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Appendix

A.

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 ρCi/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:

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

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:

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

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:

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

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:

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

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.

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

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

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

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:

$$F_f * C_v * Q_F * e^{-\lambda_i * t_s} = 4.635 \quad \text{pCi/kg in meat for Mn-54}$$

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:

$$\sum_i DFI_{ija} * \left[U_{va} * f_g * C_v + U_{ma} * C_m + U_{Fa} * C_f + U_{La} * f_l * C_L \right]$$

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

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^{-6}	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^{-6}	4×10^{-3}	1×10^{-9}	1×10^{-4}
		I	5×10^{-6}	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^{-6}	1×10^{-1}	1×10^{-7}	5×10^{-3}
		I	2×10^{-5}	1×10^{-1}	8×10^{-7}	5×10^{-3}
Antimony	Sb 122	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}
	Sb 124	S	2×10^{-7}	7×10^{-4}	5×10^{-9}	2×10^{-5}
		I	2×10^{-6}	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^{-6}	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^{-6}	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^{-6}	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^{-2}	3×10^{-9}	4×10^{-4}
		I	2×10^{-7}	1×10^{-2}	7×10^{-9}	4×10^{-4}
Bromine (35)	Br 82	S	1×10^{-6}	8×10^{-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^{-8}	2×10^{-4}
		I	7×10^{-6}	5×10^{-3}	3×10^{-8}	2×10^{-4}
	Cd 115m	S	4×10^{-6}	7×10^{-4}	1×10^{-8}	3×10^{-5}
		I	4×10^{-6}	7×10^{-4}	1×10^{-8}	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^{-2}	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^{-2}	4×10^{-7}	2×10^{-3}
		I	3×10^{-6}	3×10^{-2}	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}	8×10^{-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}	8×10^{-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^{-13}	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^{-5}	6×10^{-2}	4×10^{-7}	2×10^{-3}
		I	1×10^{-5}	6×10^{-2}	4×10^{-7}	2×10^{-3}
Dysprosium (66)	Dy 165	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}
	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}	6×10^{-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^{-6}	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)
		I	2×10^{-7}	9×10^{-4}	6×10^{-9}	3×10^{-5}
Hydrogen (1)	H3	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^{-9}	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^{-6}	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	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}
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^{-8}	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^{-5}	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^{-9}	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^{-3}	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^{-8}
		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^{-8}
		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^{-3}	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^{-8}	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^{-6}	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^{-3}	2×10^{-7}	9×10^{-6}
		I	1×10^{-6}	6×10^{-3}	3×10^{-8}	2×10^{-7}
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^{-5}	2×10^{-1}	1×10^{-6}	7×10^{-3}
		I	3×10^{-5}	2×10^{-1}	1×10^{-6}	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^{-2}	1×10^{-8}	8×10^{-4}
	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^{-8}	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^{-8}	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^{-8}	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}	8×10^{-4}	3×10^{-12}	3×10^{-5}
		I	3×10^{-11}	8×10^{-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^{-9}	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

$SA=(0.4+0.38\ E+0.0034\ E^{2})\ 10^{-6}$ $E\geq0.72$

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:

$(C_A/MPC_A)+(C_B/MPC_B)+(C_C/MPC_C)\leq1$

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. $C_A/MPC_A \leqq 1/10$) and (b) the sum of such ratios for all the radionuclides considered as not present in the mixture does not exceed ¼ i.e.

$(C_A/MPC_A + C_B/MPC_B \ldots\ldots + \leqq ¼)$.

Appendix C

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 Bisson 5/26/94
Date

Mathew J. Liannell 5/27/94
Date

Reviewed by Mark S. Stevens 5-31-94
Date

Approved by [signature] 5/31/94
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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.

APPENDIX C: EMS SOFTWARE DOCUMENTATION

ATTACHMENT 2: RESOLUTIONS OF EMS SOFTWARE TEST REPORT DISCREPANCIES

Attachment 2

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.

APPENDIX C: EMS SOFTWARE DOCUMENTATION

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: Ronald Zink 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.

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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.

