}
		I	4×10^{-7}	5×10^{-3}	1×10^{-8}	2×10^{-4}
	Ir 192	S	1×10^{-7}	1×10^{-3}	4×10^{-9}	4×10^{-5}
		I	3×10^{-8}	1×10^{-3}	9×10^{-10}	4×10^{-5}
	Ir 194	S	2×10^{-7}	1×10^{-3}	8×10^{-9}	3×10^{-5}
		I	2×10^{-7}	9×10^{-4}	5×10^{-9}	3×10^{-5}
Iron (26)	Fe 55	S	9×10^{-7}	2×10^{-2}	3×10^{-8}	8×10^{-4}
		I	1×10^{-6}	7×10^{-2}	3×10^{-8}	2×10^{-3}
	Fe 59	S	1×10^{-7}	2×10^{-3}	5×10^{-9}	6×10^{-5}
		I	5×10^{-8}	2×10^{-3}	2×10^{-9}	5×10^{-5}
Krypton (36)	Kr 85m	Sub	6×10^{-6}		1×10^{-7}	
	Kr 85	Sub	1×10^{-5}		3×10^{-7}	
	Kr 87	Sub	1×10^{-6}		2×10^{-8}	
	Kr 88	Sub	1×10^{-6}		2×10^{-8}	
Lanthanum (57)	La 140	S	2×10^{-7}	7×10^{-4}	5×10^{-9}	2×10^{-5}
		I	1×10^{-7}	7×10^{-4}	4×10^{-9}	2×10^{-5}
Lead (82)	Pb 203	S	3×10^{-6}	1×10^{-2}	9×10^{-8}	4×10^{-4}
		I	2×10^{-6}	1×10^{-2}	6×10^{-8}	4×10^{-4}
	Pb 210	S	1×10^{-10}	4×10^{-6}	4×10^{-12}	1×10^{-7}
		I	2×10^{-10}	5×10^{-3}	8×10^{-12}	2×10^{-4}
	Pb 212	S	2×10^{-8}	6×10^{-4}	6×10^{-10}	2×10^{-5}
		I	2×10^{-8}	5×10^{-4}	7×10^{-10}	2×10^{-5}
Lutetium (71)	Lu 177	S	6×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
		I	5×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
Manganese (25)	Mn 52	S	2×10^{-7}	1×10^{-3}	7×10^{-9}	3×10^{-5}
		I	1×10^{-7}	9×10^{-4}	5×10^{-9}	3×10^{-5}
	Mn 54	S	4×10^{-7}	4×10^{-3}	1×10^{-8}	1×10^{-4}
		I	4×10^{-8}	3×10^{-3}	1×10^{-9}	1×10^{-4}
	Mn 56	S	6×10^{-7}	4×10^{-3}	3×10^{-8}	1×10^{-4}
		I	5×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
Mercury (80)	Hg 197m	S	7×10^{-7}	6×10^{-3}	3×10^{-8}	2×10^{-4}
		I	8×10^{-7}	5×10^{-3}	3×10^{-8}	2×10^{-4}
	Hg 197	S	1×10^{-6}	9×10^{-3}	4×10^{-8}	3×10^{-4}
		I	3×10^{-6}	1×10^{-2}	9×10^{-8}	5×10^{-4}
	Hg 203	S	7×10^{-8}	5×10^{-4}	2×10^{-9}	2×10^{-5}
		I	1×10^{-7}	3×10^{-3}	4×10^{-9}	1×10^{-4}

APPENDIX B TO §§ 20.1—20.602—CONCENTRATIONS IN AIR AND WATER ABOVE NATURAL BACKGROUND—Continued

[See footnotes at end of Appendix B]

Element (atomic number)	Isotope [1]		Table I		Table II	
			Col. 1—Air (μCi/ml)	Col. 2—Water (μCi/ml)	Col. 1—Air (μCi/ml)	Col. 2—Water (μCi/ml)
Molybdenum (42)	Mo 99	S	7×10^{-7}	5×10^{-3}	3×10^{-8}	2×10^{-4}
		I	2×10^{-7}	1×10^{-3}	7×10^{-9}	4×10^{-5}
Neodymium (60)	Nd 144	S	8×10^{-11}	2×10^{-3}	3×10^{-12}	7×10^{-5}
		I	3×10^{-10}	2×10^{-3}	1×10^{-11}	8×10^{-5}
	Nd 147	S	4×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-5}
		I	2×10^{-7}	2×10^{-3}	8×10^{-9}	6×10^{-5}
	Nd 149	S	2×10^{-6}	8×10^{-3}	6×10^{-8}	3×10^{-4}
		I	1×10^{-6}	8×10^{-3}	5×10^{-8}	3×10^{-4}
Neptunium (93)	Np 237	S	4×10^{-12}	9×10^{-5}	1×10^{-13}	3×10^{-6}
		I	1×10^{-10}	9×10^{-4}	4×10^{-12}	3×10^{-5}
	Np 239	S	8×10^{-7}	4×10^{-3}	3×10^{-8}	1×10^{-4}
		I	7×10^{-7}	4×10^{-3}	2×10^{-8}	1×10^{-4}
Nickel (28)	Ni 59	S	5×10^{-7}	6×10^{-3}	2×10^{-8}	2×10^{-4}
		I	8×10^{-7}	6×10^{-3}	3×10^{-8}	2×10^{-4}
	Ni 63	S	6×10^{-8}	8×10^{-4}	2×10^{-9}	3×10^{-5}
		I	3×10^{-7}	2×10^{-3}	1×10^{-8}	7×10^{-5}
	Ni 65	S	9×10^{-7}	4×10^{-3}	3×10^{-8}	1×10^{-4}
		I	5×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
Niobium (Columbium) (41)	Nb 93m	S	1×10^{-7}	1×10^{-2}	4×10^{-9}	4×10^{-4}
		I	2×10^{-7}	1×10^{-2}	5×10^{-9}	4×10^{-4}
	Nb 95	S	5×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
		I	1×10^{-7}	3×10^{-3}	3×10^{-9}	1×10^{-4}
	Nb 97	S	6×10^{-6}	3×10^{-2}	2×10^{-7}	9×10^{-4}
		I	5×10^{-6}	3×10^{-2}	2×10^{-7}	9×10^{-4}
Osmium (76)	Os 185	S	5×10^{-7}	2×10^{-3}	2×10^{-8}	7×10^{-5}
		I	5×10^{-8}	2×10^{-3}	2×10^{-9}	7×10^{-5}
	Os 191m	S	2×10^{-5}	7×10^{-2}	6×10^{-7}	3×10^{-3}
		I	9×10^{-6}	7×10^{-2}	3×10^{-7}	2×10^{-3}
	Os 191	S	1×10^{-6}	5×10^{-3}	4×10^{-8}	2×10^{-4}
		I	4×10^{-7}	5×10^{-3}	1×10^{-8}	2×10^{-4}
	Os 193	S	4×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-5}
		I	3×10^{-7}	2×10^{-3}	9×10^{-9}	5×10^{-5}
Palladium (46)	Pd 103	S	1×10^{-6}	1×10^{-2}	5×10^{-8}	3×10^{-4}
		I	7×10^{-7}	8×10^{-3}	3×10^{-8}	3×10^{-4}
	Pd 109	S	6×10^{-7}	3×10^{-3}	2×10^{-8}	9×10^{-5}
		I	4×10^{-7}	2×10^{-3}	1×10^{-8}	7×10^{-5}
Phosphorus (15)	P 32	S	7×10^{-8}	5×10^{-4}	2×10^{-9}	2×10^{-5}
		I	8×10^{-8}	7×10^{-4}	3×10^{-9}	2×10^{-5}
Platinum (78)	Pt 191	S	8×10^{-7}	4×10^{-3}	3×10^{-8}	1×10^{-4}
		I	6×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
	Pt 193m	S	7×10^{-6}	3×10^{-2}	2×10^{-7}	1×10^{-3}
		I	5×10^{-6}	3×10^{-2}	2×10^{-7}	1×10^{-3}
	Pt 193	S	1×10^{-6}	3×10^{-2}	4×10^{-8}	9×10^{-4}
		I	3×10^{-7}	5×10^{-2}	1×10^{-8}	2×10^{-3}
	Pt 197m	S	6×10^{-6}	3×10^{-2}	2×10^{-7}	1×10^{-3}
		I	5×10^{-6}	3×10^{-2}	2×10^{-7}	9×10^{-4}
	Pt 197	S	8×10^{-7}	4×10^{-3}	3×10^{-8}	1×10^{-4}
		I	6×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
Plutonium (94)	Pu 238	S	2×10^{-12}	1×10^{-4}	7×10^{-14}	5×10^{-6}
		I	3×10^{-11}	8×10^{-4}	1×10^{-12}	3×10^{-5}
	Pu 239	S	2×10^{-12}	1×10^{-4}	6×10^{-14}	5×10^{-6}
		I	4×10^{-11}	8×10^{-4}	1×10^{-12}	3×10^{-5}
	Pu 240	S	2×10^{-12}	1×10^{-4}	6×10^{-14}	5×10^{-6}
		I	4×10^{-11}	8×10^{-4}	1×10^{-12}	3×10^{-5}
	Pu 241	S	9×10^{-11}	7×10^{-3}	3×10^{-12}	2×10^{-4}
		I	4×10^{-6}	4×10^{-2}	1×10^{-9}	1×10^{-3}
	Pu 242	S	2×10^{-12}	1×10^{-4}	6×10^{-14}	5×10^{-6}
		I	4×10^{-11}	9×10^{-4}	1×10^{-12}	3×10^{-5}
	Pu 243	S	2×10^{-6}	1×10^{-2}	6×10^{-8}	3×10^{-4}
		I	2×10^{-6}	1×10^{-2}	8×10^{-8}	3×10^{-4}
	Pu 244	S	2×10^{-12}	1×10^{-4}	6×10^{-14}	4×10^{-6}
		I	3×10^{-11}	3×10^{-4}	1×10^{-12}	1×10^{-5}
Polonium (84)	Po 210	S	5×10^{-10}	2×10^{-3}	2×10^{-11}	7×10^{-7}
		I	2×10^{-10}	8×10^{-4}	7×10^{-12}	3×10^{-5}

APPENDIX B TO §§ 20.1—20.602—CONCENTRATIONS IN AIR AND WATER ABOVE NATURAL BACKGROUND—Continued

[See footnotes at end of Appendix B]

Element (atomic number)	Isotope [1]		Table I		Table II	
			Col. 1—Air (μCi/ml)	Col. 2—Water (μCi/ml)	Col. 1—Air (μCi/ml)	Col. 2—Water (μCi/ml)
Potassium (19)	K42	S	2×10^{-6}	9×10^{-3}	7×10^{-8}	3×10^{-4}
		I	1×10^{-7}	6×10^{-4}	4×10^{-9}	2×10^{-5}
Praseodymium (59)	Pr 142	S	2×10^{-7}	9×10^{-4}	7×10^{-9}	3×10^{-5}
		I	2×10^{-7}	9×10^{-4}	5×10^{-9}	3×10^{-5}
	Pr 143	S	3×10^{-7}	1×10^{-3}	1×10^{-8}	5×10^{-5}
		I	2×10^{-7}	1×10^{-3}	6×10^{-9}	5×10^{-5}
Promethium (61)	Pm 147	S	6×10^{-8}	6×10^{-3}	2×10^{-9}	2×10^{-4}
		I	1×10^{-7}	6×10^{-3}	3×10^{-9}	2×10^{-4}
	Pm 149	S	3×10^{-7}	1×10^{-3}	1×10^{-8}	4×10^{-5}
		I	2×10^{-7}	1×10^{-3}	8×10^{-9}	4×10^{-5}
Protoactinium (91)	Pa 230	S	2×10^{-9}	7×10^{-3}	6×10^{-11}	2×10^{-4}
		I	8×10^{-10}	7×10^{-3}	3×10^{-11}	2×10^{-4}
	Pa 231	S	1×10^{-12}	3×10^{-5}	4×10^{-14}	9×10^{-7}
		I	1×10^{-10}	8×10^{-4}	4×10^{-12}	2×10^{-5}
	Pa 233	S	6×10^{-7}	4×10^{-3}	2×10^{-8}	1×10^{-4}
		I	2×10^{-7}	3×10^{-3}	6×10^{-9}	1×10^{-4}
Radium (88)	Ra 223	S	2×10^{-9}	2×10^{-5}	6×10^{-11}	7×10^{-7}
		I	2×10^{-10}	1×10^{-4}	8×10^{-12}	4×10^{-6}
	Ra 224	S	5×10^{-9}	7×10^{-5}	2×10^{-10}	2×10^{-6}
		I	7×10^{-10}	2×10^{-4}	2×10^{-11}	5×10^{-6}
	Ra 226	S	3×10^{-11}	4×10^{-7}	3×10^{-12}	3×10^{-6}
		I	5×10^{-11}	9×10^{-4}	2×10^{-12}	3×10^{-5}
	Ra 228	S	7×10^{-11}	8×10^{-7}	2×10^{-12}	3×10^{-6}
		I	4×10^{-11}	7×10^{-4}	1×10^{-12}	3×10^{-5}
Radon (86)	Rn 220	S	3×10^{-7}		1×10^{-8}	
	Rn 222 [3]		3×10^{-8}		3×10^{-9}	
Rhenium (75)	Re 183	S	3×10^{-6}	2×10^{-2}	9×10^{-8}	6×10^{-4}
		I	2×10^{-7}	8×10^{-3}	5×10^{-9}	3×10^{-4}
	Re 186	S	6×10^{-7}	3×10^{-3}	2×10^{-8}	9×10^{-5}
		I	2×10^{-7}	1×10^{-3}	8×10^{-9}	5×10^{-5}
	Re 187	S	9×10^{-6}	7×10^{-2}	3×10^{-7}	3×10^{-3}
		I	5×10^{-7}	4×10^{-2}	2×10^{-8}	2×10^{-3}
	Re 188	S	4×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-5}
		I	2×10^{-7}	9×10^{-4}	6×10^{-9}	3×10^{-5}
Rhodium (45)	Rh 103m	S	8×10^{-5}	4×10^{-1}	3×10^{-6}	1×10^{-2}
		I	6×10^{-5}	3×10^{-1}	2×10^{-6}	1×10^{-2}
	Rh 105	S	8×10^{-7}	4×10^{-3}	3×10^{-8}	1×10^{-4}
		I	5×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
Rubidium (37)	Rb 86	S	3×10^{-7}	2×10^{-3}	1×10^{-8}	7×10^{-5}
		I	7×10^{-8}	7×10^{-4}	2×10^{-9}	2×10^{-5}
	Rb 87	S	5×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
		I	7×10^{-8}	5×10^{-3}	2×10^{-9}	2×10^{-4}
Ruthenium (44)	Ru 97	S	2×10^{-6}	1×10^{-2}	8×10^{-8}	4×10^{-4}
		I	2×10^{-6}	1×10^{-2}	6×10^{-8}	3×10^{-4}
	Ru 103	S	5×10^{-7}	2×10^{-3}	2×10^{-8}	8×10^{-5}
		I	8×10^{-8}	2×10^{-3}	3×10^{-9}	8×10^{-5}
	Ru 105	S	7×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
		I	5×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
	Ru 106	S	8×10^{-6}	4×10^{-4}	3×10^{-9}	1×10^{-5}
		I	6×10^{-9}	3×10^{-4}	2×10^{-10}	1×10^{-5}
Samarium (62)	Sm 147	S	7×10^{-11}	2×10^{-3}	2×10^{-12}	6×10^{-5}
		I	3×10^{-10}	2×10^{-3}	9×10^{-12}	7×10^{-5}
	Sm 151	S	6×10^{-8}	1×10^{-2}	2×10^{-9}	4×10^{-4}
		I	1×10^{-7}	1×10^{-2}	5×10^{-9}	4×10^{-4}
	Sm 153	S	5×10^{-7}	2×10^{-3}	2×10^{-8}	8×10^{-5}
		I	4×10^{-7}	2×10^{-3}	1×10^{-8}	8×10^{-5}
Scandium (21)	Sc 46	S	2×10^{-7}	1×10^{-3}	8×10^{-9}	4×10^{-5}
		I	2×10^{-8}	1×10^{-3}	8×10^{-10}	4×10^{-5}
	Sc 47	S	6×10^{-7}	3×10^{-3}	2×10^{-8}	9×10^{-5}
		I	5×10^{-7}	3×10^{-3}	2×10^{-8}	9×10^{-5}
	Sc 48	S	2×10^{-7}	8×10^{-4}	6×10^{-9}	3×10^{-5}
		I	1×10^{-7}	8×10^{-4}	5×10^{-9}	3×10^{-5}
Selenium 34)	Se 75	S	1×10^{-6}	9×10^{-3}	4×10^{-8}	3×10^{-4}
		I	1×10^{-7}	8×10^{-3}	4×10^{-9}	3×10^{-4}

APPENDIX B TO §§ 20.1—20.602—CONCENTRATIONS IN AIR AND WATER ABOVE NATURAL BACKGROUND—Continued

[See footnotes at end of Appendix B]

Element (atomic number)	Isotope [1]		Table I		Table II	
			Col. 1—Air (μCi/ml)	Col. 2—Water (μCi/ml)	Col. 1—Air (μCi/ml)	Col. 2—Water (μCi/ml)
Silicon (14)	Si 31	S	6×10^{-6}	3×10^{-2}	2×10^{-7}	9×10^{-4}
		I	1×10^{-6}	6×10^{-3}	3×10^{-8}	2×10^{-4}
Silver (47)	Ag 105	S	6×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
		I	8×10^{-8}	3×10^{-3}	3×10^{-9}	1×10^{-4}
	Ag 110m	S	2×10^{-7}	9×10^{-4}	7×10^{-9}	3×10^{-5}
		I	1×10^{-8}	9×10^{-4}	3×10^{-10}	3×10^{-5}
	Ag 111	S	3×10^{-7}	1×10^{-3}	1×10^{-8}	4×10^{-5}
		I	2×10^{-7}	1×10^{-3}	8×10^{-9}	4×10^{-5}
Sodium (11)	Na 22	S	2×10^{-7}	1×10^{-3}	6×10^{-9}	4×10^{-5}
		I	9×10^{-9}	9×10^{-4}	3×10^{-10}	3×10^{-5}
	Na 24	S	1×10^{-6}	6×10^{-3}	4×10^{-8}	2×10^{-4}
		I	1×10^{-7}	8×10^{-4}	5×10^{-9}	3×10^{-5}
Strontium (38)	Sr 85m	S	4×10^{-6}	2×10^{-2}	1×10^{-7}	7×10^{-3}
		I	3×10^{-6}	2×10^{-2}	1×10^{-7}	7×10^{-3}
	Sr 85	S	2×10^{-7}	3×10^{-3}	8×10^{-9}	1×10^{-4}
		I	1×10^{-7}	5×10^{-3}	4×10^{-9}	2×10^{-4}
	Sr 89	S	3×10^{-8}	3×10^{-4}	3×10^{-10}	3×10^{-6}
		I	4×10^{-8}	8×10^{-4}	1×10^{-9}	3×10^{-5}
	Sr 90	S	1×10^{-9}	1×10^{-5}	3×10^{-11}	3×10^{-7}
		I	5×10^{-9}	1×10^{-3}	2×10^{-10}	4×10^{-5}
	Sr 91	S	4×10^{-7}	2×10^{-3}	2×10^{-8}	7×10^{-5}
		I	3×10^{-7}	1×10^{-3}	9×10^{-9}	5×10^{-5}
	Sr 92	S	4×10^{-7}	2×10^{-3}	2×10^{-8}	7×10^{-5}
		I	3×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-5}
Sulfur (16)	S 35	S	3×10^{-7}	2×10^{-3}	9×10^{-9}	6×10^{-5}
		I	3×10^{-7}	8×10^{-3}	9×10^{-9}	3×10^{-4}
Tantalum (73)	Ta 182	S	4×10^{-8}	1×10^{-3}	1×10^{-9}	4×10^{-5}
		I	2×10^{-8}	1×10^{-3}	7×10^{-10}	4×10^{-5}
Technetium (43)	Tc 96m	S	8×10^{-5}	4×10^{-1}	3×10^{-6}	1×10^{-2}
		I	3×10^{-5}	3×10^{-1}	1×10^{-6}	1×10^{-2}
	Tc 96	S	6×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
		I	2×10^{-7}	1×10^{-3}	8×10^{-9}	5×10^{-5}
	Tc 97m	S	2×10^{-6}	1×10^{-2}	8×10^{-8}	4×10^{-4}
		I	2×10^{-7}	5×10^{-3}	5×10^{-9}	2×10^{-4}
	Tc 97	S	1×10^{-5}	5×10^{-2}	4×10^{-7}	2×10^{-3}
		I	3×10^{-7}	2×10^{-3}	1×10^{-8}	8×10^{-5}
	Tc 99m	S	4×10^{-5}	2×10^{-1}	1×10^{-6}	6×10^{-3}
		I	1×10^{-5}	8×10^{-2}	5×10^{-7}	3×10^{-3}
	Tc 99	S	2×10^{-6}	1×10^{-2}	7×10^{-8}	3×10^{-4}
		I	6×10^{-6}	5×10^{-3}	2×10^{-9}	2×10^{-4}
Tellurium (52)	Te 125m	S	4×10^{-7}	5×10^{-3}	1×10^{-8}	2×10^{-4}
		I	1×10^{-7}	3×10^{-3}	4×10^{-9}	1×10^{-4}
	Te 127m	S	1×10^{-7}	2×10^{-3}	5×10^{-9}	6×10^{-5}
		I	4×10^{-8}	2×10^{-3}	1×10^{-9}	5×10^{-5}
	Te 127	S	2×10^{-6}	8×10^{-3}	6×10^{-8}	3×10^{-4}
		I	9×10^{-7}	5×10^{-3}	3×10^{-8}	2×10^{-4}
	Te 129m	S	8×10^{-8}	1×10^{-3}	3×10^{-9}	3×10^{-5}
		I	3×10^{-8}	6×10^{-4}	1×10^{-9}	2×10^{-5}
	Te 129	S	5×10^{-6}	2×10^{-2}	2×10^{-7}	8×10^{-4}
		I	4×10^{-6}	2×10^{-2}	1×10^{-7}	8×10^{-4}
	Te 131m	S	4×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-5}
		I	2×10^{-7}	1×10^{-3}	6×10^{-9}	4×10^{-5}
	Te 132	S	2×10^{-7}	9×10^{-4}	7×10^{-9}	3×10^{-5}
		I	1×10^{-7}	6×10^{-4}	4×10^{-9}	2×10^{-5}
Terbium (65)	Tb 160	S	1×10^{-7}	1×10^{-3}	3×10^{-9}	4×10^{-5}
		I	3×10^{-6}	1×10^{-3}	1×10^{-9}	4×10^{-5}
Thallium (81)	Tl 200	S	3×10^{-6}	1×10^{-2}	9×10^{-8}	4×10^{-4}
		I	1×10^{-6}	7×10^{-3}	4×10^{-8}	2×10^{-4}
	Tl 201	S	2×10^{-6}	9×10^{-3}	7×10^{-8}	3×10^{-4}
		I	9×10^{-7}	5×10^{-3}	3×10^{-8}	2×10^{-4}
	Tl 202	S	8×10^{-7}	4×10^{-3}	3×10^{-8}	1×10^{-4}
		I	2×10^{-7}	2×10^{-3}	8×10^{-9}	7×10^{-5}
	Tl 204	S	6×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
		I	3×10^{-6}	2×10^{-3}	9×10^{-10}	6×10^{-5}

