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OFFSITE DOSE CALCULATION MANUAL

JAFNPP

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449 028

OFFSITE DOSE CALCULATION MANUAL

CONTENTS:

I. INTRODUCTION & PURPOSE

The OFFSITE DOSE CALCULATION MANUAL (ODCM) is the document that outlines JAFNPP's basic methodology for calculating radiation doses resulting from releases of both gaseous and liquid effluents. This methodology is adapted from the guidance promulgated via NUREG 0133 and deviates from that guidance in only two site specific cases.

In the case of liquid effluents JAFNPP has elected to use actual $F\ell$ values (near field average dilution factor for Cil during any liquid effluent release. NUREG 0133 defines $F\ell$ as the ratio of the maximum undiluted liquid waste flow during release to the average flow from the site discharge structure to unrestricted receiving waters. JAFNPP feels that a more quantitative method would be to utilize actual empirical information in the calculation of $F\ell$ and subsequent dose assessments based in part on the $F\ell$ parameter.

In the case of gaseous effluents JAFNPP has elected to utilize empirical determinations of D/Q and χ/Q for the site boundary location obtained from 1974-75 meteorological data, this we feel allows a more accurate and realistic assessment of dose to the infant thyroid from the iodine contribution.

In all other parameters and assumptions JAFNPP has utilized the guidance of NUREG 0133 and associated supporting documents.

449 030

CALCULATION OF DOSE TO MAXIMUM EXPOSED INDIVIDUAL FROM LIQUID EFFLUENT

Technical Specifications state, "cumulative dose contri itions from liouid effluents shall be determined in accordance with the offsite dose calculation manual at least once per 31 days."

At JAFNPP, the cumulative dose contributions consider the dose contributions from the maximum exposed individual's consumption of fish and potable water. Invertebrate consumption is not a factor as JAFNPP is a fresh water site. JAFNPP takes the position that the adult is the maximum exposed individual as is recommended by NUREG 0133. (ref. 1) subsequently, JAFNPP has developed tables of Ai_τ for the adult case.

The relationships and methods that form the calculational base for dose accounting for the liquid effluent pathway are as follows: Dose contributions for the total time period $\sum_{\ell=1}^{m} \Delta t_\ell$ will be determined by calculation at least once per 31 days and a cumulative summation of these total body and critical organ doses will be maintained for each calendar quarter. These dose contributions will be calculated for all radionuclides identified by JAFNPP in liquid effluents released to unrestricted areas using the following expression:

$$D_\tau = \sum_i \left[Ai_\tau \sum_{\ell=1}^{m} \Delta t\ell \; Ci\ell \; F\ell \right]$$

Where:

D_τ = the cumulative dose commitment to the total body or any organ, τ, from the liquid effluents for the total time period $\sum_{\ell=1}^{m} \Delta t\ell$, in mrem.

449 031

$\Delta t\ell$ = the length of the ℓth time period over which $C_{i\ell}$ and F_ℓ are averaged for all liquid releases, in hours.

$C_{i\ell}$ = the average concentration of radionuclide, i. in undiluted liquid effluent during time period $\Delta t\ell$ from any liquid release, in $uci/m\ell$.

$A_{i\tau}$ = the site related ingestion dose commitment factor to the total body or any organ τ for each JAFNPP identified principal gamma and beta emitter listed in table L1-3, in mrem-ml per hr-uci

F_ℓ = the near field average dilution factor for $C_{i\ell}$ during any liquid effluent release. Defined as the ratio of the maximum undiluted liquid waste flow during release to the average flow from the site discharge structure to unrestricted receiving waters.

The term $C_{i\ell}$ is the composite undiluted concentration of radioactive material in liquid waste at the release point as determined by the radioactive liquid waste sampling and analysis program as contained in the technical specifications. All dilution factors beyond the sample point are included in the F_ℓ and $A_{i\tau}$ terms.

The term F_ℓ is a near field average dilution factor and is determined as follows:

$$F\ell = \frac{\text{Liquid Radioactive Waste Flow}}{\text{Discharge Structure Exit Flow}}$$

The liquid radioactive waste flow is the maximum flow from all continuous and batch radioactive effluent releases specified in Technical Specifications from all liquid radioactive waste management systems. The discharge structure exit flow is the average flow during disposal from the discharge structure release point into the receiving water body.

At JAFNPP, the maximum flow from all liquid effluent releases is 200 gpm and the discharge structure exit flow is 378,000 gpm with all circulating pumps in operation, thus:

$$F\ell = \frac{200}{378,000} = 5.29\ E\text{-}04$$

However, in order to provide a more accurate estimate of $F\ell$, JAFNPP will calculate $F\ell$ based on actual operating parameters that exist at the time of releases. This affords a more quantitative assessment of radiation dose resulting from liquid effluent releases at JAFNPP.

Therefore:

$$F\ell = \frac{\text{Actual Liquid Effluent Flow}}{\text{Actual Discharge Structure Exit Flow}}$$

DOSE FACTOR RELATED TO LIQUID EFFLUENTS

The equation for dose from liquid effluents requires the use of a dose factor $A_{i\tau}$ for each nuclide, i, which embodies the dose factors, pathway transfer factor, pathway usage factors, and dilution factors for the points of pathway origin. JAFNPP has followed the guidance of NUREG 0133 and has calculated $A_{i\tau}$ for the total body and critical organ of the maximum exposed individual e.g. the adult. The dose factors were compiled from table E-11 of Regulatory Guide 1.109 (ref 2) The summary dose factor is as follows:

$$A_{i\tau} = k_o \, (U_w/D_w + UF \; BFi) \; Dfi$$

Where:

$A_{i\tau}$ = composite dose parameter for the total body or critical organ of an adult for nuclide, i, for all appropriate pathways, mrem/hr per *uci/mℓ*

k_o = units conversion factor, 1.14E05 = 10^6pci/*uci* x 10^3ml/kg ÷ 8760 hr/yr

U_w = 730 kg/yr, adult water consumption

BF_i = Bioaccumulation factor for nuclide, i, in fish, pCi/kg per pCi/ℓ from table A-1 of Regulatory Guide 1.109

DF_i = dose conversion factor for nuclide i, for adults in pre-selected organs, τ, in mrem/pci, from table E-11 of Regulatory Guide 1.109

D_w = dilution factor from the near field area within one quarter mile of the release point to the Oswego City and Ononega County intake. (nearest potable water intake) A lake dilution factor of 9.2 was calculated using the quasi-steady state model as described in section C.3, "large lakes," of Regulatory Guide 1.113. (ref 3)

For the JAFNPP site Aiτ can be expressed as:

$$A_{i\tau} = 1.14E05\ (730/D_w + 21\ BF_i)\ DF_i$$

Given D_w = 9.2

$$A_{i\tau} = 1.14E05\ (79.3 + 21\ BF_i)\ DF_i$$

JAFNPP has compiled Aiτ factors for total body and critical organs for the maximum exposed individual. These are included as table L1-3

Case - Adult (Maximum exposed indiv)

Pathway: Potable Water & Fish

$A_{i\tau} = (1.14E05)(730/D_w + 21BF_i)DF$

$A_{i\tau} = (1.14E05)(7.93 + 21BF_i)DF$

otope	Dw	BFi(fish)	DFi(whole body)	DFi(crit organ)	Critical organ	Aiτ(wh.body)	Aiτ(CO
^{3}H	9.2	9.0E-01	1.05 E-07	1.05E-07	Whole body	3.21E-01	3.21E-(
^{14}C	"	4.6E03	5.68E-07	2.84E-06	Bone	6.25E03	3.12E0
^{24}Na	"	1.0E02	1.70E-06	1.70E-06	Whole body	4.08E02	4.08E0
^{32}P	"	1.0E05	7.46E-06	1.93E-04	Bone	1.78E06	4.62E0
^{51}Cr	"	2.0E02	2.66E-09	6.69E-07	GI-LLI	1.27E00	3.20E0
^{54}Mn	"	4.0E02	8.72E-07	1.40E-05	GI-LLI	8.35E02	1.34E0
^{56}Mn	"	4.0E02	2.04E-08	3.67E-06	GI-LLI	1.95E01	3.51E0
^{55}Fe	"	1.0E02	4.43E-07	2.75E-06	Bone	1.06E02	6.60E0
^{59}Fe	"	1.0E02	3.91E-06	3.40E-05	GI-LLI	9.39E02	8.17E0
^{58}Co	"	5.0E01	1.67E-06	1.51E-05	GI-LLI	2.01E02	1.82E0
^{60}Co	"	5.0E01	4.72E-06	4.02E-05	GI-LLI	5.69E02	4.84E0
^{63}Ni	"	1.0E02	4.36E-06	1.30E-04	Bone	1.04E03	3.12E0
^{65}Ni	"	1.0E02	3.13E-08	1.74E-06	GI-LLI	7.52E00	4.18E0
^{64}Cu	"	5.0E01	3.91E-08	7.10E-06	GI-LLI	4.71E00	8.56E0
^{65}Zn	"	2.0E03	6.96E-06	1.54E-05	Liver	3.33E04	7.37E0
^{69}Zn	"	2.0E03	1.37E-09	1.97E-08	Liver	6.56E00	9.43E0
^{83}Br	"	4.2E02	4.02E-08	5.79E-08	GI-LLI	4.04E01	5.82E0
^{84}Br	"	4.2E02	5.21E-08	5.21E-08	Whole body	5.24E01	5.24E0
^{85}Br	"	4.2E02	2.14E-09	2.14E-09	Whole body	2.15E00	2.15E0
^{86}Rb	"	2.0E03	9.83E-06	2.11E-05	Liver	4.70E04	1.01E0
^{8}Rb	"	2.0E03	3.21E-08	6.05E-08	Liver	1.53E02	2.89E0
^{89}Rb	"	2.0E03	2.82E-08	4.01E-08	Liver	1.35E02	1.92E0
^{89}Sr	"	3.0E01	8.84E-06	3.08E-04	Bone	6.42E02	2.23E0
^{0}Sr	"	3.0E01	1.86E-03	7.58E-03	Bone	1.35E05	5.51E0
^{1}Sr	"	3.0E01	2.29E-07	2.70E-05	GI-LLI	1.66E01	1.96E0
^{2}Sr	"	3.0E01	9.30E-08	4.26E-05	GI-LLI	6.76E00	3.09E0
^{90}Y	"	2.5E01	2.58E-10	1.02E-04	GI-LLI	1.56E-02	6.19E0

Aiτ - Liqui. Effluent - JAFNPP

Case - Adult (Maximum exposed indiv)