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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 without 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 <u>without</u> 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):

$$D_s = shf \cdot F_o \cdot \Sigma QR_{iv} \cdot [(L_i \cdot X/Q \cdot 8760^{-b}) + (1.11M_i \cdot X/Q_g \cdot 8760^{-a})]$$

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):

$$D_{sk} = \frac{shf \cdot F_o \cdot \Sigma QR_{iv} \cdot [(L_i \cdot X/Q \cdot t^{-b}) + (1.11M_i \cdot X/Q_g \cdot t^{-a})]}{(5.256 \cdot 10^5 / dur)}$$

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$_i$

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:

$$\text{the greatest (over T) of} \quad \{ 100 \cdot (\Sigma\ D_{i,T}) / QL_{rp}$$

where

$D_{i,T}$ = the dose to organ T of the controlling receptor, in the applicable quarter, due to gaseous emissions of radionuclide i (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 van der Heide Date: 9/15-93

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APPENDIX C: EMS SOFTWARE DOCUMENTATION

ATTACHMENT 4: TECHNICAL REFERENCE MANUAL, EFFLUENT MANAGEMENT SYSTEM
SOUTHERN NUCLEAR OPERATING COMPANY, JANUARY 1993, FP 75486

Canberra Nuclear
Nuclear Data Systems Division
150 Spring Lake Drive
Itasca, Illinois 60143-2096

January 1993

Southern Nuclear Operating Company Effluent Management System Technical Reference Manual

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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, while the new 10CFR20 requirement is that the diluted concentration at the site boundary be less than the ECL values given in the new 10CFR20, Appendix B, Table 2.

- 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 both liquid and gaseous calculations.

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).

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.

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.

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.

For the setting of flags to control options in the EMS code, see the EMS Operator's Manual.

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 $\hat{ECL}$ (new 10CFR20) values must not exceed unity:

OLD 10CFR20		NEW 10CFR20
$S = \Sigma_i \, C_i/MPC_i \leq 1$	OR	$S = \Sigma_i \, C_i/ECL_i \leq 1$

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 unity, 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_{req} calculation, the database must also contain the same limiting value, as the liquid MPC or ECL for each gas.

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, NO_WASTE, CALC or DOSE. For liquid releases, NONE, NO_WASTE, 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 = NO_WASTE

$$R_{cwmax} = \frac{F_{avail} \cdot f_{alloc}}{D_{req}}$$

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 NO_WASTE:

$$min\_dflow = \frac{F_{waste} \cdot D_{req}}{f_{alloc} \cdot (f_f / 100) \cdot \left[1 - \sum_i \frac{C_i}{XXX_i} \right]}$$

where XXX_i is MPC_i under OLD 10CFR20, and is ECL_i under NEW 10CFR20.

If the SET_OPT option is other than NO_WASTE:

$$min\_dflow = \frac{F_{waste} \cdot (D_{req} - 1.0)}{f_{alloc} \cdot (f_f / 100) \cdot \left[1 - \sum_i \frac{C_i}{XXX_i} \right]}$$

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, no credit is taken for dilution (setpoint equation is set to NO_DILUT), 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 STD, and the SET_OPT option is set to NO_WASTE, 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> NO_WASTE, 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 NO_WASTE, 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 <u>other than</u> NO_WASTE, 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:

$$S_{max}\ (\mu Ci/ml) = S_{adj} \cdot \Sigma\ C_i$$

where the sum extends over all gamma-emitting nuclides (nuclides of type other than O) 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:

$$S_{max}\ (cpm) = S_{adj} \cdot (R_{mon} - B) + B$$

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 setpoint calculated as above and default values determined by the user. 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. Otherwise, the current background is not added to the default value.

Setpoint in μCi/ml

A candidate setpoint is calculated based on the expected response:

$$S_{exp} = f_{tol} \Sigma C_i \quad \ldots$$

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 Setpoints (μCi/ml)

Recommended Setpoint in User Units (e.g. cpm)

The candidate setpoint based on expected monitor response is calculated as follows:

$$S_{exp}(cpm) = f_{tol} \cdot (R_{mon} - B) + f_{Btol} \cdot B$$

where

f_{Btol} = background tolerance factor (set using QBF on the releasept table)

If the default setpoint value includes background:

$$B_{rp} = 0$$

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, except for the nuclide-specific response. 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 $C^{dp} = [\ \Sigma\ C_i]\ [F/(F+F_o)]$

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:

$D_{i\tau r}$ = 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.

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.