APPENDIX B TO §§ 20.1—20.602—CONCENTRATIONS IN AIR AND WATER ABOVE NATURAL BACKGROUND—Continued

[See footnotes at end of Appendix B]

Element (atomic number)	Isotope [1]		Table I		Table II	
			Col. 1—Air (μCi/ml)	Col. 2—Water (μCi/ml)	Col. 1—Air (μCi/ml)	Col. 2—Water (μCi/ml)
Thorium (90)	Th 227	S	3×10^{-10}	5×10^{-4}	1×10^{-11}	2×10^{-5}
		I	2×10^{-10}	5×10^{-4}	6×10^{-12}	2×10^{-5}
	Th 228	S	9×10^{-12}	2×10^{-4}	3×10^{-13}	7×10^{-6}
		I	6×10^{-12}	4×10^{-4}	2×10^{-13}	1×10^{-5}
	Th 230	S	2×10^{-12}	5×10^{-5}	8×10^{-14}	2×10^{-6}
		I	1×10^{-11}	9×10^{-4}	3×10^{-13}	3×10^{-5}
	Th 231	S	1×10^{-6}	7×10^{-3}	5×10^{-8}	2×10^{-4}
		I	1×10^{-6}	7×10^{-3}	4×10^{-8}	2×10^{-4}
	Th 232	S	3×10^{-11}	5×10^{-5}	1×10^{-12}	2×10^{-6}
		I	3×10^{-11}	1×10^{-3}	1×10^{-12}	4×10^{-5}
	Th natural	S	6×10^{-11}	6×10^{-5}	2×10^{-12}	2×10^{-6}
		I	6×10^{-11}	6×10^{-4}	2×10^{-12}	2×10^{-5}
	Th 234	S	6×10^{-8}	5×10^{-4}	2×10^{-9}	2×10^{-5}
		I	3×10^{-8}	5×10^{-4}	1×10^{-9}	2×10^{-5}
Thulium (69)	Tm 170	S	4×10^{-8}	1×10^{-3}	1×10^{-9}	5×10^{-5}
		I	3×10^{-8}	1×10^{-3}	1×10^{-9}	5×10^{-5}
	Tm 171	S	1×10^{-7}	1×10^{-2}	4×10^{-9}	5×10^{-4}
		I	2×10^{-7}	1×10^{-2}	8×10^{-9}	5×10^{-4}
Tin (50)	Sn 113	S	4×10^{-7}	2×10^{-3}	1×10^{-8}	9×10^{-5}
		I	5×10^{-8}	2×10^{-3}	2×10^{-9}	8×10^{-5}
	Sn 125	S	1×10^{-7}	5×10^{-4}	4×10^{-9}	2×10^{-5}
		I	8×10^{-8}	5×10^{-4}	3×10^{-9}	2×10^{-5}
Tungsten (Wolfram) (74)	W 181	S	2×10^{-6}	1×10^{-2}	8×10^{-8}	4×10^{-4}
		I	1×10^{-7}	1×10^{-2}	4×10^{-9}	3×10^{-4}
	W 185	S	8×10^{-7}	4×10^{-3}	3×10^{-8}	1×10^{-4}
		I	1×10^{-7}	3×10^{-3}	4×10^{-9}	1×10^{-4}
	W 187	S	4×10^{-7}	2×10^{-3}	2×10^{-8}	7×10^{-5}
		I	3×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-5}
Uranium (92)	U 230	S	3×10^{-10}	1×10^{-4}	1×10^{-11}	5×10^{-6}
		I	1×10^{-10}	1×10^{-4}	4×10^{-12}	5×10^{-6}
	U 232	S	1×10^{-10}	6×10^{-4}	3×10^{-12}	3×10^{-5}
		I	3×10^{-11}	6×10^{-4}	9×10^{-13}	3×10^{-5}
	U 233	S	5×10^{-10}	9×10^{-4}	2×10^{-11}	3×10^{-5}
		I	1×10^{-10}	9×10^{-4}	4×10^{-12}	3×10^{-5}
	U 234	S [4]	6×10^{-10}	9×10^{-4}	2×10^{-11}	3×10^{-5}
		I	1×10^{-10}	9×10^{-4}	4×10^{-12}	3×10^{-5}
	U 235	S [4]	5×10^{-10}	8×10^{-4}	2×10^{-11}	3×10^{-5}
		I	1×10^{-10}	8×10^{-4}	4×10^{-12}	3×10^{-5}
	U 236	S	6×10^{-10}	1×10^{-3}	2×10^{-11}	3×10^{-5}
		I	1×10^{-10}	1×10^{-3}	4×10^{-12}	3×10^{-5}
	U 238	S [4]	7×10^{-11}	1×10^{-3}	3×10^{-12}	4×10^{-5}
		I	1×10^{-10}	1×10^{-3}	5×10^{-12}	4×10^{-5}
	U 240	S	2×10^{-7}	1×10^{-3}	8×10^{-9}	3×10^{-5}
		I	2×10^{-7}	1×10^{-3}	6×10^{-9}	3×10^{-5}
	U-natural	S [4]	1×10^{-10}	1×10^{-3}	5×10^{-12}	3×10^{-5}
		I	1×10^{-10}	1×10^{-3}	5×10^{-12}	3×10^{-5}
Vanadium (23)	V 48	S	2×10^{-7}	9×10^{-4}	6×10^{-9}	3×10^{-5}
		I	6×10^{-8}	8×10^{-4}	2×10^{-9}	3×10^{-5}
Xenon (54)	Xe 131m	Sub	2×10^{-5}		4×10^{-7}	
	Xe 133	Sub	1×10^{-5}		3×10^{-7}	
	Xe 133m	Sub	1×10^{-5}		3×10^{-7}	
	Xe 135	Sub	4×10^{-6}		1×10^{-7}	
Ytterbium (70)	Yb 175	S	7×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
		I	6×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
Yttrium (39)	Y 90	S	1×10^{-7}	6×10^{-4}	4×10^{-9}	2×10^{-5}
		I	1×10^{-7}	6×10^{-4}	3×10^{-9}	2×10^{-5}
	Y 91m	S	2×10^{-5}	1×10^{-1}	8×10^{-7}	3×10^{-3}
		I	2×10^{-5}	1×10^{-1}	6×10^{-7}	3×10^{-3}
	Y 91	S	4×10^{-8}	8×10^{-4}	1×10^{-9}	3×10^{-5}
		I	3×10^{-8}	8×10^{-4}	1×10^{-9}	3×10^{-5}
	Y 92	S	4×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-5}
		I	3×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-5}
	Y 93	S	2×10^{-7}	8×10^{-4}	6×10^{-9}	3×10^{-5}
		I	1×10^{-7}	8×10^{-4}	5×10^{-9}	3×10^{-5}

APPENDIX B TO §§ 20.1—20.602—CONCENTRATIONS IN AIR AND WATER ABOVE NATURAL BACKGROUND—Continued

[See footnotes at end of Appendix B]

Element (atomic number)	Isotope [1]		Table I		Table II	
			Col. 1—Air (μCi/ml)	Col. 2—Water (μCi/ml)	Col. 1—Air (μCi/ml)	Col. 2—Water (μCi/ml)
Zinc (30)	Zn 65	S	1×10^{-7}	3×10^{-3}	4×10^{-9}	1×10^{-4}
		I	6×10^{-8}	5×10^{-3}	2×10^{-9}	2×10^{-4}
	Zn 69m	S	4×10^{-7}	2×10^{-3}	1×10^{-8}	7×10^{-5}
		I	3×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-5}
	Zn 69	S	7×10^{-6}	5×10^{-2}	2×10^{-7}	2×10^{-3}
		I	9×10^{-6}	5×10^{-2}	3×10^{-7}	2×10^{-3}
Zirconium (40)	Zr 93	S	1×10^{-7}	2×10^{-2}	4×10^{-9}	8×10^{-4}
		I	3×10^{-7}	2×10^{-2}	1×10^{-8}	8×10^{-4}
	Zr 95	S	1×10^{-7}	2×10^{-3}	4×10^{-9}	6×10^{-5}
		I	3×10^{-8}	2×10^{-3}	1×10^{-9}	6×10^{-5}
	Zr 97	S	1×10^{-7}	5×10^{-4}	4×10^{-9}	2×10^{-5}
		I	9×10^{-8}	5×10^{-4}	3×10^{-8}	2×10^{-5}
Any single radionuclide not listed above with decay mode other than alpha emission or spontaneous fission and with radioactive half-life less than 2 hours.		Sub	1×10^{-6}		3×10^{-8}	
Any single radionuclide not listed above with decay mode other than alpha emission or spontaneous fission and with radioactive half-life greater than 2 hours.			3×10^{-9}	9×10^{-5}	1×10^{-10}	3×10^{-6}
Any single radionuclide not listed above, which decays by alpha emission or spontaneous fission.			6×10^{-13}	4×10^{-7}	2×10^{-14}	3×10^{-8}

[1] Soluble (S); Insoluble (I).

[2] "Sub" means that values given are for submersion in a semispherical infinite cloud of airborne material.

[3] These radon concentrations are appropriate for protection from radon-222 combined with its short-lived daughters. Alternatively, the value in Table I may be replaced by one-third (⅓) "working level." (A "working level" is defined as any combination of short-lived radon-222 daughters, polonium-218, lead-214, bismuth-214 and polonium-214, in one liter of air, without regard to the degree of equilibrium, that will result in the ultimate emission of 1.3×10^{5} MeV of alpha particle energy.) The Table II value may be replaced by one-thirtieth (1/30) of a "working level." The limit on radon-222 concentrations in restricted areas may be based on an annual average.

[4] For soluble mixtures of U-238, U-234 and U-235 in air chemical toxicity may be the limiting factor. If the percent by weight-enrichment) of U-235 is less than 5, the concentration value for a 40-hour workweek, Table I, is 0.2 milligrams uranium per cubic meter of air average. For any enrichment, the product of the average concentration and time of exposure during a 40-hour workweek shall not exceed 8×10^{-3} SA μCi-hr/ml, where SA is the specific activity of the uranium inhaled. The concentration value for Table II is 0.007 milligrams uranium per cubic meter of air. The specific activity for natural uranium is 6.77×10^{-7} curies per gram U. The specific activity for other mixtures of U-238, U-235 and U-234, if not known, shall be:

$SA = 3.6\times10^{-7}$ curies/gram U U-depleted

$SA = (0.4 + 0.38\,E + 0.0034\,E^{2})\,10^{-6}$ $E \geq 0.72$

where E is the percentage by weight of U-235, expressed as percent.

NOTE: In any case where there is a mixture in air or water of more than one radionuclide, the limiting values for purposes of this Appendix should be determined as follows:

1. If the identity and concentration of each radionuclide in the mixture are known, the limiting values should be derived as follows: Determine, for each radionuclide in the mixture, the ratio between the quantity present in the mixture and the limit otherwise established in Appendix B for the specific radionuclide when not in a mixture. The sum of such ratios for all the radionuclides in the mixture may not exceed "1" (i.e., "unity")

EXAMPLE: If radionuclides A, B, and C are present in concentrations C_A, C_B, and C_C, and if the applicable MPC's, are MPC_A, and MPC_B, and MPC_C respectively, then the concentrations shall be limited so that the following relationship exists:

$(C_A/MPC_A)+(C_B/MPC_B)+(C_C/MPC_C) \leq 1$

2. If either the identity or the concentration of any radionuclide in the mixture is not known, the limiting values for purposes of Appendix B shall be:

a. For purposes of Table I, Col. 1—6×10^{-13}

b. For purposes of Table I, Col. 2—4×10^{-7}

c. For purposes of Table II, Col. 1—2×10^{-14}

d. For purposes of Table II, Col. 2—3×10^{-8}

3. If any of the conditions specified below are met, the corresponding values specified below may be used in lieu of those specified in paragraph 2 above.

a. If the identity of each radionuclide in the mixture is known but the concentration of one or more of the radionuclides in the mixture is not known the concentration limit for the mixture is the limit specified in Appendix "B" for the radionuclide in the mixture having the lowest concentration limit; or

b. If the identity of each radionuclide in the mixture is not known, but it is known that certain radionuclides specified in Appendix "B" are not present in the mixture, the concentration limit for the mixture is the lowest concentration limit specified in Appendix "B" for any radionuclide which is not known to be absent from the mixture; or

c. Element (atomic number) and isotope	Table I		Table II	
	Col. 1—Air (μCi/ml)	Col. 2—Water (μCi/ml)	Col. 1—Air (μCi/ml)	Col. 2—Water (μCi/ml)
If it is known that Sr 90, I 125, I 126, I 129, I 131 (I 133, Table II only), Pb 210, Po 210, At 211, Ra 223, Ra 224, Ra 226, Ac 227, Ra 228, Th 230, Pa 231, Th 232, Th-nat, Cm 248, Cf 254, and Fm 256 are not present		9×10^{-5}		3×10^{-6}
If it is known that Sr 90, I 125, I 126, I 129 (I 131, I 133, Table II only), Pb 210, Po 210, Ra 223, Ra 226, Ra 228, Pa 231, Th-nat, Cm 248, Cf 254, and Fm 256 are not present		6×10^{-5}		2×10^{-6}
If it is known that Sr 90, I 129 (I 125, I 126, I 131, Table II only), Pb 210, Ra 226, Ra 228, Cm 248, and Cf 254 are not present		2×10^{-5}		6×10^{-7}
If it is known that (I 129, Table II only), Ra 226, and Ra 228 are not present		3×10^{-6}		1×10^{-7}
If it is known that alpha-emitters and Sr 90, I 129, Pb 210, Ac 227, Ra 228, Pa 230, Pu 241, and Bk 249 are not present	3×10^{-9}		1×10^{-10}	
If it is known that alpha-emitters and Pb 210, Ac 227, Ra 228, and Pu 241 are not present	3×10^{-10}		1×10^{-11}	
If it is known that alpha-emitters and Ac 227 are not present	3×10^{-11}		1×10^{-12}	
If it is known that Ac 227, Th 230, Pa 231, Pu 238, Pu 239, Pu 240, Pu 242, Pu 244, Cm 248, Cf 249 and Cf 251 are not present	3×10^{-12}		1×10^{-13}	

4. If a mixture of radionuclides consists of uranium and its daughters in ore dust prior to chemical separation of the uranium from the ore, the values specified below may be used for uranium and its daughters through radium-226, instead of those from paragraphs 1, 2, or 3 above.

a. For purposes of Table I, Col. 1—1×10^{-10} μCi/ml gross alpha activity; or 5×10^{-11} μCi/ml natural uranium or 75 micrograms per cubic meter of air natural uranium.

b. For purposes of Table II, Col. 1—3×10^{-12} μCi/ml gross alpha activity; 2×10^{-12} μCi/ml natural uranium; or 3 micrograms per cubic meter of air natural uranium.

5. For purposes of this note, a radionuclide may be considered as "not present in a mixture if (a) the ratio of the concentration of that radionuclide in the mixture (C_A) to the concentration limit for that radionuclide specified in Table II of Appendix "B" (MPC_A) does not exceed 1/10, (i.e. $C_A/MPC_A \leq 1/10$) and (b) the sum of such ratios for all the radionuclides considered as not present in the mixture does not exceed ¼ i.e.

$(C_A/MPC_A + C_B/MPC_B \ldots\ldots + \leq ¼)$.

APPENDIX C

EMS SOFTWARE DOCUMENTATION

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EMS SOFTWARE DOCUMENTATION
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APPENDIX C: EMS SOFTWARE DOCUMENTATION

ATTACHMENT 1: EFFLUENT MANAGEMENT SYSTEM SOFTWARE TEST REPORT FOR SEABROOK STATION, MAY 1994

EFFLUENT MANAGEMENT SYSTEM:
SOFTWARE TEST REPORT
FOR
SEABROOK STATION
MAY 1994

Prepared by Joseph Brien — 5/26/94 Date

Matthew J. Iannelli — 5/27/94 Date

Reviewed by Michael S. Strum — 5-31-94 Date

Approved by R. H. Whitfield — 5/31/94 Date

Yankee Atomic Electric Company
Nuclear Services Division
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Bolton, Massachusetts 01740

Table of Contents

1.0 INTRODUCTION

Software testing as described in Reference [1] has been conducted for the Seabrook Station version of the Canberra Effluent Management System (EMS). The results and conclusions are presented in this report.

1.1 Background

Canberra Industries Inc. developed the EMS software to assist nuclear power plant personnel track effluent emissions and perform associated dose calculations. North Atlantic Energy Service Corporation purchased a Seabrook-specific version the Canberra EMS software which must meet specific requirements and incorporate site-specific information provided in the Offsite Dose Calculation Manual (ODCM) [2]. Software testing was conducted to provide assurances that the Seabrook EMS program produces results which are consistent with current ODCM assumptions and methods. All executions of the EMS program were performed at Seabrook Station on the target software. All executions of ODCM Method II were conducted at Yankee Atomic Electric Company in Bolton, Massachusetts.

1.2 Acceptance Criteria

The operability of the EMS software will be accepted if (i) information contained in the EMS data files is consistent with the ODCM, (ii) test results from the EMS program are consistent with results from ODCM methods, (iii) Technical Specifications requirements are met by the EMS software, and (iv) the EMS software meets design specifications.

Final user (Seabrook) acceptance is contingent on Seabrook approval of verification testing results and criteria established by user needs.

2.0 SUMMARY OF OBSERVATIONS

The EMS software testing included (i) identifying appropriate meteorological set up data, (ii) review of dose and dose rate conversion factor development, (iii) assessments for liquid releases, and (iv) assessments for gaseous releases. ODCM Method I was used initially to confirm dose results from the EMS program. However, the simplified nature of ODCM Method I made it difficult to change the values of various parameters or obtain meaningful comparisons (other than "bottom line" comparisons). The more adaptable ODCM method, Method II, was then used to confirm EMS doses. Observations made during the software testing are summarized below.

2.1 EMS Dose and Dose Rate Conversion Factors

The EMS software uses precalculated conversion factors which are contained in a data file. The dose conversion factors for both liquid and gaseous effluent releases were developed for four age groups (adult, teen, child and infant), and for specific organs (bone, liver, total body, kidney, lung, GI tract and skin). The liquid release dose conversion factors in the EMS program are the summation of the components for water recreation and ingestion of aquatic foods. The gaseous release dose conversion factors are exposure pathway-specific (e.g., inhalation, ground plane, milk ingestion, etc.).