$Ai\tau = (1.14E05)(730/D_w + 21BFi)DF$

Pathway: Potable Water & Fish

$Ai\tau = (1.14E05)(7.93 + 21BFi)DF$

otope	DW	BFi(fish)	DFi(whole body)	DFi(crit organ)	Critical organ	Ai (wh.body)	Aiτ(CO)
Y	9.2	2.5E01	3.52E-12	2.67E-10	GI-LLI	2.13E-04	1.62E-(
Y	"	2.5E01	3.77E-09	7.76E-05	GI-LLI	2.29E-01	4.71E01
Y	"	2.5E01	2.47E-11	1.48E-05	GI-LLI	1.50E-03	8.99E0
Y	"	2.5E01	7.40E-11	8.50E-05	GI-LLI	4.49E-03	5.16E0
Zr	"	3.3E00	6.60E-09	3.09E-05	GI-LLI	5.81E-02	2.72E0
Zr	"	3.3E00	1.55E-10	1.05E-04	GI-LLI	1.36E-03	9.24E0
Nb	"	3.0E04	1.86E-09	2.10E-05	GI-LLI	1.33E02	1.50E06
Mo	"	1.0E01	8.20E-07	9.99E-06	GI-LLI	2.03E01	2.48E0
Tc	"	1.5E01	8.89E-09	4.13E-07	GI-LLI	3.27E-01	1.52E0
Tc	"	1.5E01	3.59E-09	6.59E-09	Kidney	1.32E-01	2.42E-(
Ru	"	1.0E01	7.97E-08	2.16E-05	GI-LLI	1.98E00	5.36E0
Ru	"	1.0E01	6.08E-09	9.42E-06	GI-LLI	1.51E-01	2.34E0
Ru	"	1.0E01	3.48E-07	1.78E-04	GI-LLI	8.64E00	4.42E0
Ag	"	(1)	8.79E-08	6.04E-05	GI-LLI	2.89E-01	1.99E0
Te	"	4.0E02	3.59E-07	1.09E-05	Kidney	3.44E02	1.04E04
Te	"	4.0E02	8.25E-07	2.75E-05	Kidney	7.90E02	2.63E04
Te	"	4.0E02	2.38E-08	8.68E-06	GI LLI	2.28E01	8.31E0
Te	"	4.0E02	1.82E-06	5.79E-05	GI-LLI	1.74E03	5.54E04
Te	"	4.0E02	7.65E-09	1.32E-07	Kidney	7.33E00	1.26E0
Te	"	4.0E02	7.05E-07	8.40E-05	GI-LLI	6.75E02	8.05E04
Te	"	4.0E02	6.22E-09	8.63E-08	Kidney	5.96E00	8.27E01
Te	"	4.0E02	1.53E-06	7.71E-05	GI-LLI	1.46E03	7.39E04
I	"	1.5E01	8.80E-07	1.89E-04	Thyroid	3.23E01	6.95E0
I	"	1.5E01	3.41E-06	1.95E-03	Thyroid	1.25E02	7.17E04
I	"	1.5E01	1.90E-07	1.90E-05	Thyroid	6.99E00	6.99E0
I	"	1.5E01	7.53E-07	3.63E-04	Thyroid	2.77E01	1.33E0
I	"	1.5E01	1.03E-07	4.99E-06	Thyroid	3.79E00	1.83E0

Ai[illegible] Liq[illegible]id E[illegible]ue[illegible] - J[illegible]PP

Cas[illegible] - Adult - (Maximum exposed indiv)

Pathway: Potable Water & Fish

$Ai\tau = (1.14E05)(730/D_w \quad 21BFi)DF$

$Ai\tau = (1.14E05)(7.93 + 21BFi)DF$

otope	I_w	BFi(fish)	Dfi(whole body)	DFi(crit organ)	Critical organ	Aiτ(wh body)	Aiτ(CO)
^{135}I	9.2	1.5E01	4.28E-07	7.65E-05	Thyroid	1.57E01	2.81E
^{134}Cs	"	2.0E03	1.21E-04	1.48E-04	Liver	5.79E05	7.08E
^{136}Cs	"	2.0E03	1.85E-05	2.57E-05	Liver	[illegible].85E04	1.23E
^{137}Cs	"	2.0E03	7.14E-05	1.09E-04	Liver	[illegible]1E05	5.21E
^{138}Cs	"	2.0E03	5.40E-08	1.09E-07	Liver	2.[illegible]E02	5.21E
^{139}Ba	"	4.0E00	2.84E-09	1.72E-07	GI-LLI	[illegible]97E-02	1.80E
^{140}Ba	"	4.0E00	1.33E-06	4.18E-05	GI-LLI	1.39E01	4.38E
^{141}Ba	"	4.0E00	1.59E-09	4.[illegible]1E-08	Bone	1.66E-02	4.93E-
^{142}Ba	"	4.0E00	1.34E-09	2.13E-08	Bone	1.40E-02	2.23E-
^{140}La	"	2.5E01	3.33E-10	9.25E-05	GI-LLI	2.02E-02	5.61E
^{142}La	"	2.5E01	1.45E-11	4.25E-07	GI-LLI	8.80E-04	2.58E
^{141}Ce	"	1.0E00	7.18E-10	2.42E-05	GI-LLI	2.36E-03	7.98E
^{143}Ce	"	1.0E00	1.35E-10	4.56E-05	GI-LLI	4.45E-04	1.50E
^{144}Ce	"	1.0E00	2.62E-08	1.65E-04	GI-LLI	8.64E-02	5.44E
^{143}Pr	"	2.5E01	4.56E-10	4.03E-05	GI-LLI	2.77E-02	2.44E
^{144}Pr	"	2.5E01	1.53E-12	3.01E-11	Bone	9.29E-05	1.82E-
^{147}Nd	"	2.5E01	4.35E-10	3.49E-05	GI-LLI	2.64E-02	2.12E
^{187}W	"	1.2E03	3.01E-08	2.82E-05	GI-LLI	8.64E01	8.10E
^{239}NP	"	1.0E01	6.45E-11	2.40E-05	GI-LLI	1.60E-03	5.96E

440 038

SETPOINT DETERMINATION

LIQUID EFFLUENT MONITOR

The purpose of this section is to outline the method utilized at JAFNPP to assure that the radioactivity release concentration in the discharge tunnel does not exceed the values specified in 10CFR20, Appendix B, Table II, Column II for unrestricted areas. The liquid effluent control monitor is set to alarm and automatically close the waste discharge valve and terminate the release prior to exceeding the limits referenced supra.

The calculated setpoints for the liquid effluent monitor satisfy the following equation:

$$\frac{cf}{F + f} \leq C$$

Where:

C = the effluent concentration limit implementing 10CFR20 for the site in μci/ml. This value will be derived from radioanalytical analysis of liquid effluent to be released. This value will be supplied for each liquid release.

c = the setpoint, in μci/ml, of the liquid effluent monitor measuring the radioactivity concentration in the effluent line prior to dilution and subsequent release. This setpoint represents a value which, if exceeded, would result in concentrations exceeding the limits of 10CFR20, Appendix B, Table II, Column II, to an unrestricted area.

f = the liquid effluent flow as measured at the liquid effluent monitor location in gallons/min.

F = the dilution water flow as determined via pump curves and current plant operating configuration (measured in gallons/min).

Note: F is large compared to f therefore F + f = F

The value C will be calculated for each release and the parameters for f and F will be supplied based on current plant operating configurations. The setpoint will be calculated in terms of μci/ml and the liquid effluent monitor will be adjusted to insure that liquid releases are secured prior to exceeding limits specified in 10CFR 20, Appendix B, Table II, Column II to an unrestricted area.

The method by which the liquid effluent monitor is calibrated involves a series of detailed steps that basically are as follows:

1. An external radiation survey in the area of the liquid effluent monitor is made to ascertain if background radiation levels have changed subsequent to the previous calibration.
2. Detector high voltage is measured and various electronic parameters are reviewed to assure that the electronics hardware is functional.

3. A check source is inserted in the shield and the plateau of maximum efficiency and stability is selected.
4. An efficiency calibration is performed by utilizing a series of cannisters containing actual liquid waste effluent of various radioactivity levels. Both the radioactivity level and isotopic content of the cannisters are ascertained by multi-channel pulse height analysis.
5. The μci/ml concentrations for the above cannisters are plotted versus the liquid effluent monitor reading in c/s. A K-factor is calculated (μci/ml per c/s) for each cannister. The average of the K-factors is calculated and recorded.

An example of a typical liquid release setpoint calculation is as follows:

Assume: $C = 3E\text{-}07\ \mu ci/ml$

$f = 100gpm\ (63.3\ ml/sec/gpm) = 6.33E03 ml/sec$

$F = 3.78E05\ gpm\ (63.3 ml/sec/gpm) = 2.39E07 ml/sec$

$c =$

Where: $$c \leq \frac{CF}{f}$$

$$c \leq \frac{3E\text{-}07 \mu ci/ml \quad 2.39E07\ ml/sec}{6.33E03\ ml/sec}$$

$$c \leq 1.13E\text{-}03\ \mu ci/ml$$

449 041

The setpoint of 1.13E-03 µci/ml will be applied to the liquid effluent monitor to insure concentrations of radioactive material in liquid effluent released to unrestricted areas to not exceed the limits specified in 10CFR 20 Appendix B, Table II, Column II. Rarher, the liquid release will be determined via the operation of a automatic isolation valve.

IMPLEMENTATION OF 10CFR20 - AIRBORNE RELEASES IODINES & PARTICULATES WITH HALF-LIVES GREATER THAN 8 DAYS

Technical Specifications state: "The instantaneous dose rate in unrestricted areas due to radioactive materials released in gaseous effluents from the site shall be limited to the following values:

b. The dose rate limit for all radioiodine and for all radioactive materials in particulate form and radionuclides other than noble gases with half lives greater than 8 days shall be $\leq$ 1500 mrem/yr to any organ."

This specification shall be implemented using the following general releationships:

$$\sum_i Pi \left[WsQis + WvQiv\right] < 1500 \text{ mrem/yr}$$

Where:

Pi = The dose parameter for radionuclides other than noble gases for the inhalation pathway in mrem/yr per $\mu Ci/m^3$ and for food and ground plane pathways in m^2 mrem/yr per μCi/second. The dose factors are based on the critical individual organ and most restrictive age group (infant).

Section PI-1 - of Gaseous Effluents - Calculation of Pi (inhalation), contains the bases and models for calculation of Pi (inhalation) and its tabulated values. Designated Pi (in).

449 043

Section PI-2 of this manual, Gaseous Effluents - Calculation of Pi (ground plane) contains the bases and models for calculation of Pi (ground plane) and its tabulated volumes. Designated Pi (gp).

Section PI-3 of this manual, Gaseous Effluents - Calculation of Pi(food) contains the bases and models for calculation of Pi (food) and its tabulated values. Designated Pi(f).

Pi (dep) = Pi(gp) + Pi(f). Tabulated values of Pi(dep) are included in this section.

$\dot{Q}is$ = The release rate of radionuclide, i, in gaseous effluents from free-standing stack in µci/sec.

$\dot{Q}iv$ = The release rate of radionuclides, i, in gaseous effluents from all vent releases, in µCi/sec.

W_s = The highest calculated annual average dispersion parameter for estimating the dose to an individual at the controlling location due to free standing stack releases:

$W_{s(in)}$ = 8.07E-08 sec/m^3, for the inhalation pathway, stack release. The location is the unrestricted area boundary in the ESE sector.

$W_{s(dep)}$ = 4.79E-09 m^{-2}, for the food and ground plane pathway, stack release. The location is the unrestricted area boundary in the east sector.

449 044

W_v = The highest calculated annual average dispersion parameter for estimating the dose to an individual at the controlling location due to all vent releases:

$W_{v(in)}$ = 6.73E-07 s/m^3, for the inhalation pathway release. The location is the unrestricted area boundary in the ENE sector.

$W_{v(dep)}$ = 4.77E-09 m^{-2} for the food and ground plane pathway, vent release. The location is the unrestricted area boundary in the east sector.