If the denom_typ option from the Options Table is 1, then:

$$F_{sr} = F_w \cdot R_{mix}$$

Otherwise, if denom_typ is 2, then:

$$F_{sr} = \frac{F_w}{F_{dil}} \cdot R_{mix}$$

Otherwise:

$$F_{sr} = \frac{F_w}{F_w + F_{dil}} \cdot R_{mix}$$

F_w = flow rate of undiluted waste effluent

F_{dil} = flow rate of the dilution flow

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.

Also, the sum extends over all time periods s.

$A_{i\tau r}$ is available as an editable table, but can be recalculated with different parameters and pathways with the Dose Factor Processing (DFP) option. The equations used are presented in Chapter 4 of this manual.

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

D_τ =sum of all open release points in mrem/day by organ τ 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 to the end of the release.

$D_{a\tau}$ =Additional Anticipated Dose for liquid releases by organ τ and quarter of release.

NOTE: The 31 day dose projections on the Approval/Results screen include additional doses 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.

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.

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 "old" 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:

$$Q_i = C_i \cdot V_f \cdot \text{duration of release (min)} \cdot 28316.85 \cdot U_F$$

$$(\mu Ci) = (\mu Ci/ml)(\text{cubic feet/min})\ (\text{min})\ (\text{ml/cubic feet})$$

where:

V_f = vent flow rate in user units (usually CFM)

C_i = concentration in μCi/ml

U_F = the flow-rate units conversion factor which converts from user units to CFM

The activity release rate in μCi/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.

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.

3.3a COMPLIANCE WITH OLD 10CFR20

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:

$$\Sigma_i K_i \; shf \; \Sigma_v \; [\; \overline{(X/Q)}_{vr} \; \dot{Q}_{iv}] < 500 \text{ mRem/yr} \cdot f_{alloc} \cdot f_s$$

OR

$$\Sigma_v shf \; \Sigma_i \; [\; V_{ir} \; \dot{Q}_{iv}] < 500 \text{ mRem/yr} \cdot f_{alloc} \cdot f_s$$

Elevated Stack ≥ 80m

$$\Sigma_i \; shf \; (L_i + 1.1M_i) \;\; \Sigma_v \; [\; \overline{(X/Q)}_{vr} \; \dot{Q}_{iv}] < 3000 \text{ mRem/yr} \cdot f_{alloc} \cdot f_s$$

OR

$$\Sigma_v \; shf \; \Sigma_i [(L_i \; \overline{(X/Q)}_{ir} + 1.1B_{ir}) \; \dot{Q}_{iv}] < 3000 \text{ mRem/yr} \cdot f_{alloc} \cdot f_s$$

Elevated Stack ≥ 80m

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:

$$\Sigma_i \; \Sigma_p \; \Sigma_v \; [f_p \; P_{ip} \; W_{mv} \; \dot{Q}_i \;] < 1500 \text{ mRem/yr} \cdot f_{alloc} \cdot f_s$$

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

3.3b COMPLIANCE WITH NEW 10CFR20

The diluted site boundary ECL ratio is compared to the limiting value permitted by Tech Spec:

$$4.72 \cdot 10^{-4} \sum_{v} \left[f_v \cdot \overline{(X/Q)}_v \sum_{i} \left[\frac{C_{iv}}{ECL_i} \right] \right] < R_{max}$$

where:

$4.72 \cdot 10^{-4}$ is a units conversion factor, determined by: (1 m^3 / 35.31 ft^3) • (1 minutes / 60 s).

f_v is the waste flow rate for release point v, in CFM.

$\overline{(X/Q)}_v$ is the noble gas X/Q for the distance which matches the site boundary distance, in sec/m^3. The table used (ground-level, mixed-mode, or elevated) is specified by the release point definition.

C_{iv} is the concentration of nuclide i, in μCi/mL.

ECL_i is the effluent concentration limit of nuclide i in μCi/mL.

R_{max} is the maximum MPC ratio limit from the release point setpoint definition.

and the sum extends over all open gaseous release points v on the entire site.

3.4 SETPOINT DETERMINATION FROM NEW/OLD 10CFR20

Using QBF, the 10CFR20 option parameter for gaseous effluents in the options table of the database can be set to one of three values: NEW, OLD, or MIN.

If the 10CFR20 option is set to NEW, setpoint calculations are determined based on the Effluent Concentration Limits as stated in the new 10CFR20, Appendix B, Table 2, Column 1.

If the 10CFR20 option is set to OLD, setpoints are determined from Dose Rate Limits set forth in the Technical Specifications and stored in the Dose Limits Table.