Dose conversion factors are provided in the EMS program for all exposure pathways addressed in the ODCM. The development of all dose conversion factors in the EMS program followed the pathway-specific equations in the Effluent Management System Technical Reference Manual [3]. The EMS conversion factors for several radionuclides were examined to determined that the development process was consistent to the Technical Reference Manual and the ODCM.

2.1.1 Liquid Release Dose Conversion Factors

Although the individual components for the ingestion of aquatic foods were found to be consistent with the ODCM, a discrepancy was discovered in the water recreation component. The mixing ratio for shoreline activity used in the development of the EMS dose factors is equal to 0.025. While this value is inconsistent with ODCM Method I (which employs a mixing ratio of 0.1), it is consistent with ODCM Method II. It is identified as a discrepancy because it is unclear which set of ODCM assumptions (those for Method I or those for Method II) the EMS program is expected to adopt.

2.1.2 Gaseous Release Dose Conversion Factors

The EMS program uses dose conversion factors from Regulatory Guide 1.109 for assessment of noble gas releases. The dose factors in the EMS program were verified against and found to be consistent with Table B-1 of Regulatory Guide 1.109 [4].

The development methods for the other gaseous dose factors (i.e., for inhalation, ground plane, milk ingestion, meat ingestion, and ingestion of vegetables) were reviewed against applicable equations in the Technical Reference Manual and information in the ODCM. It is noted that the dose factors for ingestion of milk and meat are based on the fraction of year that animals are allowed to graze on pasture land (Fp) equal to 1.0. This is not consistent with the ODCM which calls for the use of an Fp value equal to 0.5.

The dose conversion factors in the EMS program for gaseous releases incorporate a shielding factor (SF) equal to 1.0. The EMS program is designed with a way of changing the value of SF (via use of the Options Table), but the factor is applied uniformly to both doses and dose rates. In contrast, the ODCM calls for the use of different values for SF in the calculations for doses and

dose rates.

2.2 Liquid Release Testing

Dose estimates from the EMS program for hypothetical liquid effluent discharges (containing single nuclide and radionuclide mixtures) are nearly identical to results from ODCM Method II when input data are based on the same mixing ratio value, indicating that the calculation method used in the EMS program is consistent with the ODCM. Additionally, the EMS routine(s) responsible for liquid effluent concentrations comparisons to MPC values and monitor set point determinations was observed to be operating properly.

2.3 Gaseous Release Testing

The agreement between estimates for total body dose rates, skin dose rates, and air (gamma and beta) doses due to emission of noble gases from the ODCM methods and the EMS program is excellent, indicating that the EMS calculation method is consistent with the ODCM.

There is also excellent agreement between inhalation doses from the EMS program and ODCM Method II indicating that, for the inhalation pathway, the calculational method and assumptions in the EMS program are consistent with those in the ODCM. The evaluation of the dose estimates via inhalation pathway included both long and short release durations for an elevated (mixed mode) and a ground level release point. The excellent agreement between the EMS and ODCM Method II also confirms that the release duration adjustment term, t^{-a}, is applied properly in the EMS program. However, an incorrect receptor location was reported on the EMS printout in the tests (D-2c and D-2d) in which the Plant Vent was changed to be recognized as a ground level release point.

Also noted during testing was that the EMS routine(s) responsible for calculating effluent concentration-to-MPC ratios and radionuclide release rates

appears to be operating properly for gaseous releases.

The EMS program incorporates the assumption that the fraction of elemental iodine is equal to 1.0 (consistent with NUREG-0133 [5]). In contrast, the fraction of elemental iodine is assumed equal to 0.5 in the ODCM methods (consistent with Regulatory Guide 1.109). Consequently, the EMS program produces dose estimates due to radioiodine that are at least a factor of two greater than doses from the ODCM methods. This difference increases to about a factor of 4 when the current values for Fp and SF assumed in the EMS program and ODCM methods are used in the dose calculations. The different assumptions for elemental iodine fractions should not present a problem because each program is based on NRC guidance: the EMS is based on NUREG-0133, the ODCM methods are based on Regulatory Guide 1.109. The EMS program takes the more conservative approach for determining doses from radioiodine.

Making appropriate adjustments for Fp, SF, and the fraction of elemental iodine (when radioiodine input was used) and comparing results for organ doses due to I131, H3, Co60 and Cs137 revealed that the calculational methods used in the EMS program are consistent with the ODCM for all exposure pathways (i.e., ground plane, inhalation, milk ingestion, meat ingestion, and vegetables ingestion).

Technical Specification 3.11.2.1 and the ODCM require the calculation of organ dose rates due to effluent discharges of I131, I133, H3 and particulates with a half-life greater than 8 days. However, in all test cases involving these types of nuclides, organ dose rate information did not appear on Page 4 of the EMS printout. Instead, the message "No calculations performed - check Sample & Receptors" appeared. The EMS set up data and input were reviewed with no apparent error identified. Since the test cases included Cs137, Co60, I131, and

H3, the missing dose rate information was unexpected. It is noted that organ dose rate information was provided on Page 4 of the EMS printout during a demonstration of the EMS program prior to testing.

3.0 TEST CONCLUSIONS

Although the dose conversion factors are based on information which is not completely consistent with the assumptions in the ODCM, the calculational methods used to determine doses from liquid and gaseous effluent discharges are consistent with the ODCM methods.

Other conclusions are:

1. As stated in Section 2.1.1, the development of the EMS liquid effluent dose factors is consistent with ODCM Method II, but not with Method I due to the mixing ratio value. If the EMS program is intended to be a hybrid method, the dose factors are consistent with the ODCM and are acceptable. On the other hand, if the EMS program is intended to provide automated ODCM Method I calculations, then the dose factor should be recalculated using a mixing ratio for shoreline activity equal to 0.1.

2. Since the EMS program is not designed to support the use of two shielding factors (one for dose rates and one for doses), use of a shielding factor equal to 1.0 is acceptable with the understanding that, although the dose rates produced by the EMS program will be consistent with the ODCM, the doses from the EMS program will be based on a more conservative assumption than doses from the ODCM methods.

3. Under the normal ODCM assumption for elemental iodine, the results from the EMS program will be at least a factor of two greater than results from the ODCM methods. The different assumptions regarding the elemental iodine fraction do not present a problem because each program is based on NRC guidance: the EMS program is based on NUREG-0133, and the ODCM is based on Regulatory Guide 1.109. Of the two methods, the EMS program takes the more conservative approach toward estimating doses from

radioiodine in gaseous effluent.

4. The radiation monitor set point determination method for liquid releases produces a set point value that is consistent the ODCM set point method.

5. The EMS routine that is responsible for comparison of liquid effluent concentrations and MPC values is operating properly.

6. The release duration adjustment term, t^{-a}, is used consistently to the ODCM.

4.0 SUMMARY OF DISCREPANCIES

Discrepancy	Area of Impact	Potential Solution(s)
Mixing ratio for shoreline activity used in EMS program.	Doses associated with liquid effluent discharges.	Clarify whether the EMS program is expected to follow ODCM assumptions for Method I or Method II. If determined to follow Method I, recalculate dose factors for liquid releases.
EMS dose factors based on Fp value which is not consistent with ODCM.	Doses due to ingestion of milk and meat.	Recalculate EMS dose factors for milk and meat ingestion pathways to incorporate Fp value consistent with the ODCM. Accept added conservatism in EMS in calculations of doses via milk and meat ingestion pathways.
Shielding factor (SF) applied uniformly to dose rates and doses in EMS program.	Doses associated with gaseous effluent discharges.	Accept use of SF = 1.0 and the added conservatism for doses. Modify EMS software to accommodate use of two values for SF (one for dose rates and one for doses).
Incorrect receptor location identified on EMS printout for ground level release point.	Potential assignment of doses to the wrong receptor.	Discuss with Canberra.
Assumed fraction of elemental iodine used in EMS program differs from ODCM methods.	Dose estimates due to iodine in gaseous effluents.	Accept added conservatism in doses due to iodine. Modify EMS software to use fraction for elemental iodine that is consistent with ODCM.

Discrepancy	Area of Impact	Potential Solution(s)
Missing organ dose rate information on EMS printout for effluent discharges containing I131, I133, H3, and particulates.	Technical Specification required dose rate not calculated.	Discuss with Canberra.

References

1. Yankee Atomic Electric Company, Effluent Monitoring System Software Test Plan for Seabrook Station, May, 1994.

2. NAESC, Station Offsite Dose Calculation Manual, Rev 13, 9/24/93.

3. Southern Nuclear Operating Company Effluent Management System Technical Reference Manual (07-0545), January 1993.

4. NRC Regulatory Guide 1.109, Calculation of Annual Doses to Man from Routine Releases of Reactor Effluents for the Purposes of Evaluating Compliance with 10CFR Part 50, Appendix I, Revision I, October 1977.

5. NRC NUREG-0133, Preparation of Radiological Effluent Technical Specifications for Nuclear Power Plants, October 1978.

ATTACHMENT 2: RESOLUTIONS OF EMS SOFTWARE TEST REPORT DISCREPANCIES

2. Resolution of EMS Software Test Report Discrepancies

The following discrepancy resolutions apply to the findings contained in the "Effluent Management System Test Report for Seabrook Station, May 1994" as noted on pages 9 and 10 (see Attachment #1 of Appendix C of the ODCM). With the positive resolution of the discrepancies identified in the EMS dose code, use of EMS as a computerized alternative approach (designated as Method IA in the ODCM) to determine compliance with the radioactive effluent dose and dose rate limits is acceptable since the results are comparable with the currently approved dose methods.

Discrepancy:

Mixing ratio for shoreline activity used in EMS Program not equal to the value used in the ODCM Method I (Mp = 1.0).

Resolution:

The mixing ratio for the shoreline activity pathway in the EMS is consistent with the ODCM Method II approved value of 0.025, and therefore does provide for a calculated dose that is within the parameters already approved in the ODCM. The use of the EMS code (ODCM Method IA) for calculating liquid doses is acceptable for determining compliance with the dose limits of the Technical Specifications without the need to modify the assumption used for the shoreline mixing ratio.

Discrepancy:

EMS dose factors based on Fp (fraction of year animals are on pasture) value which is not consistent with ODCM.

Resolution:

ODCM Method I assumes that the pasture season in the North East is 6 months long each year (Fp + 0.5). Method II allows for the pasture fraction to be set equal to 0.0 for the first and fourth quarters which equates the non-growing period of the year. The second and third quarters correspond to the growing season where the pasture fraction is assumed to be 1.0. The EMS software assumes an Fp value of 1.0 for animal grazing (meat and milk pathways) for all conditions. This is a moderately conservative approach compared to Method I and the off grazing season conditions modeled in Method II. It is equal to the grazing season assumptions of Method II as applied in the second and third quarters. As a result, the added conservatism in the EMS calculations for doses via milk and meat pathways are within acceptable margins and guidance provided in NRC NUREG-0133 for demonstrating compliance with Technical Specification dose limits. No changes to the EMS software are necessary.

Discrepancy:

Shielding factors (SF) applied uniformly to dose rates and doses in the EMS program.

2. Resolution of EMS Software Test Report Discrepancies (Continued)

Resolution:

The EMS program for gaseous releases incorporates a shielding factor (SF) equal to 1.0 for both dose rate and total dose determinations. In contrast, both Method I and II use a SF value of 1.0 instantaneous dose rate calculations, but a value of 0.7 for integrated doses based on assumptions in NRC Reg. Guide 1.109. The use of a SF equal to 1.0 for the external ground plane exposure pathway for both dose rate and total dose is a moderately conservative assumption that is within the bounds already assumed in the ODCM dose modeling. As a result, no modification to the EMS code as an acceptable approach (Method IA) for demonstrating compliance with Technical Specification dose/dose rate limits is required for SF.

Discrepancy:

Incorrect receptor location identified on EMS printout for ground level release point.

Resolution:

Incorrect name is identified on report with no impact on dose or dose rate calculations which were verified to be correct.

Discrepancy:

Assumed fraction of elemental iodine used in EMS program differs from ODCM Methods I and II.

Resolution:

For ODCM Methods I and II, the fraction of elemental iodine assumed for gaseous releases in 0.5 based on the guidance in NRC Reg. Guide 1.109. The EMS code assumes an elemental iodine fraction of 1.0 based on the guidance in NUREG-0133. Consequently, the EMS program (Method IA) will produce a moderately conservative estimate of dose impact (factor of 2) for iodine radionuclides if present in the release estimations when compared to existing approved methods. As a result, no modification to the EMS code is necessary for use in the ODCM for determining compliance with Technical Specification dose limits.

Discrepancy:

Missing organ dose rate information on EMS printout for effluent discharges containing I-131, I-133, H-3, and particulates.

Resolution:

This required information is easily obtainable from the permit closure process with flashing indication if any dose or dose rate limits are exceeded.

ATTACHMENT 3: SOFTWARE REQUIREMENTS SPECIFICATION FOR NORTH ATLANTIC ENERGY SERVICE CORPORATION, SEABROOK STATION, EFFLUENT MANAGEMENT SYSTEMS, REVISION 04, FP 75486

Software Requirements Specification
for
North Atlantic Energy Services Corporation
Seabrook Station
Effluent Management Systems
48-8448

Revision 04

Nuclear Data Systems Division Software Product

Originator: David J. Homan WJW 9/15/93 Date: 9/14/93

Approved: Peter van der Heide Date: 9/15-93
Engineering (CI/NDS)

Approved: Date: 9/20/93
Quality Assurance Manager(CI/NDS)

Approved: Date: 10/29/93
Project Manager (Seabrook Station)

Revision History

Initials	Revision	Date	Description
DJH	00	2/26/93	Initial version
DJH	01	3/22/93	Updated incorrect dose equation
DJH	02	4/30/93	Updated to include all dose and dose rate equations
DJH	03	8/3/93	Updated based on modifications to software and customer's requested modification to the use of the default nuclide for gaseous permit processing.
DJH	04	9/14/93	Updated based on customer's request to remove modification to the default nuclide for gaseous permit processing.

1. Scope

This document establishes the software requirements for the Effluent Management System (EMS) software to be installed at North Atlantic Energy Services Corporation's Seabrook Station.

2. Applicable Documents

2.1 The following two documents are included as part of this SRS, and this SRS refers to specific sections of them:

2.1.1 "Southern Nuclear Operating Company Effluent Management System Operator's Manual" (07-0544), Version 1, January 1993.

2.1.2 "Southern Nuclear Operating Company Effluent Management System Technical Reference Manual" (07-0545), Version 2, January 1993.

Note: The above documents contain material (including screens and report formats) imported from final manuals for other EMS packages. Utility and plant names shown on screens and reports in these manuals are not significant, since they are determined by database data that will be customized to fit the Seabrook Station's usage.

2.2 The following document is a reference source for calculation methods of the EMS software. This SRS may refer to specific sections.

2.2.1 "Seabrook Station Offsite Dose Calculation Manual," Revision 12, January 1993.

3. Interfaces

3.1 Hardware

The EMS software shall run on the following CPU model: DEC Microvax 3100, Model 80.

3.2 Software

The software shall be written under VMS version 5.4-2 or later, using INGRES version 6.4 or later. It shall be written in VAX/FORTRAN or VAX-DCL. Utility programs provided by INGRES that are installed on the hardware configuration may be used if applicable.

3.3 Human

The user may be expected to have received operator training from the system manager, Canberra/NDS, or the plant training department prior to using any part of the EMS software. Knowledge of INGRES or VMS shall not be assumed. The menus of operations are intended to be self-explanatory, but an Operator's Manual shall be developed.

The user may be expected to have enough knowledge of USNRC-regulated nuclear power plant effluent management to provide accurate and appropriate inputs, and to determine the validity of the software's results.

3.4 Packaging

A distribution kit will be produced for the customer. Any removable medium supported by the operating hardware delivered to the Seabrook Station is an acceptable distribution medium.

4. Definitions

EMS - Effluent Management System. Software for determining effluent monitor setpoints, tracking activity releases and dose impacts of individual releases, and generating semi-annual release reports.

SRS - Software Requirements Specification.

SNC - Southern Nuclear Operating Company

5. Principal Changes from Existing Package

The following paragraphs summarize the principal changes to the existing software that are required for the Seabrook Station system, and are intended only as introductory material. Specifics of the required Seabrook Station EMS functionality are presented in the following sections.

5.1 The EMS software will be developed by customizing the generic EMS package. In general, the most important changes from previous versions are as follows:

5.1.1 Modification to Gaseous Permit Processing to allow scaling of nuclides for Plant Vent Spike release point.

5.1.2 Modification of noble gas dose rate and dose calculation methods to use a third set of X/Q values.

5.1.3 Modification of noble gas dose rate and dose calculation methods to multiply X/Q and D/Q values by a factor depending on the release duration.

5.1.4 Modification to setpoint calculations to calculate setpoints for low gamma concentration releases.

5.1.5 Modification of Permit Processing to automatically correct the expected waste flow if it is greater than the calculated maximum waste flow.

5.1.6 Modification of Liquid Permit Processing to determine dilution flow rate based on the number of pumps operating.

5.1.7 Modification of the permit reports to include Month-to-Date Cumulative Doses and Alert Setpoints.

5.1.8 Modification of Post-Release Permit Processing to update the monitor response.

5.1.9 Addition of data to database to support and control the above operations.

6. EMS Functionality

6.1 Database Maintenance Transactions

The functionality of the EMS Database Maintenance transactions shall be described in section 2 of the EMS Operator's Manual (Reference 2.1.1), with the following revisions:

6.1.1 On the Release Point Setpoint transaction [EM-DM-RP (Form 2)], and the Discharge Point Setpoint transaction [EM-DM-DP (Form 2)], the following parameter shall be added to the list of those which can be entered, stored, and which appear on the printed report for these transactions:

- SCAL_NUC: For a gaseous release, a flag to denote that this release point will have nuclide concentrations scaled so that the total concentration matches a value entered by the user.

6.1.2 On the Release Point Setpoint transaction [EM-DM-RP (Form 2)] and the Discharge Point Setpoint transaction [EM-DM-DP (Form 2)], the following parameter shall be added to the list of those which can be entered, stored, and which appear on the printed report for these transactions:

- DILOOKUP: For a liquid release, a flag to denote that permits for this release point will have a selection screen appear for the user to select the proper dilution flow for the release based on the number of pumps operating.

6.1.3 On the Release Point Setpoint transaction [EM-DM-RP (Form 2)], and the Discharge Point Setpoint transaction [EM-DM-DP (Form 2)], the following parameter shall be added to the list of those which can be entered, stored, and which appear on the printed report for these transactions:

- DEF_NUC: For a liquid or gaseous release, this parameter will contain the default nuclide that will be used in setpoint calculations for low gamma concentration releases. This parameter is used in conjunction with the DEF_CONC parameter.

6.1.4 On the Release Point Setpoint transaction [EM-DM-RP (Form 2)], and the Discharge Point Setpoint transaction [EM-DM-DP (Form 2)], the following parameter shall be added to the list of those which can be entered, stored, and which appear on the printed report for these transactions:

- DEF_CONC: For a liquid or gaseous release, this parameter will contain the default concentration that will be used in setpoint calculations for low gamma concentration releases. This parameter is used in conjunction with the DEF_NUC parameter.

6.1.5 On the Release Point Setpoint transaction [EM-DM-RP (Form 2)], and the Discharge Point Setpoint transaction [EM-DM-DP (Form 2)], the following parameter shall be added to the list of those which can be entered, stored, and which appear on the printed report for these transactions:

- DEF_TYPE: For a liquid or gaseous release, this parameter will contain the default nuclide type that will be used in setpoint calculations for low gamma concentration releases. This parameter is used in conjunction with the DEF_NUC and DEF_CONC parameters. (Note: For a gaseous release, the default nuclide type shall determine which monitor setpoint should use the default nuclide and concentration.)

6.1.6 On the Release Point Setpoint transaction [EM-DM-RP (Form 2)], and the Discharge Point Setpoint transaction [EM-DM-DP (Form 2)], the following parameter shall be added to the list of those which can be entered, stored, and which appear on the printed report for these transactions:

- ALRT_SET: For a liquid or gaseous release, this parameter will contain the multiplier to be used in the calculation of Alert Alarm Setpoints for permit reports.

6.1.7 On the Release Point transaction [EM-DM-RP (Form 1)], the meaning of the Response Option will change. When set to "Y", this option will denote the display of a Monitor Response window during the Post-Release Permit Processing, rather than during the Pre-Release Permit Processing. The Response Option parameter, itself, will remain unchanged for this transaction, but the response entered should include the monitor background values.

6.1.8 On the Dilution Streams transaction [EM-DM-DS], the following parameters will be removed: the number of extra dilution flow rates and the four dilution flow rates.

These parameters will be replaced with two column fields. One column will contain the dilution flow rate, while another will contain the pump configuration description (such as "Jockey Pump" or "5"). In this transaction, the dilution flow rate for particular pump configuration can be added.