To estimate the dose rate for radioiodines and radioactive material in particulate form other than noble gases, and with half-lives greater than 8 days the following relationship shall be used:

$$\sum_i \left\{ Pi(in)\left[(W_{s(in)})(\dot{Q})is + (W_{v(in)})(\dot{Q})iv\right] + Pi(dep)\left[(W_{s(dep)})(\dot{Q})is + (W_{v(dep)})(\dot{Q})iv\right]\right. = \text{dose rate (mrem/yr)}$$

Pi(deposition) = Pi(food) + Pi(ground plane)

ISOTOPE	Pi(food)	+	Pi(ground plane)	=	Pi(deposition)
Cr-51	4.78E06		7.88E06		1.27E07
Mn-54	3.97E07		1.29E10		1.29E10
Fe-59	3.99E08		4.56E08		8.55E08
Co-58	6.17E07		6.18E08		6.79E08
Co-60	2.14E08		5.17E09		5.38E09
Zn-65	1.94E10		7.90E08		2.02E10
Sr-89	1.28E10		3.58E04		1.28E10
Sr-90	1.24E11		-		1.24E11
Zr-95	8.46E05		4.08E08		4.09E08
I-131	1.08E12		2.98E07		1.08E12
I-133	9.74E09		4.26E06		9.74E09
Cs-134	6.92E10		3.27E09		7.25E10
Cs-136	5.88E09		2.41E08		6.12E09
Cs-137	6.13E10		1.34E09		6.26E10
Ba-140	2.46E08		3.35E07		2.79E08
Ce-141	1.39E07		2.19E07		3.58E07
* H-3	-		-		-
P-32	1.63E11		-		1.63E11
Fe-55	1.38E08		-		1.38E08
C-14	2.38E09		-		2.38E09

* The concentration of H-3 in milk is based on its airborne concentration rather than the deposition rate.

$P_i(dep) = 2.4 \times 10^3$ mrem/yr per $\mu Ci/m^3$, for H-3 only

449 046

IMPLEMENTATION OF 10CFR20 - AIRBORNE RELEASES
NOBLE GASES

Technical Specifications state:

"The instantaneous dose rate in unrestricted areas due to radioactive materials released in gaseous effluents from the site shall be limited to the following values:

a. The dose rate limit for noble gases shall be $\leq$ 500 mrem/yr to the total body and $\leq$ 3000 mrem/yr to the skin, and "

This specification shall be implemented using the following relationship:

Release rate limit for noble gases:

$$\sum_i \left[(Ki)(\overline{\chi/Q})_s(\dot{Q}is) + (Ki)(\overline{\chi/Q})_v(\dot{Q})iv)\right] < 500 \text{ mrem/yr, and}$$

$$\sum_i \left[(Li+1.1Mi)(\overline{\chi/Q})s(\dot{Q})is + (Li+1.1Mi)(\overline{x/Q})v(\dot{Q})iv\right] < 3000 \text{ mrem/yr}$$

$$= \sum_i \left[(Si)(\overline{\chi/Q})s\ (\dot{Q})is + (Si)(\overline{\chi/Q})v(\dot{Q})iv\right] < 3000 \text{ mrem/yr}$$

Where:

Ki = The total body dose factor due to gamma emissions for each identified noble gas radionuclide, in mrem/yr per $\mu Ci/m^3$.

Li = The skin dose factor due to beta emissions for each identified noble gas radionuclide, in mrem/yr per $\mu Ci/m^3$.

Si = (Li + 1.1 Mi) in mrem/yr per $\mu Ci/m^3$.

Mi = The air dose factor due to gamma emissions for each identified noble gas radionuclide, in mrad/yr per $\mu Ci/m^3$ (unit conversion constant of 1.1 mrem/mrad converts air dose to skin dose).

$\dot{Q}is$ = The release rate of radionuclides, i in gaseous effluents from free-standing stack, in µCi/sec.

Qiv = The release rate of radionuclides, i, in gaseous effluent from all vent releases, in µCi/sec.

$(\chi/Q)s$ = 8.07E-08 sec/m^3. For free-standing stack releases. The highest calculated annual average relative concentration for any area beyond the unrestricted area boundary.

$(\chi/Q)v$ = 6.73E-07 sec/m^3. For all vent releases. The highest calculated annual average relative concentration for any area at or beyond the unrestricted area boundary.

Table NG-1

TOTAL BODY DOSE FACTORS

Ki

NUCLIDE	γ - BODY *		10^6(pCi/μCi)	Ki **
Kr-83m	7.56×10^{-8}	X	10^6	7.56×10^{-2}
Kr-85m	1.17×10^{-3}	X	10^6	1.17×10^{3}
Kr-85	1.61×10^{-5}	X	10^6	1.61×10^{1}
Kr-87	5.92×10^{-3}	X	10^6	5.92×10^{3}
Kr-88	1.47×10^{-2}	X	10^6	1.47×10^{4}
Kr-89	1.66×10^{-2}	X	10^6	1.66×10^{4}
Kr-90	1.56×10^{-2}	X	10^6	1.56×10^{4}
Xe-131m	9.15×10^{-5}	X	10^6	9.15×10^{1}
Xe-133m	2.51×10^{-4}	X	10^6	2.51×10^{1}
Xe-133	2.94×10^{-4}	X	10^6	2.94×10^{2}
Xe-135m	3.12×10^{-3}	X	10^6	3.12×10^{3}
Xe-135	1.81×10^{-3}	X	10^6	1.81×10^{3}
Xe-137	1.42×10^{-3}	X	10^6	1.42×10^{3}
Xe-138	8.83×10^{-3}	X	10^6	8.83×10^{3}
Ar-41	8.84×10^{-3}	X	10^6	8.84×10^{3}

* from Regulatory Guide 1.109, Table B-1

** Ki (mrem/yr per $\mu Ci/m^3$)

449 049

Table NG-2

SKIN DOSE FACTORS

Li

NUCLIDE	β - SKIN *		10^6(pCi/μCi)	Li **
Kr-83m		X	10^6	
Kr-85m	1.46×10^{-3}	X	10^6	1.46×10^3
Kr-85	1.34×10^{-3}	X	10^6	1.34×10^3
Kr-87	9.73×10^{-3}	X	10^6	9.73×10^3
Kr-88	2.37×10^{-3}	X	10^6	2.37×10^3
Kr-89	1.01×10^{-2}	X	10^6	1.01×10^4
Kr-90	7.29×10^{-3}	X	10^6	7.29×10^3
Xe-131m	4.76×10^{-4}	X	10^6	4.76×10^2
Xe-133m	9.94×10^{-4}	X	10^6	9.94×10^2
Xe-133	3.06×10^{-4}	X	10^6	3.06×10^2
Xe-135m	7.11×10^{-4}	X	10^6	7.11×10^2
Xe-135	1.86×10^{-3}	X	10^6	1.86×10^3
Xe-137	1.22×10^{-2}	X	10^6	1.22×10^4
Xe-138	4.13×10^{-3}	X	10^6	4.13×10^3
Ar-41	2.69×10^{-3}	X	10^6	2.69×10^3

* from Regulatory Guide 1.109, Table B-1

** Li (mrem/yr per μCi/m^3)

440 050

Table NG-3

AIR DOSE FACTORS

Mi

NUCLIDE	γ - Air *		10^6(pCi/μCi)	Mi **
Kr-83m	1.93×10^{-5}	X	10^6	1.93×10^{1}
Kr-85m	1.23×10^{-3}	X	10^6	1.23×10^{3}
Kr-85	1.72×10^{-5}	X	10^6	1.72×10^{1}
Kr-87	6.17×10^{-5}	X	10^6	6.17×10^{3}
Kr-88	1.52×10^{-2}	X	10^6	1.52×10^{4}
Kr-89	1.73×10^{-2}	X	10^6	1.73×10^{4}
Kr-90	1.63×10^{-2}	X	10^6	1.63×10^{4}
Xe-131m	1.56×10^{-4}	X	10^6	1.56×10^{2}
Xe-133m	3.27×10^{-4}	X	10^6	3.27×10^{2}
Xe-133	3.53×10^{-4}	X	10^6	3.53×10^{2}
Xe-135m	3.36×10^{-3}	X	10^6	3.36×10^{3}
Xe-135	1.92×10^{-3}	X	10^6	1.92×10^{3}
Xe-137	1.51×10^{-3}	X	10^6	1.51×10^{3}
Xe-138	9.21×10^{-3}	X	10^6	9.21×10^{3}
Ar-41	9.30×10^{-3}	X	10^6	9.30×10^{3}

* from Regulatory Guide 1.109, Table B-1

** Mi (mrad/yr per μCi/m^3)

Table NG-4

AIR DOSE FACTORS

Si = (Li+1.1Mi)

NUCLIDE	Li *	Mi **	Si = (Li+1.1Mi) ***
Kr-83m		1.93×10^{1}	2.12E03
Kr-85m	1.46×10^{3}	1.23×10^{3}	2.81×10^{3}
Kr-85	1.34×10^{3}	1.72×10^{1}	1.36×10^{3}
Kr-87	9.73×10^{3}	6.17×10^{3}	1.62×10^{4}
Kr-88	2.37×10^{3}	1.52×10^{4}	1.91×10^{4}
Kr-89	1.01×10^{4}	1.73×10^{4}	2.91×10^{4}
Kr-90	7.29×10^{3}	1.63×10^{4}	2.52×10^{4}
Xe-131m	4.76×10^{2}	1.56×10^{2}	6.48×10^{2}
Xe-133m	9.94×10^{2}	3.27×10^{2}	1.35×10^{3}
Xe-133	3.06×10^{2}	3.53×10^{2}	6.94×10^{2}
Xe-135m	7.11×10^{2}	3.36×10^{3}	4.41×10^{3}
Xe-135	1.86×10^{3}	1.92×10^{3}	3.97×10^{3}
Xe-137	1.22×10^{4}	1.51×10^{3}	1.39×10^{3}
Xe-138	4.13×10^{3}	9.21×10^{3}	1.43×10^{4}
Ar-41	2.69×10^{3}	9.30×10^{3}	1.29×10^{4}

* From Table NG-2 (mrad/yr per $\mu Ci/m^3$)

** From Table NG-3 (mrad/yr per $\mu Ci/m^3$)

*** Si (mrem/yr per $\mu Ci/m^3$)

449 052

GASEOUS EFFLUENTS

CALCULATION OF PI (INHALATION)

SECTION PI-1

The Pi parameter contained in the radioiodine and particulates Specification represents the transport pathway of the ith radionuclide, the receptors usage of the pathway media, and the dosimetry of the exposure. Pathway usage rated and the internal dosimetry are functions of the receptor's age; however, the youngest age group, the infant, will always receive the maximum dose under the exposure conditions for Specification 3.11.2.1.

Pi (inhalation) = K' (BR)DFAi (mrem/yr per $\mu Ci/m^3$)

Where:

K' = a constant of conversion, $10^6 pCi/\mu Ci$

BR = the breathing rate of the infant age group ($1400 m^3/yr$)

DFAi = the maximum organ inhalation dose factor for the infant age group for the ith radionuclide, in mrem/pCi. Taken from Table E-10 of Regulatory Guide 1.109.

