ATTACHMENT IV

REVISION 5 TO THE ODCM

September 7, 1984

SUBJECT: OFFSITE DOES CALCULATION MANUAL - REVISION 5

The General Office Radwaste Engineering Staff is transmitting to you this date, Revision 5 of the Offsite Dose Calculation Manual. As this revision affects the manual's generic section, the approval of each station manager has been obtained. Please update your copy no. 29, and discard affected pages.

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NOTE: As this letter contains "LOEP" information, please insert this letter in front of the August 7, 1984 letter.

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Mary L. Birch
Mary L. Birch
System Engineer
Radwaste Engineering

Approval Date: 8-29-84
Effective Date: 9-10-84

J. W. Hampton
J. W. Hampton, Manager
Catawba Nuclear Station

Approval Date: 8/24/84
Effective Date: 9-10-84

M. D. McIntosh
M. D. McIntosh, Manager
McGuire Nuclear Station

Approval Date: 8/21/84
Effective Date: 9-10-84

M. S. Tuckman
M. S. Tuckman, Manager
Oconee Nuclear Station

If you have any questions concerning Revision 5, please call Jim Stewart at (704) 373-5444.

James M. Stewart, Jr.
James M. Stewart, Jr.
Associate Health Physicist
Radwaste Engineering
WC-2339

JMS/nem

1.0 RELEASE RATE CALCULATIONS

The release rate calculations presented in the following sections are site release limits. Sites containing two or more units shall administratively control releases to assure that the release rate calculations limit releases as stated in the Technical Specifications. Administrative controls could limit the number of releases occurring at one time and/or apportion the release rate between the units.

1.1 LIQUID EFFLUENTS

To comply with Technical Specifications and to assure that the concentration of radioactive liquid effluents from the site to the unrestricted area is limited to the concentrations of 10CFR20, Appendix B, Table II, Column 2, the following release rate calculation shall be performed:

$$f \leq F \div \left(\sigma \sum_{i=1}^{n} \frac{C_i}{MPC_i}\right)$$

where:

C_i = The concentration of radionuclide, 'i', in undiluted liquid effluent, in μCi/ml.

MPC_i = the concentration of radionuclide, 'i', from 10CFR20, Appendix B, Table II, Column 2, in μCi/ml.

f = the undiluted effluent flow from the tank, in gpm.

F = the dilution flow from the site discharge structure to unrestricted area receiving waters, in gpm.

σ = recirculation factor at equilibrium; this factor accounts for the fraction of discharged water reused by the station; this factor is one for stations on rivers or lakes where discharged water cannot be reused, and varies for sites where water is recirculated and is specified in the appropriate Appendix.

1.2 GASEOUS EFFLUENTS

In order to comply with the Technical Specifications and to assure that the dose rate, at any time, in the unrestricted area due to radioactive materials released in gaseous effluents from the site is limited to ≤500 mrem/yr to the total body and ≤3000 mrem/yr to the skin for the noble gases and is limited to ≤1500 mrem/yr to any organ for all radioiodine and for all radioactive materials in particulates form and radionuclides other than noble gases with half lives greater than 8 days, the following release rate calculations shall be performed. These calculations, when solved for 'f', i.e. flowrate, are the release rates for noble gases and for radioiodines, particulates and other radionuclides with half-lives greater than 8 days. The most conservative of release rates calculated shall control the release rate.

1.2.1 Noble Gases

$$\sum_i K_i \times [(\overline{X/Q})\tilde{Q}_i] < 500 \text{ mrem/yr, and}$$

$$\sum_i (L_i + 1.1\, M_i)\, [(\overline{X/Q})\tilde{Q}_i] < 3000 \text{ mrem/yr}$$

where:

K_i = The total body dose factor due to gamma emissions for each identified noble gas radionuclide, in mrem/yr per $\mu Ci/m^3$ from Table 1.2-1.

L_i = The skin dose factor due to beta emissions for each identified noble gas radionuclide, in mrem/yr per $\mu Ci/m^3$ from Table 1.2-1.

M_i = The air dose factor due to gamma emissions for each identified noble gas radionuclide, in mrad/yr per $\mu Ci/m^3$ from Table 1.2-1 (unit conversion constant of 1.1 mrem/mrad converts air dose to skin dose).

P_i = The dose parameter for radionuclides other than noble gases for the inhalation pathway, in mrem/yr per $\mu Ci/m^3$ and for the food and ground plane pathways in m^2.(mrem/yr per μCi/sec) from Table 1.2-2. The dose factors are based on the critical individual organ and most restrictive age group (child or infant).

$\tilde{Q}_i$ = The release rate of radionuclides, 'i', in gaseous effluent from all release points at the site, in μCi/sec.

$\overline{X/Q}$ = The highest calculated annual average dispersion parameter for any area at or beyond the unrestricted area boundary.