6.1.9 On the Meteorological Data transaction [EM-DM-ME (Form 1)], several menu options will added to the list of MET DATA TABLES. These additional menu items are as follows:

X/Q - Noble Gases (Gamma)
"a" Factor - D/Q-Part/Iodines
"a" Factor - Noble Gases
"a" Factor - X/Q-Part/Iodines
"a" Factor - Gamma Noble Gases

6.1.10 On the Meteorological Data transaction [EM-DM-ME (Form 1)], the following menu items will be used to store short-term (1 hour) D/Q and X/Q values.

D/Q - Partics/Radioiodines
X/Q - Partics/Radioiodines
X/Q - Decayed Noble Gases
X/Q - Noble Gases (Gamma)

Note: This specification item only denotes a change in the meaning for the values on this transaction and requires no further changes to the software.

6.1.11 On the Meteorological Data transaction [EM-DM-ME (Form 1)], the X/Q, D/Q, and "a" Factor values are defined for various elevations, distances, and directions from the plant vent or stack. This combination with the "mode of release" parameter on the Release Point transaction [EM-DM-RP (Form 1)], and the receptor definition on the Gas Receptors transaction [EM-DM-GR], allow the X/Q, D/Q, and "a" factors to be different for each receptor and/or release point.

Note: This specification item is only for clarification and no additional code changes need to be made to this transaction.

6.2 Editing Values through INGRES QBF

In addition to the interactive forms-based EMS Database Maintenance transactions, certain flags and values must be edited through INGRES QBF on the database tables which contain data not accessible through the forms-based transactions.

6.2.1 Some columns of the Quarterly Dilution Volume table (QDVOL), which has no other use in the Seabrook Station version of EMS, will be used for recording monthly dilution volume for use in semi-annual reports. Once per month, an authorized user will use QBF to append a record to the QDVOL table as follows:

sampleid	(sample ID)	0 [not used]
dvdate	(dilution volume date)	The first day of the month to which the volume applies (time not required).
tvol	(total volume)	Dilution volume for the month, in user units.
aflow	(average flowrate)	0 [not used]

6.3 Liquid Pre-Release Processing

6.3.1 User Interface and Functionality

Liquid Pre-Release Processing functionality for the EMS software shall be as described in section 3 of the EMS Operator's Manual (Reference 2.1.1), with the following revisions:

6.3.1.1 On the Liquid Permit Definition Screen (Screen 3.04):

Upon entering the permit definition screen, if the DILOOKUP parameter is set to "Y" for the release point associated with the current permit being processed, the Dilution Flow Rate parameter will default to zero.

If a user uses the "Tab" or "Return" key to exit the Dilution Flow Rate parameter on the Permit Definition Screen and the Dilution Flow Rate parameter has a value of zero, a selection screen with two columns of data will appear. One column will contain the pump configuration description, while the other will contain the dilution flow rate for each associated pump configuration.

Upon selection of the Dilution Flow Rate, the selection screen will disappear and the selected dilution flow rate will appear in the Dilution Flow Rate parameter on the Permit Definition Screen. The cursor will then automatically advance to the Dilution Volume Parameter.

6.3.1.2 On the Liquid Permit Definition Screen (Screen 3.04):

When a "Fill" (F14) or a "Save" (F10) without a "Fill" is executed, if the DILOOKUP parameter is set to "Y" for the release point associated with the current permit being processed and the Dilution Flow Rate parameter is set to zero, a selection screen, as described above will appear.

Once a selection of the Dilution Flow Rate is complete, the selection screen will disappear and the "Fill" operation will continue. Upon completion, the selected dilution flow rate will appear in the Dilution Flow Rate parameter on the Permit Definition Screen.

If the Dilution Flow Rate parameter on the Permit Definition Screen is not set to zero and the DILOOKUP parameter is set to "Y", the fill will proceed as normal <u>without</u> the dilution flow rate selection screen appearing.

6.3.1.3 Prior to entering the Liquid Permit Approval Screen (Screen 3.09):

If it is determined that the computed maximum waste flow is less than the anticipated waste flow, the anticipated waste flow will be changed to have the value of the computed maximum waste flow. If the anticipated waste flow is modified, setpoint, dose, and dose rate values will be recalculated based on the new value.

6.3.1.4 For releases with low or zero gamma emitter concentrations that result in a pre-diluted MPC ratio less than 10%, a default concentration will be used for setpoint calculations. This default concentration will not be used for updating curie, dose rates, or dose totals.

The default nuclide will be attained from the DEF_NUC parameter. The default concentration for this nuclide will be attained from the DEF_CONC parameter. The default type for this nuclide should be attained from the DEF_TYPE parameter.

6.3.1.5 The Monitor Response Screens for Release Points and Discharge Points (Screen 3.08) will no longer appear while processing a Pre-Release Permit when the Response Option is set to "Y" on the Release Point transaction [EM-DM-RP (Form 1)].

6.3.2 Associated Reports

Liquid Pre-Release Permit Reports shall be as described in section 3 (pages 3-53 through 3-58) of the EMS Operator's Manual (Reference 2.1.1), with the following revisions:

6.3.2.1 On the Pre-Release Permit Report (3.01), the Cumulative Month-to-Date Doses will appear on the page with the report category of Cumulative Maximum Individual Dose for Controlling Age Group at Controlling Location. The Month-to-Date dose values will contain the summation of the doses for all "Open" and "Closed" permits including the permit for which the report is being generated. These dose values will appear immediately below the "This Release" row of doses.

6.3.2.2 On the Pre-Release Permit Report (3.01), an Alert Alarm Setpoint will appear below the Max Monitor Setpoint Value. The Alert Alarm Setpoint will be calculated by using the multiplying the release point setpoint value by a multiplier specified with the ALRT_SET parameter mentioned above.

6.3.2.3 On the Liquid Special Report (3.02), an Alert Alarm Setpoint will appear below the Release Point and Discharge Point Setpoint values in the Radiation Monitor(s) portion of the report.

6.3.2.4 On the Pre-Release Permit Report (3.01), the calculation of setpoint data for additional dilution flow rates (under Pre-Release Calculations) will use dilution flow rate values from the Dilution Streams transaction [EM-DM-DS] for a specific dilution stream. Up to four dilution flow rates which are larger than the dilution flow rate parameter entered on the Liquid Permit Definition Screen (3.06) will be used.

6.3.3 Underlying Calculations

The calculations performed by the EMS software for Liquid Pre-Release Permits shall produce the same results as those described in Chapter 2 (sections 2.1-2.6) of the EMS Technical Reference Manual (Reference 2.1.2), with no revisions.

6.4 Liquid Post-Release Processing

6.4.1 User Interface and Functionality

Liquid Post-Release Processing functionality for the EMS software shall be as described in section 3 of the EMS Operator's Manual (Reference 2.1.1), with the following revisions:

6.4.1.1 On the Liquid Permit Definition Screen (Screen 3.13):

If the DILOOKUP parameter is set to "Y" for the release point and a user uses the "Tab" or "Return" key to exit the Dilution Flow Rate parameter on the Permit Definition Screen and the Dilution Flow Rate parameter has a value of zero, a selection screen with two columns of data will appear. One column will contain the pump configuration description, while the other will contain the dilution flow rate for each associated pump configuration.

Upon selection of the Dilution Flow Rate, the selection screen will disappear and the selected dilution flow rate will appear in the Dilution Flow Rate parameter on the Permit Definition Screen. The cursor will then automatically advance to the Dilution Volume Parameter.

6.4.1.2 On the Liquid Permit Definition Screen (Screen 3.13):

When a "Fill" (F14) or a "Save" (F10) without a "Fill" is executed, if the DILOOKUP parameter is set to "Y" for the release point associated with the current permit being processed and the Dilution Flow Rate parameter is set to zero, a selection screen, as described above will appear.

Once a selection of the Dilution Flow Rate is complete, the selection screen will disappear and the "Fill" operation will continue. Upon completion, the selected dilution flow rate will appear in the Dilution Flow Rate parameter on the Permit Definition Screen.

If the Dilution Flow Rate parameter on the Permit Definition Screen is not set to zero and the DILOOKUP parameter is set to "Y", the fill will proceed as normal without the dilution flow rate selection screen appearing.

6.4.1.3 (Item removed since actual waste flow is known at time of post release processing.)

6.4.1.4 The Monitor Response Screens for Release Points and Discharge Points (Screen 3.08) will appear while processing a Post-Release Permit when the Response Option is set to "Y" on the Release Point transaction [EM-DM-RP (Form 1)]. These screens will appear following the Nuclide Concentration Screen (Screen 3.15). The monitor response values entered should include the monitor background values.

6.4.2 Associated Reports

Liquid Post-Release Permit Report shall be as described in section 3 (pages 3-59 through 3-62 of the EMS Operator's Manual (Reference 2.1.1), with the following revisions:

6.4.2.1 On the Post-Release Permit Report (3.03), the Cumulative Month-to-Date Doses will appear on the page with the report category of Cumulative Maximum Individual Dose for Controlling Age Group at Controlling Location. The Month-to-Date dose values will contain the summation of the doses for all "Open" and "Closed" permits including the permit for which the report is being generated. These dose values will appear immediately below the "This Release" row of doses.

6.4.3 Underlying Calculations

The calculations performed by the EMS software for Liquid Post-Release Permits shall produce the same results as those described in Chapter 2 (section 2.7) of the EMS Technical Reference Manual (Reference 2.1.2), with no revisions.

6.5 Liquid Permit Editing

6.5.1 User Interface and Functionality

Functionality for editing liquid permits through the EMS software shall be as described in section 3 of the EMS Operator's Manual (Reference 2.1.1), with the following revisions:

The appearance and functionality of the liquid permit definition screen and the monitor response screen shall be modified as described for the Pre-Release stage in sections 6.3.1 and 6.4.1 above.

6.5.2 Associated Reports

The permit report format and contents for edited open and closed liquid permits shall be as specified above for original permit reports, in sections 6.3.2 and 6.4.2, respectively.

6.5.3 Underlying Calculations

The calculation methods for editing open and closed liquid permits shall be as specified above for original calculations, in sections 6.3.3 and 6.4.3, respectively.

6.6 Liquid Permit Deletion

Functionality for deleting liquid permits through the EMS software shall be described section 3 or the EMS operator's Manual (Reference 2.1.1).

6.7 Gaseous Pre-Release Processing

6.7.1 User Interface and Functionality

Gaseous Pre-Release Processing functionality for the EMS software shall be as described in section 4 of the EMS Operator's Manual (Reference 2.1.1), with the following revisions:

6.7.1.1 On the Gaseous Permit Definition Screen (Screen 4.05):

The Initial Pressure and Final Pressure parameters shall be deleted.

6.7.1.2 On the Gaseous Nuclide Concentration Screen (Screen 4.06):

If the SCAL_NUC parameter is set to "Y", when exiting the Concentration Screen by hitting "Process" (Do), the user will be prompted for the total nuclide concentration of permit. The concentrations are then "scaled" and then stored internally. As a result, the concentrations displayed on the screen will remain unchanged. (See the Underlying Calculations section for Pre-Release Permit Processing for an explanation of the "scaling" of concentrations.)

NOTE: This method requires the VAX_GSP (F12) file transfer has occurred bringing the representative nuclide concentration values to the screen prior to "Save" of data.

6.7.1.3 For releases with low or zero gamma emitter concentrations that result in a pre-diluted MPC ratio less than 10%, a default concentration will be used for setpoint calculations. This default concentration will not be used for updating curie, dose rates, or dose totals.

The default nuclide will be attained from the DEF_NUC parameter. The default concentration for this nuclide will be attained from the DEF_CONC parameter. The default type for the default nuclide should be attained from the DEF_TYPE parameter.

6.7.1.4 The Monitor Response Screens for Release Points and Discharge Points (Screen 4.08) will no longer appear while processing a Pre-Release Permit when the Response Option is set to "Y" on the Release Point transaction [EM-DM-RP (Form 1)].

6.7.1.5 Prior to entering the Gaseous Permit Approval Screen (Screen 4.09):

If it is determined that the computed maximum waste flow is less than the anticipated waste flow, the anticipated waste flow will be changed to have the value of the computed maximum waste flow. If the anticipated waste flow is modified, setpoint, dose, and dose rate values will be recalculated based on the new value.

6.7.2 Associated Reports

Gaseous Pre-Release Permit Reports shall be as described in section 4 (pages 4-49 through 4-58) of the EMS Operator's Manual (Reference 2.1.1), with the following revisions:

6.7.2.1 On the Pre-Release Permit Report (4.01), the Cumulative Month-to-Date Doses will appear on the pages with the report category of Cumulative Dose at Site Boundary and Cumulative Maximum Individual Dose for Controlling Age Group at Controlling Location. The Month-to-Date dose values will contain the summation of the doses for all "Open" and "Closed" permits including the permit for which the report is being generated. These dose values will appear immediately below the "This Release" row of doses.

6.7.2.2 On the Pre-Release Permit Report (4.01), the "scaled" noble gas concentrations shall appear on the Isotopic Identification page of the report if the SCAL_NUC parameter is set to "Y" for the release point where the release is being made.

6.7.2.3 On the Pre-Release Permit Report (4.01), the Noble Gas Alert Alarm Setpoint will appear below the Max Monitor Setpoint values. The Alert Alarm Setpoint will be calculated by multiplying the noble gas monitor setpoint value by a multiplier specified with the ALRT_SET parameter mentioned above.

6.7.2.4 On the Gaseous Special Report (4.02), the Noble Gas Alert Alarm Setpoint will appear below the Release Point and Discharge Point Setpoint values in the Radiation Monitor(s) portion of the report. It will be calculated as mentioned above.

6.7.2.5 On the Pre-Release Permit Report (4.01), the Initial and Final Pressure parameters will be removed from the Pre-Release Data section of page one of the report.

6.7.3 Underlying Calculations

The calculations performed by the EMS software for Gaseous Pre-Release Permits shall produce the same results as those described in Chapter 3 (section 3.1-3.6) of the EMS Technical Reference Manual (Reference 2.1.2), with the following revisions and clarifications:

6.7.3.1 Dose Calculations will appear in the site specific technical reference manual as follows:

- For Noble Gas Total Body Dose Rate (for vents or stacks < 80 meters):

$$D_t = shf \cdot X/Q_g \cdot 8760^{-a} \cdot F_o \cdot \Sigma (K_i \cdot QR_{iv})$$

where

D_t = the total body dose rate due to gamma emissions by noble gas releases from vent v (mrem/yr)

shf = shielding factor (dimensionless)

QR_{iv} = release rate of noble gas radionuclides, i, in gaseous effluents from vent or stack v (μCi/sec).

F_o = occupancy factor defined for the receptor at the given location (dimensionless)

K_i = total body dose factor due to gamma emissions for noble gas radionuclide I (mrem/yr per $\mu Ci/m^3$)

X/Q_g = highest value of the noble gas 1-hour X/Q for gamma radiation for vent or stack v at the site boundary, (sec/m^3)

8760^{-a} = adjustment factor used to convert the 1-hour X/Q value to an average 1 year X/Q value (dimensionless)

where

8760 = number of hours in a year

a = "a" factor for gamma noble gas X/Q

- For Noble Gas Total Body Dose (for vents or stacks < 80 meters):

$$D_{tb} = \frac{shf \cdot F_o \cdot \Sigma (K_i \cdot QR_{iv}) \cdot X/Q_g \cdot t^{-a}}{(5.256 \cdot 10^5 / dur)}$$

where

D_{tb} = total body dose from gaseous effluents (mrem)

$5.256 \cdot 10^5$ = number of minutes in a year

dur = duration of the release (minutes)

t^{-a} = adjustment factor to convert the 1-hour X/Q value to the short term X/Q value for the release (dimensionless)

where

t = duration of release (hours)

a = "a" factor for gamma noble gas X/Q

- For Noble Gas Skin Dose Rate (for vents or stacks < 80 meters):

$$D_S = shf \cdot F_o \cdot \Sigma\, QR_{iv} \cdot [(L_i \cdot X/Q \cdot 8760^{-b}) + (1.11 M_i \cdot X/Q_g \cdot 8760^{-a})]$$

where

D_S = skin dose rate from gaseous effluents (mrem/yr)

X/Q = highest value of the noble gas 1-hour X/Q for vent or stack v at the site boundary (sec/m^3)

M_i = air dose factor due to gamma emissions for noble gas radionuclide i (mrad/yr per $\mu Ci/m^3$)

1.11 = conversion factor from mrad to mrem

L_i = skin dose factor due to beta emissions for noble gas radionuclide i (mrem/yr per $\mu Ci/m^3$)

b = "a" factor for noble gas X/Q

- For Noble Gas Skin Dose (for vents or stacks < 80 meters):

$$D_{sk} = \frac{shf \cdot F_o \cdot \Sigma\, QR_{iv} \cdot [(L_i \cdot X/Q \cdot t^{-b}) + (1.11 M_i \cdot X/Q_g \cdot t^{-a})]}{(5.256 \cdot 10^5 / dur)}$$

where

D_{sk} = total skin dose from gaseous effluents (mrem)

- For Noble Gas Air Dose due to gamma radiation (for vents or stacks < 80 meters):

$$D_\gamma = (3.17 \cdot 10^{-8}) \cdot X/Q_g \cdot t^{-a} \cdot F_o \cdot \Sigma M_i \cdot Q_{iv}$$

where

D_γ = total gamma air dose from gaseous effluents (mrad)

$3.17 \cdot 10^{-8}$ = inverse of number of seconds in a year

Q_{iv} = release of noble gas radionuclides, i, in gaseous effluents from vent or stack v (μCi)

$$Q_{iv} = QR_{iv} \cdot dur \cdot 60$$

where

60 = number of seconds in a minute

- For Noble Gas Air Dose due to beta radiation (for vents or stacks < 80 meters):

$$D_\beta = (3.17 \cdot 10^{-8}) \cdot X/Q \cdot t^{-b} \cdot F_o \cdot \Sigma N_i \cdot Q_{iv}$$

where

D_β = total beta air dose from gaseous effluents (mrad)

N_i = air dose factor due to beta emissions for noble gas radionuclide i (mrad/yr per $\mu Ci/m^3$)

- For Critical Organ Dose Rate--Inhalation Pathway and all Pathways for H-3, C-14 (for vents or stacks < 80 meters):

$$DR_{\tau a} = X/Q_r \cdot 8760^{-c} \cdot \Sigma P_{ip\tau a} \cdot QR_{iv}$$

where

$DR_{\tau a}$ = dose rate for age group a and organ τ from iodines and particulates with half lives greater than 8 days in gaseous effluents (mrem/yr)

$P_{ip\tau a}$ = dose factor for each radionuclide i, pathway p, organ τ, and age group a (mrem/yr per $\mu Ci/m^3$)

X/Q_r = highest value of the radioiodine/particulate 1-hour X/Q for vent or stack v at the site boundary (sec/m^3)

c = "a" factor for Radioiodine/Particulate X/Q

Note: It is assumed $P_{ip\tau a}$ will not contain long term X/Q or D/Q values.

- For Critical Organ Dose Rate--Ground and Food Pathways (for vents or stacks < 80 meters):

$$DR_{\tau a} = D/Q \cdot 8760^{-d} \cdot \Sigma R_{ip\tau a} \cdot QR_{iv}$$

where

D/Q = highest value of the 1-hour deposition factor at the distance of the site boundary ($1/m^2$)

d = "a" factor for D/Q

$R_{ip\tau a}$ = dose factor for each radionuclide i, pathway p, organ τ, and age group a (m^2 • mrem/yr per μCi/sec)

Note: It is assumed $R_{ip\tau a}$ will not contain long term X/Q or D/Q values.

- For Critical Organ Dose-Inhalation Pathway and all Pathways for H-3, C-14 (for vents or stacks < 80 meters):

$$D_{\tau a} = (3.17 \cdot 10^{-8}) \cdot X/Q_r \cdot t^{-c} \cdot F_o \cdot \Sigma P_{ip\tau a} \cdot Q_{iv}$$

where

$D_{\tau a}$ = dose for age group a and organ τ from iodines and particulates with half lives greater than 8 days in gaseous effluents (mrem)

Note: It is assumed $P_{ip\tau a}$ will not contain long term X/Q or D/Q values.

- For Critical Organ Dose-Ground and Food Pathways (for vents or stacks < 80 meters):

$$D_{\tau a} = (3.17 \cdot 10^{-8}) \cdot D/Q \cdot t^{-d} \cdot F_o \cdot \Sigma R_{ip\tau a} \cdot Q_{iv}$$

Note: It is assumed $R_{ip\tau a}$ will not contain long term X/Q or D/Q values.

6.7.3.2 On the Nuclide Concentration Screen (Screen 4.06), nuclide concentrations will be "scaled" if the SCAL_NUC parameter is set properly for a Release Point. This "scaling" is described as follows:

$$C_{inew} = (t / s) \cdot C_i$$

where

C_{inew} = concentration (after "scaling") of nuclide$_i$
s = sum of all nuclide concentrations on the Nuclide Concentration Screen.
t = total nuclide concentration entered by the user
C_i = concentration (before "scaling") of nuclide$_i$

6.8 Gaseous Post-Release Processing

6.8.1 User Interface and Functionality

Gaseous Post-Release Processing functionality for the EMS software shall be as described in section 4 of the EMS Operator's Manual (Reference 2.1.1), with the following revisions:

6.8.1.1 On the Gaseous Permit Definition Screen (Screen 4.14):

The Initial Pressure and Final Pressure parameters shall be deleted.