Resolution of units yields:

Pi (inhalation) = 1.4×10^9 DFAi

449 053

Pi (inhalation)

NUCLIDE	CONSTANT (pCi/μCi)	DFAi (mrem/pCi)	ORGAN	Pi (mrem/yr per μCi/m^3)
H-3	1.4E09	4.62E-07	Total body	6.47E02
Cr-51		9.17E-06	Lung	1.28E04
Mn-54		7.14E-04	Lung	1.00E06
Fe-59		7.25E-04	Lung	1.02E06
Co-58		5.55E-04	Lung	7.77E05
CO-60		3.22E-03	Lung	4.51E06
Zn-65		4.62E-04	Lung	6.47E05
Sr-89		1.45E-03	Lung	1.03E06
Sr-90		2.92E-02	Bone	4.09E07
Zr-95		1.25E-03	Lung	1.75E06
I-131		1.06E-02	Thyroid	1.48E07
I-133		2.54E-03	Thyroid	3.56E06
Cs-134		5.02E-04	Liver	7.03E05
Cs-136		9.61E-05	Liver	1.35E05
Cs-137		4.37E-04	Liver	6.12E05
Ba-140		1.14E-03	Lung	1.60E06
Ce-141		3.69E-04	Lung	5.17E05
			449 054	
P-32		1.45E-03	Bone	2.03E06
Fe-55		6.21E-05	Lung	9.25E04
C-14		1.89E-05	Bone	2.65E04

GASEOUS EFFLUENTS

CALCULATION OF PI (GROUND PLANE)

SECTION PI-2

The factor Pi (ground plane) represents the dose parameter contained in the radioiodine and particulates Specification for the ground plane pathway. This dose factor is based on the critical individual organ (skin or total body), and the most restrictive age groups (infant).

$$Pi = K'K''DFGi\ (1-e^{-\lambda it})/\lambda i\ \ (m^2\ \text{mrem/yr per}\ \mu ci/sec)$$

Where:

K' = Constant of unit conversion, 10^6 pCi/μCi

K'' = Constant of unit conversion, 8760 hr/yr

λi = Decay constant for the ith radionuclide sec^{-1}

t = Exposure period, 3.15 x 10^7 sec (1 year)

Resolution of units yields:

$$Pi\ (\text{ground plane}) = 8.76E09\ DFG_i\ (1-e^{-\lambda it})/\lambda i$$

The deposition rate onto the ground plane results in a ground plane concentration that is assumed to persist over a year with radiological decay the only operating removal mechanism for each radionuclide. The ground plane dose conversion factors for the ith radionuclides, DFG_i, are taken from Regulatory Guide 1.109, Table E-6

Pi (ground plane)

NUCLIDE	CONSTANT	DFGi (mrem/hr per pCi/m^2)	λi (sec^{-1})	Pi (m^{2}mrem/yr per µCi/sec)
H-3	8.76E09	0	1.78E-09	0
Cr-51		2.60E-10	2.89E-07	7.88E06
Mn-54		6.80E-09	2.57E-08	1.29E10
Fe-59		9.4E-09	1.80E-07	4.56E08
Co-58		8.20E-09	1.13E-07	6.18E08
Co-60		2.00E-08	4.18E-09	5.17E09
Zn-65		4.60E-09	3.29E-08	7.90E08
Sr-89		6.50E-13	1.58E-07	3.58E04
Sr-90		not given	7.60E-10	0
Zr-95		5.80E-09	1.22E-07	4.08E08
I-131		3.40E-09	9.95E-07	2.98E07
I-133		4.50E-09	9.26E-06	4.26E06
Cs-134		1.40E-08	1.07E-08	3.27E09
Cs-136		1.70E-08	6.17E-07	2.41E08
Cs-137		4.90E-09	7.28E-10	1.34E09
Ba-140		2.40E-09	6.27E-07	3.35E07
Ce-141		6.20E-10	2.48E-07	2.19E07
P-32	449 056	0	5.61E-07	0
Fe-55		0	8.14E-09	0
C-14		0	3.84E-12	0

GASEOUS EFFLUENTS
CALCULATION OF PI (FOOD)
SECTION PI-3

The factor Pi (food) represents the dose parameter contained in the radioiodine and particulate Specification for the food pathway. The organ with the maximum ingestion dose factor will be the limiting organ, and the infant, the limiting age group.

$$\text{Pi (food)} = K'r\left[\frac{Q_F(Uap)}{Yp\ (\lambda i+\lambda w)}\right] Fm\ DFL_i \left[e^{-\lambda i t f}\right]\ (m^2.\ \text{mrem/yr per}\ \mu\text{Ci/sec.}$$

Where:

K' = Constant of conversion

Q_F = The cow's consumption rate, in Kg/day (wet weight)

Uap = The infant's milk consumption rate, in liters/yr

Yp = The agricultural productivity by unit area, in Kg/m^2

Fm = The stable element transfer coefficients, in days/liter

r = Fraction of deposited activity retained on cow's feed grass

DFLi = The maximum organ ingestion dose factor for the ith radionuclide, in m rem/pCi

λi = The decay constant for the ith radionuclide, in sec^{-1}

λw = The decay constant for removal of activity on leaf and plant surfaces by weathering, 5.73×10^{-7} sec^{-1} (corresponding to a 14 day half-time)

tf = The transport time from pasture to cow, to milk, to infant, in sec

449 057

A fraction of the airborne deposition is captured by the ground plant vegetation cover. The captured material is removed from the vegetation (grass) by both radiological decay and weathering processes.

Regulatory Guide 1.109 provides the following paramaters:

1. Q_F = 50Kg/day (Table E-3)
2. Uap = 330 liters/yr (Table E-5)
3. Yp = 0.7 Kg/m^2 (Table E-15)
4. t_f = 2 days (1.73×10^5 sec) (Table E-15)
5. r = 1.0 for radioiodines; r = 0.2 for particulates (Table I-15)
6. Fm values - Table E-1
7. DFLi values - Table E-14

Resolution of units yields (all radionuclides except H-3):

$$Pi\ (food) = 2.4 \times 10^{10} \frac{rFm}{\lambda i + \lambda w} DFLi \left[e^{-\lambda i t f}\right]$$ (m^2. m rem/yr per μCi/sec)

The concentration of tritium in milk is based on its airborne concentration rather than the deposition rate.

$$Pi = K'K''\ F_m\ QF\ Uap\ DFLi\ \left[0.75(0.5/H)\right]$$

Where:

K''' = Constant of conversion, 10^3 gm/kg

H = Absolute humidity of the atmosphere in gm/m^3

0.75 = Fraction of total feed that is water

0.5 = The ratio of the specific activity of the feed grass water to the atmospheric water

449 058

Regulatory Guide 1.109 provides the following parameters:

1. Fm = 1.0×10^{-2} day/liter (Table E-1)
2. DFLi = 3.08×10^{-7} m rem/pCi (Table E-14)

Assuming an average absolute humidity of 8 grams/m^3, the resolution of units yields (H-3 only)

$$P_i \text{ (food)} = 2.4 \times 10^3 \text{ m rem/yr per } \mu Ci/m^3$$

	CONSTANT	r	Fm	λi	λw	DFLi	tf	Pi
Cr-51	2.4E10	0.2	2.2E-03	2.89E-07	5.73E-07	4.11E-07	1.73E05	4.78E06
Mn-54			2.5E-04	2.57E-08		1.99E-05		3.97E07
Fe-59			1.2E-03	1.80E-07		5.38E-05		3.99E08
Co-58			1.0E-03	1.13E-07		8.98E-06		6.17E07
Co-60			1.0E-03	4.18E-09		2.57E-05		2.14E08
Zn-65			3.9E-02	3.29E-08		6.31E-05		1.94E10
Sr-89			8.0E-04	1.58E-07		2.51E-03		1.28E10
Sr-90			8.0E-04	7.60E-10		1.85E-02		1.24E11
Zr-95			5.0E-06	1.22E-07		2.50E-05		8.46E05
I-131			6.0E-03	9.95E-07		1.39E-02		1.08E+12
I-133			6.0E-03	9.26E-06		3.31E-03		9.74E09
Cs-134			1.2E-02	1.07E-08		7.03E-04		6.92E10
Cs-136			1.2E-02	6.17E-07		1.35E-04		5.88E09
Cs-137			1.2E-02	7.28E-10		6.11E-04		6.13E10
Ba-140			4.0E-04	6.27E-07		1.71E-04		2.46E08
Ce-141			1.0E-04	2.48E-07		2.48E-05		1.39E07
P-32			2.5E-02	5.61E-07		1.70E-03		1.63E11
Fe-55			1.2E-03	8.14E-09		1.39E-05		1.38E08
C-14			1.2-02	3.84E-12		2.37E-05		2.38E09

449 060

GASEOUS EFFLUENTS

SETPOINT DETERMINATIONS

Setpoint determinations are provided in this section for the following release points:

1. Reactor Building Ventilation Exhaust
2. Reactor Building Refueling Floor Ventilation Exhaust
3. Radwaste Building Ventilation Exhaust
4. Turbine Building Ventilation Exhaust
5. Main Stack

Calculated setpoints represent a safe margin of assurance that the instantaneous gaseous release rates will not produce a dose rate to an individual at or beyond the site boundary equal to or greater than 500 mrem/yr total body, or 3000 mrem/yr skin, based on radioactive noble gases.

I. Bases:

To achieve a reasonable level of operational flexibility while maintaining a safe margin of assurance that instantaneous gaseous release limits are not exceeded, the following calculational bases are set forth:

A. Limit apportionment

For conservatism 75% of the dose rate limit will be allowed with the following release path apportionment:

1. 15% of limit applied to Reactor Building Vent Exhaust

2. 15% of limit applied to Reactor Building Refueling Floor Vent Exhaust.
3. 18.75% of limit applied to Radwaste Building Vent Exhaust
4. 18.75% of limit applied to Turbine Building Vent Exhaust
5. 7.5% of limit applied to Main Stack

Using these conservative assumptions, simultaneous attainment of all setpoints would actuate alarm/trip conditions at 75% of the allowable instantaneous release rate, not considering any other built-in conservatisms.

B. Atmospheric dispersion factors

1. $(\overline{\chi/Q})$ stack = 8.07E-08 sec/m^3

2. $(\overline{\chi/Q})$ vent = 6.73E-07 sec/m^3

The chosen atmospheric dispersion factors are the most restrictive, site boundary, vent and stack χ/Q values calculated using site historical annual average meterological data.

C. Gaseous Effluent Component Determination

To reflect a conservative and realistic approach in determining isotopic make-up and calculation of appropriate dose factors for application in setpoint determination, a "weighted average" method is used. This method reflects the contribution of specific radionuclides in the effluent stream, and applies the requisite dose factor for that radionuclide in

weighted manner to the overall effluent stream. To ascertain a representative sample of effluent stream, 18 months of typical operating data is used.

