Callaway Energy Center 2018 Annual Radioactive Effluent Release Report

Revision 1

Renewed Facility Operating License NPF-30

Docket Numbers 50-483 and 72-1045

Ameren MISSOURI | Callaway Energy Center

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Abstract

The Annual Radioactive Effluent Release Report covers the operation of the Callaway Energy Center during the year 2018. The report includes a summary of the quantities of radioactive liquid and gaseous effluents and solid waste released from the unit. The report also includes an annual summary of hourly meteorological data collected during the year and an assessment of radiation dose to the Member of the Public from liquid and gaseous effluents.

1. Introduction

This Annual Radioactive Effluent Release Report (ARERR) is submitted by Union Electric Co., dba Ameren Missouri, in accordance with the requirements of 10 CFR 50.36a and 10 CFR 72.44(d)(3), Callaway Energy Center Technical Specification 5.6.3, and HI-STORM UMAX Certificate of Compliance Section 5.1.c. This report is for the period January 1, 2018 to December 31, 2018.

The doses to the Member of the Public from all liquid and gaseous effluents discharged during the reporting period were small fractions of the NRC and EPA regulatory limits and the Radioactive Effluent Control limits in the Offsite Dose Calculation Manual.

Radionuclide concentrations in liquid and gaseous effluents were obtained by effluent sampling and radiological analysis in accordance with the requirements of FSAR-SP/ODCM Radiological Effluent Control (REC) Table 16.11-1 and Table 16.11-4. Gamma spectroscopy was the primary analysis technique used to determine the radionuclide composition and concentration of liquid and gaseous effluents. Composite samples were analyzed for the hard to detect nuclides by an independent laboratory. Tritium and gross alpha were measured for both liquid and gaseous effluents using liquid scintillation counting and gas flow proportional counting techniques, respectively. The total radioactivity in effluent releases was determined from the measured concentrations of each radionuclide present and the total volume of effluents discharged.

2. Gaseous Effluents

The quantity of radioactive material released in gaseous effluents during the reporting period is summarized in Table A-1. The quarterly and annual sums of all radionuclides discharged in gaseous effluents are reported in Tables A-1A and A-1B. All gaseous effluent releases are considered to be ground level.

The quantity of ^{14}C released in gaseous effluents was calculated as described in EPRI Technical Report 1021106[1].

There were no radioactive effluents from the Independent Spent Fuel Storage Installation (ISFSI). The HI-STORM UMAX Canister Storage System does not create any radioactive materials or have any radioactive waste treatment systems. Specification 3.1.1, "Multi-Purpose Canister (MPC)", provides assurance that there are no radioactive effluents from the ISFSI.[2]

3. Liquid Effluents

The quantity of radioactive material released in liquid effluents during the reporting period is summarized in Table A-2. The quarterly and annual sums of all radionuclides discharged in liquid effluents are reported in Table A-2A. All liquid effluents were discharged in batch mode; there were no continuous liquid discharges for the reporting period. Dilution by the Missouri River, in the form of the near- field dilution factor, is utilized in the ODCM dose calculation methodology.

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[1] *Estimation of Carbon- 14 in Nuclear Power Plant Gaseous Effluents*, Technical Report 1011106, Electric Power Research Institute, December, 2010.

[2] Certificate of Compliance No. 1040, Appendix A, Technical Specifications for the HI_STORM UMAX Canister Storage System, Specification 5.1.

4. Solid Waste Storage and Shipments

The volume and activity of solid waste shipped for disposal is provided in Table A-3. Table A-3 is presented in the format of rev. 1 to Regulatory Guide 1.21 because the data is not readily available in the format recommended by rev. 2 to Regulatory Guide 1.21.

5. Dose Assessments

The annual evaluation of dose to the Member of the Public is calculated in accordance with the methodology and parameters in the ODCM and is reported in Tables A-4 and A-5.

5.1 Table A-4, Dose Assessments, 10 CFR 50, Appendix I

The dose assessments reported in Table A-4 were calculated using the methodology and parameters in the ODCM and demonstrate compliance with 10 CFR 50, Appendix I. The gamma air dose and beta air dose were calculated at the nearest Site Boundary location with the highest value of X/Q, as described in the ODCM. The maximum organ dose from gaseous effluents was calculated for the ingestion, inhalation, and ground plane pathways at the location of the nearest resident with the highest value of D/Q, as described in the ODCM. The organ dose does not include the dose from ^{14}C, which is listed separately.

5.2 Table A-5, EPA 40 CFR 190 Individual in the Unrestricted Area

The dose assessments reported in Table A-5 are the doses to the Member of the Public from activities within the Site Boundary plus the doses at the location of the Nearest Residence. A large portion of the residual land of the Callaway Site is managed by the State of Missouri Conservation Department as the Reform Wildlife Management Area. Pursuant to the guidance provided in Regulatory Guide 1.21, rev.2, the dose reported in Table A-5 is the sum of the dose from gaseous effluents (at the Nearest Resident location and within the Site Boundary), plus the dose contribution due to activities within the Site Boundary and the organ dose from inhalation of ^{14}C (at the Nearest Resident location and within the Site Boundary). The dose assessments in Table A-5 demonstrate compliance with 10 CFR 20.1301(e) and 40 CFR 190.

6. Supplemental Information

6.1 Abnormal Releases or Abnormal Discharges

There were no abnormal releases or abnormal discharges during the reporting period.

6.2 Non- routine Planned Discharges

There were no non- routine planned discharges during the reporting period.

6.3 Radioactive Waste Treatment System Changes

There were no major changes to the liquid or gaseous radwaste treatment system during the reporting period.

6.4 Annual Land Use Census Changes

There were no changes identified in the locations for dose calculation. Changes in sample locations identified in the Land Use Census are described in the Annual Radioactive Environmental Operating Report.

6.5 Effluent Monitoring System Non- functionality

BM-RE-52, Steam Generator Blowdown Discharge Monitor, has been non- functional since 2010 when the surveillances were changed to on- demand. The procedures for performing discharges by this pathway were voided in 2007. The last discharge via this pathway was Q2 1986[3], therefore the associated action statement has been met since BMRE52 became non- functional. Callaway Energy Center is in the process of removing BM-RE-52 from ODCM/ FSAR-SP Table 16.11-2, Radioactive Effluent Monitoring Instrumentation and the associated discharge point from ODCM/FSAR-SP Table 16.11-1, Radioactive Liquid Waste Sampling and Analysis Program.

GT-RE-22, Containment Purge System Monitor, was non- functional for a period of approximately 20 hours to perform an instrument calibration. The containment purge valves were closed and there were no purges in progress during this time; therefore the associated action was met. GT-RE-22 was also non-functional for a period of approximately 3 days due to loss of flow requiring a motor replacement.

6.6 Offsite Dose Calculation Manual Changes

The Offsite Dose Calculation Manual consists of two documents: APA-ZZ-01003 (Methodology and Parameters) and FSAR-SP Chapter 16.11 Radiological Effluent Controls (RECs). Both were revised in 2018. A complete copy of APA-ZZ-01003, rev. 23 and FSAR-SP Chapter 16.11 are attached with revision bars showing the areas of change.

The changes to APA-ZZ-01003, rev. 23 (June, 2018) incorporated the following changes:

- Section 5.1 was revised to delete the phrase referring to HPCI 9901 because HPCI 9901 is obsolete. HPCI 1506, rev. 1, superseded portions of HPCI 9901, the remainder is superseded by HTP-ZZ-DTI-REMP-SMPL-SCHED, REMP Sample Locations and Analysis Schedule". (CR 201705399)
- Section 10, "Bibliography", was revised to update the revision level of CDP-ZZ-00200, Appendix B, ANSI N42.18-2004 (redesignation of ANSI N13.10-1974), and HPCI 1604.
- Table 1 was revised to add the Dose Commitment Factors for ^{117m}Sn. (CR 201706108)

[3] Callaway Plant Semiannual Radioactive Effluent Release Report, January- June 1986, Table 2B.

The changes to FSAR-SP Chapter 16.11 (RECs) were to revise "Operable" to "Functional" and "Specifications" to "Requirements" (LDCN 15-007 & LDCN 17-008) in accordance with NRC recommendations, and to allow the Annual Radioactive Effluent Release Report to be submitted in any format acceptable to the NRC (LDCN 17-006) in accordance with Regulatory Guide 1.21, revision 2. These changes were effective in June and August, 2018.