6.8.1.2 On the Gaseous Nuclide Concentration Screen (Screen 4.15):

If the SCAL_NUC parameter is set to "Y", when exiting the Concentration Screen by hitting "Process" (Do), the user will be prompted for the total nuclide concentration of permit. The value entered for the total nuclide concentration while opening the permit shall be displayed as a default value which can be modified. Once the value is entered/accepted the concentrations are then "scaled" and then stored internally. As a result, the concentrations displayed on the screen will remain unchanged. (See the Underlying Calculations section for Post-Release Permit Processing for an explanation of the "scaling" of concentrations.)

NOTE: This method requires the VAX_GSP (F12) file transfer has occurred bringing the representative nuclide concentration values to the screen prior to "Save" of data.

6.8.1.3 The Monitor Response Screens for Release Points and Discharge Points (Screen 4.08) will appear while processing a Post-Release Permit when the Response Option is set to "Y" on the Release Point transaction [EM-DM-RP (Form 1)]. These screens will appear following the Nuclide Concentration Screen (Screen 4.15). The monitor response values should include the monitor background values.

6.8.1.4 (Item removed since actual waste flow is known at time of post release processing.)

6.8.2 Associated Reports

Gaseous Post-Release Permit Reports shall be as described in section 4 (pages 4-58 through 4-63) of the EMS Operator's Manual (Reference 2.1.1), with the following revisions:

6.8.2.1 On the Post-Release Permit Report (4.03), the Cumulative Month-to-Date Doses will appear on the pages with the report category of Cumulative Dose at Site Boundary and Cumulative Maximum Individual Dose for Controlling Age Group at Controlling Location. The Month-to-Date dose values will contain the summation of the doses for all "Open" and "Closed" permits including the permit for which the report is being generated. These dose values will appear immediately below the "This Release" row of doses.

6.8.2.2 On the Post-Release Permit Report (4.03), the "scaled" noble gas concentrations shall appear on the Isotopic Identification page of the report if the SCAL_NUC parameter is set to "Y" for the release point where the release is being made.

6.8.2.3 On the Post-Release Permit Report (4.03), the Initial and Final Pressure parameters will be removed from the Pre-Release Data section of page one of the report.

6.8.3 Underlying Calculations

The calculations performed by the EMS software for Gaseous Post-Release Permits shall produce the same results as those described in Chapter 3 (section 3.7) of the EMS Technical Reference Manual (Reference 2.1.2), with the following revisions and clarifications:

6.8.3.1 Dose Calculations will appear in the site specific technical reference manual as follows:

- For Noble Gas Total Body Dose Rate (for vents or stacks < 80 meters):

$$D_t = shf \cdot X/Q_g \cdot 8760^{-a} \cdot F_o \cdot \Sigma (K_i \cdot QR_{iv})$$

where

D_t = the total body dose rate due to gamma emissions by noble gas releases from vent v (mrem/yr)

shf = shielding factor (dimensionless)

QR_{iv} = release rate of noble gas radionuclides, i, in gaseous effluents from vent or stack v (μCi/sec).

F_o = occupancy factor defined for the receptor at the given location (dimensionless)

K_i = total body dose factor due to gamma emissions for noble gas radionuclide i (mrem/yr per $\mu Ci/m^3$)

X/Q_g = highest value of the noble gas 1-hour X/Q for gamma radiation for vent or stack v at the site boundary, (sec/m^3)

8760^{-a} = adjustment factor used to convert the 1-hour X/Q value to an average 1 year X/Q value (dimensionless)

where

8760 = number of hours in a year

a = "a" factor for gamma noble gas X/Q

- For Noble Gas Total Body Dose (for vents or stacks < 80 meters):

$$D_{tb} = \frac{shf \cdot F_o \cdot \Sigma (K_i \cdot QR_{iv}) \cdot X/Q_g \cdot t^{-a}}{(5.256 \cdot 10^5 / dur)}$$

where

D_{tb} = total body dose from gaseous effluents (mrem)

$5.256 \cdot 10^5$ = number of minutes in a year

dur = duration of the release (minutes)

t^{-a} = adjustment factor to convert the 1-hour X/Q value to the short term X/Q value for the release (dimensionless)

where

t = duration of release (hours)

a = "a" factor for gamma noble gas X/Q

- For Noble Gas Skin Dose Rate (for vents or stacks < 80 meters):

$$D_s = shf \cdot F_o \cdot \Sigma QR_{iv} \cdot [(L_i \cdot X/Q \cdot 8760^{-b}) + (1.11 M_i \cdot X/Q_g \cdot 8760^{-a})]$$

where

D_s = skin dose rate from gaseous effluents (mrem/yr)

X/Q = highest value of the noble gas 1-hour X/Q for vent or stack v at the site boundary (sec/m^3)

M_i = air dose factor due to gamma emissions for noble gas radionuclide i (mrad/yr per $\mu Ci/m^3$)

1.11 = conversion factor from mrad to mrem

L_i = skin dose factor due to beta emissions for noble gas radionuclide i (mrem/yr per $\mu Ci/m^3$)

b = "a" factor for noble gas X/Q

- For Noble Gas Skin Dose (for vents or stacks < 80 meters):

$$D_{sk} = \frac{shf \cdot F_o \cdot \Sigma\, QR_{iv} \cdot [(L_i \cdot X/Q \cdot t^{-b}) + (1.11 M_i \cdot X/Q_g \cdot t^{-a})]}{(5.256 \cdot 10^5 / dur)}$$

where

D_{sk} = total skin dose from gaseous effluents (mrem)

- For Noble Gas Air Dose due to gamma radiation (for vents or stacks < 80 meters):

$$D_\gamma = (3.17 \cdot 10^{-8}) \cdot X/Q_g \cdot t^{-a} \cdot F_o \cdot \Sigma\, M_i \cdot Q_{iv}$$

where

D_γ = total gamma air dose from gaseous effluents (mrad)

$3.17 \cdot 10^{-8}$ = inverse of number of seconds in a year

Q_{iv} = release of noble gas radionuclides, i, in gaseous effluents from vent or stack v (μCi)

$Q_{iv} = QR_{iv} \cdot dur \cdot 60$

where

60 = number of seconds in a minute

- For Noble Gas Air Dose due to beta radiation (for vents or stacks < 80 meters):

$$D_\beta = (3.17 \cdot 10^{-8}) \cdot X/Q \cdot t^{-b} \cdot F_o \cdot \Sigma N_i \cdot Q_{iv}$$

where

D_β = total beta air dose from gaseous effluents (mrad)

N_i = air dose factor due to beta emissions for noble gas radionuclide i (mrad/yr per $\mu Ci/m^3$)

- For Critical Organ Dose Rate--Inhalation Pathway and all Pathways for H-3, C-14 (for vents or stacks < 80 meters):

$$DR_{\tau a} = X/Q_r \cdot 8760^{-c} \cdot \Sigma P_{ip\tau a} \cdot QR_{iv}$$

where

$DR_{\tau a}$ = dose rate for age group a and organ τ from iodines and particulates with half lives greater than 8 days in gaseous effluents (mrem/yr)

$P_{ip\tau a}$ = dose factor for each radionuclide i, pathway p, organ τ, and age group a (mrem/yr per $\mu Ci/m^3$)

X/Q_r = highest value of the radioiodine/particulate 1-hour X/Q for vent or stack v at the site boundary (sec/m^3)

c = "a" factor for Radioiodine/Particulate X/Q

Note: It is assumed $P_{ip\tau a}$ will not contain long term X/Q or D/Q values.

- For Critical Organ Dose Rate--Ground and Food Pathways (for vents or stacks < 80 meters):

$$DR_{\tau a} = D/Q \cdot 8760^{-d} \cdot \Sigma R_{ip\tau a} \cdot QR_{iv}$$

where

D/Q = highest value of the 1-hour deposition factor at the distance of the site boundary ($1/m^2$)

d = "a" factor for D/Q

$R_{ip\tau a}$ = dose factor for each radionuclide i, pathway p, organ τ, and age group a (m^2 • mrem/yr per μCi/sec)

Note: It is assumed $R_{ip\tau a}$ will not contain long term X/Q or D/Q values.

- For Critical Organ Dose-Inhalation Pathway and all Pathways for H-3, C-14 (for vents or stacks < 80 meters):

$$D_{\tau a} = (3.17 \cdot 10^{-8}) \cdot X/Q_r \cdot t^{-c} \cdot F_o \cdot \Sigma P_{ip\tau a} \cdot Q_{iv}$$

where

$D_{\tau a}$ = dose for age group a and organ τ from iodines and particulates with half lives greater than 8 days in gaseous effluents (mrem)

Note: It is assumed $P_{ip\tau a}$ will not contain long term X/Q or D/Q values.

- For Critical Organ Dose-Ground and Food Pathways (for vents or stacks < 80 meters):

$$D_{\tau a} = (3.17 \cdot 10^{-8}) \cdot D/Q \cdot t^{-d} \cdot F_o \cdot \Sigma R_{ip\tau a} \cdot Q_{iv}$$

Note: It is assumed $R_{ip\tau a}$ will not contain long term X/Q or D/Q values.

6.8.3.2 On the Nuclide Concentration Screen (Screen 4.15), nuclide concentrations will be "scaled" if the SCAL_NUC parameter is set properly for a Release Point. This "scaling" is described as follows:

$$C_{inew} = (t / s) \cdot C_i$$

where

C_{inew} = concentration (after "scaling") of $nuclide_i$
s = sum of all nuclide concentrations on the Nuclide Concentration Screen.
t = total nuclide concentration entered by the user
C_i = concentration (before "scaling") of $nuclide_i$

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6.9 Gaseous Permit Editing

6.9.1 User Interface and Functionality

Functionality for editing gaseous permits through the EMS software shall be described in section 4 of the EMS Operator's Manual (Reference 2.1.1), with the following revisions:

The appearance and functionality of the gaseous permit definition screen, the monitor response screen, and nuclide concentration shall be modified as described for the Pre- and Post-Release stages in sections 6.7.1 and 6.8.1 above.

6.9.2 Associated Reports

The permit report format and contents for edited open and closed gaseous permits shall be as specified above for original permit reports, in sections 6.7.2 and 6.8.2, respectively.

6.9.3 Underlying Calculations

The calculation methods for editing open and closed gaseous permits shall be specified for original calculations, in sections 6.7.3 and 6.8.3, respectively.

6.10 Gaseous Permit Deletion

Functionality for deleting gaseous permits through the EMS software shall be described section 4 or the EMS operator's Manual (Reference 2.1.1).

6.11 Semi-Annual Reporting

6.11.1 User Interface and Functionality

Semi-Annual Reporting functionality for the EMS software shall be as described in section 5 of the EMS Operator's Manual (Reference 2.1.1), with the following revisions:

6.11.1.1 On Report 5.01 (Gaseous Summation of All Releases):

- Compute each value on line A.3 of the report by taking

$$\text{the greater of} \quad \begin{cases} 100 \cdot D_{ag} / QL_{ag} \\ 100 \cdot D_{ab} / QL_{ab} \end{cases}$$

where

D_{ag} = the gamma air dose in the applicable quarter at the site boundary receptor due to noble gas emissions (mrem)

D_{ab} = the beta air dose in the applicable quarter at the site boundary due to noble gas emissions (mrem)

QL_{ag} = the quarterly limit on D_{ag} (mrem) [usually 5]

QL_{ab} = the quarterly limit on D_{ab} (mrem) [usually 10]

A note will be made at the bottom of the report stating whether the beta air dose and its associated limit or gamma air dose and its associated limit were used for the Percent of Applicable Limit of Fission and Activation Products..

- The values on lines B.3, C.3, and D.3 will be the equivalent. They will be calculated as follows:

$$\text{the greatest (over T) of} \quad \left\{ 100 \cdot (\Sigma\ D_{i,T}) / QL_{rp} \right.$$

where

$D_{l,T}$ = the dose to organ T of the controlling receptor, in the applicable quarter, due to gaseous emissions of radionuclide l (mrem)

The summation is over all non-noble gas radionuclides with half-lives greater than 8 days, including radioiodines, particulates, and tritium.

QL_{rp} = the quarterly limit on the controlling receptor organ dose due to gaseous effluents (mrem) [usually 7.5]

6.11.1.2 On Report 5.02 (Liquid Summation of All Releases):

- For each quarter q in the report, calculate the reportable dilution volume (DV_{rq}, in liters) for the portion of the quarter that is within the report dates. It is the sum of the reportable monthly dilution volumes (DV_{rm}) in user units for all the months in the quarter that are within the report dates:

$$DV_{rq} = 28.31685 \cdot sd\_lvolf \cdot \Sigma\, DV_{rm}$$

The values DV_{rm} are from the column tvol of the QDVOL table. The value DV_{rq} is included in the report on line F, and is used in the calculations below. "sd_lvolf" should be the user unit conversion factor to convert from user units to ft^3. 28.31685 is a unit conversion factor from ft^3 to liters.

- For each space on a line titled "AVERAGE DILUTED CONCENTRATION DURING PERIOD", the average concentration (Cq, in μCi/ml) for the respective quarter is computed as follows (where i ranges over only the nuclides in the category):

$$C_q = \Sigma\, C_{iq} = \Sigma\, [Act_{iq} / (1000 \cdot DV_{rq})]$$

where

Act_{iq} = total activity of nuclide i released during the portion of the quarter q that is within the period (μCi)

DV_{rq} = reportable dilution flow for the portion of quarter q that is within the report period (liters), as calculated above.

- Compute each value on line A.3 and B.3 of the report by taking

the greater of $\begin{cases} 100 \cdot D_{lt} / QL_{lt} \\ 100 \cdot D_{lo} / QL_{lo} \end{cases}$

where

D_{lt} = the liquid total body dose in the applicable quarter at the site boundary receptor (mrem)

D_{lo} = the liquid maximum organ dose in the applicable quarter at the site boundary (mrem)

QL_{lt} = the quarterly limit on D_{lt} (mrem) [usually 1.5]

QL_{lo} = the quarterly limit on D_{lo} (mrem) [usually 5]

A note will be made at the bottom of the report stating whether the liquid total body dose and its associated limit or maximum organ dose and its associated limit were used for the Percent of Applicable Limit.

- Compute each value on line C.3 of the report as follows:

$$P_q = 100 \cdot C_q / L_{dg}$$

where

C_q = sum of noble gas concentrations

P_q = Percentage applicable to a given quarter for dissolved and entrained gases

L_{dg} = Liquid dissolved gas limit (μCi/ml) [usually 2.0E-04]

6.11.2 EMS Trend Plots

Trend Plotting functionality for the EMS software shall be described in section 5 of the EMS Operator's Manual (Reference 2.1.1) with no revisions.

6.12 End-of-the-Year Data Archiving

6.12.1 User Interface and Functionality

End-of-the-Year Data Archiving functionality for the EMS software shall be described in section 6 of the EMS Operator's Manual (Reference 2.1.1) with no revisions.

Documentation Review Report

Document Reviewed SRS SEABROOK STATION EMS RS-8448-04

Does the document meet the requirements? (Yes) or No

Is the document approved? (Yes) or No

If not please state the exceptions:

Signature: Peter von der Heide Date: 9/15-93

Documentation Review Report

Document Reviewed JRS (25-8448-04) SEARBOX CMS

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If not please state the exceptions:

Signature: Lauren Gillette Date: 9/19/93

ATTACHMENT 4: TECHNICAL REFERENCE MANUAL, EFFLUENT MANAGEMENT SYSTEM

NAESCO SEABROOK STATION, JULY 1994, FP 75486

Canberra Industries, Inc.
800 Research Parkway
Meriden, CT 06450

July 1994

NAESCO Seabrook Station
EMS Technical Reference Manual
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The information in this manual describes the product as accurately as possible, but is subject to change without notice.

Printed in the United States of America.

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CHAPTER 1

INTRODUCTION

The Effluent Management System (EMS) Software implements the requirements for determining limits and doses for the routine liquid and gaseous releases from nuclear power plants. The calculations and methodology are based on those described in U. S. Nuclear Regulatory Commission Regulatory Guide 1.109 and references described therein. These equations reduce to those described in NUREG-0133 by proper selection of parameters.

This manual describes the calculations used in the LRW/GRW program for handling liquid and gaseous releases and preparing the semi-annual report, and the equations used in the DFP option for calculating the relevant dose factors.

This manual describes the new 10CFR20 (1992) as well as old 10CFR20 requirements.

For a nuclear power plant, the Off-Site Dose Calculation Manual (ODCM) describes the methods used at that plant for complying with the effluent release portions of the technical specifications and the requirements of 10CFR20 and Appendix I of 10CFR50.

The concentration and dose limits that are required to be met are:

- For radioactive liquid effluents, the concentrations released to areas beyond the site boundary are limited to:

  MPC values given in old 10CFR20, Appendix B, Table II.
  OR
  ECL values given in new 10CFR20, Appendix B, Table 2.

  where ECL values are effluent concentration limit values.

- For radioactive liquid effluents, the maximum dose to any member of the public will be less than the limits given in 10CFR50, Appendix I.

- For gaseous effluents, the old 10CFR20 requires that the dose rate at any location beyond the site boundary will be limited to the annual dose limits given in the Technical Specifications and corresponding to the concentrations in Appendix B of the old 10CFR20. The old 10CFR20 approach for gaseous effluents has been accepted by the NRC for use under the new 10CFR20.

- For gaseous effluents, the maximum dose to any member of the public will be less than the limits given in 10CFR50, Appendix I.

- The maximum dose to any member of the public will not exceed the limits given in 40CFR190.

The equations employed for calculating the dose and dose factors are taken from NUREG-0133[1] and Regulatory Guide 1.109.[2]

For a particular nuclear plant, the ODCM describes the physical configuration of release sources and release points for routine and non-routine liquid and gaseous effluents, the monitor setpoint calculations, dose, and dose rate calculations.

1.1 SETPOINT CALCULATIONS

Calculations are made for the radiation monitors to determine the alarm/trip setpoint so that 10CFR20 compliance is met. For the old 10CFR20 compliance, liquid calculations use the maximum permissible concentrations from 10CFR20 App. B, Table 2, column 2, and the more conservative value (smaller) of the soluble and insoluble values while gas calculations use dose rate equations and limits from NUREG-0133. To comply with the new 10CFR20 requirements, the effluent concentration limits are used for liquid setpoint calculations. For gaseous setpoint calculations under the new 10CFR20, the NRC is still allowing the use of dose rate equations and limits from NUREG-0133..

In the terminology of EMS, individual sources of radiation, such as storage tanks, the containment building, etc., are defined as "release points." Several release points may lead to the same "discharge point."

Setpoint calculations produce monitor limiting values in activity units (μCi/ml or μCi/cc). These are then converted to user units, e.g. counts per minute (cpm). For gaseous releases, setpoint can be reported as release rates (μCi/sec). The reporting units for each monitor can be defined separately.

EMS allows setpoints to be set for both the release points and the discharge points. In the case that the release point and the discharge point are the same, or use the same physical monitor, the same discharge setpoint value is reported for both. This use of the same discharge setpoint value can be disabled.

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EMS has a "nuclide specific" option. In this option only the nuclides listed in the monitor slope table are used in the setpoint calculations.

1.2 RELEASE PROCESSING

For batch releases, the processing of releases consists of sampling the tank or volume of air, analyzing the radionuclide content, then using the radionuclide concentrations and estimated release flows, volumes, etc. and calculating the doses and setpoints, comparing to the 10CFR20 limits, and comparing to the 10CFR50 limits. If the limits are not exceeded, the pre-release permit is signed off and the release can occur. After the release, post-release processing performs the same calculations (except the setpoints are not needed) and the database is updated with the actual values for the release.

For continuous releases, many installations prefer not to generate an actual pre-release permit, but for the sake of analogous operation, pre-release calculations must still be made in EMS. After review, the post-release calculations are made to update the database.

EMS does not allow more that one open release at a time for a single release point. However, multiple releases may be open for one discharge point. Also, for discharge points, the setpoint is calculated by summing over all open releases for the time period involved. An alternative approach if a new permit must be opened before the actual information for the previous permit are available is to go ahead and close the release using the pre-release values and then edit this closed release later when the actual information becomes available.

1.3 COMPOSITE NUCLIDES

The standard radionuclide analysis, with high-resolution germanium detectors, quantifies the gamma-emitting radionuclides. Pure beta emitters, nuclides that decay by K-capture, and alpha emitters are handled with other detection mechanisms. These are usually not tracked individually by sample, but as a composite of many samples over a month or quarter period. The concentrations of the composite nuclides are combined with the concentrations of the individual nuclides determined from gamma analysis for each sample.