II. Calculations (ground level releases):

A. Calculation of weighted average K_i - Average Weighted Total Body Dose Factor.

1. Reported releases for the first half of 1976 and all of 1977 - noble gases, ground level are used.

Nuclide	Fraction of Total	Ki #	Weighted Ki
Kr-85	0.000	1.61E01	0.00
Kr-85m	0.023	1.17E03	2.69E01
Kr-87	0.001	5.92E03	5.92E00
Kr-88	0.002	1.47E04	2.94E01
Xe-133	0.592	2.94E02	1.74E02
Xe-135	0.053	1.81E03	9.59E01
Xe-135m	0.001	3.12E03	3.12E00
Xe-138	0.000	8.83E03	0.00
Xe-133m	0.001	2.51E02	2.15E-01
Xe-131m	0.000	9.15E01	0.00
Ar-41	0.001	8.84E03	8.84E00
Unidentified	0.324	1.66E04 *	5.38E03

** Weighted average Ki = 1.14E03

449 063

Total body dose factor (mrem/yr per $\mu Ci/m^3$)

* Unidentified nuclide assumes highest possible Ki (Kr-89)

** Nuclides with 0.001 fraction of total or less not included in weighted Ki

B. Reactor Building Vent Exhaust:

1. Weighted average Ki = 1.14E03 mrem/yr per $\mu Ci/m^3$
2. Monitor calibration factor = 1.32E-02 µCi/sec per CPM

$$(Ki)(\chi/Q)v(\dot{Q})iv = (.15)(500)\ mrem/yr)$$

$$(1.14E03)(6.73E-07)(\dot{Q})iv = 75\ mrem/yr$$

$$(\dot{Q})iv = 9.78E04\ \mu Ci/sec$$

$$\text{Setpoint} = \left[\frac{9.78E04\ \mu Ci}{sec}\right]\left[\frac{CPM\ sec}{1.3E\text{-}02\ \mu Ci}\right] = 7.52E06\ CPM$$

Assume 20% additional conservatism for instrument error, etc:

$$(7.52E06CPM)(0.8) \approx \underline{6.00E06\ CPM\ Setpoint}$$

C. Reactor Building Refueling Floor Vent Exhaust:

1. Weighted average Ki = 1.14E03 mrem/yr per $\mu Ci/m^3$
2. Monitor Calibration Factor = 1.8E-02 µCi/sec per CPM

$$(Ki)(\chi/\dot{Q})v(\dot{Q})iv = (.15)(500)\ mrem/yr)$$

$$(1.14E03)(6.73E-07)(\dot{Q})iv = 75\ mrem/yr$$

$$(\dot{Q})iv = 9.78E04\ \mu Ci/sec$$

$$\text{Setpoint} = \left[\frac{9.78\text{E}04\mu\text{Ci}}{\text{sec}}\right]\left[\frac{\text{CPM sec}}{1.82\text{E-}02\mu\text{Ci}}\right] = 5.43\text{E}06 \text{ CPM}$$

Assume 20% additional conservatism for instrument error, etc:

(5.43E06CPM)(0.8) = <u>4.3E06 CPM Setpoint</u>

D. Radwaste Building Vent Exhaust:

1. Weighted average Ki = 1.14E03 mrem/yr per $\mu Ci/m^3$
2. Monitor calibration Factor = 4.4E-01 µCi/sec per CPM

$$(Ki)(\chi/Q)v(\dot{Q})iv = (.1875)(500 \text{ mrem/yr})$$

$$(1.14E03)(6.73E\text{-}07)(\dot{Q})iv = 93.75 \text{ mrem/yr}$$

$$(\dot{Q})iv = 1.22E05 \ \mu Ci/sec$$

$$\text{Setpoint} = \left[\frac{1.22\text{E}05\mu\text{Ci}}{\text{sec}}\right]\left[\frac{\text{CPM sec}}{4.4\text{E-}01\mu\text{Ci}}\right] = 2.77\text{E}05 \text{ CPM}$$

Assume 20% additional conservatism for instrument error, etc:

(2.77E05CPM)(0.8) = <u>2.2E05 CPM Setpoint</u>

E. Turbine Building Vent Exhaust:

1. Weighted average Ki = 1.14E03 mrem/yr per $\mu Ci/m^3$
2. Monitor calibration factor = 4.3E-02 µCi/sec per CPM

$$(K_i)(\chi/Q)_v(\dot{Q})_{iv} = (.1875)(500\ \text{mrem/yr})$$

$$(1.14E03)(6.73E\text{-}07)(\dot{Q})_{iv} = 93.75\ \text{mrem/yr}$$

$$(\dot{Q})_{iv} = 1.22E05\ \mu\text{Ci/sec}$$

$$\text{Setpoint} = \left[\frac{1.22E05\ \mu\text{Ci}}{\text{sec}}\right]\left[\frac{\text{CPM sec}}{4.3E\text{-}02\ \mu\text{Ci}}\right] = 2.84E06\ \text{CPM}$$

Assume 20% additional conservatism for instrument error, etc:

$$(2.84E06\text{CPM})(0.8) \cong \underline{2.2E06\ \text{CPM Setpoint}}$$

F. Comparison of Total Body Dose vs Skin Dose:

1. Calculation of weighted average Ni - Average Weighted Skin Dose Factor
2. Reported releases for the first half of 1976 and all of 1977 - noble gases, ground level are used.

449 066

$$(Ki)(\chi/Q)v(\dot{Q})iv = (.1875)(500\ \text{mrem/yr})$$

$$(1.14E03)(6.73E\text{-}07)(\dot{Q})iv = 93.75\ \text{mrem/yr}$$

$$(\dot{Q})iv = 1.22E05\ \mu Ci/sec$$

$$\text{Setpoint} = \left[\frac{1.22E05\mu Ci}{sec}\right]\left[\frac{CPM\ sec}{4.3E\text{-}02\ \mu Ci}\right] = 2.84E06\ CPM$$

Assume 20% additional conservatism for instrument error, etc:

$$(2.84E06CPM)(0.8) \cong \underline{2.2E06\ CPM\ Setpoint}$$

F. Comparison of Total Body Dose vs Skin Dose:

1. Calculation of weighted average Ni - Average Weighted Skin Dose Factor
2. Reported releases for the first half of 1976 and all of 1977 - noble gases, ground level are used.

Nuclide	Fraction of Total	Ni#	Weighted Ni
Kr-85	0.000	1.36E03	0.000
Kr-85m	0.023	2.81E03	6.46E01
Kr-87	0.001	1.59E04	1.59E01
Kr-88	0.002	1.91E04	3.82E01
Xe-133	0.592	6.94E02	4.11E02
Xe-135	0.053	3.97E03	2.10E02
Xe-135m	0.001	4.41E03	4.41E00
Xe-138	0.000	1.43E04	0.000
Xe-133m	0.001	1.35E03	1.35E00
Xe-131m	0.000	6.48E02	0.000
Ar-41	0.001	1.29E04	1.29E01
Unidentified	0.342	2.91E04 *	9.95E03

** Weighted Average Ki = 2.13E03

\# Skin Dose Factor (mrem/yr per $\mu Ci/m^3$)

* Unidentified nuclide assumes highest possible Ni (Kr-89)

** Nuclides with 0.001 fraction of total, or less not included in weighted Ni.

G. Reactor Building Vent Exhaust:

1. Weighted average Ni = 2.13E03 mrem/yr per $\mu Ci/m^3$

$$(Ni)(\chi/Q)_v(\dot{Q})iv = (0.15)(3000\ mrem/yr)$$

$$(2.13E03)(6.73E\text{-}07)(\dot{Q})iv = 450\ mrem/yr$$

$$(\dot{Q})iv = 3.14E05\ \mu Ci/sec\ *$$

* Total Body More Restrictive

H. Reactor Building Refueling Floor Vent Exhaust

1. Weighted average Ni = 2.13E03 mrem/yr per $\mu Ci/m^3$

$$(Ni)(\chi/Q)v(\dot{Q})iv = (0.15)(3000\ mrem/yr)$$

$$(2.13E03)(6.73E\text{-}07)(\dot{Q})iv = 450\ mrem/yr$$

$$(\dot{Q})iv = 3.14E05\ \mu Ci/sec\ *$$

* Total Body More Restrictive

I. Radwaste Building Vent Exhaust

1. Weighted average Ni = 2.13E03 mrem/yr per $\mu Ci/m^3$

$$(Ni)(\chi/Q)v(\dot{Q})iv = (0.1875)(3000\ mrem/yr)$$

$$(2.13E03)(6.73E\text{-}07)(\dot{Q})iv = 562.5\ mrem/yr$$

$$(\dot{Q})iv = 3.92E05\ \mu Ci/sec\ *$$

* Total Body More Restrictive

J. Turbine Building Vent Exhaust

1. Weighted average Ni = 2.13E03 mrem/yr per $\mu Ci/m^3$

$$(Ni)(\chi/Q)v(\dot{Q})iv = (0.1875)(3000 \text{ mrem/yr})$$

$$(2.13E03)(6.73E-07)(\dot{Q})iv = 562.5 \text{ mrem/yr}$$

$$(\dot{Q})iv = 3.92E05 \ \mu Ci/sec \quad *$$

* Total Body More Restrictive

III. Calculations (elevated release):

A. Calculation of weighted average Ki - Average Weighted Total Body Dose Factor.

1. Reported releases for the first half of 1976 and all of 1977 - noble gases, elevated releases are used.

449 070

Nuclide	Fraction of Total	Ki #	Weighted Ki
Kr-85	0.032	1.61E01	5.15E-01
Kr-85m	0.081	1.17E03	9.48E01
Kr-87	0.035	5.92E03	2.07E02
Kr-88	0.087	1.47E04	1.28E03
Xe-133	0.392	2.94E02	1.15E02
Xe-135	0.302	1.81E03	5.47E02
Xe-135m	0.000	3.12E03	0.000
Xe-138	0.012	8.83E03	1.06E02
Xe-133m	0.007	2.51E02	1.76E00
Xe-131m	0.042	9.15E01	3.84E00
Ar-41	0.009	8.84E03	7.96E01
Unidentified	0.002	1.66E04 *	3.32E01

** Weighted Average Ki = 2.24E02

Total Body Dose Factor (mrem/yr per $\mu Ci/m^3$)

* Unidentified nuclide assumes highest possible Ki (Kr-89)

** Nuclides with 0.000 fraction of total not included in weighted Ki

B. Main Stack:

1. Weighted average Ki = 2.24E02 mrem/yr per $\mu Ci/m^3$
2. Monitor calibration factor = 5.2E-01 μCi/sec per CPS

$$(K_i)(\chi/Q)_s(\dot{Q})_{is} = (0.075)(500 \text{ mrem/yr})$$

$$(2.24E02)(8.07E\text{-}08)(\dot{Q})_{is} = 37.5 \text{ mrem/yr}$$

$$(\dot{Q})_{is} = 2.07E06 \ \mu Ci/sec$$

$$\text{Setpoint} = \left[\frac{2.07E06 \mu Ci}{sec}\right]\left[\frac{CPS \ sec}{5.2E\text{-}01 \ \mu Ci}\right] = 3.98E06 \text{ CPS}$$

Assume 20% additional conservation for instrument error, etc:

$$(3.98E06CPS)(0.8) \stackrel{\sim}{=} \underline{3.0E6 \text{ CPS Setpoint}}$$

C. Comparison of Total Body Dose vs Skin Dose:

1. Calculation of weighted average Ni - Average Weighted Skin Dose Factor
2. Reported releases for first half of 1976 and all of 1977 noble gases, elevated releases are used.

Nuclide	Fraction of Total	Ni #	Weighted Ni
Kr-85	0.032	1.36E03	4.35E01
Kr-85m	0.081	2.81E03	2.28E02
Kr-87	0.035	1.59E04	5.56E02
Kr-88	0.087	1.91E04	1.66E03
Xe-133	0.392	6.94E02	2.72E02

Nuclide	Fraction of Total	Ni #	Weighted Ni
Xe-135	0.302	3.97E03	1.20E03
Xe-135m	0.000	4.41E03	0.000
Xe-138	0.012	1.43E04	1.72E02
Xe-133m	0.007	1.35E03	9.45E00
Xe-131m	0.042	6.48E02	2.72E01
Ar-41	0.009	1.29E04	1.16E02
Unidentified	0.002	2.91E04 *	5.82E01

** Weighted Average Ni = 3.96E02

\# Skin Dose Factor (mrem/yr per $\mu Ci/m^3$)

* Unidentified nuclide assumes highest possible Ni (Kr-89)

** Nuclides with 0.000 fraction of total are not included in weighted Ni.

D. Main Stack

1. Weighted average Ni = 3.96E02 mrem/yr per $\mu Ci/m^3$

$(Ni)(\chi/Q)s(\dot{Q})is$ = (0.075)(3000 mrem/yr)

$(3.96E02)(8.07E-08)(\dot{Q})is$ = 225 mrem/yr

$(\dot{Q})is$ = 7.04E06 $\mu Ci/sec$ *

* Total Body More Restrictive

CALCULATION OF DOSE

10CFR50

IODINES & PARTICULATES

Technical Specifications limit the dose to an individual from radioiodines, radioactive materials in particulate form, and radionuclides other than noble gases with half-lives greater than 8 days in gaseous effluents released to unrestricted areas to the following:

1. During any calendar quarter to $\leq$ 7.5 mrem.
2. During any calendar year to $\leq$ 15 mrem.

Dose is determined as follows:

1. During any calendar quarter:

$$3.17 \times 10^{-8} \sum_i R_i \left[W_s \tilde{Q}is + w_s \tilde{q}is + W_v \tilde{Q}_{iv} + w_v \tilde{q}iv \right] \leq 7.5 \text{ mrem}$$

2. During any calendar year:

$$3.17 \times 10^{-8} \sum_i R_i \left[W_s \tilde{Q}is + w_s \tilde{q}is + W_v \tilde{Q}_{iv} + w_v \tilde{q}iv \right] \leq 15 \text{ mrem}$$

Where:

$\tilde{Q}_i$ = The releases of radionuclides, radioactive materials in particulate form, and radionuclides other than noble gases in gaseous effluents, i, for long term

releases greater than 500 hrs/yr, in μCi. Releases shall be cumulative over the calendar quarter or year as appropriate.