W = The highest calculated annual average dispersion parameter for estimating the dose to an individual at the controlling location.

$$\tilde{Q}_i = k_1 C_i f \div k_2 = 4.72E{+}2\ C_i f$$

where:

C_i = the concentration of radionuclide, 'i', in undiluted gaseous effluent, in μCi/ml.

f = the undiluted effluent flow, in cfm.

k_1 = conversion factor, 2.83E+04 ml/ft^3.

k_2 = conversion factor, 6.0E+01 sec/min.

1.2.2 Radioiodines, Particulates, and Others

$$\sum_i P_i\, [W\, \tilde{Q}_i] < 1500 \text{ mrem/yr}$$

where the terms are as defined above.

TABLE 1.2-2
(1 of 1)
DOSE PARAMETERS FOR RADIOIODINES AND RADIOACTIVE PARTICULATE, GASEOUS EFFLUENTS*

P(I), DOSE PARAMETERS FOR RADIOIODINES AND RADIOACTIVE PARTICULATES IN GASEOUS EFFLUENTS

	Pathways			Pathways	
Radionuclide	Inhalation (mrem/yr per $\mu Ci/m^3$)	Food and Ground (m^2.mrem/yr per μCi/sec)	Radionuclide	Inhalation (mrem/yr per $\mu Ci/m^3$)	Food and Ground (m^2.mrem/yr per μCi/sec)
H 3	1.125 E+03	2.4E+03	RU 103	6.625 E+05	1.6E+08
Alpha Act	1.100 E+08	1.8E+10	RU 106	1.432 E+07	2.0E+08
CR 51	1.698 E+04	1.1E+07	AG 110M	5.476 E+06	1.5E+10
MN 54	1.576 E+06	1.1E+09	CD 115M	2.920 E+05	5.2E+07
FE 55	1.110 E+05	1.1E+08	SN 123	3.550 E+06	3.7E+09
FE 59	1.269 E+06	7.2E+08	SN 126	1.120 E+07	1.1E+10
CO 58	1.106 E+06	5.8E+08	SB 124	3.240 E+06	1.4E+09
CO 60	7.067 E+06	4.6E+09	SB 125	2.320 E+06	9.1E+08
NI 63	8.214 E+05	3.0E+10	TE 127M	1.408 E+06	1.0E+09
ZN 65	8.399 E+04	1.8E+10	TE 129M	1.761 E+06	1.3E+09
RB 86	1.983 E+05	2.1E+10	CS 134	1.014 E+06	5.6E+10
SR 89	2.157 E+06	1.1E+10	CS 136	1.709 E+05	5.7E+09
SR 90	1.010 E+08	1.0E+11	CS 137	9.065 E+05	5.0E+10
Y 91	2.627 E+06	5.9E+06	BA 140	1.743 E+06	2.6E+08
ZR 95	2.231 E+06	3.5E+08	CE 141	5.439 E+05	3.2E+07
NB 95	6.142 E+05	3.8E+08	CE 144	1.195 E+07	1.6E+08
MO 99	1.354 E+05	3.2E+08	I 131	1.624 E+07	1.0E+12
			I 133	3.848 E+06	9.6E+09

*If SR-90 analysis is performed, use P(I) given in I-131 for unidentified components. If SR-90 and I-131 analyses are performed, use P(I) given in CS-137 for unidentified components. If SR-90, I-131, and CS-137 analyses are performed, use P(I) given in Zn-65 for unidentified components.

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where:

1.14E5 = 10^6pCi/μCi x 10^3ml/kg ÷ 8760 hr/yr.

U_{aw} = Water consumption by age group, ℓ/yr.

infant	330
child	510
teen	510
adult	730

D_w = Dilution factor from the near field area to the potable water intake.

U_{af} = fish consumption by age group, kg/yr.

infant	--
child	6.9
teen	16
adult	21

BF_i = Bioaccumulation factor for radionuclide, 'i', in fish, pCi/kg per pCi/l, from Table 3.1-1.

$DF_{ai\tau}$ = Dose conversion factor for radionuclide, 'i', by age group in pre-selected organ, τ, in mrem/pCi, from Tables 3.1-2, 3.1-3, 3.1-4, and 3.1-5, respectively.

Using the above information, $A_{ai\tau}$ values for the adult have been calculated for each site. This information is provided in the Table "X" 4.0-3 where "X" is the appendix for the site in question.

3.1.2 Gaseous Effluents

The dose contributions from measured quantities of radioactive materials identified in gaseous effluent released to unrestricted areas shall be calculated for the maximum exposed individual using the following equations:

3.1.2.1 Noble Gases

For gamma radiation:

$$D_\gamma = 3.17\ E\text{-}8 \sum_{i=1} M_i\ [(\overline{X/Q})\ \tilde{Q}_i]$$

For beta radiation:

$$D_\beta = 3.17\ E\text{-}8 \sum_{i=1} N_i\ [(\overline{X/Q})\ \tilde{Q}_i]$$

where:

3.17E-08 = The inverse of the number of seconds in a year.

M_i = The air dose factor due to gamma emissions for each identified noble gas radionuclide, in mrad/yr per μCi/m^3 from Table 1.2-1.