For liquid releases, the composite nuclides are generally H-3, Fe-55, Sr-89, Sr-90, and gross alpha. For gaseous releases, Fe-55 is generally not included.

In EMS, these are contained in an editable file designated by the composite ID number. Each release point definition specifies which composite ID is used with the release point. These can be the composite nuclides, or any other nuclides desired.

Composite samples produced by taking portions of the samples from individual releases are analyzed after the releases are over. Since these generally do not vary much from one period to the next, it is common to use the most recent values. However, EMS provides the option of updating the composite values for the proper time period and recalculating the activity and dose values in the database.

The EMS composite update process processes only those nuclides listed in the Composite ID for the release point. For each nuclide, the curies and doses based on the previous value are subtracted from the cumulative totals and the curies and doses based on the correct value are added into the cumulative totals.

For the setting of flags to control options in the EMS code, see the NAESCO Seabrook Station EMS Operator's Manual 07-0589.

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CHAPTER 2

LIQUID RELEASE CALCULATIONS

2.1 LIQUID PRE-RELEASE PERMIT

A liquid pre-release permit is generated with a program that uses the nuclide activities to determine the radiation monitor setpoint (for 10CFR20 compliance) and the potential doses for 10CFR50 compliance.

Continuous releases are treated similarly.

2.2 10CFR20 COMPLIANCE

10CFR20 compliance calculations are broken down into two paths. The first path calculates compliance with the old 10CFR20 in which the calculations are based on Maximum Permissible Concentrations. The second path complies with the new 10CFR20 and is Effluent Concentration Limits based.

10CFR20 requires that the sum of concentrations divided by MPC (old 10CFR20) or ECL (new 10CFR20) values must not exceed unity for MPCs or 10 for ECLs:

OLD 10CFR20		NEW 10CFR20
$S = \Sigma_i \, C_i/MPC_i \leq 1$	OR	$S = \Sigma_i \, C_i/ECL_i \leq 10$

for concentrations C_i released from the site. MPC_i is the maximum permissible concentration from the old 10CFR20, Appendix B, Table II, Column 2, for nuclide i and ECL_i is the effluent concentration limit from the new 10CFR20, Appendix B, Table 2, Column 2, for nuclide i.

If the summation is greater than the limit, then dilution is required. The required dilution factor is:

If the 10CFR20 option is OLD:

$$D_{req} = \frac{\sum_i \frac{C_i}{MPC_i}}{f \cdot R_{max}}$$

where

D_{req} = Total required dilution factor

C_i = Concentration of nuclide i in μCi/mL

MPC_i = Maximum permissible concentration of nuclide i in μCi/mL

f = Release point setpoint safety factor (usually equal to 0.5) from the release point definition.

R_{max} = The maximum MPC ratio from the release point setpoint definition.

If the 10CFR20 option is NEW:

$$D_{req,g} = \frac{\sum_{i=g} \frac{C_i}{ECL_i}}{f \cdot R_{max}}$$

$$D_{req,ng} = \frac{\sum_{i=ng} \frac{C_i}{ECL_i}}{f \cdot R_{max}}$$

$$D_{req} = D_{req,g} + Dreq,ng$$

where

$D_{req,g}$ = Required dilution factor for gamma-emitters

$D_{req,ng}$ = Required dilution factor for non-gamma-emitters

ECL_i = Effluent concentration limit of nuclide i in μCi/mL

and the sums extend over gamma-emitters (g) and non-gamma-emitters (ng), respectively.

Any nuclides with $MPC_i \leq 0$ are excluded from the sum.
Any nuclides with $ECL_i \leq 0$ are excluded from the sum.

The available dilution flow is the minimum dilution stream flow that can be ensured for the period of the release, corrected for other releases in process and any activity in the dilution stream, and reduced by a safety factor.

$$F_{avail} = F_{ant} \ (f_f/100) \ (1 - \Sigma \ C_i/XXX_i)$$

where

C_i = Concentration (μCi/ml) for nuclide i for the dilution stream sample

XXX_i = MPC_i or ECL_i

f_f = Flow safety factor, in percent

F_{ant} = Anticipated dilution flow rate for the release

The anticipated dilution factor is then

$$D_{ant} = (F_{waste} + f_{alloc} F_{avail}) / F_{waste}$$

where

F_{waste} = waste flow anticipated for this release

F_{avail} = available dilution flow

f_{alloc} = fraction of available dilution stream flow allocated to this release

Dissolved and Entrained Gases

To implement 10CFR20, it is also required that the total concentration of dissolved and entrained gases in liquid effluents be less than a specified value (normally, 2 E-04 μCi/mL under OLD 10CFR20, or 1 E-04 μCi/mL under NEW 10CFR20). EMS stores this limit in the Activity Limits transaction, checks this limit for each liquid permit, and indicates on the permit approval screen whether or not it is exceeded. To include dissolved noble gases in the D_{reg} calculation, the database must also contain the same limiting value, as the liquid MPC or ECL for each noble gas nuclide.

2.3 MAXIMUM WASTE FLOW

The maximum waste flow calculation is based on the setting of the SET_OPT option in the WFLOW_M class of options in the Release Point Setpoint definition. This option can take on four values: NONE, NWAS (no waste), CALC or DOSE. For liquid releases, NONE, NWAS, and CALC are allowed.

For liquid releases,

Wmax = the minimum of R_{wmax} and R_{cwmax}

where

W_{max} = Maximum permissible waste flow rate for this release

R_{wmax} = Release point maximum waste flow rate, as set in the release point definition

If the SET_OPT option = NONE:

R_{cwmax} = waste flow rate for the sample, F_{waste}

If the required dilution factor, D_{req} (section 2.2) for the sample is greater than 1, R_{cwmax} becomes:

$$R_{cwmax} = \frac{F_{avail} \cdot f_{alloc}}{D_{req} - 1.0}$$

If the SET_OPT option = CALC

$$R_{cwmax} = \frac{F_{avail} \cdot f_{alloc} + F_{waste}}{D_{req}}$$

If the SET_OPT option = NWAS

$$R_{cwmax} = \frac{F_{avail} \cdot f_{alloc}}{D_{req}}$$

2.4 MINIMUM DILUTION FLOW RATE

If $D_{req} > 1$, the minimum dilution flow rate is determined as follows:

If the SET_OPT option is NWAS:

$$min\_dflow = \frac{F_{waste} \cdot D_{req}}{f_{alloc} \cdot (f_f / 100) \cdot \left[1 - \sum_i \frac{C_i}{XXX_i} \right]}$$

where XXX_i is MPC_i under OLD 10CFR20, and is ECL_i under NEW 10CFR20.

If the SET_OPT option is other than NWAS:

$$min\_dflow = \frac{F_{waste} \cdot (D_{req} - 1.0)}{f_{alloc} \cdot (f_f / 100) \cdot \left[1 - \sum_i \frac{C_i}{XXX_i} \right]}$$

Otherwise:

$$min\_dflow = 0.0$$

2.5 SETPOINT CALCULATIONS

Setpoints are calculated for individual release points, and for the discharge point that may combine several release points.

A setpoint adjustment factor, S_{adj} is determined from the value of D_{req}.

If $D_{req} > 1$ or the dilution factor option is N, and the setpoint equation is set to STD:

$$S_{adj} = D_{ant} / D_{req}$$

If the dilution factor option is Y, and $0 < D_{req} \leq 1.0$ or if the dilution factor option is Y, and the setpoint equation is set to NO_DIL, then no credit is taken for dilution, and the setpoint adjustment factor is:

$$S_{adj} = 1/D_{req}$$

If neither of these conditions is true, $S_{adj} = 0$.

After the above tests, further tests are made based on the setting of the setpoint equation option, SETP_EQN. These <u>may</u> change S_{adj} as follows:

If the SETP_EQN is set to DILUT, and $F_{waste} > 0$, then:

$$S_{adj} = \frac{F_{ant} + F_{waste}}{F_{waste}}$$

If the SETP_EQN is set to STD, and the SET_OPT option is set to NWAS, and $F_{waste} > 0$, then:

$$S_{adj} = \frac{f_{alloc} \cdot F_{avail}}{F_{waste} \cdot D_{req}}$$

Otherwise, if the SETP_EQN option is set to STD, and the SET_OPT option is set to <u>other than</u> NWAS, and $F_{waste} > 0$, then:

$$S_{adj} = \frac{(f_{alloc} \cdot F_{avail}) + F_{waste}}{F_{waste} \cdot D_{req}}$$

Otherwise, if the SETP_EQN option is set to LOW_ACT, and the SET_OPT option is set to NWAS, and $F_{waste} > 0$, then:

$$S_{adj} = \frac{\frac{(f_{alloc} \cdot F_{avail})}{F_{waste}} - D_{req,ng}}{D_{req,g}}$$

Otherwise, if the SETP_EQN option is set to LOW_ACT, and the SET_OPT option is set to other than NWAS, and $F_{waste} > 0$, then:

$$S_{adj} = \frac{\frac{(f_{alloc} \cdot F_{avail}) + F_{waste}}{F_{waste}} - D_{req,ng}}{D_{req,g}}$$

Otherwise, S_{adj} is unchanged.

The setpoint adjustment factor is further tested against a limiting value ($S_{adj,lim}$ which is set using the Release Point transaction in Database Maintenance).

If $S_{adj} > S_{adj,lim}$ then $S_{adj} = S_{adj,lim}$

All of this leads to the maximum setpoint value, S_{max}, based on the gamma-emitting radionuclide mix:

$$S_{max}\ (\mu Ci/ml) = S_{adj} \Sigma C_i$$

where the sum extends over all gamma-emitting nuclides (nuclides of type other than 0) in which their concentrations are greater than 0.

In user units (cpm or other as set in the Flow Monitor Parameters transaction in Database Maintenance), the maximum setpoint is:

$$S_{max}\ (cpm) = S_{adj}(R_{mon} - B) + B$$

where

B = monitor background (cpm)

R_{mon} = monitor response (cpm)

$$= offset + slope \cdot \Sigma C_i + quad \cdot (\Sigma C_i)^2 + B$$

where offset, slope, and quad are the coefficients in a quadratic fit to the monitor response to nuclide activity.

EMS provides an option to calculate nuclide specific responses so that R_{mon} is the sum of responses for each nuclide, rather than the sum of the nuclide concentrations, as shown above. In the nuclide-specific case,

$$R_{mon} = \Sigma \left[offset_i + slope_i \cdot C_i + quad_i \cdot (C_i)^2 \right] + B$$

where the sum extends over all nuclides which have response factors stored in the database for the monitor of interest.

Recommended Setpoint

The setpoint recommended for actual use is based on a comparison of the maximum setpoint calculated as above, to setpoints based on expected response time a tolerance factor (to allow for variations in monitor response during release) and to default values determined by the user. The user can restrict which setpoint value is usually reported by what values are used when setting these tolerance factors and default setpoint values.

The default setpoint in user units (e.g. cpm) can be defined with or without background included. If the cunitnopt parameter (defined in the release point and discharge point tables) equals 0, the default value does not include background; and the current background is added to the default value to get the reported default setpoint. Otherwise, the current background is not added to the default value.

Setpoint in μCi/ml

Note: In this version of the software, the reported setpoint is the user units setpoint. The setpoint calculations using the original concentrations (μCi/ml) is still being done by the software and stored in the sampledata table. To get reported setpoints in μCi/ml, the monitor slope should be set to 1.0 in the Release Point transaction of Database Maintenance and the UNITS parameter for the monitor should be set to μCi/ml in the Activity Monitors transaction. If the Isotopic specific response option is turned on for the release point, then this individual nuclide slopes in the Monitor Slopes can be used to map the response from the nuclide to that of a monitor calibration source (e.g. Cs^{137} equivalent response)

A candidate setpoint is calculated based on the expected response:

$$S_{exp} = f_{tol} \Sigma C_i$$

where

f_{tol} = setpoint tolerance factor (can be set for the release point using QBF)

= 2 if not specified by the user

Now compare the S_{exp} value to the default table value S_{def}:

If $S_{exp} < S_{max}$

and if

$S_{exp} < S_{def}$ and $S_{def} \leq S_{max}$

then use S_{def} Case 1

Otherwise use S_{exp}. Case 2,5

If $S_{exp} \geq S_{max}$ use S_{max}. Case 3

If $S_{max} = 0$, use S_{def} Case 4

Case 4 occurs if no activity is detectable in the sample ($S_{adj} = 0$).

Case 1	Case 2	Case 3	Case 4	Case 5
		S_{exp}----		S_{def}----
S_{max}----	S_{max}----	S_{max}----		S_{max}----
	S_{exp}----			S_{exp}----
S_{def}----	S_{def}----	S_{def}----	S_{def}----	
S_{exp}----				
0 ----	0 ----	0 ----	0 ----	0 ----
Use S_{def}	Use S_{exp}	Use S_{max}	Use S_{def}	Use S_{exp}

Schematic of Liquid Setpoint Cases

Recommended Setpoint in User Units (e.g. cpm)

The candidate setpoint based on expected monitor response is calculated as follows:

$$S_{exp}(cpm) = f_{tol} * (R_{mon} - B) + f_{Btol} * B$$

where

f_{Btol} = background tolerance factor (set using QBF on the releasept table)

If the default setpoint value includes background:

$$B_{rp} = 0$$

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If the default setpoint value does not include background:

$$B_{rp} = B$$

where B is the monitor background count rate and B_{rp} is used below.

If S_{exp} (cpm) < S_{max} (cpm)

and if

S_{exp} (cpm) < S_{def} (cpm) + B_{rp} and

S_{def} (cpm) + B_{rp} ≤ S_{max} (cpm)

then use S_{def} (cpm) + B_{rp} Case 1

Otherwise, use S_{exp} (cpm) Case 2, 5

If S_{exp} (cpm) > S_{max} (cpm)

use S_{max} (cpm) Case 3

If S_{max} (cpm) = 0, use S_{def} + B_{rp} Case 4

NOTE: S_{max} is due to concentration only (i.e., excludes background) for Case 4

Setpoint for Discharge Point

For the discharge point, the total MPC/ECL fraction is:

$$\frac{(\Sigma C_i/MPC_i)_o \cdot F_o + (\Sigma C_i/MPC_i) \cdot F}{F_o + F}$$

OR

$$\frac{(\Sigma C_i/ECL_i)_o \cdot F_o + (\Sigma C_i/ECL_i) \cdot F}{F_o + F}$$

where

$(\Sigma\ C_i/MPC_i)_o$ = total MPC fraction for existing concurrent releases for this discharge point excluding this additional release.

$\Sigma\ C_i/MPC_i$ = total MPC fraction for the new release

$(\Sigma\ C_i/ECL_i)_o$ = total ECL fraction for existing concurrent releases for this discharge point excluding this additional release.

$\Sigma\ C_i/ECL_i$ = total ECL fraction for the new release

F_o = discharge point waste flow excluding new the release point waste flow to be added.

F = projected waste flow for the new release point to be added

The radiation monitor for the discharge point has setpoint equations identical to those presented above for the release points with the following exceptions:

1. The LOW_ACT setpoint equation option is not supported.

2. For the nuclide-specific response, the concentrations are modified as in:

$$C_i^{dp} = C_i\ [F/(F + F_o)]$$

$$R_{dpmon} = [\ \Sigma\ (offset_i + slope_i \cdot C_i^{dp} + quad_i \cdot (C_i^{dp})^2\ ] + R_{dpmon_o}$$

where

C_i^{dp} = the discharge point isotope concentration from this release point

R_{dpmon} = the discharge monitor response in user units

R_{dpmono} = the discharge monitor response before the current release is added including the background

For non-isotope specific response:

$$R_{dpmon} = [\ offset + slope \cdot C^{dp} + quad \cdot (C^{dp})^2\ ] + R_{dpmon_o}$$

where $C^{dp} = [\ \Sigma\ C_i]\ [F/(F+F_o)]$

Setpoints in μCi/sec

Setpoints in units of μCi/sec can be obtained by setting the UNITS parameter for the monitor to "μCi/s" or "μCi/sec" (Case sensitive. 1st 5 characters must match) in the Activity Monitors transaction and setting the monitor slope to 1.0 as in the μCi/ml setpoint calculation. The user units setpoint, as calculated above for the setpoint in μCi/ml units, will be multiplied by the corresponding effluent flow rate (release point or discharge point) for the monitor to get a reported setpoint in μCi/sec.

2.6 DOSE CALCULATIONS FOR LIQUID RELEASES

The EMS software calculates and stores the dose for each receptor, for each nuclide, and for each organ. The dose is the total over all pathways which apply to that receptor. A receptor is defined by receptor ID, age group (infant, child, teen, or adult), sector, and distance from the plant.

The equation used in the liquid permit processing to calculate the dose received by receptor r from a released nuclide i is:

$$D_{i\tau r} = A_{i\tau r} \Sigma\ \Delta t_s\ C_{is}\ F_{sr}$$

where:

The sum extends over all time periods.

$D_{i\tau r}$ = the cumulative dose or dose commitment to the total body or an organ τ by nuclide i for receptor r from the liquid effluents for the total time period of the release, in mrem.

$A_{i\tau r}$ = site-related ingestion dose or dose commitment factor for receptor r to the total body or organ τ for radionuclide i, in mrem/hr per μCi/ml. $A_{i\tau r}$ is available as an editable table, but can be recalculated with different parameters and pathways with the Dose Factor Processing (DFP) option. The

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equations used are presented in Chapter 4 of this manual.

Δt_s = length of time period s, over which the concentration and F value are averaged, for all liquid releases, in hours.

C_{is} = the average concentration of radionuclide i in undiluted liquid effluent during time period Δt_s from any liquid release, in μCi/ml.

F_{sr} = the near field average dilution factor for receptor r during any liquid effluent release.

$$F_{sr} = \frac{F_w}{Denom}$$

The value of Denom depends upon several variables and nested if statements. The derivation of the Denom value is shown in the logic and equations shown below.

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If the STREAM_FLO option in the OPTIONS Table is set to Y, then

$$Denom = F_{strm} \cdot (U_f / 60) \cdot (1/R_{mix})$$

else (river stream flow is not used)

If the denom_typ option from the Options Table is 1, (dose from a dilution stream) then

$$Denom = (U_f/60) \cdot (1/R_{mix})$$

Else if denom_typ is 2, (dilution flow includes waste flow) then

$$Denom = F_{dil} \cdot (U_f/60) \cdot (1/R_{mix})$$

else (denom_typ is not 1 or 2)

if the QV_OPT option in the OPTIONS table is set to ON, (dilution flow is from the QDVOL table) then

$$Denom = (F_w + F_{qvol}) \cdot (U_f/60) \cdot (1/R_{mix})$$

else (the normal standard calculation)

$$Denom = (F_w + F_{dil}) \cdot (U_f/60) \cdot (1/R_{mix})$$

end of if on QV_OPT option

end of if on denom_typ option

end of if on stream_flo option

If Denom is greater than 0.0 then

If Denom > 1000. and option to limit the denominator is Y, then

Denom = 1000.

end of if denom is too large

end of if denom is greater than 0.0

$$Denom = Denom / (U_f/60)$$

Where:

F_{strm}= River stream flow past the site in user liquid flow rate units. The value used during permit processing is the value obtained from the STATIONDATA table. The value is entered into the STATIONDATA table using the QBF utility. If the value is to be changed often, it would be possible to write a command procedure which get the value from the user and write it into the table.

F_w = flow rate of undiluted waste effluent in user liquid flow rate units.

$U_f/60$ = Flow rate units conversion factor for liquid releases/60. U_f converts from user units to CFM so this factor converts to CFS.

F_{dil} = flow rate of the dilution flow in user liquid flow rate units.

R_{mix} = mixing ratio = fraction of the release that reaches the receptor. Separate mixing ratios are stored for each pathway for each receptor.

A mixing ratio of zero for a pathway receptor indicates that the pathway is not present for the receptor. The first non-zero value is used in the dose calculation.

The different mixing ratios for the pathways are incorporated into the composite A_i factors calculated by the dose factor processing (DFP) program.

F_{qvol} = Flow rate from user entered quarterly dilution flow rate. These values are from the AFLOW column of the QDVOL table for the release.

If stream flow option is being used and the average river stream flow is known at the time the liquid release is processed, then the command procedure which runs the liquid permit processing could be modified to ask for the stream flow value and put it into the stationdata table before the permit is processed. If the average river stream flow is not known at the time the liquid release is processed, then some other provision must be made for correcting the cumulative dose totals in the CUMDOSE table so that it is based on the correct stream flow value. If the average stream flow for

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the month is used, then each liquid release point entry in the CUMDOSE table for the month could be multiplied by the ratio of the actual stream flow for the month divided by the default value contained in the STATIONDATA table. Caution: Since there is no record stored in the database of what stream flow value was used to calculate the dose values, the user must verify that no correction is applied more than once to each dose value.