If the 10CFR20 option is set to MIN, setpoint calculations are determined by a combination of the NEW and OLD procedures. The nratios (release point) for both NEW and OLD 10CFR20 are calculated, then the minimum of the two is determined and used in the setpoint calculations.

3.4a NEW 10CFR20 NRATIO

The total fraction of effluent concentration limit for the sampled mix of isotopes for the specified release point is given by:

$$rp\_tecl\_hi = units \cdot \overline{(X/Q)}_v \cdot rp\_wflow \bullet rp\_utecl$$

$$rp\_tecl\_lo = \frac{rp\_utecl\_g}{\frac{f_s \cdot f_{alloc}}{units \cdot \overline{(X/Q)}_v \cdot rp\_wflow} - rp\_utecl\_ng}$$

where:

rp_tecl_hi is the diluted total fraction of effluent concentration limit for the release point, at the site boundary, for use in the high-gamma-activity case.

rp_tecl_lo is the diluted total fraction of effluent concentration limit for the release point, at the site boundary, for use in the low-gamma-activity case.

rp_utecl is the undiluted total fraction of effluent concentration limit for the release point.

$$rp\_utecl\_g = \frac{1 \text{ cc/mL}}{R_{max}} \cdot \sum_{i=g} \frac{C_i}{ECL_i}$$

$$rp\_utecl\_ng = \frac{1 \text{ cc/mL}}{R_{max}} \cdot \sum_{i=ng} \frac{C_i}{ECL_i}$$

$$rp\_utecl = rp\_utecl\_g + rp\_utecl\_ng$$

where:

rp_utecl_g = undiluted total fraction of the effluent limit, for gamma-emitters

rp_utecl_ng = undiluted total fraction of the effluent limit, for non-gamma-emitters

R_{max} = the maximum MPC ratio from the release point setpoint definition

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.

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$\overline{(X/Q)}_v$ is the noble gas X/Q for the distance which matches the site boundary distance, in sec/m^3. The table used (ground-level, mixed-mode, or elevated) is specified in the release point definition.

rp_wflow is the effluent flow rate for the release point, in CFM

units is the units conversion factor

units = (1 m^3/35.31 ft^3) · (1 min/60 sec) = 4.72 E-04

The total fraction of effluent concentration limit for the sampled mix of isotopes for the specified discharge point is given by:

$$dp\_tecl = units \cdot \overline{(X/Q)}_v \cdot dp\_wflow \bullet dp\_utecl$$

$$dp\_tecl\_lo = \frac{dp\_utecl\_g}{\frac{f_s \cdot f_{alloc}}{units \cdot \overline{(X/Q)}_v \cdot dp\_wflow} - dp\_utecl\_ng}$$

where:

dp_tecl_hi is the diluted total fraction of the effluent concentration limit for the discharge point, at the site boundary, for use in the high-gamma-activity case.

dp_tecl_lo is the diluted total fraction of the effluent concentration limit for the discharge point, at the site boundary, for use in the low-gamma-activity case.

dp_utecl is the undiluted total fraction of the effluent concentration limit for the discharge point.

$$dp\_utecl\_g = \frac{\sum_v [rp\_utecl\_g_v \cdot rp\_wflow_v]}{dp\_wflow}$$

$$dp\_utecl\_ng = \frac{\sum_v [rp\_utecl\_ng_v \cdot rp\_wflow_v]}{dp\_wflow}$$

$$dp\_utecl = dp\_utecl\_g + dp\_utecl\_ng$$

where:

dp_utecl_g is the undiluted total ECL fraction for gamma-emitters for the designated discharge point.

dp_utecl_ng is the undiluted total ECL fraction for non-gamma-emitters for the designated discharge point.

$dp\_utecl\_g_v$ is the undiluted total ECL fraction for gamma-emitters for the designated point v, as calculated above.

$dp\_utecl\_ng_v$ is the undiluted total ECL fraction for gamma-emitters for the designated point v, as calculated above.

rp_wflow_v is the waste flow for release point v.

dp_wflow is the waste flow for the discharge point: the sum of the waste flows for all open release points on the discharge point.

and the sums extend over all open release points v on the discharge point.