6.7 Process Control Program Changes

There was one revision to APA-ZZ-01011, "Process Control Program" during the reporting period. The changes were related to auditing requirements for vendors and did not affect significant aspects of the ODCM.

6.8 Corrections to Previous Reports

This report represents revision 1 to the original report (revision 0) submitted on April 30, 2019 under ULNRC -06504. Revision 0 omitted the data in Table A-1, Table A-1A, Table A-1B, Table A-2, Table A-2A, Table A-4, and Table A-5 due to difficulties extracting the data. The omitted data is provided in this report.

FSAR-SP Chapter 16.11 (RECs), which constitutes one part of the Callaway Offsite Dose Calculation Manual, was inadvertently omitted from the original report. It is included in this report.

Table A-3 to revision 0 of this report contained errors due to erroneously reporting package volume vice waste volume. During the investigation, issues were also discovered with Table A-3 of the 2017 report. These errors resulted from a 2017 shipment that was still in a "staged shipment" status in the software when the data for Table A-3 was generated for the ARERR. The software does not consider shipments in "staged shipment" status when compiling the report. The issues with Table A-3 are described in CR 201904190.

This report represents a full and complete 2018 Annual Radioactive Effluents Release Report and it provides a corrected Table A-3 for the 2017 report.

6.9 Other Information Related to Radioactive Effluents

Meteorological dispersion parameters, data recovery rate, and Joint Frequency Tables for the monitoring period are attached as Appendix B.

Appendix A

Tables of Quantities Released in Liquid and Gaseous Radioactive Effluents and in Solid Radioactive Waste Shipments

Tables of Doses from the Discharge of Liquid and Gaseous Radioactive Effluents

Table A-1: Gaseous Effluents- Summation of All Releases							
Summation of All Releases	Unit	Quarter 1	Quarter 2	Quarter 3	Quarter 4	Total	Estimated Uncertainty (%)[4]
Fission & Activation Gases	Ci	5.03E-02	1.17E-01	4.67E-02	6.55E-02	2.80E-01	20
Average Release Rate	μCi/s	6.38E-03	1.48E-02	5.93E-03	8.31E-03	8.86E-03	
% of Limit	%	N/A	N/A	N/A	N/A	N/A	
^{131}Iodine	Ci	ND*	ND*	ND*	ND*	ND*	N/A
Average Release Rate	μCi/s	N/A	N/A	N/A	N/A	N/A	
% of Limit	%	N/A	N/A	N/A	N/A	N/A	
Particulates	Ci	ND*	ND*	ND*	ND*	ND*	N/A
Average Release Rate	μCi/s	N/A	N/A	N/A	N/A	N/A	
% of Limit	%	N/A	N/A	N/A	N/A	N/A	
Gross Alpha	Ci	4.86E-07	2.05E-07	1.72E-07	2.58E-07	1.12E-06	
^{3}H	Ci	4.77E+00	8.98E+00	1.06E+01	5.66E+00	3.00E+01	14
Average Release Rate	μCi/s	6.05E-01	1.14E+00	1.34E+00	7.18E-01	9.51E-01	
% of Limit	%	N/A	N/A	N/A	N/A	N/A	
^{14}C [5]	Ci	3.30E+00	3.30E+00	3.30E+00	3.30E+00	1.32E+01	

*ND means measurements were performed but no activity was detected.

[4] Safety Analysis calculation 87-063-00, January 6, 1988

[5] ^{14}C activity is estimated based on EPRI report TR-1021106, *Estimation of ^{14}C in Nuclear Power Plant Effluents*, December, 2010.

Table A-1A: Gaseous Effluents- Ground Level Release- Batch Mode						
Fission & Activation Gases	Units	Quarter 1	Quarter 2	Quarter 3	Quarter 4	Total for the year
^{41}Ar	Ci	5.03E-02	1.17E-01	4.67E-02	6.55E-02	2.80E-01
Iodines & Halogens	Units	Quarter 1	Quarter 2	Quarter 3	Quarter 4	Total for the year
	Ci	ND*	ND*	ND*	ND*	ND*
Particulates	Units	Quarter 1	Quarter 2	Quarter 3	Quarter 4	Total for the year
	Ci	ND*	ND*	ND*	ND*	ND*
^{3}H	Ci	3.65E-02	5.34E-01	3.25E-01	1.80E-01	1.08E+00
Gross α	Ci	ND	ND	ND	ND	ND
^{14}C	Ci	2.56E-02	2.56E-02	2.56E-02	2.56E-02	1.02E-01

*ND means measurements were performed but no activity was detected.

Table A-1B: Gaseous Effluents- Ground Level Release- Continuous Mode						
Fission & Activation Gases	**Units**	**Quarter 1**	**Quarter 2**	**Quarter 3**	**Quarter 4**	**Total for the year**
	Ci	ND*	ND*	ND*	ND*	ND*
Iodines & Halogens	**Units**	**Quarter 1**	**Quarter 2**	**Quarter 3**	**Quarter 4**	**Total for the year**
	Ci	ND*	ND*	ND*	ND*	ND*
Particulates	**Units**	**Quarter 1**	**Quarter 2**	**Quarter 3**	**Quarter 4**	**Total for the year**
	Ci	ND*	ND*	ND*	ND*	ND*
^{3}H	Ci	4.74E+00	8.44E+00	1.03E+01	5.48E+00	2.89E+01
Gross α	Ci	4.86E-07	2.05E-07	1.72E-07	2.58E-07	1.12E-06
^{14}C	Ci	3.27E+00	3.27E+00	3.27E+00	3.27E+00	1.31E+01

*ND means measurements were performed but no activity was detected.

Table A-2: Liquid Effluents- Summation of All Releases

Summation of All Liquid Releases	Unit	Quarter 1	Quarter 2	Quarter 3	Quarter 4	Total	Estimated Uncertainty (%)[6]
Fission and Activation Products[7]	Ci	2.14E-02	4.35E-03	1.83E-03	5.19E-03	3.28E-02	20
Avg Diluted Conc	µCi/ml	1.21E-07	3.5E-08	1.93E-08	3.54E-08	6.04E-08	
% of Limit	%	N/A	N/A	N/A	N/A	N/A	
^{3}H	Ci	5.28E+01	1.01E+01	1.16E+02	3.35E+02	5.13E+02	14
Avg Diluted Conc	µCi/ml	2.98E-04	8.13E-05	1.22E-03	2.28E-03	9.45E-04	
% of Limit	%	N/A	N/A	N/A	N/A	N/A	
Dissolved & Entrained Gases	Ci	ND*	ND*	ND*	ND*	ND*	27
Avg Diluted Conc	µCi/ml	N/A	N/A	N/A	N/A	N/A	
% of Limit	%	N/A	N/A	N/A	N/A	N/A	
Gross α	Ci	0.00E+00	0.00E+00	1.33E-05	1.81E-05	3.13E-05	29
Avg Diluted Conc	µCi/ml	0.00E+00	0.00E+00	1.40E-10	1.23E-10	5.77E-11	
Vol Liquid Effluent[8]	Liters	5.91E+06	3.94E+06	3.67E+06	3.94E+06	1.74E+07	
Dilution Volume[9]	Liters	1.71E+08	1.20E+08	9.12E+07	1.43E+08	5.26E+08	
Avg river flow[10]	m^3/s	1.70E+03	2.58E+03	3.07E+03	3.80E+03	2.79E+03	
Time period for releases	hrs	1.20E+02	8.54E+01	8.08E+01	9.76E+01	3.84E+02	

*ND means measurements were performed but no activity was detected.

[6] Safety Analysis calculation 87-063-00, January 6, 1988
[7] Excludes ^{3}H, noble gases, and gross alpha.
[8] Primary system liquid effluent plus secondary liquid effluent, prior to dilution.
[9] Does not include Missouri River dilution.
[10] Average Missouri River flow for the year at the Hermann, MO monitoring station as reported by the USGS.