2.7 31 DAY PROJECTED DOSE CALCULATIONS

The 31 Day Projected Dose values appear on the Standard and Special Permit Reports. The Projected Dose values are calculated as follows:

$$D_{p\tau} = (D_\tau \cdot p) + D_{a\tau}$$

where:

$D_{p\tau}$ =the 31 Day Projected Dose by organ τ, by reactor unit

D_τ =the total dose in mrem by organ τ, by reactor unit for the quarter containing the release start date from all closed and open releases when an answer of "Y" is specified for the "Update Totals" field on the release point definition screen.

p =the Projection Factor which is the result of 31 divided by the number of days from start of the quarter containing the release start date to the end of the release. The quarterly and annual projection values on the standard pre-release report use a projection factor with 92 days or 365 days instead of 31 days in the numerator and do not include the additional anticipated dose term.

$D_{a\tau}$ =Additional Anticipated Dose for liquid releases by organ τ and quarter of release by reactor unit.

NOTE: The 31 day dose projections on the Approval/Results screen is the site total for all units.

2.8 POST-RELEASE PROCESSING

After the release is made, actual concentrations are used to check 10CFR20 limits, and the actual dilution flow and waste flow are used instead of the anticipated dilution flow and waste flow.

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For batch releases, the duration is determined from the start and end dates and times, and is used with the volume input to calculate the release rate.

Dose calculations are the same as for the pre-release, but with actual release flow rates and release duration.

Setpoint calculations are not performed at the post-release stage.

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CHAPTER 3

GASEOUS RELEASE CALCULATIONS

The "annual average X/Q" method is used, in which fixed X/Q and D/Q values are used for each receptor for all dose calculations, regardless of actual wind direction and speed prevailing during a given release. Doses are calculated for each receptor location and age group specified in the Gas Receptors transaction. The controlling individual is the age group and location which receives the maximum organ dose.

3.1 GAS PRE-RELEASE PERMIT

The pre-release permit is produced by a program that uses user-entered estimates of flow rates and release times to calculate doses and activities. The dose rate from the potential release is added to the maximum dose rate occurring for all other releases during the duration of this release for 10CFR20 compliance. The noble gas or air doses and the organ doses are checked against the corresponding limits for 10CFR50 compliance.

3.2 RADIONUCLIDE ACTIVITIES AND COMPOSITE VALUES

The radionuclide results are read from one set of composite activity database records, and from three spectrum analysis result files, and saved in an activity array. If a nuclide appears in more than one spectrum, only the last value read for that nuclide is used. In case of duplication, the one not desired should be edited out of the nuclide list. The samples are read in the following order:

1. Composite Records
2. Particulate File
3. Radioiodine File
4. Noble Gas File

The activity (Q_i) and the activity release rate ($\dot{Q}_i$) are calculated for each nuclide i.

Activity Released

For the plant stack and turbine building vent:

$$Q_i = C_i \cdot V_v \cdot 28316.85 \cdot U_F \cdot 1^{e-6}$$

$$(\mu Ci) = (\mu Ci/ml)(\text{cubic feet})\ (ml/\text{cubic feet})$$

where:

V_v = vent release volume in user units (usually FT^3)

C_i = concentration in $\mu Ci/ml$

U_F = the flow-rate units conversion factor which converts from user units to CFM

Note: The C_i value also includes the scaled noble gas nuclides for a release (if any exists).

The activity release rate in $\mu Ci/sec$ is

$$\dot{Q}_i = C_i \cdot V_f \cdot 28316.85 \cdot U_F/60$$

For containment purge:

$$\dot{Q}_i = C_i \cdot \text{pump release rate (CFM)} \cdot 28316.85 \cdot U_F/60$$

$$Q_i = \dot{Q}_i \cdot \text{duration of release (min)} \cdot 60$$

3.3 10CFR20 COMPLIANCE

The maximum dose rate during the release is determined by summing together the dose rates for this release, with all concurrent releases in the database for the time of the release.

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The database contains all releases for which both pre- and post-release reports have been made (the post-release program enters the data into the cumulative totals). Pre-releases that have not been completed, and which occur during the release under consideration, are also added into the maximum dose rate to account for releases not yet added to the cumulative totals.

The three dose rates (whole body, skin, organ) are compared to the old 10CFR20 limits (old and new 10CFR20 are described below) as defined in the Dose Limits transaction in Database Maintenance.

The dose rate at or beyond the site boundary due to gaseous effluents from the site is limited to:

(a) Release rate limit for noble gases:

$$\Sigma_i K_i \text{ shf } \Sigma_v \left[\overline{(X/Q)}_{vr} \dot{Q}_{iv} \right] < 500 \text{ mRem/yr} \cdot f_{alloc} \cdot f_s$$

OR

$$\Sigma_v \text{shf } \Sigma_i \left[V_{ir} \dot{Q}_{iv} \right] < 500 \text{ mRem/yr} \cdot f_{alloc} \cdot f_s \quad \text{Elevated Stack} \geq 80\text{m}$$

$$\Sigma_i \text{ shf } (L_i + 1.1M_i) \ \Sigma_v \left[\overline{(X/Q)}_{vr} \dot{Q}_{iv} \right] < 3000 \text{ mRem/yr} \cdot f_{alloc} \cdot f_s$$

OR

$$\Sigma_v \text{ shf } \Sigma_i \left[(L_i \ \overline{(X/Q)}_{ir} + 1.1B_{ir}) \dot{Q}_{iv} \right] < 3000 \text{ mRem/yr} \cdot f_{alloc} \cdot f_s \quad \text{Elevated Stack} \geq 80\text{m}$$

where the terms are defined below.

(b) Release rate limit for all radionuclides and radioactive materials in particulate form, with half lives greater than 8 days:

$$\Sigma_i \Sigma_p \Sigma_v \left[f_p P_{ip} W_{mv} \dot{Q}_i \right] < 1500 \text{ mRem/yr} \cdot f_{alloc} \cdot f_s$$

where:

i = index over all radionuclides

v = index over all vents or stacks for the unit

p = index over all pathways

r = index for receptor locations

K_i = the total body dose factor due to gamma emissions for noble gas radionuclide i, in mrem/yr per $\mu Ci/m^3$.

L_i = the skin dose factor due to beta emissions for noble gas radionuclide i, in mrem/yr per $\mu Ci/m^3$.

V_{ir} = the elevated plume gamma total body dose factor for nuclide i at receptor location r, in mrem/yr per $\mu Ci/sec$.

M_i = the air dose factor due to gamma emissions for noble gas radionuclide i, in mrad/yr per $\mu Ci/m^3$.

B_{ir} = the elevated plume gamma skin dose factor for nuclide i at receptor location r, in mrad/yr per $\mu Ci/sec$.

1.1 = mrad to mrem conversion factor in mrem/mrad

P_{ip} = the dose factor for the critical organ for nuclides other than noble gases for the inhalation pathway (in units of mrem/yr per $\mu Ci/m^3$) and for ground plane and food pathways (in units of m^2 (mrem/yr per $\mu Ci/sec$)). The most restrictive age group is used.

f_p = factor to select which pathways are included in the calculation. Factor = 1 to include a pathway, 0 to exclude.

W_{mv} = $(\overline{X/Q})_{mv}$ for tritium and the inhalation pathway and = $(D/Q)_{mv}$ for other nuclides and pathways.

$(\overline{X/Q})_{vr}$ = the highest value of the annual average atmospheric dispersion factor at the site boundary, for all sectors, in sec/m^3.

$(\overline{X/Q})_{mv}$ = the highest value of the annual average atmospheric dispersion factor at the distance of the site boundary, for all sectors, in sec/m^3.

$\overline{(D/Q)}_{mv}$ = the highest value of the annual average deposition factor at the distance of the site boundary, for all sectors, in m^{-2}.

$\dot{Q}_{iv}$ = the average release rate of nuclide i in gaseous effluent from release point v, in μCi/sec. Noble gases may be averaged over a period of 1 hour, and any other nuclides may be averaged over a period of 1 week.

500 = site dose rate limit for whole body in mrem/year.

3000 = site dose rate limit for skin in mrem/year

1500 = site dose rate limit for any organ in mrem/year

shf = noble gas dose shielding factor

f_{alloc} = fraction of the dose limit allocated to this release point

f_s = safety factor for the release point

3.4 SETPOINT DETERMINATION

Setpoints are determined from Dose Rate Limits set forth in the Technical Specifications and stored in the Dose Limits Table.

The ratio of dose rate limit to dose rate for a single release point is given below for these three cases:

Noble Gases

nratio = r_g = lesser of the ratios

(total body dose rate limit/total body dose rate) and
(skin dose rate limit/skin dose rate)

= for a vent release, lesser of

$$\frac{500 \text{ mrem/yr}}{\text{shf } \Sigma_i K \cdot \dot{Q}_{iv} \cdot \overline{(X/Q)}_{mv}}$$

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and

$$\frac{3000 \text{ mrem/yr}}{\text{shf} \sum (L_i + 1.1M_i) \cdot \dot{Q}_{iv} \cdot \overline{(X/Q)}_{mv}}$$

= for an Elevated Stack ≥ 80m, lesser of

$$\frac{500 \text{ mrem/yr}}{\text{shf} \sum V_{ir} \cdot \dot{Q}_i}$$

and

$$\frac{3000 \text{ mrem/yr}}{\text{shf} \sum [L_i \cdot \overline{(X/Q)}_r + 1.1B_{ir}] \cdot \dot{Q}_i}$$

Radioiodines and Particulates

In these cases, the ratio is obtained by summing over the appropriate nuclide indices:

$$\text{rpratio} = \frac{1500 \text{ mrem/yr}}{\sum P_i \cdot \dot{Q}_{iv} \cdot W_{mv}} = \text{maximum organ dose rate}$$

When the sum is over nuclides and the inhalation, ground plane and cow's milk pathways are all turned on.

3.4a SETPOINTS

Setpoints are determined for radiation monitors on individual release points, and also for radiation monitors at the discharge points that may combine the effluent from several release points.

Calculations for the monitor response are made for noble gases, radioiodines, and particulates.

For a release point, the expected monitor response to a given nuclide concentration is:

R_{mon} = monitor response (cpm) + B

= offset + [slope • $\sum C_i$] + [quad • $(\sum C_i)^2$] + B

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where offset, slope, and quad are the coefficients in a quadratic fit to the monitor response to nuclide activity, and B is the monitor background.

EMS provides an option to calculate nuclide specific responses so that R_{mon} is determined from the response for each nuclide, rather than the sum of the nuclide concentrations, as shown above. In that case,

$$R_{mon} = \Sigma \ (\text{offset}_i + [\text{slope}_i \cdot C_i] + [\text{quad}_i \cdot (C_i)^2]) + B$$

The expected response for discharge points is based on the sum of the the expected response for releases already in progress plus the expected response due to release point being considered.

$$R_{dpmon} = R_{dpmon}_o + \Sigma \ [\text{offset}_i + \text{slope}_i \cdot C_i^{dp} + \text{quad}_i \cdot (C_i^{dp})^2]$$

where

$$C_i^{dp} = C_i \cdot (F_{rp} / F_{dp})$$

C_i = concentration for the release point

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F_{rp} = flow rate for the release point

F_{dp} = flow rate for the discharge point

R_{dpmon} = discharge point monitor response for the release in progress

R_{dpmon_o} = the discharge monitor response before the current release is added including the background

and $offset_i$, $slope_i$ and $quad_i$ are the quadratic response coefficients of the discharge point monitor.

Non-isotope specific response:

$$R_{mon}^{dp} = offset + slope \cdot (\Sigma C_i^{dp}) + quad \cdot (\Sigma C_i^{dp})^2 + R_{dpmon_o}$$

All other equations are the same as for the individual release point, but use the discharge point monitor response and the discharge point allocation factor and safety factors.

EMS allows for setpoint calculations based on the standard or response method. Thus, each release point will have associated with it, a setpoint equation: STD or RESP. This can be set in the Release Point (Setpoint) transaction of Database Maintenance.

<u>If the release point setpoint equation = STD</u> :

The limiting setpoint for the monitor (in µCi/ml) is given by:

$$S_{max} = f_s \cdot f_{alloc} \cdot ratio \cdot SUM$$

The limiting setpoint for the monitor (in user units, e.g., cpm) is given by:

$$SU_{max} = f_s \cdot f_{alloc} \cdot ratio \cdot (R_{mon} - B) + B$$

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where

offset = 1. noble gas offset factor
2. radioiodine offset factor
3. particulate offset factor

slope = 1. noble gas slope factor
2. radioiodine slope factor
3. particulate slope factor

quad = 1. noble gas quadratic factor
2. radioiodine quadratic factor
3. particulate quadratic factor

f_s = safety factor for the release point

f_{alloc} = dose rate allocation factor for the release point

ratio = 1. nratio for noble gases
2. rpratio for radioiodines
3. rpratio for particulates

SUM = 1. Σ noble gas concentrations, for noble gases
2. Σ radioiodine concentrations, for radioiodines
3. Σ particulate concentrations, for particulates

R_{mon} = 1. noble gas monitor response
2. radioiodine monitor response
3. particulate monitor response

B = 1. observed background response for the noble gas monitor
2. observed background response for the radioiodine monitor
3. observed background response for the particulate monitor

NOTE :Separate calculations are made for noble gases, radioiodine, and particulates

The limiting setpoint for gaseous releases is determined separately for noble gases, radioiodines, and particulates for each release point and discharge point.

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If the release point setpoint equation = RESP :

The reported setpoint for the monitor (in μCi/ml) now becomes:

$$S_{max} = [mrtol \bullet (SUM - B)] + (mrtolb \bullet B)$$

The limiting setpoint for the monitor (in user units, e.g., cpm) now becomes:

$$SU_{max} = [mrtol \bullet (Rmon - B)] + (mrtolb \bullet B)$$

where

mrtol = 1. monitor response tolerance factor (noble gas)
2. monitor response tolerance factor (radioiodine)
3. monitor response tolerance factor (particulate)

SUM = as defined above

B = as defined above

mrtolb = 1. monitor tolerance background factor (noble gas)
2. monitor tolerance background factor (radioiodine)
3. monitor tolerance background factor (particulate)

R_{mon} = as defined above

3.4b REPORTED SETPOINTS

The setpoint reported on the pre-release reports are in user defined units. If the release point setpoint equation is STD, then the maximum setpoint is compared with the response and default setpoints.

NOTE : The response setpoint as defined in this section is not necessarily the same as the maximum setpoint based on the RESP setpoint equation, as defined in the previous section. $S_{response}$ is defined below.

The reported setpoint is as follows:

1. Reported = $S_{response}$
   if $S_{response} < S_{max} < S_{default}$
   OR
   if $S_{default} < S_{response} < S_{max}$

2. Reported = S_{max}
   if $S_{response} \geq S_{max}$

3. Reported = $S_{default}$
   if $S_{response} < S_{default} < S_{max}$

where

S_{max} = as defined in the previous section

$$S_{response} = \begin{cases} mrtol \cdot SUM & [\mu Ci/ml] \\ [mrtol \cdot (Rmon - B)] + (mrtolb \cdot B) & [User\ Units] \end{cases}$$

$S_{default}$ = normal setpoint defined for the release point in units of [µCi/ml] and [User Units].

NOTE : Separate checks are made for each setpoint in [µCi/ml] and [User Units] for the noble gas, radioiodine, and particulate monitors.

Setpoints in µCi/sec

Setpoints in units of µCi/sec can be obtained by setting the UNITS parameter for the monitor to "µCi/s" or "µCi/sec" (Case sensitive. 1st 5 characters must match) in the Activity Monitors transaction and setting the monitor slope to 1.0 as in the µCi/ml setpoint calculation. The user units setpoint, as calculated above for the setpoint in µCi/ml units, will be multiplied by the corresponding effluent flow rate (release point or discharge point) for the monitor to get a reported setpoint in µCi/sec.

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3.5 MAXIMUM WASTE FLOW

The maximum waste flow calculation is based on what the WFLOW_M option (release point setpoint calculation option) is set to. This option can take on one of three values: NONE, DOSE, and CALC. Gaseous release point setpoint WFLOW_M can be set to either NONE or DOSE.

For gaseous releases,

$$Wmax = \text{the minimum of } R_{wmax} \text{ and } R_{cwmax}$$

where

R_{wmax} = Release point maximum waste flow rate as stored in the release point definition

If WFLOW_M option = NONE

R_{cwmax} = waste flow rate for the sample, V_f

If WFLOW_M option = DOSE

$$R_{cwmax} = \frac{f_s \cdot nratio \cdot V_f}{F_{wsfac}}$$

where

f_s = Safety factor for the release point

nratio = nratio as described in section 3.4

V_f = Waste flow rate for the release (sample)

F_{wsfac} = Waste flow rate DOSE setpoint safety factor

3.6 DOSE RATE AND CUMULATIVE DOSE CALCULATIONS

Noble Gas Dose and Dose Rate Calculations

The dose rate and dose contribution due to noble gases in gaseous effluents are calculated using the following expressions:

For Noble Gas Air Dose due to gamma radiation (for vents or stacks < 80 meters):

$$D_\gamma = (3.17 \cdot 10^{-8}) \cdot X/Q_g \cdot t^{-a} \cdot f_o \cdot \Sigma M_i \cdot Q_{iv}$$

For Noble Gas Air Dose due to beta radiation (for vents or stacks < 80 meters):

$$D_\beta = (3.17 \cdot 10^{-8}) \cdot X/Q \cdot t^{-b} \cdot f_o \cdot \Sigma N_i \cdot Q_{iv}$$

For Noble Gas Total Body Dose Rate (for vents or stacks < 80 meters):

$$D_t = shf \cdot X/Q_g \cdot 8760^{-a} \cdot f_o \cdot \Sigma (K_i \cdot QR_{iv})$$

For Noble Gas Total Body Dose (for vents or stacks < 80 meters):

$$D_{tb} = \frac{shf \cdot f_o \cdot \Sigma (K_i \cdot QR_{iv}) \cdot X/Q_g \cdot t^{-a}}{(5.256 \cdot 10^5 \ / \ dur)}$$

For Noble Gas Skin Dose Rate (for vents or stacks < 80 meters):

$$D_s = shf \cdot f_o \cdot \Sigma QR_{iv} \cdot [(L_i \cdot X/Q \cdot 8760^{-b}) + (1.11M_i \cdot X/Q_g \cdot 8760^{-a})]$$

For Noble Gas Skin Dose (for vents or stacks < 80 meters):

$$D_{sk} = \frac{shf \cdot f_o \cdot \Sigma QR_{iv} \cdot [(L_i \cdot X/Q \cdot t^{-b}) + (1.11M_i \cdot X/Q_g \cdot t^{-a})]}{(5.256 \cdot 10^5 \ / \ dur)}$$

where

D_β = total beta air dose from gaseous effluents (mrad)

D_γ = total gamma air dose from gaseous effluents (mrad)

D_t = the total body dose rate due to gamma emissions by noble gas releases from vent v (mrem/yr)

D_{tb} = total body dose from gaseous effluents (mrem)

D_s = skin dose rate from gaseous effluents (mrem/yr)

D_{sk} = skin dose from gaseous effluents (mrem)

1.11 = conversion factor from mrad to mrem

$3.17 \cdot 10^{-8}$ = inverse of number of seconds in a year

$5.256 \cdot 10^{5}$ = number of minutes in a year

8760^{-a} = adjustment factor used to convert the 1-hour X/Q value to an average 1 year X/Q value (dimensionless)

8760 = number of hours in a year

a = "a" factor for gamma noble gas X/Q

b = "a" factor for noble gas X/Q

t^{-a} = adjustment factor to convert the 1-hour X/Q value to the short term X/Q value for the release (dimensionless)

t = duration of release (hours)

dur = duration of the release (minutes)

f_o = occupancy factor defined for the receptor at the given location (dimensionless)

K_i = total body dose factor due to gamma emissions for noble gas radionuclide i (mrem/yr per $\mu Ci/m^3$)

L_i = skin dose factor due to beta emissions for noble gas radionuclide i (mrem/yr per $\mu Ci/m^3$)

M_i = air dose factor due to gamma emissions for noble gas radionuclide i (mrad/yr per $\mu Ci/m^3$)

N_i = air dose factor due to beta emissions for noble gas radionuclide i (mrad/yr per $\mu Ci/m^3$)

$3.17 \cdot 10^{-8}$ = inverse of number of seconds in a year

Q_{iv} = release of noble gas radionuclides, i, in gaseous effluents from vent or stack v (μCi)

QR_{iv} = release rate of noble gas radionuclides, i, in gaseous effluents from vent or stack v ($\mu Ci/sec$).

shf = shielding factor (dimensionless)

X/Q = highest value of the noble gas 1-hour X/Q for vent or stack v at the site boundary (sec/m^3)

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X/Q_g = highest value of the noble gas 1-hour X/Q for gamma radiation for vent or stack v at the site boundary, (sec/m^3)

Organ Dose Calculations

For Critical Organ Dose Rate--Inhalation Pathway and all Pathways for H-3, C-14 (for vents or stacks < 80 meters):

$$DR_{\tau a} = X/Q_r \cdot 8760^{-c} \cdot \Sigma P_{ip\tau a} \cdot QR_{iv}$$

For Critical Organ Dose Rate--Ground and Food Pathways (for vents or stacks < 80 meters):

$$DR_{\tau a} = D/Q \cdot 8760^{-d} \cdot \Sigma R_{ip\tau a} \cdot QR_{iv}$$

For Critical Organ Dose-Inhalation Pathway and all Pathways for H-3, C-14 (for vents or stacks < 80 meters):

$$D_{\tau a} = (3.17 \cdot 10^{-8}) \cdot X/Q_r \cdot t^{-c} \cdot f_o \cdot \Sigma P_{ip\tau a} \cdot Q_{iv}$$

For Critical Organ Dose-Ground and Food Pathways (for vents or stacks < 80 meters):

$$D_{\tau a} = (3.17 \cdot 10^{-8}) \cdot D/Q \cdot t^{-d} \cdot f_o \cdot \Sigma R_{ip\tau a} \cdot Q_{iv}$$

where

$DR_{\tau a}$ = dose rate for age group a and organ τ from iodines and particulates with half lives greater than 8 days in gaseous effluents (mrem/yr)

$D_{\tau a}$ = dose for age group a and organ τ from iodines and particulates with half lives greater than 8 days in gaseous effluents (mrem)

c = "a" factor for Radioiodine/Particulate X/Q

d = "a" factor for D/Q

D/Q = highest value of the 1-hour deposition factor at the distance of the site boundary ($1/m^2$)

$P_{ip\tau a}$ = dose factor for each radionuclide i, pathway p, organ τ, and age group a (mrem/yr per $\mu Ci/m^3$)

$R_{ip\tau a}$ = dose factor for each radionuclide i, pathway p, organ τ, and age group a (m^2 • mrem/yr per $\mu Ci/sec$)

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X/Q_r = highest value of the radioiodine/particulate 1-hour X/Q for vent or stack v at the site boundary (sec/m^3)

Note: It is assumed P_{ipTa} will not contain long term X/Q or D/Q values.