$\tilde{q}_i$ = The releases of radionuclides, radioactive materials in particulate form and radionuclides other than noble gases in gaseous effluents, i, for short term releases equal to or less than 500 hrs/yr, in μCi. Releases shall be cumulative over the calendar quarter or year as appropriate.

W = The dispersion parameter for estimating the dose to an individual at the controlling location for long term releases (greater than 500 hrs/yr):

$W = (\overline{\chi/Q})$ for the inhalation pathway in sec/m^3.

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

w = The dispersion parameter for estimating the dose to an individual at the controlling location for short term releases (equal to or less than 500 hrs/yr):

$w = (\overline{\chi/q})$ for the inhalation pathway in sec/m^3.

$w = (\overline{D/q})$ for the food and ground plane pathway in meters $^{-2}$.

3.17×10^{-8} = The inverse of the number of seconds in a year.

R_i = The dose factor for each identified radionuclide, i, in m^2 (mrem/yr) per μCi/sec or mrem/yr per μCi/m^3.

Dose shall be calculated using the following formula:

$$\text{Dose} = 3.17\text{E-}08 \sum_i \Big\{ R_i^I \left[W_s\tilde{Q}_{is} + w_s\tilde{q}_{is} + W_v\tilde{Q}_{iv} + w_s\tilde{q}_{iv} \right] + W_s\tilde{Q}_{is} \left[R_i^G + R_i^C + R_i^M + R_i^V \right] + w_s\tilde{q}_{is} \left[R_i^G + R_i^C + R_i^M + R_i^V \right] + W_v\tilde{Q}_{iv} \left[R_i^G + R_i^C + R_i^M + R_i^V \right] + w_v\tilde{q}_{iv} \left[R_i^G + R_i^C + R_i^M + R_i^V \right] \Big\}$$

Where:

1. all W and w factors in the first argument are the appropriate (χ/Q) values.
2. all W and w factors in the 2nd, 3rd, 4th, and 5th terms of the equation are appropriate (D/Q) values.

R_i Factors

clide	Infant $R_i^I[\chi/Q]$	Child $R_i^I[\chi/Q]$	$R_i^G[D/Q]$	Infant $R_i^C[D/Q]$	Child $R_i^C[D/Q]$	Child $R_i^M[D/Q]$	Child $R_i^V[D/Q]$
r-51	1.28E04	1.70E04	5.52E06	4.71E06	5.41E06	4.67E05	6.23E0
Mn-54	1.00E06	1.58E04	1.62F09	3.90E07	2.10E07	8.02E06	6.65E0
e-59	1.02E06	1.27E06	3.20E08	3.92E08	2.03E08	6.34E08	6.69E0
Co-58	7.77E05	1.11E06	4.45E08	6.06E07	7.08E07	9.59E07	3.76E0
o-60	4.51E06	7.07E06	2.53E10	2.10E08	2.39E08	3.84E08	1.71E0
n-65	6.47E07	9.95E05	8.57E08	1.91E10	1.10E10	1.00E09	2.16E0
Sr-89	2.03E06	2.16E06	2.52E04	1.26E10	6.63E09	4.83E08	3.61E1
r-90	4.09E07	1.01E08	- - - -	1.22E11	1.12E11	1.04E10	1.24E1
Zr-95	1.75E06	2.23E06	2.92E08	8.31E05	8.84E05	6.18E08	9.02E0
-131	1.48E07	1.62E07	2.10E07	1.06E12	4.35E11	5.55E10	4.77E1
33	3.56E06	3.85E06	2.98E06	9.60E09	3.95E09	1.30E02	8.20E0
Cs-134	7.03E05	1.01E06	7.97E09	6.81E10	3.72E10	1.51E09	2.63E1
-136	1.35E05	1.71E05	1.69E08	5.77E09	2.76E09	4.38E07	2.22E0
-137	6.12E05	9.07E05	1.20E10	6.03E10	3.23E10	1.33E09	2.39E1
Bu-140	1.60E06	1.74E06	2.35E07	2.41E08	1.17E08	4.39E07	2.77E0
-141	5.17E05	5.44E05	1.53E07	1.37E07	1.36E07	1.38E07	4.06E0
H-3	6.47E02	1.12E03	0	2.38E03	3.51E02	2.34E02	4.01E0
-32	2.03E06	2.60E06	0	1.61E11	7.79E10	7.43E09	3.38E0
e-55	8.69E04	1.11E05	0	1.35E08	1.12E08	4.58E08	8.01E0
C-14	2.65E04	3.59E04	0	2.34E09	1.20E09	3.84E08	8.89E0

$$R_i^G + R_i^C + R_i^M + R_i^V$$

Nuclide	Child	Infant
Cr-51	1.76E07	1.02E07
Mn-54	2.31E09	1.66E09
Fe-59	1.83E09	7.12E08
Co-58	9.88E08	5.06E08
Co-60	2.76E10	2.55E10
Zn-65	1.50E10	2.00E10
Sr-89	4.32E10	1.26E10
Sr-90	1.36E12	1.22E11
Zr-95	1.81E09	2.93E08
I-131	5.38E11	1.06E12
I-133	4.77E09	9.60E09
Cs-134	7.30E10	7.61E10
Cs-136	3.19E09	5.94E09
Cs-137	6.95E10	7.23E10
Ba-140	4.61E08	2.65E08
Ce-141	4.49E08	2.90E07
H-3	4.60E03	2.38E03
P-32	8.87E10	1.61E11
Fe-55	1.37E09	1.35E08
C-14	2.47E09	2.34E09

CALCULATION OF $R_i^I [\chi/Q]$

INHALATION PATHWAY FACTOR

$$R_i^I [\chi/Q] = K' (BR)a(DFAi)a \quad (\text{mrem/yr per } \mu Ci/m^3)$$

Where:

K' = constant of unit conversion, 10^6 pCi/μCi

(BR)a = breathing rate of the receptor of age group (a) in m^3/yr.

(DFAi)a = The maximum organ inhalation dose factor for the receptor of age group(a) for the i^{th} radionuclide, in mrem/pCi. The total body is considered as an organ in the selection of (DFAi)a.

Only the infant and the child R factors are calculated for the purpose of this manual, since they are the most restrictive age groups.

Breathing Rates:

Infant = 1400 (m^3/yr) *

Child = 3700 (m^3/yr) *

* From Table E-5 of Regulatory Guide 1.109

449 079

R_i^I Infant

Radionuclide	(pCi/μCi) K'	(m³/yr) BR	mrem/Pci* DFAi	Organ	R_i^I mrem/yr per μCi/m³
Cr-51	10^6	1.4E03	9.17E-06	Lung	1.28E04
Mn-54	↓	↓	7.14E-04	Lung	1.00E06
Fe-59			7.25E-04	Lung	1.02E06
Co-58			5.55E-04	Lung	7.77E05
Co-60			3.22E-03	Lung	4.51E06
Zn-65			4.62E-04	Lung	6.47E07
Sr-89			1.45E-03	Lung	2.03E06
Sr-90			2.92E-02	Bone	4.09E07
Zr-95			1.25E-03	Lung	1.75E06
I-131			1.06E-02	Thyroid	1.48E07
I-133			2.54E-03	Thyroid	3.56E06
Cs-134			5.02E-04	Liver	7.03E05
Cs-136			9.61E-05	Liver	1.35E05
Cs-137			4.37E-04	Liver	6.12E05
Ba-140			1.14E-03	Lung	1.60E06
Ce-141			3.69E-04	Lung	5.17E05
H-3			4.62E-07	Body	6.47E02
P-32			1.45E-03	Bone	2.03E06
Fe-55			6.21E-05	Lung	8.69E04
C-14	↓	↓	1.89E-05	Bone	2.65E04

* From Table E-10, Regulatory Guide 1.109

R_i^I Child

Radionuclide	(pCi/μCi) K'	(m³/yr) BR	mrem/Pci* DFAi	Organ	R_i^I mrem/yr per μCi/m³
Cr-51	10^6	3.7E03	4.59E-06	Lung	1.70E04
Mn-54	↓	↓	4.26E-04	Lung	1.58E06
Fe-59			3.43E-04	Lung	1.27E06
Co-58			2.99E-04	Lung	1.11E06
Co-60			1.91E-03	Lung	7.07E06
Zn-65			2.69E-04	Lung	9.95E05
Sr-89			5.83E-04	Lung	2.16E06
Sr-90			2.73E-02	Bone	1.01E08
Zr-95			6.03E-04	Lung	2.23E06
I-131			4.39E-03	Thyroid	1.62E07
I-133			1.04E-03	Thyroid	3.85E06
Cs-134			2.74E-04	Liver	1.01E06
Cs-136			4.62E-05	Liver	1.71E05
Cs-137			2.45E-04	Bone	9.07E05
Ba-140			4.71E-04	Lung	1.74E06
Ce-141			1.47E-04	Lung	5.44E05
H-3			3.04E-07	Body	1.12E03
P-32			7.04E-04	Bone	2.60E06
Fe-55			3.00E-05	Lung	1.11E05
C-14			9.70E-06	Bone	3.59E04

* From Table E-9, Regulatory Guide 1.109

449 081

CALCULATION OF R_i^G [D/Q]

GROUND PLANE PATHWAY FACTOR

$$R_i^G [D/Q] = K'K'' (SF) DFG_i \left[(1-e^{-\lambda i\ t})/\lambda i \right] \ (m^2 \cdot \text{mrem/yr per } \mu\text{Ci/sec})$$

Where:

K' = A constant of conversion, 10^6 pCi/μCi

K'' = A constant of conversion, 8760 hr/yr

λi = Decay constant for the ith radionuclide, sec^{-1}

t = The exposure time, 4.73 x 10^8 sec (15 years)

DFGi = The ground plane dose conversion factor for the ith radionuclide (mrem/hr per pCi/m^2)

SF = Shielding factor (dimensionless)