Table A-2A: Liquid Effluents- Batch Mode						
Fission & Activation Products	Units	Quarter 1	Quarter 2	Quarter 3	Quarter 4	Total for the year
^{51}Cr	Ci	1.09E-04	0.00E+00	0.00E+00	0.00E+00	1.09E-04
^{58}Co	Ci	4.57E-03	1.29E-03	7.29E-05	4.11E-04	6.34E-03
^{60}Co	Ci	1.88E-03	1.00E-03	1.72E-04	2.86E-03	5.92E-03
^{63}Ni	Ci	1.56E-04	4.86E-04	1.27E-03	9.71E-04	2.88E-03
^{124}Sb	Ci	1.62E-03	1.95E-05	0.00E+00	0.00E+00	1.64E-03
^{125}Sb	Ci	1.30E-02	1.54E-03	3.16E-04	9.43E-04	1.58E-02
^{137}Cs	Ci	1.12E-04	1.44E-05	0.00E+00	5.69E-06	1.32E-04
Total	Ci	2.14E-02	4.35E-03	1.83E-03	5.19E-03	3.28E-02
Dissolved & Entrained Gases	Units	Quarter 1	Quarter 2	Quarter 3	Quarter 4	Total for the year
Total	Ci	ND*	ND*	ND*	ND*	ND*
^{3}H	Ci	5.28E+01	1.01E+01	1.16E+02	3.35E+02	5.13E+02
Gross α	Ci	0	0	1.33E-05	1.81E-05	3.13E-05

*ND means measurements were performed but no activity was detected.

Table A-3: Low-Level Waste Shipped for 2018

Resins, Filters, And Evaporator Bottoms			
Waste Class	Volume		Curies Shipped
	ft³	m³	
A	1.30E+02	3.68E+00	1.32E+00
B	0.00E+00	0.00E+00	0.00E+00
C	0.00E+00	0.00E+00	0.00E+00
Unclassified	0.00E+00	0.00E+00	0.00E+00
All	1.30E+02	3.68E+00	1.32E+00

Major Nuclides for the Above Table: H-3, C-14, Mn-54, Fe-55, Co-60, Ni-63, Sr-90, Tc-99, I-129, Cs-137, Pu-238, Pu-241, Am-241, Cm-242, Cm- 243

Dry Active Waste (DAW)			
Waste Class	Volume		Curies Shipped
	ft³	m³	
A	4.66E+03	1.32E+02	1.87E-01
B	0.00E+00	0.00E+00	0.00E+00
C	0.00E+00	0.00E+00	0.00E+00
Unclassified	0.00E+00	0.00E+00	0.00E+00
All	4.66E+03	1.32E+02	1.87E-01

Major Nuclides for the Above Table: Mn-54, Fe-55, Co-58, Co-60, Ni-63, Nb-95, Sb-125, Cs-137

Irradiated Components			
Waste Class	Volume		Curies Shipped
	ft³	m³	
A	0.00E+00	0.00E+00	0.00E+00
B	0.00E+00	0.00E+00	0.00E+00
C	0.00E+00	0.00E+00	0.00E+00
Unclassified	0.00E+00	0.00E+00	0.00E+00
All	0.00E+00	0.00E+00	0.00E+00

Major Nuclides for the Above Table: N/A

Table A-3: Low-Level Waste for 2018 (continued)			
Other Waste			
Waste Class	**Volume ft³**	**Volume m³**	**Curies Shipped**
A	0.00E+00	0.00E+00	0.00E+00
B	0.00E+00	0.00E+00	0.00E+00
C	0.00E+00	0.00E+00	0.00E+00
Unclassified	0.00E+00	0.00E+00	0.00E+00
All	0.00E+00	0.00E+00	0.00E+00
Major Nuclides for the Above Table: N/A			
Sum Of All Low-Level Waste Shipped From Site			
Waste Class	**Volume ft³**	**Volume m³**	**Curies Shipped**
A	4.79E+03	1.36E+02	1.51E+00
B	0.00E+00	0.00E+00	0.00E+00
C	0.00E+00	0.00E+00	0.00E+00
Unclassified	0.00E+00	0.00E+00	0.00E+00
All	4.79E+03	1.36E+02	1.51E+00
Major Nuclides for the Above Table: H-3, C-14, Mn-54, Fe-55, Co-58, Co-60, Ni-63, Sr-90, Nb-95, Tc-99, Sb-125, I-129, Cs-137, Pu-238, Pu-239, Pu-241, Am-241, Cm-242, Cm-243			

SOLIDIFICATION AGENT

None used.

IRRADIATED FUEL SHIPMENTS (Disposition)

There were no shipments of irradiated fuel during the reporting period.

Table A-4: Dose Assessments, 10 CFR 50, Appendix I					
	Quarter 1	Quarter 2	Quarter 3	Quarter 4	Yearly total
Liquid Effluent Dose Limit, Total Body (mrem)	1.5	1.5	1.5	1.5	3
Total Body Dose (mrem)	3.95E-04	6.53E-05	2.61E-04	5.95E-04	1.33E-03
% Limit	0.03%	0.00%	0.02%	0.04%	0.04%
Liquid Effluent Dose Limit, Maximum Organ (mrem)	5	5	5	5	10
Maximum Organ Dose (mrem)	5.40E-04	1.58E-04	3.75E-04	6.72E-04	1.52E-03
% Limit	0.01%	0.00%	0.01%	0.01%	0.02%
Gaseous Effluent Dose Limit, Gamma Air (mrem)	5	5	5	5	10
Gamma Air Dose (mrad)	2.17E-05	5.04E-05	2.01E-05	2.82E-05	1.20E-04
% Limit	0.00%	0.00%	0.00%	0.00%	0.00%
Gaseous Effluent Dose Limit, Beta Air (mrem)	10	10	10	10	20
Beta Air Dose (mrad)	7.64E-06	1.78E-05	7.09E-06	9.95E-06	4.25E-05
% Limit	0.00%	0.00%	0.00%	0.00%	0.00%
Gaseous Effluent Dose Limit, Maximum Organ (mrem)	7.5	7.5	7.5	7.5	15
Maximum organ dose[11] (mrem)	1.19E-03	2.25E-03	2.65E-03	1.42E-03	7.51E-03
% Limit	0.02%	0.03%	0.04%	0.02%	0.05%
^{14}C Maximum organ dose (mrem)[12]	4.00E-03	4.00E-03	4.00E-03	4.00E-03	1.62E-02

[11] Iodine, ^{3}H, and particulates with greater than an 8 day half- life.
[12] Not included in above totals

Table A-5: EPA 40 CFR 190 Individual in the Unrestricted Area			
	Whole Body	**Thyroid**	**Max Other Organ**
Dose Limit	25 mrem	75 mrem	25 mrem
Dose	1.26E-02	1.26E-02	2.72E-02
% Limit	0.05%	0.02%	0.11%

Appendix B

Meteorological Dispersion Parameters and Joint Frequency Tables; Totals of Hours at Each Wind Speed & Direction for the period January 1, 2018- December 31, 2018

Meteorological Dispersion Parameters for the Reporting Period

Nearest Resident Dispersion Parameters

Direction: NNW

Distance: 2897 meters

X/Q, Undecayed and Undepleted:	9.37E-07 sec/m^3
X/Q Decayed and Undepleted:	9.22E-07 sec/m^3
X/Q Decayed and Depleted:	7.79E-07 sec/m^3
D/Q Deposition rate:	2.63E-09 m^{-2}

Site Boundary Dispersion Parameters

Direction: SSW

Distance: 1400 meters

X/Q, Undecayed and Undepleted:	1.47E-06 sec/m^3
X/Q Decayed and Undepleted:	1.46E-06 sec/m^3
X/Q Decayed and Depleted:	1.30E-06 sec/m^3
D/Q Deposition rate:	5.50E-09 m^{-2}

Meteorological Data Recovery Rate

10 meters elevation	Hours of valid data: 8757
	Total hours in period: 8760
	Recovery rate: 99.97%
60 meters elevation	Hours of valid data: 8757
	Total hours in period: 8760
	Recovery rate: 99.97%