The maximum exposed individual is determined by the maximum dose received by any organ. The summation extends over all applicable nuclides and pathways.

3.7 RESOLVING DOUBLE-COUNTING OF DOSE AND ACTIVITY

Gaseous release points fall into three categories for double-counting of dose and activity. One, a release point will not have activity sampled twice. Two, a release point can have activity that is sampled again downstream and would be double-counted if no corrections were applied. Three, a release point can have samples containing activity already sampled once upstream which would be double-counted if no corrections were applied. The last two categories can be called the "CAUSE" release point and the "EFFECT" release point, respectively.

To avoid double-counting dose and activity, only the "EFFECT" release point will have its activity and concentrations corrected as follows. Corrected activity is calculated as follows:

$$A_{cei} = A_{ei} - A_{ci}$$

where:

A_{cei} =the corrected "EFFECT" release point activity for nuclide i which defaults to zero if its value is less than zero.

A_{ei} =the initial "EFFECT" release point activity for nuclide i

A_{ci} =the "CAUSE" release point activity for nuclide i

Corrected concentrations are calculated as follows:

$$C_{cei} = (A_{cei} / V_e) \cdot 35.315$$

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where:

C_{cei} =the corrected "EFFECT" release point concentrations for nuclide i

V_e =the waste volume for the "EFFECT" release point

35.315 =conversion factor from Ci/ft^3 to $\mu Ci/ml$ ($Ci/ft^3 \cdot ft^3/1728\ in^3 \cdot in^3/16.387\ cm^3$)

3.8 31 DAY PROJECTED DOSE CALCULATIONS

The 31 Day Projected Dose values appear on the Standard and Special Permit Reports. The Projected Dose values are calculated as follows:

$$D_{p\tau} = (D_\tau \cdot p) + D_{a\tau}$$

where:

$D_{p\tau}$ =the 31 Day Projected Dose by organ τ, by reactor unit

D_τ =the total dose in mrem by organ τ, by reactor unit for the quarter containing the release start date from all closed and open releases when an answer of "Y" is specified for the "Update Totals" field on the release point definition screen.

p =the Projection Factor which is the result of 31 divided by the number of days from the start of the quarter to the end of the release. The quarterly and annual projection values on the standard pre-release report use a projection factor with 92 days or 365 days instead of 31 days in the numerator and do not include the additional anticipated dose term.

$D_{a\tau}$ =Additional Anticipated Dose for gaseous releases by organ τ and quarter of release, by reactor unit.

NOTE: The 31 day dose projections on the Approval/Results screen is the site total for all units.

3.9 GAS POST-RELEASE PROCESSING

After a pre-release permit has been approved, the post-release program is run to:

- Enter actual release start and stop times, flow rates, etc.
- Check 10CFR20 limits
- Check 10CFR50 limits
- Add the dose and activity data into the cumulative totals.

Compliance with 10CFR20 limits is checked in the same way as described for the pre-release program.

Dose rates are calculated and compared to 10CFR20 limits. Monitor setpoints are not calculated at the post release stage.

CHAPTER 4

LIQUID DOSE FACTOR EQUATIONS

The DFP option is used to calculate the liquid dose factors described previously. Dose factors are calculated separately for each nuclide, organ, and age group. The age group, applied to a specific receptor's dose calculations, is part of the receptor specification.

For a particular receptor, the total dose factor ($A_{i\tau r}$) is a sum over each pathway p with its specific mixing ratio:

$$A_{i\tau r} = \frac{1}{R_{mix,r}} \Sigma R_{mix,r,p} A_{i\tau,r,p}$$

where

$A_{i\tau,r,p}$ = the dose factor for nuclide i, organ τ, receptor age group r, and pathway p

$R_{mix,r,p}$ = mixing ratio for the pathway

$R_{mix,r}$ = mixing ratio for the receptor, which is the first non-zero value of $R_{mix,r,p}$ encountered during the calculation

The user specifies which pathways are included by setting the mixing ratios for the pathways desired to the correct non-zero value. If the receptor mixing ratio for a given pathway is zero, that term is not included in the sum.

The DFP option of EMS uses a more expanded form for liquid dose factors than is given in NUREG-0133. These equations are taken from R.G. 1.109, and account for nuclide decay as well as shoreline doses. If desired, parameters may be selected to reduce the calculations to match NUREG-0133 exactly.

Four different forms of equations are used for the dose factors.

4.1 POTABLE WATER

The dose factor for potable water is:

$$A_{i\tau,r,p} = k_o \cdot (U_{r,p}/dw) \cdot N_i \cdot DF_{i\tau,r} \cdot e(-\lambda_i t_p)$$

where

$A_{i\tau,r,p}$ = dose parameter for organ τ, for the receptor age group r, for nuclide i, due to exposure pathway p, in mrem/hr per μCi/ml

k_o = units conversion factor, = 1.142E5 = 1E6(pCi/μCi) • 1000 (ml/Kg)/ 8760 hr/yr

$U_{r,p}$ = usage factor for pathway p and age group r

dw = additional dilution factor for potable water

N_i = fraction of the radionuclide activity released to the water discharge path that reaches a specific receptor.

$DF_{i\tau,r}$ = ingestion dose conversion factor for nuclide i for receptor age group r in organ τ, in mrem/pCi (Tables E-7 to E-11 of R.G. 1.109)

λ_i = decay constant for nuclide i

t_p = average transit time in seconds

4.2 AQUATIC FOODS PATHWAYS

The liquid dose factor is

$$A_{i\tau,r,p} = k_o \cdot U_{r,p} \cdot BF_{i,p} \cdot N_i \cdot DF_{i\tau,r} \cdot \exp(-\lambda_i t_p)$$

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where

$BF_{i,p}$ = bioaccumulation factor for pathway p and nuclide i (from Reg. Guide 1.109, Table A-1). Other variables are as defined on the previous page.

4.3 SHORELINE RECREATION PATHWAY

The pathway-specific dose factors for shoreline deposition are given by:

$$A_{i\tau,r,p} = k_s \, W_s \, N_i \, U_{f,r,p} \, \frac{1 - e^{-\lambda_i t_b}}{\lambda_i} \, e^{-\lambda_i \, t_{sd}} \, DFG_{i\tau}$$

where

W_s = shoreline width factor

k_s = conversion factor = $k_o \cdot k_c \cdot mtv/3600$

- k_c = water to sediment transfer coefficient in L/kg hr
- mtv = Mass density of sediment in kg/m^2, 40 kg/m^2
- 3600 = Seconds per hour units conversion factor

t_b = length of time sediment is exposed to contaminated water, 4.716E8 sec

t_{sd} = transit time to deposit activity on shoreline

$DFG_{i\tau}$ = the dose conversion factor for standing on ground contaminated with nuclide i, in mrem/hr per pCi/m^2

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4.4 IRRIGATED VEGETABLE PATHWAY

$$A_{iT,r,p} = 1.14 \cdot 10^5 \cdot U_{f,r,p} CF_{iv} \cdot DF_{iT,r}$$

where:

$1.14 \cdot 10^5$ = a units conversion factor

CF_{iv} = the concentration factor for radionuclide i in irrigated vegetables, as applicable to the vicinity of the plant site (pCi/kg)/(pCi/L).

Calculation of the Concentration Factor

The calculation of the concentration factor for radionuclide i in irrigated vegetables, CF_{iv} as used in the equation for A_{iT}, is calculated as follows for all radionuclides other than Tritium:

$$CF_{iv} = N_i \cdot M \cdot I \left[\frac{r\,(1 - e^{-\lambda_{Ei} t_e})}{Y_v \lambda_{Ei}} + \frac{f_I B_{iv} (1 - e^{-\lambda_i t_b})}{P\,\lambda_i} \right] e^{-\lambda_i t}$$

For Tritium, the equation is as follows:

$$CF_{iv} = N_i \cdot M \cdot L_v$$

where

M = the additional dilution factor from the near field of the discharge structure to the point of irrigation water usage.

I = the average irrigation rate during the growing season ($L/m^2 h$).

r = the fraction of irrigation-deposited activity retained on the edible portions of leafy vegetables. There are separate values available for radioiodines and particulates.

Y_v = the agricultural productivity of irrigated leafy vegetables (kg/m^2).

f_I = the fraction of the year that vegetables are irrigated.

B_{iv} = the crop to soil concentration factor applicable to radionuclide i (pCi/kg vegetables)/(pCi/kg soil).

P = the effective surface density of soil (kg/m^2).

λ_i = the decay constant for radionuclide i (h^{-1}).

λ_{Ei} = the effective removal rate for activity deposited on crop leaves (h^{-1}), calculated as $\lambda_{Ei} = \lambda_i + \lambda_w$

λ_w = the rate constant for removal of activity from plant leaves by weathering (h^{-1}).

t_e = the period of leafy vegetable exposure during the growing season (h).

t_b = the period of long-term buildup of activity in soil (h).

t_h = the time between harvest of vegetable and human consumption (h).

L_v = the water content of leafy vegetable edible parts (L/kg).

4.5 REDUCTION TO NUREG-0133 EQUATIONS

NUREG-0133 does not have shoreline deposit equations, which can be eliminated by setting the Water Recreation Mixing Ratio to zero in the Liquid Receptor Transaction definition under EMS.

For the other equations, reduction to NUREG-0133 is obtained by setting:

N_i = 1 (this can be set in the definition of Fraction of Activity Reaching Receptor in DFP)

average transit time t_p = 0 (this can be set in the definition of Dose Calculation Parameters in DFP)

CHAPTER 5

GAS DOSE FACTOR CALCULATIONS

The DFP option is used to calculate the gas dose factors described previously. Dose factors are calculated separately for each nuclide, organ, and age group. The age group, applied to a specific receptor's dose calculations, is part of the receptor specification.

The same gas dose factors are used for both the site boundary dose rate calculations and for the maximum individual controlling location dose calculation.

The dose factor for each particulate or iodine nuclide i (or tritium) is given below. It is a function of pathway, organ, and age group. The pathways considered are:

1. Inhalation
2. Ground
3. Milk (Cow or Goat)
4. Meat
5. Vegetable

5.1 INHALATION PATHWAY

$$P_{iTa} = K'(BR)_a \ (DFA_{iT})_a \ \text{(mrem/yr per } \mu Ci/m^3 \text{)}$$

$$K' = 1E6 \ pCi/\mu Ci$$

$(BR)_a$ = breathing rate for age group a, in cubic m/yr

$(DFA_{i\tau})_a$ = inhalation dose factor for organ τ, for age group a, for nuclide i, in mrem/pCi

5.2 GROUND PLANE PATHWAY

$$R_{i\tau a} = K'K''(SF)\ DFG_{i\tau}\ [(1 - e^{-\lambda_i t})/\lambda_i]$$

(m^2 -mrem/yr per μCi/sec)

where

K' = 1E6 pCi/μCi

K'' = 8760 hr/yr

λ_i = decay constant for nuclide i, in sec^{-1}

t = exposure time (sec) = 4.73E8 (15 years)

$DFG_{i\tau}$ = ground plane conversion factor for nuclide i, organ τ (The same $DFG_{i\tau}$ factors apply to all age groups. The factors labelled total body in the database are applied to all other organs)

SF = shielding factor

5.3 MILK PATHWAY

$$R_{i\tau a} = K'\ (DFL_{i\tau})_a\ e^{-\lambda_i t_f}\ Q_F\ F_{mi}\ U_{ap} \cdot$$

$$\left\{ f_p f_s \left[\frac{r\ (1-e^{-(\lambda_i+\lambda_w)t_e})}{Y_p\ (\lambda_i + \lambda_w)} + B_{iv} \frac{(1 - e^{-\lambda_i t_b})}{p\ \lambda_i} \right] \right.$$

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$$+ (1-f_p f_s) e^{-\lambda_i t_h} \left[\frac{r\,(1-e^{-(\lambda_i + \lambda_w) t_e})}{Y_s\,(\lambda_i + \lambda_w)} + B_{iv} \frac{(1 - e^{-\lambda_i t_b})}{p\,\lambda_i} \right] \Bigg|$$

$(m^2$ - mrem/yr per μCi/sec)

where

K' = 1E6 pCi/μCi

Q_F = feed consumption rate by the milk animal (cow or goat) (Kg/day)

U_{ap} = age group a milk consumption (cow or goat)

Y_p = agricultural productivity by unit area of pasture feed grass, in Kg/sq. m

Y_s = agricultural productivity by unit area of stored feed, in Kg/sq. m

F_{mi} = stable element transfer coefficient for nuclide i, from feed to milk, in days/liter

B_{iv} = factor for uptake of radionuclides from soil by crops

r = fraction of deposited activity retained on animal feed grass (cow or milk). Separate values are used for radioiodines than all other particulates.

$(DFL_{i\tau})_a$ = ingestion dose factor for organ τ, for nuclide i, for receptor in age group a, in mrem/pCi

λ_i = decay constant for nuclide i

λ_w = decay constant for removal of activity on leaf and plant surfaces by weathering, in sec^{-1}

t_f = transport time from pasture to cow or goat to milk to receptor, in sec.

t_h = transport time from pasture to harvest to cow or goat to milk to receptor, in sec.

t_e = seasonal crop exposure time, in sec.

f_p = fraction of year that animal is on pasture

f_s = fraction of animal feed that is pasture grass while animal is on pasture

Carbon-14 in Milk

$$R_{iTa} = K'K''' F_{mi} Q_F U_{ap} (DFL_{iT})_a p_c (0.11/0.16) e^{-\lambda_i t_f}$$

(m^2-mrem/yr per μCi/sec)

where

K''' = 1E3 gm/Kg

p_c = fractional equilibrium ratio

0.11 = fraction of total plant mass that is natural carbon

0.16 = concentration of natural carbon in the atmosphere (g/m3)

and all other parameters as defined above

Only Q_F and U_{ap} depend on cow or goat.

Tritium in Milk

$$R_{iTa} = K'K''' F_{mi} Q_F U_{ap} (DFL_{iT})_a \cdot (0.75) (0.5/H) e^{-\lambda_i t_f}$$

(m^2-mrem/yr per μCi/sec)

where

K''' = 1E3 gm/Kg

H = absolute humidity, gm/cubic meter

0.75 = fraction of total feed that is water

0.5 = ratio of specific activity of feed grass water to the atmospheric water

and all other parameters as defined above

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Only Q_F and U_{ap} depend on cow or goat.

5.4 MEAT PATHWAY

$$R_{iTa} = K' \ (DFL_{iT})_a \ e^{-\lambda_i t_f} \ Q_F \ F_{fi} \ U_{ap} \cdot$$

$$\left\{ f_p f_s \left[\frac{r \ (1-e^{-(\lambda_i+\lambda_w)t_e})}{Y_p \ (\lambda_i+\lambda_w)} + B_{iv} \frac{1-e^{-\lambda_i t_b}}{p \ \lambda_i} \right] \right.$$

$$\left. + (1-f_p f_s) e^{-\lambda_i t_h} \left[\frac{r \ (\ 1-e^{-(\lambda_i+\lambda_w)t_e} \ )}{Y_s \ (\lambda_i+\lambda_w)} + B_{iv} \frac{1-e^{-\lambda_i t_b}}{p \ \lambda_i} \right] \right\}$$

where

F_{fi} = stable element transfer coefficient for nuclide i, from feed to meat, in days/Kg

U_{ap} = receptor's meat consumption (Kg/yr)

t_h = transport time from crop field to receptor, in sec

t_f = transport time from pasture to receptor, in sec

and all other factors are as described for the cow-milk pathway

Carbon-14 in Meat

$$R_{iTa} = K'K'' \ F_{fi} \ Q_F \ U_{ap} \ (DFL_{iT})_a \ P_C \ (0.11/0.16) \ e^{-\lambda_i t_f}$$

(m^2-mrem/yr per μCi/sec)

where all terms are as defined above.

Tritium in Meat

$$R_{i\tau a} = K'K''' F_{fi} Q_F U_{ap} (DFL_{i\tau})_a \cdot (0.75)\ (0.5/H)\ e^{-\lambda_i t_f}$$

$(m^2\text{-mrem/yr per } \mu Ci/sec)$

where all terms are as defined above.

5.5 VEGETABLE PATHWAY

$$R_{i\tau a} = K'\ (DFL_{i\tau})_a \left\{ U_a^L\ f_L\ e^{-\lambda_i t_L} \cdot \left[\frac{r\ (1-e^{-(\lambda_i+\lambda_w)t_e})}{Y_v\ (\lambda_i+\lambda_w)} + \frac{B_{iv}\ (1-e^{-\lambda_i t_b})}{p\ \lambda_i} \right] \right.$$

$$\left. + U_a^S\ f_g\ e^{-\lambda_i t_s} \cdot \left[\frac{r\ (1-e^{-(\lambda_i+\lambda_w)t_e})}{Y_{sv}\ (\lambda_i+\lambda_w)} + \frac{B_{iv}\ (1-e^{-\lambda_i t_b})}{p\ \lambda_i} \right] \right\}$$

$(m^2 mrem/yr \text{ per } \mu Ci/sec)$

where

U_a^L = consumption rate of fresh leafy vegetation for age group a, in Kg/yr

U_a^S = consumption rate of stored vegetation for age group a, in Kg/yr

f_L = fraction of annual intake of leafy vegetation grown locally

f_g = fraction of annual intake of stored vegetation grown locally

t_L = average time between harvest of leafy vegetation and consumption, in sec.

t_s = average time between harvest of stored vegetation and consumption, in sec.

t_b = long term sediment exposure time, in sec.

t_e = seasonal crop exposure time, in sec.

Y_v = vegetation areal density, in Kg/m^2

Y_{sv} = stored vegetation areal density, in KG/m^2

p = effective soil surface density

B_{iv} = soil to vegetation transfer factor for nuclide i

All other factors are as defined above.

Carbon-14 in Vegetables

$$R_{iTa} = K'K'' \ (U_a^L + U_a^S) \ (DFL_{iT})_a \ P_C \ (0.11/0.16) \ e^{-\lambda_i t_f}$$

(m^2-mrem/yr per μCi/sec)

where all variables are as defined earlier.

Tritium in Vegetables

$$R_{iTa} = K'K'' \ (U_a^L + U_a^S) \ (DFL_{iT})_a \cdot (0.75) \ (0.5/H) \ e^{-\lambda_i t_f}$$

(m^2-mrem/yr per μCi/sec)

where all variables are as defined earlier.

5.6 REDUCTION TO NUREG-0133 EQUATIONS

Inhalation and ground plane pathways are the same in R.G. 1.109 and NUREG-0133. For the other pathways (milk, meat, and vegetable), these equations reduce to the NUREG-0133 values by setting:

$$t_b = 0$$

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t_e = 9.999E19

t_f = 0 (in tritium equations only)

There are no C-14 equations in NUREG-0133, which can be obtained by setting p_c = 0.

APPENDIX A

REFERENCES

1. Boegli, J.S., R.R. Bellamy, W.L. Britz, and R.L. Waterfield, "Preparation of Radiological Effluent Technical Specifications for Nuclear Power Plants, "NUREG-0133" (October 1978).

2. Calculation of Annual Doses to Man from Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10CFR Part 50, Appendix I, U.S. NRC Regulatory Guide 1.109, Rev. 1 (October 1977).

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