R_i^G

Nuclide	(pCi/μCi) K'	hr/yr K''	* SF	** DFG_i	(sec) t	(sec^{-1}) λi	R_i^G
Cr-51	10^6	8.76E03	7.0E-01	2.6E-10	4.73E08	2.89E-07	5.52E06
Mn-54				6.8E-09		2.57E-08	1.62E09
Fe-59				9.4E-09		1.80E-07	3.20E08
Co-58				8.2E-09		1.13E-07	4.45E08
Co-60				2.00E-08		4.18E-09	2.53E10
Zn-65				4.6E-09		3.29E-08	8.57E08
Sr-89				6.5E-13		1.58E-07	2.52E04
Sr-90				not given		7.60E-10	0
Zr-95				5.8E-09		1.22E-07	2.92E08
I-131				3.4E-09		9.95E-07	2.10E07
I-133				4.5E-09		9.26E-06	2.98E06
Cs-134				1.4E-08		1.07E-08	7.97E09
Cs-136				1.7E-08		6.17E-07	1.69E08
Cs-137				4.9E-09		7.28E-10	1.20E10
Ba-140				2.4E-09		6.27E-07	2.35E07
Ce-141				6.2E-10		2.48E-07	1.53E07
H-3				0		1.78E-09	0
P-32				0		5.61E-07	0
Fe-55				0		8.14E-09	0
C-14				0		3.84E-12	0

* From Table E-15 Regulatory Guide 1.109

** From Table E-6 Regulatory Guide 1.109

449 083

CALCULATION OF R_i^c [D/Q]

Grass - Cow - Milk Pathway Factor

$$R_i \, [D/Q] = K' \frac{Q_F(Uap)}{\lambda_i+\lambda w} Fm(r)(DFL_i)a \left[\frac{fpfs}{Y_p} + \frac{(1-fpfs)e^{-\lambda ith}}{Ys}\right] e^{-\lambda itf}$$

Where:

K' = Constant of conversion, 10^6 pCi/μCi

Q_F = Cow's consumption rate, in Kg/day (wet weight)

Uap = Receptor's milk consumption rate for age (a), in liters/yr

Y_p = Agricultural productivity by unit area of stored feed, in Kg/m^2

Y_s = The agricultural productivity by unit area of stored feed, in Kg/m^2

F_m = Stable element transfer coefficients, in days/liter

γ = Fraction of deposited activity retained on cow's feed grass.

$(DFL_i)a$ = The maximum organ ingestion dose factor for the ith radionuclide for the receptor in age group (a) in mrem/pCi

λ_i = Decay constant for the ith radionuclide, in sec^{-1}

λw = Decay constant for removal of activity on leaf and plant surfaces by weathering, 5.73×10^{-7} sec^{-1} (corresponding to a 14 day half-life)

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t_f = The transport time from pasture, to cow, to milk, to receptor in sec.

th = The transport time from pasture, to harvest, to cow, to milk, to receptor, in sec

f_p = Fraction of the year that the cow is on pasture.

f_s = Fraction of the cow feed that is pasture grass while the cow is on pasture

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Parameters are taken from the following sources:

Parameter		Value	Table (R.G. 1.109)
r (dimensionless)		1.0 for radioiodine	E-15
		0.2 for particulates	E-15
F_m (days/liter)		Each stable element	E-1
U_{ap} (liters/yr)	- infant	330	E-5
	- child	330	E-5
	- teen	400	E-5
	- adult	310	E-5
$(DFL_i)_a$ (mrem/pCi)		Each radionuclide	E-11 to E-14
Y_p (kg/m^2)		0.7	E-15
Y_s (kg/m^2)		2.0	E-15
t_f (seconds)		1.73 X 10^5 (2 days)	E-15
t_h (seconds)		7.78 X 10^6 (90 days)	E-15
Q_f (kg/day)		50	E-3
f_s *			
f_p **			

* f_s and f_p are assumed to be unity

Only the R_i^C values for the infant and the child are for the purpose of this manual as they are the most restrictive age groups.

449 086

The concentration of tritium in milk is based on the airborne concentration rather than the deposition. Therefore, the R_i^C is based on χ/Q:

$$R_i^C[\chi/Q] = K'K'''F_m Q_F U_{ap} (DFL_i)_a \; 0.75(0.5/H) \quad (\text{mrem/yr per } \mu\text{Ci/m}^3)$$

Where:

- K''' = a constant of unit conversion, 10^3 gm/kg.
- H = absolute humidity of the atmosphere, in gm/m^3.
- 0.75 = the fraction of total feed that is water.
- 0.5 = the ratio of the specific activity of the feed grass water to the atmospheric water.

and other parameters and values are given above. The value of H may be considered as 8 grams/meter^3, in lieu of site specific information.

R_i^C [D/Q] Grass-Cow-Milk Pathway Factor (infant)

cl.	K'	QF	Uap	Yp	Ys	Fm	r	DFLi	Organ	λi	λw	tf	th	fp	fs	R_i^C
-51	10^6	50	330	0.7	2.0	2.2E-03	0.2	4.11E-07	GI-LLI	2.89E-7	5.73E-7	1.73E5	7.78E6	1	1	4.71E06
n-54						2.5E-04	0.2	1.99E-05	Liver	2.57E-8						3.90E07
e-59						1.2E-03	0.2	5.38E-05	Liver	1.8E-7						3.92E08
-58						1.0E-03	0.2	8.98E-06	Body	1.13E-7						6.06E07
o-60						1.0E-03	0.2	2.57E-05	GI-LLI	4.18E-9						2.10E08
n-65						3.9E-02	0.2	6.31E-05	Liver	3.29E-8						1.91E10
r-89						8.0E-04	0.2	2.51E-03	Bone	1.58E-7						1.26E10
r-90						8.0E-04	0.2	1.85E-02	Bone	7.6E-10						1.22E11
r-95						5.0E-06	0.2	2.50E-05	GI-LLI	1.22E-7						8.31E05
-131						6.0E-03	1.0	1.39E-02	Thyroid	9.95E-7						1.06E12
-133						6.0E-03	1.0	3.31E-03	Thyroid	9.26E-6						9.60E09
-134						1.2E-02	0.2	7.03E-04	Liver	1.07E-8						6.81E10
-136						1.2E-02	0.2	1.35E-04	Liver	6.17E-7						5.77E09
-137						1.2E-02	0.2	6.11E-04	Liver	7.28E-10						6.03E10
-140						4.0E-04	0.2	1.71E-04	Bone	6.27E-7						2.41E08
-141						1.0E-(4	0.2	2.48E-05	GI-LLI	2.48E-7						1.37E07
3						1.0E-02	0.2	3.08E-07	Body	1.78E-9						2.38E03
2						2.5E-02	0.2	1.70E-03	Bone	5.61E-7						1.61E11
55						1.2E-03	0.2	1.39E-05	Bone	8.14E-9						1.35E08
14						1.2E-02	0.2	2.37E-05	Bone	3.84E-12						2.34E09

R_i^C [D/Q] Grass-Cow-Milk Pathway Factor (child)

Nucl.	K'	Q_F	Uap	Yp	Ys	Fm	r	DFLi	Organ	λi	λw	tf	th	fp	fs	R_i^C
Cr-51	10^6	50	330	0.7	2.0	2.2E-03	0.2	4.72E-7	GI-LLI	2.89E-7	5.73E-7	1.73E5	7.78E6	1	1	5.41E06
Mn-54						2.5E-04	0.2	1.07E-5	Liver	2.57E-8						2.10E07
Fe-59						1.2E-03	0.2	2.78E-5	GI-LLI	1.8E-7						2.03E08
Co-58						1.0E-03	0.2	1.05E-5	GI-LLI	1.13E-7						7.08E07
Co-60						1.0E-03	0.2	2.93E-5	GI-LLI	4.18E-9						2.39E08
Zn-65						3.9E-02	0.2	3.65E-5	Liver	3.29E-8						1.10E10
Sr-89						8.0E-04	0.2	1.32E-3	Bone	1.58E-7						6.63E09
Sr-90						8.0E-04	0.2	1.70E-2	Bone	7.6E-10						1.12E11
Zr-95						5.0E-06	0.2	2.66E-5	GI-LLI	1.22E-7						8.84E05
I-131						6.0E-03	1.0	5.72E-3	Thyroid	9.95E-7						4.35E11
I-133						6.0E-03	1.0	1.36E-3	Thyroid	9.26E-6						3.95E09
Cs-134						1.2E-02	0.2	3.84E-4	Liver	1.07E-8						3.72E10
Cs-136						1.2E-02	0.2	6.46E-5	Liver	6.17E-7						2.76E09
Cs-137						1.2E-02	0.2	3.27E-4	Bone	7.28E-10						3.23E10
a-140						4.0E-04	0.2	8.31E-5	Bone	6.27E-7						1.17E08
e-141						1.0E-04	0.2	2.47E-5	GI-LLI	2.48E-7						1.36E07
H-3						1.0E-02	0.2	2.03E-7	Body	1.78E-9						3.52E02
-32						2.5E-02	0.2	8.25E-4	Bone	5.61E-7						7.79E10
e-55						1.2E-03	0.2	1.15E-5	Bone	8.14E-9						1.12E08
C-14						1.2E-02	0.2	1.21E-5	Bone	3.84E-12						1.20E09

CALCULATION OF R_i^M [D/Q]

GRASS - COW - MEAT PATHWAY FACTOR

$$R_i^M \left[D/Q\right] = K' \frac{Q_F\ (Uap)}{\lambda i+\lambda w} F_f(r)(DFLi)_a \left[\frac{fpfs}{Y_p} + \frac{(1-fpfs)e^{-\lambda ith}}{Y_s}\right] e^{-\lambda itf}$$

in units of (m^2 mrem/yr per μCi/sec)

Where:

F_f = Stable element transfer coefficients, in days/kg.

Uap = The receptor's meat consumption rate for age (a), in kg/yr.

t_f = Transport time from pasture to receptor, in sec.

th = The transport time from crop field to receptor, in sec.

and all other terms are defined in the calculation of Grass - Cow - Milk Pathway Factor section of this manual.

449 090

Parameter	Value	Table (R.G. 1.109)
r (dimensionless)	1.0 for radioiodine	E-15
	0.2 for particulates	E-15
F_f (days/kg)	Each stable element	E-1
U_{ap} (kg/yr) - infant	0	E-5
- child	41	E-5
- teen	65	E-5
- adult	110	E-5
$(DFL_i)a$ (mrem/pCi)	Each radionuclide	E-11 to E-14
Y_p (kg/m^2)	0.7	E-15
Y_s (kg/m^2)	2.0	E-15
t_f (seconds)	1.73×10^6 (20 days)	E-15
t_h (seconds)	7.78×10^6 (90 days)	E-15
Q_f (kg/day)	50	E-3

The concentration of tritium in meat is based on its airborne concentration rather than the deposition. Therefore, the R_i^M is based on χ/Q :

$$R_i^M \; \chi/Q \; = \; K'K''F_f Q_F U_{ap} (DFL_i)_a \left[0.75(0.5/H)\right] \quad \text{(mrem/yr per } \mu\text{Ci/m}^3$$

where all terms are defined above and in the Calculation of Grass - Cow - Milk Pathway Factor section of this manual. Since the infant's consumption rate for this pathway is zero, the child becomes the limiting age group and R values are tabulated for this group.