Joint Frequency Distribution: Hours at Wind Speed and Direction												
January- December, 2018												
All Stabilities												
Elevations: Winds 10m Stability 60m												
Wind Direction Sector	Wind Speed Range (m/s)											
	<0.50	0.5- 1	1.1- 1.5	1.6- 2	2.1- 3	3.1- 4	4.1- 5	5.1- 6	6.1- 8	8.1- 10	>10.00	Total
N	3	26	61	55	137	121	99	57	26	0	0	585
NNE	2	35	71	66	151	113	87	20	4	0	0	549
NE	2	36	50	61	125	76	28	6	4	0	0	388
ENE	6	29	57	62	111	83	28	6	1	0	0	383
E	4	32	49	54	111	70	42	25	8	1	0	396
ESE	8	26	46	62	104	72	51	12	6	0	0	387
SE	5	68	96	133	236	95	58	2	2	0	0	695
SSE	6	42	75	164	344	171	67	27	17	0	0	913
S	2	49	49	76	260	224	166	113	56	0	0	995
SSW	2	27	58	62	184	183	81	50	27	0	0	674
SW	0	19	51	68	171	128	55	35	11	0	0	538
WSW	3	36	31	52	75	46	23	16	11	0	0	293
W	1	26	49	34	69	60	48	24	17	2	0	330
WNW	0	22	65	49	94	100	57	28	17	1	0	433
NW	4	39	69	91	146	111	60	41	19	0	0	580
NNW	3	30	48	61	168	138	77	64	16	0	0	605
Tot	51	542	925	1150	2486	1791	1027	526	242	4	0	8744
Hours of Calm	13											
Hours of Variable Direction	0											
Hours of Valid Data	8757											
Hours of Missing Data	3											
Hours in Period	8760											

Joint Frequency Distribution: Hours at Wind Speed and Direction												
January- December, 2018												
Class A Extremely Unstable based on lapse rate												
Elevations: Winds 10m Stability 60m												
Wind Direction Sector	Wind Speed Range (m/s)											
	<0.50	0.5- 1	1.1- 1.5	1.6- 2	2.1- 3	3.1- 4	4.1- 5	5.1- 6	6.1- 8	8.1- 10	>10.00	Total
N	0	0	0	0	1	6	2	0	0	0	0	9
NNE	0	0	0	0	2	3	4	0	0	0	0	9
NE	0	0	0	0	0	0	0	0	1	0	0	1
ENE	0	0	0	0	2	3	1	0	1	0	0	7
E	0	0	0	0	1	1	0	0	0	0	0	2
ESE	0	0	0	0	0	5	2	0	0	0	0	7
SE	0	0	0	0	4	2	5	0	0	0	0	11
SSE	0	0	0	0	2	4	3	0	1	0	0	10
S	0	0	0	0	3	7	3	8	6	0	0	27
SSW	0	0	0	0	3	13	9	8	5	0	0	38
SW	0	0	0	0	6	13	12	14	2	0	0	47
WSW	0	0	0	0	0	5	3	0	0	0	0	8
W	0	0	0	0	0	0	4	2	0	1	0	7
WNW	0	0	0	0	0	4	3	7	4	1	0	19
NW	0	0	0	0	0	7	4	3	3	0	0	17
NNW	0	0	0	0	0	3	3	3	0	0	0	9
Tot	0	0	0	0	24	76	58	45	23	2	0	228
Hours of Calm	0											
Hours of Variable Direction	0											
Hours of Valid Data	228											
Hours of Missing Data	3											
Hours in Period	8760											

Joint Frequency Distribution: Hours at Wind Speed and Direction												
January- December, 2018												
Class B Moderately Unstable based on lapse rate												
Elevations: Winds 10m Stability 60m												
Wind Direction Sector	Wind Speed Range (m/s)											
	<0.50	0.5- 1	1.1- 1.5	1.6- 2	2.1- 3	3.1- 4	4.1- 5	5.1- 6	6.1- 8	8.1- 10	>10.00	Total
N	0	0	0	0	3	7	13	0	0	0	0	23
NNE	0	0	0	0	10	2	4	0	0	0	0	16
NE	0	0	0	0	2	0	0	0	0	0	0	2
ENE	0	0	0	1	7	5	0	0	0	0	0	13
E	0	0	0	0	5	1	2	4	0	0	0	12
ESE	0	0	0	0	2	7	2	0	0	0	0	11
SE	0	0	0	1	7	7	9	0	0	0	0	24
SSE	0	0	0	0	6	4	1	1	2	0	0	14
S	0	0	0	1	11	11	9	3	4	0	0	39
SSW	0	0	1	0	13	22	5	7	2	0	0	50
SW	0	0	0	0	14	17	11	5	0	0	0	47
WSW	0	0	0	1	2	4	1	1	0	0	0	9
W	0	0	0	0	0	8	7	0	1	0	0	16
WNW	0	0	0	0	2	8	4	0	0	0	0	14
NW	0	0	0	0	8	3	10	3	0	0	0	24
NNW	0	0	0	0	3	3	7	3	0	0	0	16
Tot	0	0	1	4	95	109	85	27	9	0	0	330
Hours of Calm	0											
Hours of Variable Direction	0											
Hours of Valid Data	330											
Hours of Missing Data	3											
Hours in Period	8760											

Joint Frequency Distribution: Hours at Wind Speed and Direction											
January- December, 2018											
Class C Slightly Unstable based on lapse rate											
Elevations: Winds 10m Stability 60m											
Wind Direction Sector	Wind Speed Range (m/s)										
	<0.50	0.5- 1	1.1- 1.5	1.6- 2	2.1- 3	3.1- 4	4.1- 5	5.1- 6	6.1- 8	8.1- 10	>10.00	Total
N	0	0	0	0	5	10	5	2	5	0	0	27
NNE	0	0	0	2	14	11	12	2	1	0	0	42
NE	0	0	0	0	10	5	3	0	2	0	0	20
ENE	0	0	1	2	9	2	1	2	0	0	0	17
E	0	0	1	2	7	6	4	1	0	1	0	22
ESE	0	0	0	1	3	11	7	2	0	0	0	24
SE	0	0	0	4	24	14	4	0	0	0	0	46
SSE	0	0	3	4	14	11	9	1	3	0	0	45
S	0	0	0	2	21	17	13	7	1	0	0	61
SSW	0	0	2	4	14	28	8	6	7	0	0	69
SW	0	0	0	3	30	21	8	5	1	0	0	68
WSW	0	0	1	3	9	7	0	2	0	0	0	22
W	0	0	0	3	6	11	5	1	0	0	0	26
WNW	0	0	0	2	8	13	4	4	0	0	0	31
NW	0	0	0	0	12	13	2	5	1	0	0	33
NNW	0	0	0	3	9	14	9	9	2	0	0	46
Tot	0	0	8	35	195	194	94	49	23	1	0	599
Hours of Calm	0										
Hours of Variable Direction	0										
Hours of Valid Data	599										
Hours of Missing Data	3										
Hours in Period	8760										

Joint Frequency Distribution: Hours at Wind Speed and Direction											
January- December, 2018											
Class D Neutral based on lapse rate											
Elevations: Winds 10m Stability 60m											
Wind Direction Sector	Wind Speed Range (m/s)										
	<0.50	0.5- 1	1.1- 1.5	1.6- 2	2.1- 3	3.1- 4	4.1- 5	5.1- 6	6.1- 8	8.1- 10	>10.00	Total
N	0	3	14	24	74	90	72	51	21	0	0	349
NNE	0	8	19	32	86	88	65	18	3	0	0	319
NE	0	5	14	23	86	63	22	6	1	0	0	220
ENE	0	6	17	16	63	50	20	4	0	0	0	176
E	0	3	10	18	58	51	32	19	8	0	0	199
ESE	0	1	13	27	48	33	36	10	5	0	0	173
SE	0	2	19	31	80	55	31	1	1	0	0	220
SSE	0	5	15	23	62	56	32	14	7	0	0	214
S	0	5	12	16	49	62	51	49	37	0	0	281
SSW	0	3	8	18	36	43	29	21	10	0	0	168
SW	0	2	14	26	57	39	20	11	8	0	0	177
WSW	0	7	10	25	34	12	15	13	11	0	0	127
W	0	3	18	14	27	26	26	21	16	1	0	152
WNW	0	2	15	20	56	70	46	16	13	0	0	238
NW	0	2	11	25	84	77	42	30	15	0	0	286
NNW	0	2	4	24	78	95	58	47	14	0	0	322
Tot	0	59	213	362	978	910	597	331	170	1	0	3621
Hours of Calm	0											
Hours of Variable Direction	0											
Hours of Valid Data	3621											
Hours of Missing Data	3											
Hours in Period	8760											