$\overline{(X/Q)}_v$ is the noble gas X/Q for the distance which matches the site boundary distance, in sec/m^3. The table used (ground-level, mixed-mode, or elevated) is specified by the discharge point definition.

units is the units conversion factor

units = $(1\ m^3/35.31\ ft^3) \cdot (1\ min/60\ sec)$ = 4.72E-04

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Noble Gases

For the release point:

If the release point setpoint equation is set to LOW_ACT, then:

nratio = 1 / rp_tecl_lo

Otherwise:

nratio = 1 / rp_tecl_hi

For the discharge point:

If the discharge point setpoint equation is set to LOW_ACT, then:

nratio = 1 / rp_tecl_lo

Otherwise:

nratio = 1 / rp_tecl_hi

Radioiodines and Particulates

For the release point:

If the release point setpoint equation is set to LOW_ACT, then:

rpratio = 1 / rp_tecl_lo

Otherwise:

rpratio = 1 / rp_tecl_hi

For the discharge point:

If the discharge point setpoint equation is set to LOW_ACT, then:

rpratio = 1 / dp_tecl_lo

Otherwise:

rpratio = 1 / dp_tecl_hi

3.4b OLD 10CFR20 NRATIO

The ratio of dose rate limit to dose rate for a single release point is given below for these three cases:

Noble Gases

$$\text{nratio} = r_g = \text{lesser of the ratios}$$

(total body dose rate limit/total body dose rate) and
(skin dose rate limit/skin dose rate)

= for a vent release, lesser of

$$\frac{500 \text{ mrem/yr}}{\text{shf } \Sigma_i K \cdot \dot{Q}_{iv} \cdot \overline{(X/Q)}_{mv}}$$

and

$$\frac{3000 \text{ mrem/yr}}{\text{shf } \Sigma\ (L_i + 1.1M_i) \cdot \dot{Q}_{iv} \cdot \overline{(X/Q)}_{mv}}$$

= for an Elevated Stack ≥ 80m, lesser of

$$\frac{500 \text{ mrem/yr}}{\text{shf } \Sigma\ V_{ir} \cdot \dot{Q}_i}$$

and

$$\frac{3000 \text{ mrem/yr}}{\text{shf } \Sigma\ [\ L_i \cdot \overline{(X/Q)}_r + 1.1B_{ir}] \cdot \dot{Q}_i}$$

Radioiodines and Particulates

In these cases, the ratio is obtained by summing over the appropriate nuclide indices:

$$\text{rpratio} = \frac{1500 \text{ mrem/yr}}{\Sigma\ P_i \cdot \dot{Q}_{iv} \cdot W_{mv}} = \text{maximum organ dose rate}$$

When the sum is over nuclides and the inhalation, ground plane and cow's milk pathways are all turned on.

3.4c 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:

$$R_{mon} = \text{monitor response (cpm)} + B$$

$$= \text{offset} + [\text{slope} \cdot \Sigma C_i] + [\text{quad} \cdot (\Sigma C_i)^2] + B$$

where offset, slope, and quad are the coefficients in a quadratic fit to the monitor response to nuclide activity, 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 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

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:

$$SU_{max} = f_s \cdot f_{alloc} \cdot ratio \cdot (R_{mon} - B) + B$$

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.

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

3.4d REPORTED SETPOINTS

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

$$S_{response} = \begin{cases} \text{mrtol} \bullet \text{SUM} & [\mu Ci/ml] \\ [\text{mrtol} \bullet (\text{Rmon} - B)] + (\text{mrtolb} \bullet B) & [\text{User Units}] \end{cases}$$

$S_{default}$ = 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.

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 = the minimum of R_{wmax} 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 (i.e., 3.4a & 3.4b)

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 Total Body Dose Rate Calculations

The total body dose rate due to gamma emissions by noble gas releases from vent v is calculated by using the following expressions:

$$\dot{D}_t = 1.14 \cdot 10^{-4} \ (shf) \ \overline{(X/Q)}_v \ \sum_i (K_i \cdot \dot{Q}_{iv}) \quad \text{Vent} < 80m$$

$$\dot{D}_t = 1.14 \cdot 10^{-4} \ (shf) \ \sum_i (V_i \cdot \dot{Q}_{iv}) \quad \text{Elevated Stack} \geq 80m$$

where:

$\dot{D}_t$ = the total body dose rate due to gamma emissions by noble gas releases from vent v, in mrem/h.

$1.14 \cdot 10^{-4}$ = inverse of the number of hours in a year.