N_i = The air dose factor due to beta emissions for each identified noble gas radionuclide, in mrad/yr per $\mu Ci/m^3$ from Table 1.2-1.

$\overline{X/Q}$ = The highest calculated annual average relative concentration for any area at or beyond the unrestricted area boundary.

$\tilde{Q}_i$ = The release of noble gas radionuclides, 'i', in gaseous effluents, in μCi.

3.1.2.2 Radioiodines, Particulates, and Others

These calculations apply to all radioiodines, radioactive materials in particulate form and radionuclides other than noble gases with half-lives greater than 8 days:

$$D = 3.17\ E\text{-}8 \sum_i R_i\ [W\tilde{Q}_i]$$

where:

3.17E-08 = The inverse of the number of seconds in a year.

$\tilde{Q}_i$ = The release of radioiodines, radioactive materials in particulate form and radionuclides other than noble gases in gaseous effluents, 'i', in μCi. Releases shall be cumulative over the calendar quarter or year as appropriate.

W = The annual average dispersion or deposition parameter for estimating the dose to an individual at the controlling location.

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

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

R_i = The dose factor for each identified radionuclide, 'i', in m^2.(mrem/yr) per $\mu Ci/sec$ or mrem/yr per $\mu Ci/m^3$, for each pathway. (Tables 3.1-12 → 3.1-30)

where:

Inhalation Pathway Factor, $R_i^I\ [X/Q]$

$$R_i^I\ [X/Q] = K'(BR)_a\ (DFA_i)_a \text{ (mrem/yr per } \mu Ci/m^3)$$

where:

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

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

The breathing rates $(BR)_a$ for the various age groups are tabulated below, as given in Regulatory Guide 1.109.

3.3.4 Fuel Fabrication

No fuel fabrication operations occur within fifty miles of any Duke Nuclear Station. The increment of dose from fabrication operations to any individual within fifty miles of any Duke Nuclear Station is negligible.

3.3.5 Nuclear Power Production

The production of electricity for public use using light-water-cooled nuclear power stations results in increments of dose to individuals within fifty miles of any station due to liquid and gaseous effluent releases and direct radiation or skyshine. The increments of dose resulting from liquid and gaseous effluent releases will be calculated using the methodology presented in Sections 3.1.1 and 3.1.2. The dose from direct radiation, skyshine, and radiation from the station storage facilities has been estimated using conservative assumptions (see Section 3.1.3).

In certain situations more than one nuclear power station site may contribute to the doses to be considered in making fuel cycle dose assessments in accordance with 40CFR190. Situations involving more than one station will be presented in the section on site specific information.

3.3.6 Fuel Reprocessing

No fuel reprocessing operations occur within fifty miles of any Duke Nuclear Station. The increment of dose from reprocessing operations to any individual within fifty miles of any Duke Nuclear Station is negligible.

To summarize, only dose increments from nuclear power production operations (Section 3.3.5) need be considered in calculations to demonstrate compliance with the requirements of 40CFR190.

TABLE 3.1-3
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INGESTION DOSE FACTORS FOR TEENAGER
(MREM PER PCI INGESTED)

NUCLIDE	BONE	LIVER	T.BODY	THYROID	KIDNEY	LUNG	GI-LLI
BA 140	2.84E-05	3.48E-08	1.83E-06	NO DATA	1.18E-08	2.34E-08	4.38E-05
BA 141	6.71E-08	5.01E-11	2.24E-08	NO DATA	4.65E-11	3.43E-11	1.43E-13
BA 142	2.99E-08	2.99E-11	1.84E-09	NO DATA	2.53E-11	1.99E-11	9.18E-20
LA 140	3.48E-09	1.71E-09	4.55E-10	NO DATA	NO DATA	NO DATA	9.82E-05
LA 142	1.79E-10	7.95E-11	1.98E-11	NO DATA	NO DATA	NO DATA	2.42E-06
CE 141	1.33E-08	8.88E-09	1.02E-09	NO DATA	4.18E-09	NO DATA	2.54E-05
CE 143	2.35E-09	1.71E-06	1.91E-10	NO DATA	7.67E-10	NO DATA	5.14E-05
CE 144	6.96E-07	2.88E-07	3.74E-08	NO DATA	1.72E-07	NO DATA	1.75E-04
PR 143	1.31E-08	5.23E-09	6.52E-10	NO DATA	3.04E-09	NO DATA	4.31E-05
PR 144	4.30E-11	1.76E-11	2.18E-12	NO DATA	1.01E-11	NO DATA	4.74E-14
ND 147	9.38E-09	1.02E-08	6.11E-10	NO DATA	5.99E-09	NO DATA	3.68E-05
W 187	1.46E-07	1.19E-07	4.17E-08	NO DATA	NO DATA	NO DATA	3.22E-05
NP 239	1.76E-09	1.66E-10	9.22E-11	NO DATA	5.21E-10	NO DATA	2.67E-05