Joint Frequency Distribution: Hours at Wind Speed and Direction												
January- December, 2018												
Class E Slightly Stable based on lapse rate												
Elevations: Winds 10m Stability 60m												
Wind Direction Sector	Wind Speed Range (m/s)											
	<0.50	0.5- 1	1.1- 1.5	1.6- 2	2.1- 3	3.1- 4	4.1- 5	5.1- 6	6.1- 8	8.1- 10	>10.00	Total
N	0	6	11	17	39	8	7	4	0	0	0	92
NNE	0	7	20	20	36	9	2	0	0	0	0	94
NE	0	4	13	20	27	7	3	0	0	0	0	74
ENE	1	4	15	33	28	23	6	0	0	0	0	110
E	0	6	23	26	37	11	4	1	0	0	0	108
ESE	0	5	18	22	46	16	4	0	1	0	0	112
SE	0	13	34	61	102	17	9	1	1	0	0	238
SSE	0	5	21	69	137	69	21	11	4	0	0	337
S	0	8	11	30	95	109	87	46	8	0	0	394
SSW	1	7	16	15	77	73	30	8	3	0	0	230
SW	0	8	16	24	49	26	4	0	0	0	0	127
WSW	2	9	10	16	27	17	3	0	0	0	0	84
W	0	8	17	11	32	12	6	0	0	0	0	86
WNW	0	4	21	16	26	5	0	1	0	0	0	73
NW	0	8	14	38	29	11	1	0	0	0	0	101
NNW	0	4	12	17	62	22	0	2	0	0	0	119
Tot	4	106	272	435	849	435	187	74	17	0	0	2379
Hours of Calm	0											
Hours of Variable Direction	0											
Hours of Valid Data	2379											
Hours of Missing Data	3											
Hours in Period	8760											

Joint Frequency Distribution: Hours at Wind Speed and Direction

January- December, 2018

Class F Moderately Stable based on lapse rate

Elevations: Winds 10m Stability 60m

Wind Direction Sector	Wind Speed Range (m/s)											
	<0.50	0.5- 1	1.1- 1.5	1.6- 2	2.1- 3	3.1- 4	4.1- 5	5.1- 6	6.1- 8	8.1- 10	>10.00	Total
N	0	4	17	8	14	0	0	0	0	0	0	43
NNE	1	4	19	9	3	0	0	0	0	0	0	36
NE	2	13	13	10	0	0	0	0	0	0	0	38
ENE	1	11	19	9	2	0	0	0	0	0	0	42
E	1	12	13	8	3	0	0	0	0	0	0	37
ESE	6	14	13	12	5	0	0	0	0	0	0	50
SE	2	36	39	31	14	0	0	0	0	0	0	122
SSE	2	19	27	52	101	20	1	0	0	0	0	222
S	1	14	9	18	74	17	3	0	0	0	0	136
SSW	0	8	16	13	39	4	0	0	0	0	0	80
SW	0	4	14	10	11	12	0	0	0	0	0	51
WSW	1	9	5	7	2	1	1	0	0	0	0	26
W	0	9	11	5	3	3	0	0	0	0	0	31
WNW	0	10	19	8	2	0	0	0	0	0	0	39
NW	3	17	24	19	8	0	1	0	0	0	0	72
NNW	0	5	14	15	13	1	0	0	0	0	0	48
Tot	20	189	272	234	294	58	6	0	0	0	0	1073

Hours of Calm	6
Hours of Variable Direction	0
Hours of Valid Data	1079
Hours of Missing Data	3
Hours in Period	8760

Joint Frequency Distribution: Hours at Wind Speed and Direction												
January- December, 2018												
Class G Extremely Stable based on lapse rate												
Elevations: Winds 10m Stability 60m												
Wind Direction Sector	Wind Speed Range (m/s)											
	<0.50	0.5- 1	1.1- 1.5	1.6- 2	2.1- 3	3.1- 4	4.1- 5	5.1- 6	6.1- 8	8.1- 10	>10.00	Total
N	3	13	19	6	1	0	0	0	0	0	0	42
NNE	1	16	13	3	0	0	0	0	0	0	0	33
NE	0	14	10	8	0	1	0	0	0	0	0	33
ENE	4	8	5	1	0	0	0	0	0	0	0	18
E	3	11	2	0	0	0	0	0	0	0	0	16
ESE	2	6	2	0	0	0	0	0	0	0	0	10
SE	3	17	4	5	5	0	0	0	0	0	0	34
SSE	4	13	9	16	22	7	0	0	0	0	0	71
S	1	22	17	9	7	1	0	0	0	0	0	57
SSW	1	9	15	12	2	0	0	0	0	0	0	39
SW	0	5	7	5	4	0	0	0	0	0	0	21
WSW	0	11	5	0	1	0	0	0	0	0	0	17
W	1	6	3	1	1	0	0	0	0	0	0	12
WNW	0	6	10	3	0	0	0	0	0	0	0	19
NW	1	12	20	9	5	0	0	0	0	0	0	47
NNW	3	19	18	2	3	0	0	0	0	0	0	45
Tot	27	188	159	80	51	9	0	0	0	0	0	514
Hours of Calm 7												
Hours of Variable Direction 0												
Hours of Valid Data 521												
Hours of Missing Data 3												
Hours in Period 8760												

Joint Frequency Distribution: Hours at Wind Speed and Direction											
January- December, 2018											
All Stabilities											
Elevations: Winds 60m Stability 60m											
Wind Direction Sector	Wind Speed Range (m/s)										
	<0.50	0.5- 1	1.1- 1.5	1.6- 2	2.1- 3	3.1- 4	4.1- 5	5.1- 6	6.1- 8	8.1- 10	>10.00	Total
N	0	2	9	18	50	97	121	117	96	18	0	528
NNE	0	0	7	17	76	117	141	99	62	3	0	522
NE	0	3	12	14	68	92	95	60	31	4	0	379
ENE	1	4	7	14	74	99	110	56	36	1	0	402
E	1	7	12	18	56	108	108	72	30	8	1	421
ESE	0	3	11	17	59	92	106	92	41	7	1	429
SE	0	7	27	46	205	187	107	51	12	1	0	643
SSE	0	6	13	31	106	153	171	135	92	18	0	725
S	0	6	14	16	72	130	171	219	311	105	9	1053
SSW	0	0	11	18	50	97	152	174	254	45	6	807
SW	0	5	8	11	75	118	109	116	159	35	9	645
WSW	1	4	11	18	60	54	57	50	58	21	13	347
W	0	2	7	20	37	43	46	64	68	29	15	331
WNW	0	3	9	13	43	55	86	105	104	41	20	479
NW	0	4	3	10	42	101	98	126	127	42	18	571
NNW	0	1	3	8	47	76	99	105	113	22	1	475
Tot	3	57	164	289	1120	1619	1777	1641	1594	400	93	8757
Hours of Calm	0										
Hours of Variable Direction	0										
Hours of Valid Data	8757										
Hours of Missing Data	3										
Hours in Period	8760										

Joint Frequency Distribution: Hours at Wind Speed and Direction												
January- December, 2018												
Class A Extremely Unstable based on lapse rate												
Elevations: Winds 60m Stability 60m												
Wind Direction Sector	Wind Speed Range (m/s)											
	<0.50	0.5- 1	1.1- 1.5	1.6- 2	2.1- 3	3.1- 4	4.1- 5	5.1- 6	6.1- 8	8.1- 10	>10.00	Total
N	0	0	0	0	0	4	5	2	0	0	0	11
NNE	0	0	0	0	0	1	3	3	0	0	0	7
NE	0	0	0	0	0	0	0	0	1	1	0	2
ENE	0	0	0	0	1	3	3	0	0	0	0	7
E	0	0	0	0	0	1	0	0	0	0	0	1
ESE	0	0	0	0	0	1	5	0	0	0	0	6
SE	0	0	0	0	2	2	3	4	0	0	0	11
SSE	0	0	0	0	1	2	4	3	0	1	0	11
S	0	0	0	0	0	5	5	2	8	6	0	26
SSW	0	0	0	0	1	2	12	5	12	7	0	39
SW	0	0	0	0	0	4	14	3	19	7	0	47
WSW	0	0	0	0	0	0	2	4	3	0	0	9
W	0	0	0	0	0	0	0	1	2	2	1	6
WNW	0	0	0	0	0	0	1	9	3	10	4	27
NW	0	0	0	0	0	2	1	1	6	1	3	14
NNW	0	0	0	0	0	0	1	1	2	0	0	4
Tot	0	0	0	0	5	27	59	38	56	35	8	228
Hours of Calm	0											
Hours of Variable Direction	0											
Hours of Valid Data	228											
Hours of Missing Data	3											
Hours in Period	8760											