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Noble Gas Dose Calculations

The dose contribution due to noble gases in gaseous effluents is calculated using the following expressions:

For any time period, for air dose due to gamma radiation:

$$D_\gamma = 3.17 \cdot 10^{-8} \Sigma M_i \cdot (\overline{X/Q})_v \cdot Q_{iv} \qquad \text{Vent} < 80\text{m}$$

OR

$$D_\gamma = 3.17 \cdot 10^{-8} \Sigma B_{ir} \cdot Q_{iv} \qquad \text{Elevated Stack} \geq 80\text{m}$$

and for air dose due to beta radiation:

$$D_\beta = 3.17 \cdot 10^{-8} \Sigma N_i \cdot (\overline{X/Q})_v \cdot Q_{iv} \qquad \text{Vent} < 80\text{m}$$

OR

$$D_\beta = 3.17 \cdot 10^{-8} \cdot \Sigma N_i \cdot (\overline{X/Q})_v \cdot Q_{iv} \qquad \text{Elevated Stack} \geq 80\text{m}$$

and for total body dose:

$$D_t = \frac{shf \cdot f_o \cdot \Sigma K_i \cdot (\overline{X/Q})_v \cdot \dot{Q}_{iv}}{(5.256E+05/duration)} \qquad \text{Vent} < 80\text{m}$$

OR

$$D_t = \frac{shf \cdot f_o \cdot \Sigma V_{ir} \cdot \dot{Q}_{iv}}{(5.256E+05/duration)} \qquad \text{Elevated Stack} \geq 80\text{m}$$

and for skin dose:

$$D_s = \frac{shf \cdot f_o \cdot \Sigma (L_i + 1.1M_i) \cdot (\overline{X/Q})_v \cdot \dot{Q}_{iv}}{(5.256E+05/duration)} \qquad \text{Vent} < 80\text{m}$$

OR

$$D_s = \frac{shf \cdot f_o \cdot \Sigma [(L_i \cdot (\overline{X/Q})_V) + 1.1B_{ir})] \cdot \dot{Q}_{iv}}{(5.256E+05/duration)} \qquad \text{Elevated Stack} \geq 80\text{m}$$

where:

D_γ = the total gamma air dose from gaseous effluents, in mrad.

D_β = the total beta air dose from gaseous effluents, in mrad.

D_t = the total body dose from gaseous effluents, in mrem.

D_s = the total skin dose from gaseous effluents, in mrem.

$3.17 \cdot 10^{-8}$ = inverse of number of seconds in a year

5.256E+05 = number of minutes in a year

f_o = The occupancy factor defined for the receptor at the given location, a dimensionless number ≤ 1.0 .

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 $\mu Ci/m^3$.

M_i = the air dose factor due to gamma emissions for noble gas radionuclide i, in mrad/yr per $\mu Ci/m^3$.

N_i = the air dose factor due to beta emissions for noble gas radionuclide i, in mrad/yr per $\mu Ci/m^3$.

V_i = the gamma total body dose factor for nuclide i at receptor location r, in mrem/yr per $\mu Ci/sec$.

B_i = the gamma skin dose factor for nuclide i at receptor location r, in mrem/yr per $\mu Ci/sec$.

$\overline{(X/Q)}_v$ = the highest value of the annual average atmospheric dispersion factor for vent or stack v at the site boundary, for all sectors, in sec/m^3.

Q_{iv} = the release of noble gas radionuclides, i, in gaseous effluents from vent or stack v in μCi. Releases are cumulative over the time period selected for the report.

$\dot{Q}_{iv}$ = the release rate of noble gas radionuclides, i, in gaseous effluents from vent or stack v in μCi/sec. Release rates are cumulative over the time period selected for the report.

duration = the duration of the release in minutes

Organ Dose Calculations

For any time period, organ doses from particulates and iodines are:

$$D_{\tau a} = 3.17 \cdot 10^{-8} \cdot f_o \cdot \Sigma R_{ip\tau a} \cdot W_{pv} \cdot Q_{iv}$$

where:

$3.17 \cdot 10^{-8}$ = inverse of number of seconds in a year

$D_{\tau a}$ = the cumulative dose for age group a and organ τ from iodines and particulates with half lives greater than 8 days in gaseous effluents, in mrem.

$R_{ip\tau a}$ = the dose factor for each radionuclide i, pathway p, organ τ, and age group a, in m^2 (mrem/yr) per μCi/sec or mrem/yr per $\mu Ci/m^3$.