449 091

TABULATION OF R_i^M [D/Q] (Child)

Nucl.	K'	Qf	Uap	Ys	Yp	λi	r	DFLi	Organ	λw	Ff	th	tf	fp	fs	R_i^M
Cr-51	10^6	50	41	2.0	0.7	2.89E-07	.2	4.72E-07	GI-LLI	5.73E-07	2.4E-03	7.78E06	1.73E06	1	1	4.67E05
Mn-54						2.57E-08	.2	1.07E-05	Liver		8.0E-04					8.02E06
Fe-59						1.8E-07	.2	2.78E-05	GI-LLI		4.0E-02					6.34E08
Co-58						1.13E-07	.2	1.05E-05	GI-LLI		1.3E-02					9.59E07
Co-60						4.18E-09	.2	2.93E-05	GI-LLI		1.3E-02					3.84E08
Zn-65						3.29E-08	.2	3.65E-05	Liver		3.0E-02					1.00E09
Sr-89						1.58E-07	.2	1.32E-03	Bone		6.0E-04					4.83E08
Sr-90						7.60E-10	.2	1.10E-02	Bone		6.0E-04					1.04E10
Zr-95						1.22E-07	.2	2.66E-05	GI-LLI		3.4E-02					6.18E08
-131						9.95E-07	1	5.72E-02	Thyroid		2.9E-03					5.55E10
-133						9.26E-06	1	1.36E-03	Thyroid		2.9E-03					1.30E02
s-134						1.07E-08	.2	3.84E-04	Liver		4.0E-03					1.51E09
s-136						6.17E-07	.2	6.46E-05	Liver		4.0E-03					4.38E07
s-137						7.28E-10	.2	3.27E-04	Bone		4.0E-03					1.33E09
a-140						6.27E-07	.2	8.31E-05	Bone		3.2E-03					4.39E07
-141						2.48E-07	.2	2.47E-05	GI-LLI		1.2E-03					1.38E07
H-3						1.78E-09	.2	2.03E-07	Body		1.2E-02					2.34E02
P-32						5.61E-07	.2	8.25E-04	Bone		4.6E-02					7.43E09
e-55						8.14E-09	.2	1.15E-05	Bone		4.0E-02					4.58E08
-14						3.84E12	.2	1.21E-05	Bone		3.1E-02					3.84E08

449 092

CALCULATION OF R_i^V [D/Q]

VEGETATION PATHWAY FACTOR

$$R_i^V\,[D/Q] = K'\left[\frac{(r)}{Y_v\,(\lambda_i+\lambda_w)}\right](DFL_i)_a\left[U_a^L\, f_L e^{-\lambda_i t_L} + U_a^s\, f_g e^{-\lambda_i t_h}\right]$$

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

Where:

K' = constant of conversion, 10^6 pCi/μCi

U_a^L = consumption rate of fresh leafy vegetation by the receptor in age group (a), in Kg/yr.

f_L = fraction of annual intake of fresh leafy vegetation grown locally.

f_g = the fraction of the annual intake of stored vegetation grown locally.

t_L = the average time between harvest of leafy vegetation and its consumption, in seconds.

t_h = the average time between harvest of stored vegetation and its consumption, in seconds.

Y_v = the vegetation area density, in kg/m^2.

all other factors are defined in the Calculation of Grass-Cow-Milk Pathway Factor section of this manual.

449 093

Parameter	Value	Table (R.G. 1.109
r (dimensionless)	1.0 for radioiodines 0.2 for particulates	E-1
$(DFL_i)_a$ (mrem/pCi)	Each radionuclide	E-11 to E-14
U_a^L (kg/yr) - infant	0	E-5
- child	26	E-5
- teen	42	E-5
- adult	64	E-5
U_a^S (kg/yr) - infant	0	E-5
- child	520	E-5
- teen	630	E-5
- adult	520	E-5
f_L (dimensionless)	site specific (default = 1.0)	
f_g (dimensionless)	site specific (default = 0.76) (see Ref. 6, pg.28)	
t_L (seconds)	8.6×10^4 (1 day)	E-15
t_h (seconds)	5.18×10^6 (60 days)	E-15
Y_v (kg/m^2)	2.0	E-15

The concentration of tritium in vegetation is based on the airborne concentration rather than the deposition. Therefore, the R_i^V is based on χ/Q :

$$R_i^V \; \chi/Q = K'K''' \quad U_a^L f_L + U_a^S f_g \; (DFL_i)a \left[0.75(0.5/H)\right]$$ (mrem/yr per μCi/m^3).

442 024

where all terms have been defined above and in the grass-cow-milk Pathway Calculation section of this manual.

Since the infant consumption rate is zero, only the child R_i^V values are calculated.

R_i^v [D/Q]

ncl.	K'	U_a^L	U_a^s	Yv		λw	r	DFLi	λi	fl	fg	t_L	t_h			R_i^v
-51	10^6	26	520	2.0		5.73E-07	0.2	4.27E-07	2.89E-07	1.0	0.76	8.6E4	5.18E6			6.23E06
-54							0.2	1.07E-05	2.57E-08							6.65E08
-59							0.2	2.78E-05	1.8E-07							6.69E08
-58							0.2	1.05E-05	1.13E-07							3.76E08
-60							0.2	2.93E-05	4.18E-09							1.71E09
-65							0.2	3.65E-05	3.29E-08							2.16E09
-89							0.2	1.32E-03	1.58E-07							3.61E10
-90							0.2	1.70E-02	7.6E-10							1.24E12
-95							0.2	2.66E-05	1.22E-07							9.02E08
131							1.0	5.72E-03	9.95E-07							4.77E10
133							1.0	1.36E-03	9.2E-06							8.20E08
-134							0.2	3.84E-04	1.07E-08							2.63E10
-136							0.2	6.46E-05	6.17E-07							2.22E08
s-137							0.2	3.27E-04	7.28E-10							2.39E10
-140							0.2	8.31E-05	6.27E-07							2.77E08
-141							0.2	2.47E-05	2.48E-07							4.06E08
i-3							0.2	2.03E-07	1.78E-09							4.01E03
-32							0.2	8.25E-04	5.61E-07							3.38E09
e-55							0.2	1.15E-05	8.14E-09							8.01E08
-14							0.2	1.21E-05	3.84E-12							8.89E08

449 096

IMPLEMENTATION OF 10CFR50

AIRBORNE RELEASES

NOBLE GASES

Technical Specifications state:

a. "The air dose in unrestricted areas due to noble gases released in gaseous effluents shall be limited to the following:

   1. During any calendar quarter, to $\leq$ 5 mrad for gamma radiation and $\leq$ 10 mrad for beta radiation.

   2. During any calendar year $\leq$ 10 mrad for gamma radiation and $\leq$ 20 mrad for beta radiation.

This specification shall be implemented using the following relationships:

a. During any calendar quarter, for gamma radiation:

$$3.17 \times 10^{-8} \sum_i \{M_i \left[(\chi/Q)_v \tilde{Q}_{iv} + (\chi/q)_v \tilde{q}_{iv} + (\chi/Q)_s \tilde{Q}_{is} + (\chi/q)_s \tilde{q}_{is}\right]\} \leq 5\text{mrad}$$

During any calendar quarter, for beta radiation

$$3.17 \times 10^{-8} \sum_i \{ N_i \left[(\chi/Q)_v \tilde{Q}_{iv} + (\chi/q)_v \tilde{q}_{iv} + (\chi/Q)_s \tilde{Q}_{is} + (\chi/q)_{is} q_{is}\right]\} \leq 10\text{mrad}$$

b. During any calendar year for gamma radiation:

$$3.17 \times 10^{-8} \sum_i \{M_i \left[(\chi/Q)_v \tilde{Q}_{iv} + (\chi/q)_v \tilde{q}_{iv} + (\chi/Q)_s \tilde{Q}_{is} + (\chi/q)_s \tilde{q}_{is}\right]\} \leq 10 \text{ mrad}$$

During any calendar year for beta radiation:

$$3.17 \times 10^{-8} \sum_i \{N_i \left[(\chi/Q)_v \tilde{Q}_{iv} + (\chi/q)_v \tilde{q}_{iv} + (\chi/Q)_s \tilde{Q}_{is} + (\chi/q)_s \tilde{q}_{is}\right]\} \leq 20 \text{ mrad}$$

e

$(\overline{\chi/Q})_v$ = 6.73E-07 sec/m^3. For vent releases. The highest calculated annual average relative concentration for area at or beyond the unrestricted area boundary for long term releases (greater than 500 hrs/year).

$(\overline{\chi/q})_v$ = 4.20E-06 sec/m^3. For vent releases. The relative concentration for areas at or beyond the unrestricted area boundary for short term releases (equal to or less than 500 hrs/year).

$(\overline{\chi/Q})_s$ = 8.07E-08 sec/m^3. For free-standing stack releases. The highest calculated annual average relative concentration for areas at or beyond the unrestricted area boundary for long term releases (greater than 500 hrs/year).

449 098

$(\overline{\chi/q})_s$ = 2.00E-08 sec/m^3. For free-standing stack releases. The relative concentration for areas at or beyond the unrestricted area boundary for short term releases (less than or equal to 500 hrs/yr).

M_i = The air dose factor due to gamma emission for each identified noble gas radionuclide in mrad/yr per $\mu Ci/m^3$.

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

$\tilde{q}_{is}$ = The average release of noble gas radionuclides in gaseous effluents, i, for short term releases (equal to or less than 500 hrs/year) from the free-standing stack, in μCi. Releases shall be cumulative over the calendar quarter or year as appropriate.

$\tilde{q}_{iv}$ = The average release of noble gas radionuclides in gaseous effluents, i, for short term releases (equal to or less than 500 hrs/year) from all vents, in μCi. Releases shall be cumulative over the calendar quarter or year as appropriate.

449 099

$\tilde{Q}_{is}$ = The average release of noble gas radionuclides in gaseous releases, i, for long term releases (greater than 500 hrs/year) from the free standing stack, in μCi. Release shall be cumulative over the calendar quarter of year as appropriate.

$\tilde{Q}_{iv}$ = The average release of noble gas radionuclides in gaseous effluents, i, for long term releases (greater than 500 hrs/yr) from all vents, in μCi. Releases shall be cumulative over the calendar quarter or year as appropriate.

3.17×10^{-8} = The inverse of the number of seconds in a year.

449 100

AIR DOSE FACTORS #

Nuclide	M_i *	N_i **
Kr-83m	1.93E01	2.88E02
Kr-85m	1.23E03	1.97E03
Kr-85	1.72E01	1.95E03
Kr-87	6.17E03	1.03E04
Kr-88	1.52E04	2.93E03
Kr-89	1.73E04	1.06E04
Kr-90	1.63E04	7.83E03
Xe-131m	1.56E02	1.11E03
Xe-133m	3.27E02	1.48E03
Xe-133	3.53E02	1.05E03
Xe-135m	3.36E03	7.39E02
Xe-135	1.92E03	2.46E03
Xe-137	1.51E03	1.27E04
Xe-138	9.21E03	4.75E03
Ar-41	9.30E03	3.28E03

449 101

* From Table B-1, Regulatory Guide 1.109

** From Table B-1, Regulatory Guide 1.109

\# Values are multiplied by 10^6 pCi/μCi to yield units of mrad/yr per μCi/m^3

REFERENCES

1. "Preparation of Radiological Effluent Technical Specifications for Nuclear Power Plants", NUREG-0133, Oct. 1978 USNRC.

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", Regulatory Guide 1.109, Oct. 1977, Rev 1, USNRC.

3. "James A. FitzPatrick Nuclear Power Plant, Compliance With 10CFR50, Appendix I", Submitted to USNRC in 1976, Prepared by Stone & Webster - pp. 1.3-9.

4. "Code of Federal Regulations, Title 10 Parts 20, 50, 100", USNRC.

5. "Environmental Technical Specifications, Appendix B to Facility Operating License # DPR-59 for James A. FitzPatrick Nuclear Power Plant, Power Authority State of New York." October 1974, USNRC.

6. "Handbook of Radionuclides", Yen Wang, Chemical Rubber Company, 1969.

7. "Radiological Health Handbook", U.S. Department of HEW, Jan. 1970.