Joint Frequency Distribution: Hours at Wind Speed and Direction											
January- December, 2018											
Class B Moderately Unstable based on lapse rate											
Elevations: Winds 60m Stability 60m											
Wind Direction Sector	Wind Speed Range (m/s)										
	<0.50	0.5- 1	1.1- 1.5	1.6- 2	2.1- 3	3.1- 4	4.1- 5	5.1- 6	6.1- 8	8.1- 10	>10.00	Total
N	0	0	0	0	2	3	10	6	1	0	0	22
NNE	0	0	0	0	3	8	2	2	0	0	0	15
NE	0	0	0	0	1	1	0	0	0	0	0	2
ENE	0	0	0	0	2	8	3	0	0	0	0	13
E	0	0	0	0	1	3	1	2	3	0	0	10
ESE	0	0	0	0	1	5	4	2	1	0	0	13
SE	0	0	0	0	2	10	7	3	0	0	0	22
SSE	0	0	0	0	4	1	5	2	1	1	0	14
S	0	0	0	0	5	9	7	6	7	4	0	38
SSW	0	0	0	1	5	11	20	7	6	5	0	55
SW	0	0	0	0	0	12	10	13	9	3	0	47
WSW	0	0	0	0	1	2	0	4	2	1	0	10
W	0	0	0	0	0	0	4	5	4	0	1	14
WNW	0	0	0	0	1	4	4	7	5	0	0	21
NW	0	0	0	0	0	4	1	8	6	3	0	22
NNW	0	0	0	0	1	2	2	3	4	0	0	12
Tot	0	0	0	1	29	83	80	70	49	17	1	330
Hours of Calm	0										
Hours of Variable Direction	0										
Hours of Valid Data	330										
Hours of Missing Data	3										
Hours in Period	8760										

Joint Frequency Distribution: Hours at Wind Speed and Direction												
January- December, 2018												
Class C Slightly Unstable based on lapse rate												
Elevations: Winds 60m Stability 60m												
Wind Direction Sector	Wind Speed Range (m/s)											
	<0.50	0.5- 1	1.1- 1.5	1.6- 2	2.1- 3	3.1- 4	4.1- 5	5.1- 6	6.1- 8	8.1- 10	>10.00	Total
N	0	0	0	1	4	8	6	5	1	4	0	29
NNE	0	0	0	1	7	5	12	9	4	1	0	39
NE	0	0	0	0	5	9	1	4	1	1	0	21
ENE	0	0	0	0	7	5	1	1	3	0	0	17
E	0	0	0	3	2	4	5	2	1	0	1	18
ESE	0	0	0	0	3	4	10	6	1	0	0	24
SE	0	0	0	1	19	14	4	4	0	0	0	42
SSE	0	0	0	2	14	13	7	7	3	1	0	47
S	0	0	2	0	10	14	11	11	12	2	0	62
SSW	0	0	0	3	4	14	22	8	10	7	0	68
SW	0	0	0	0	11	19	14	12	10	3	1	70
WSW	0	0	0	1	5	8	3	3	1	2	0	23
W	0	0	0	2	3	2	8	8	6	2	0	31
WNW	0	0	0	1	4	4	7	6	6	4	0	32
NW	0	0	0	0	7	7	9	17	3	2	2	47
NNW	0	0	0	0	3	5	6	3	10	2	0	29
Tot	0	0	2	15	108	135	126	106	72	31	4	599
Hours of Calm	0											
Hours of Variable Direction	0											
Hours of Valid Data	599											
Hours of Missing Data	3											
Hours in Period	8760											

Joint Frequency Distribution: Hours at Wind Speed and Direction												
January- December, 2018												
Class D Neutral based on lapse rate												
Elevations: Winds 60m Stability 60m												
Wind Direction Sector	Wind Speed Range (m/s)											
	<0.50	0.5- 1	1.1- 1.5	1.6- 2	2.1- 3	3.1- 4	4.1- 5	5.1- 6	6.1- 8	8.1- 10	>10.00	Total
N	0	1	7	14	33	57	68	60	76	14	0	330
NNE	0	0	6	14	48	63	62	55	49	2	0	299
NE	0	2	11	8	43	51	54	31	18	2	0	220
ENE	0	4	6	11	39	46	49	17	21	1	0	194
E	0	2	6	9	31	46	42	20	22	8	0	186
ESE	0	1	5	11	32	30	24	32	27	7	0	169
SE	0	2	9	13	57	56	46	20	10	0	0	213
SSE	0	0	4	15	35	34	49	33	27	6	0	203
S	0	3	7	11	32	36	42	37	79	47	4	298
SSW	0	0	7	10	18	25	27	32	50	11	3	183
SW	0	3	4	7	35	29	29	29	29	15	8	188
WSW	0	0	5	9	27	25	15	10	22	15	13	141
W	0	1	4	8	17	19	11	20	33	22	13	148
WNW	0	1	6	10	24	26	33	45	74	27	15	261
NW	0	1	2	9	23	52	48	59	75	35	13	317
NNW	0	1	0	6	26	45	58	49	66	19	1	271
Tot	0	22	89	165	520	640	657	549	678	231	70	3621
Hours of Calm	0											
Hours of Variable Direction	0											
Hours of Valid Data	3621											
Hours of Missing Data	3											
Hours in Period	8760											

Joint Frequency Distribution: Hours at Wind Speed and Direction												
January- December, 2018												
Class E Slightly Stable based on lapse rate												
Elevations: Winds 60m Stability 60m												
Wind Direction Sector	Wind Speed Range (m/s)											
	<0.50	0.5- 1	1.1- 1.5	1.6- 2	2.1- 3	3.1- 4	4.1- 5	5.1- 6	6.1- 8	8.1- 10	>10.00	Total
N	0	1	1	2	6	13	23	30	13	0	0	89
NNE	0	0	0	1	9	26	36	14	5	0	0	91
NE	0	0	1	4	10	23	19	11	7	0	0	75
ENE	0	0	0	1	15	22	31	24	6	0	0	99
E	0	2	3	3	8	31	32	27	4	0	0	110
ESE	0	1	0	2	14	27	37	31	12	0	1	125
SE	0	1	6	11	77	77	41	20	2	1	0	236
SSE	0	1	2	4	28	59	72	53	39	9	0	267
S	0	1	0	3	12	33	44	95	161	43	5	397
SSW	0	0	2	2	12	21	30	68	127	14	3	279
SW	0	1	1	1	10	29	22	40	49	3	0	156
WSW	0	2	1	1	11	7	24	19	27	2	0	94
W	0	1	1	2	8	11	16	24	18	2	0	83
WNW	0	2	1	0	8	12	25	22	8	0	1	79
NW	0	0	0	0	8	23	27	26	21	0	0	105
NNW	0	0	2	1	10	11	24	31	14	1	0	94
Tot	0	13	21	38	246	425	503	535	513	75	10	2379
Hours of Calm	0											
Hours of Variable Direction	0											
Hours of Valid Data	2379											
Hours of Missing Data	3											
Hours in Period	8760											

Joint Frequency Distribution: Hours at Wind Speed and Direction												
January- December, 2018												
Class F Moderately Stable based on lapse rate												
Elevations: Winds 60m Stability 60m												
Wind Direction Sector	Wind Speed Range (m/s)											
	<0.50	0.5- 1	1.1- 1.5	1.6- 2	2.1- 3	3.1- 4	4.1- 5	5.1- 6	6.1- 8	8.1- 10	>10.00	Total
N	0	0	1	1	5	9	6	12	3	0	0	37
NNE	0	0	0	0	6	8	15	12	2	0	0	43
NE	0	1	0	2	5	5	8	6	4	0	0	31
ENE	0	0	1	1	4	8	14	7	2	0	0	37
E	0	2	3	1	6	18	19	13	0	0	0	62
ESE	0	1	3	1	2	15	16	19	0	0	0	57
SE	0	1	2	16	39	25	6	0	0	0	0	89
SSE	0	1	3	4	14	36	23	32	19	0	0	132
S	0	2	3	0	7	23	48	63	34	3	0	183
SSW	0	0	1	2	6	18	25	41	41	1	0	135
SW	0	0	0	2	8	12	14	10	33	4	0	83
WSW	1	1	3	3	6	5	5	4	2	1	0	31
W	0	0	2	2	4	6	7	5	5	1	0	32
WNW	0	0	0	0	2	6	15	13	8	0	0	44
NW	0	0	0	1	1	10	10	14	10	1	0	47
NNW	0	0	0	1	1	9	5	12	8	0	0	36
Tot	1	9	22	37	116	213	236	263	171	11	0	1079
Hours of Calm	0											
Hours of Variable Direction	0											
Hours of Valid Data	1079											
Hours of Missing Data	3											
Hours in Period	8760											