W_{pv} = the annual average dispersion parameter for estimating the dose to an individual at the critical location, as appropriate to pathway p and release point v, is shown below:

1) $\overline{(X/Q)}$, in sec/m^3, for the inhalation pathway and for tritium and C-14 in all pathways.

2) $\overline{(D/Q)}$ for the food and ground plane pathways, in $meters^3$.

Q_{iv} = the release of nuclide i in gaseous effluents from release point v. Releases are cumulative over the time period selected for the report. Only tritium, I-131, I-133, and radioiodines in particulate form with half-lives greater than 8 days are included.

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:

$$C_{cei} = (A_{cei} / V_e) \cdot 35.315$$

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 uCi/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:

$$D_{p\tau} = (D_\tau \bullet p) + D_{a\tau}$$

where:

$D_{p\tau}$ =the 31 Day Projected Dose by organ τ

D_τ =sum of all open release points in mrem/day by organ τ 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.

$D_{a\tau}$ =Additional Anticipated Dose for gaseous releases by organ τ and quarter of release.

NOTE: The 31 day dose projections on the Approval/Results screen include additional doses 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

$$A_{i\tau,r,p} = k_o \cdot U_{r,p} \cdot BF_{i,p} \cdot N_i \cdot DF_{i\tau,r} \cdot \exp(-\lambda_i t_p)$$

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:

$$A_{iT,r,p} = k_s \, W_s \, N_i \, U_{f,r,p} \, \frac{1 - e^{-\lambda_i t_b}}{\lambda_i} \, e^{-\lambda_i t_{sd}} \, DFG_{iT}$$

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_{iT} = 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)

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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

$$P_{iTa} = K'(BR)_a \ (DFA_{iT})_a \ (\text{mrem/yr per } \mu Ci/m^3)$$

$K' =$ 1E6 pCi/μCi

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$(BR)_a$ = 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

$$R_{i\tau a} = K'\ (DFL_{i\tau})_a\ e^{-\lambda_i t_f}\ Q_F\ F_{mi}\ U_{ap} \cdot$$

$$\left\{ f_p f_s \left[\frac{r\ (1-e^{-(\lambda_i+\lambda_w)t_e})}{Y_p\ (\lambda_i + \lambda_w)} + B_{iv} \frac{(1 - e^{-\lambda_i t_b})}{p\ \lambda_i} \right] \right.$$

$$+ (1-f_p f_s) e^{-\lambda_i t_h} \left[\frac{r\,(1-e^{-(\lambda_i + \lambda_w) t_e})}{Y_s\,(\lambda_i + \lambda_w)} + B_{iv} \frac{(1 - e^{-\lambda_i t_b})}{p\,\lambda_i} \right] \Bigg\}$$

$(m^2$ - 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

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

$$R_{iTa} = K'K''' \ F_{fi} \ Q_F \ U_{ap} \ (DFL_{iT})_a \ p_C \ (0.11/0.16) \ e^{-\lambda_i t_f}$$

$(m^2\text{-mrem/yr per } \mu Ci/sec)$

where all terms are as defined above.

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Tritium in Meat

$$R_{iTa} = K'K''' F_{fi} Q_F U_{ap} (DFL_{iT})_a \cdot (0.75)\ (0.5/H)\ e^{-\lambda_i t_f}$$

$(m^2\text{-mrem/yr per } \mu Ci/sec)$

where all terms are as defined above.

5.5 VEGETABLE PATHWAY

$$R_{iTa} = K'\ (DFL_{iT})_a \left\{ U_a^L f_L e^{-\lambda_i t_L} \cdot \left[\frac{r\ (1-e^{-(\lambda_i+\lambda_w)t_e})}{Y_v\ (\lambda_i+\lambda_w)} + \frac{B_{iv}\ (1-e^{-\lambda_i t_b})}{p\ \lambda_i} \right] \right.$$

$$\left. + U_a^S f_g e^{-\lambda_i t_s} \cdot \left[\frac{r\ (1-e^{-(\lambda_i+\lambda_w)t_e})}{Y_{sv}\ (\lambda_i+\lambda_w)} + \frac{B_{iv}\ (1-e^{-\lambda_i t_b})}{p\ \lambda_i} \right] \right\}$$

$(m^2\text{mrem/yr per } \mu Ci/sec)$

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:

$t_b = 0$

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.

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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).