Joint Frequency Distribution: Hours at Wind Speed and Direction												
January- December, 2018												
Class G Extremely Stable based on lapse rate												
Elevations: Winds 60m Stability 60m												
Wind Direction Sector	Wind Speed Range (m/s)											
	<0.50	0.5- 1	1.1- 1.5	1.6- 2	2.1- 3	3.1- 4	4.1- 5	5.1- 6	6.1- 8	8.1- 10	>10.00	Total
N	0	0	0	0	0	3	3	2	2	0	0	10
NNE	0	0	1	1	3	6	11	4	2	0	0	28
NE	0	0	0	0	4	3	13	8	0	0	0	28
ENE	1	0	0	1	6	7	9	7	4	0	0	35
E	1	1	0	2	8	5	9	8	0	0	0	34
ESE	0	0	3	3	7	10	10	2	0	0	0	35
SE	0	3	10	5	9	3	0	0	0	0	0	30
SSE	0	4	4	6	10	8	11	5	3	0	0	51
S	0	0	2	2	6	10	14	5	10	0	0	49
SSW	0	0	1	0	4	6	16	13	8	0	0	48
SW	0	1	3	1	11	13	6	9	10	0	0	54
WSW	0	1	2	4	10	7	8	6	1	0	0	39
W	0	0	0	6	5	5	0	1	0	0	0	17
WNW	0	0	2	2	4	3	1	3	0	0	0	15
NW	0	3	1	0	3	3	2	1	6	0	0	19
NNW	0	0	1	0	6	4	3	6	9	0	0	29
Tot	2	13	30	33	96	96	116	80	55	0	0	521
Hours of Calm	0											
Hours of Variable Direction	0											
Hours of Valid Data	521											
Hours of Missing Data	3											
Hours in Period	8760											

Appendix C

Changes to Previous Reports

Solid Waste Shipped Offsite for Disposal and Estimates of Major Nuclides by Waste Class and Stream During Period From: 01/01/2017 to 12/31/2017

Table A-3: Low Level Waste 2017 Resins, Filters, And Evaporator Bottoms			
Waste Class	**Volume**		**Curies Shipped**
	ft³	**m³**	
A	11.73E+02	4.90E+00	3.28E+01
B	11.18E+01	3.33E-01	2.02E+01
C	88.40E+00	2.38E-01	2.10E+00
Unclassified	77.59E+00	2.15E-01	8.66E+00
All	22.01E+02	5.69E+00	6.37E+01
Major Nuclides for the Above Table:H-3, C-14, Cr-51, Mn-54, Fe-55, Co-58, Co-60, Ni-59, Ni-63, Sr-90, Zr-95, Nb-94, Nb-95, Tc-99, Sn-117m, I-129, Cs-134, Cs-137, Ce-144, Pu-238, Pu-239, Pu-240, Pu-241, Pu-242, Am-241, Cm-242, Cm-243, Cm-244			
Dry Active Waste (DAW)			
Waste Class	**Volume**		**Curies Shipped**
	ft³	**m³**	
A	1.06E+04	3.01E+02	1.41E-01
B	0.00E+00	0.00E+00	0.00E+00
C	0.00E+00	0.00E+00	0.00E+00
Unclassified	0.00E+00	0.00E+00	0.00E+00
All	1.06E+04	3.01E+02	1.41E-01
Major Nuclides for the Above Table: H-3, C-14, Cr-51, Mn-54, Fe-55, Co-58, Co-60, Ni-59, Ni-63, Zn-65, Sr-90, Nb-94, Nb-95, Tc-99, Ru-106, Sb-125, I-129, Cs-134, Cs-137, Ce-144, Pu-238, Pu-239, Pu-240, Pu-241, Am-241, Cm-242, Cm-243, Cm-244			
Irradiated Components			
Waste Class	**Volume**		**Curies Shipped**
	ft³	**m³**	
A	0.00E+00	0.00E+00	0.00E+00
B	0.00E+00	0.00E+00	0.00E+00
C	0.00E+00	0.00E+00	0.00E+00
Unclassified	0.00E+00	0.00E+00	0.00E+00
All	0.00E+00	0.00E+00	0.00E+00
Major Nuclides for the Above Table: N/A			

Table A-3: Low Level Waste 2017 (continued) Other Waste			
Waste Class	Volume ft³	Volume m³	Curies Shipped
A	0.00E+00	0.00E+00	0.00E+00
B	0.00E+00	0.00E+00	0.00E+00
C	0.00E+00	0.00E+00	0.00E+00
Unclassified	0.00E+00	0.00E+00	0.00E+00
All	0.00E+00	0.00E+00	0.00E+00

Major Nuclides for the Above Table: N/A

Sum Of All Low-Level Waste Shipped From Site			
Waste Class	Volume ft³	Volume m³	Curies Shipped
A	1.08E+04	3.06E+02	33.30E+01
B	11.18E+01	3.33E-01	2.02E+01
C	88.40E+00	22.38E-01	2.10E+00
Unclassified	77.59E+00	22.15E-01	8.66E+00
All	1.08E+04	33.07E+02	6.39E+01

Major Nuclides for the Above Table: H-3, C-14, Cr-51, Mn-54, Fe-55, Co-58, Co-60, Ni-59, Ni-63, Zn-65, Sr-90, Zr-95, Nb-94, Nb-95, Tc-99, Ru-106, Sn-117m, Sb-125, I-129, Cs-134, Cs-137, Ce-144, Pu-238, Pu-239, Pu-240, Pu-241, Pu-242, Am-241, Cm-242, Cm-243, Cm-244

SOLIDIFICATION AGENT

None used.

IRRADIATED FUEL SHIPMENTS (Disposition)

There were no shipments of irradiated fuel during the reporting period.

Appendix D

Changes to the Callaway Energy Center Offsite Dose Calculation Manual for the year 2018

The Callaway Offsite Dose Calculation Manual (ODCM) is collectively comprised of two documents:

- APA-ZZ-01003 (Methodology and Parameters)
- FSAR-SP Chapter 16.11 (Radiological Effluent Controls); and

The changes to the two documents are described in the text of the report. A complete text of each document is provided in this appendix.

APA-ZZ-01003

OFF-SITE DOSE CALCULATION MANUAL

MINOR Revision 023

INFORMATION USE

June, 2018

Contents

1. Purpose and Scope

The Offsite Dose Calculation Manual (ODCM) describes the methodology and parameters used in the calculation of off-site doses resulting from radioactive gaseous and liquid effluents, in the calculation of gaseous and liquid effluent monitoring Alarm/Trip Setpoints, and in the conduct of the Radiological Environmental Monitoring Program. The ODCM also contains the Radioactive Effluent Controls and Radiological Environmental Monitoring Program required by T/S 5.5.4 and FSAR-SP Chapter 16.11.4, and descriptions of the information that should be included in the Annual Radiological Environmental Operating and Annual Effluent Release Reports required by T/S 5.6.2 and T/S 5.6.3

Compliance with the Radiological Effluent Controls limits demonstrates compliance with the limits of 10 CFR 20.1301.[1,2,3]

The ODCM consists of two parts: FSAR-SP Chapter 16.11 which contains the Radiological Effluent Controls (RECs), and APA-ZZ-01003, which contains the methodology and parameters used to implement the RECs.

2. Liquid Effluents

2.1. Liquid Effluent Monitors

Gross radioactivity monitors which provide for automatic termination of liquid effluent releases are present on the liquid effluent lines. Flow rate measurement devices are present on the liquid effluent lines and the discharge line (cooling tower blowdown). Setpoints, precautions, and limitations applicable to the operation of the Callaway Plant liquid effluent monitors are provided in the appropriate Plant Procedures. Setpoint values are calculated to assure that alarm and trip actions occur prior to exceeding ten times the Effluent Concentration Values (ECV) limits in 10 CFR Part 20 at the release point to the Unrestricted Area. The calculated alarm and trip action setpoints for the liquid effluent line monitors and flow measuring devices must satisfy the following equation:

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

Eq. 1

Where:

[1] Statements of Consideration, Federal Register, Vol. 56, No. 98, Tuesday, May 21, 1991, Subpart D, page 23374
[2] 10 CFR 50.36 a (b)
[3] Letter, F. J. Congel to J. F. Schmidt, dated April 23, 1991

C is the liquid effluent concentration value (ECV) implementing REC 16.11.1.1 for the site in μCi/ml;

c is the setpoint, in (μCi/ml), of the radioactivity monitor measuring the radioactivity concentration in the effluent line prior to dilution and subsequent release. The setpoint, which is inversely related to the volumetric flow of the effluent line and directly related to the volumetric flow of the dilution stream plus the effluent steam, represents a value, which, if exceeded, would result in concentrations exceeding ten times the values of 10 CFR Part 20 Appendix B, Table 2, Column 2, in the Unrestricted Area;

f is the undiluted waste flow rate as measured at the radiation monitor location, in volume per unit time, but in the same units as F, below; and

F is the dilution water flow rate setpoint as measured prior to the release point, in volume per unit time. If **F** is large compared to **f**, then $F + f \cong F$.[4]

If no dilution is provided then $c \leq C$.

The radioactive liquid waste stream is diluted by the plant discharge line prior to entry into the Missouri River. Normally, the dilution flow is obtained from the cooling tower blowdown, but should this become unavailable, the plant water treatment facility supplies the necessary dilution flow via a bypass line.

The limiting concentration which corresponds to the liquid radwaste effluent monitor setpoint is to be calculated using methodology from the expression above. Thus, the expression for determining the setpoint of the liquid radwaste effluent line monitor becomes:

$$c \leq \frac{C(F+f)}{f} (\mu Ci / ml)$$

Eq. 2

The alarm/trip setpoint calculations are based on the minimum dilution flow rate (corresponding to the dilution flow rate setpoint), the maximum effluent stream flow rate, and the actual isotopic analysis. Due to the possibility of a simultaneous release from more than one release pathway, a portion of the total site release limit is allocated to each pathway. The determination and usage of the allocation factor is discussed in Section 2.2. In the event the alarm/trip setpoint is reached, an evaluation will be performed using actual dilution and effluent flow values and actual isotopic analysis to ensure that REC 16.11.1.1 limits were not exceeded.

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[4] NUREG-0133, pages AA-1 thru AA-3

2.1.1. Continuous Liquid Effluent Monitors

The radiation detection monitor associated with continuous liquid effluent releases is:[5,6]

Monitor I.D.	Description
BM-RE-52	Steam Generator Blowdown Discharge Monitor

The Steam Generator Blowdown discharge is not considered to be radioactive unless radioactivity has been detected by the associated effluent radiation monitor or by laboratory analysis. The sampling frequency, minimum analysis frequency, and type of analysis performed are Per FSAR-SP Table 16.11-1.

2.1.2. Radioactive Liquid Batch Release Effluent Monitors

The radiation monitor associated with the liquid effluent batch release system is:[7]

Monitor I.D.	Description
HB-RE-18	Liquid Radwaste Discharge Monitor

This effluent stream is normally considered to be radioactive. The sampling frequency, minimum analysis frequency, and the type of analysis performed are per FSAR-SP Table 16.11-1.

2.2. Calculation of Liquid Effluent Monitor Setpoints

The dependence of the setpoint, **c**, on the radionuclide distribution, yields, calibration, and monitor parameters, requires that several variables be considered in setpoint calculations.[8]

2.2.1. Calculation of the ECV Sum

The isotopic concentration of the release(s) being considered must be determined. This is obtained from the analyses required per FSAR-SP Table 16.11-1, and is used to calculate an ECV sum (ECVSUM):

$$ECVSUM = \left(\sum_{i=g,a,s,t,f} (C_i) / (ECV_i)\right)$$

Eq. 3

Where:

$\mathbf{C_g}$ is the concentration of each measured gamma emitting nuclide observed by gamma-ray spectroscopy of the waste sample;

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[5] FSAR-SP, Section 11.5.2.2.3.1
[6] FSAR-SP, Section 11.5.2.2.3.4
[7] FSAR-SP, Section 11.5.2.2.3.2
[8] NUREG-0133, pages AA-1 thru AA-3

C_a is the concentration of ^{237}Np, ^{238}Pu, $^{239/240}Pu$, ^{241}Pu, ^{241}Am, ^{242}Cm, & $^{243/244}Cm$, in the quarterly composite sample based on previous composite sample analyses;

C_s is the measured concentrations of ^{89}Sr and ^{90}Sr as determined by analysis of the quarterly composite sample based on previous composite sample analyses;

C_t is the measured concentration of ^{3}H in the waste sample; and

C_f is the measured concentration of ^{55}Fe & ^{63}Ni as determined by analysis of the quarterly composite sample based on previous composite sample analyses.

ECV_g, ECV_s, ECV_a, ECV_f, and **ECV_t** are ten times the limiting concentrations of the appropriate radionuclides from 10 CFR 20, Appendix B, Table 2, Column 2. For dissolved or entrained noble gases, the concentration shall be limited to $2x10^{-4}$ µCi/ml total activity.

For the case ECVSUM ≤1, the monitor tank effluent concentration meets the limits of REC 16.11.1.1 without dilution and the effluent may be released at any desired flow rate. If ECVSUM > 1 then dilution is required to ensure compliance with the concentration limits of REC 16.11.1.1. If simultaneous releases are occurring or are anticipated, an allocation fraction, **N**, must be applied so that available dilution flow may be apportioned among simultaneous discharge pathways. The value of N may be any value between 0 and 1 for a particular discharge point, provided that the sum of the allocation fractions for all discharge points must be ≤1.

2.2.2. Calculation of the Maximum Permissible Liquid Effluent Discharge Flow Rate

The maximum permissible liquid effluent discharge flow rate is calculated by:

$$f_{max} \le (F + f_p) \cdot SF \cdot N \div (ECVSUM)$$

Eq. 4

Where:

f_{max} is the maximum permissible liquid effluent discharge flow rate, (in gallons/minute);

f_p is the expected undiluted liquid effluent flow rate, in gpm;

N is the allocation fraction which apportions dilution flow among simultaneous discharge pathways (see discussion above); and

SF is the safety factor; an administrative factor used to compensate for statistical fluctuations and errors of measurements. This factor also provides a margin of safety in the calculation of the maximum liquid effluent discharge flow rate (f_{max}). The value of SF should be ≤ 1.

F and **ECVSUM** are previously defined.

The dilution water supply is furnished with a flow monitor which isolates the liquid effluent discharge if the dilution flow rate falls below its setpoint value.

In the event that f_{max} is less than f_p, then the value of f_{max} is substituted into the equation for f_p, and a new f_{max} value is calculated. This substitution is performed for three iterations in order to calculate the correct value of f_{max}.

2.2.3. Calculation of Liquid Effluent Monitor Setpoint

The liquid effluent monitors are NaI(Tl) based systems and respond primarily to gamma radiation. Accordingly, their setpoint is based on the total concentration of gamma emitting nuclides in the effluent:

$$c = 0.95 \cdot \left[bkg + \left[\left(\sum C_g \right) \div SF \right] \right]$$

Eq. 5

Where:

c is the monitor setpoint as previously defined, in µCi/ml;

bkg is the monitor background prior to discharge, in µCi/ml, adjusted for monitor response; and

0.95 is a factor for conservatism to ensure the monitor trips prior to exceeding the limits of REC 16.11.1.1

$\sum C_g$ and **SF** are as previously defined.

The monitor's background is controlled at an appropriate limit to ensure adequate sensitivity. Utilizing the methodology of ANSI N13.10-1974, the background must be maintained at a value of less than or equal to 9×10^{-6} µCi/ml (relative to ^{137}Cs) in order to detect a change of 4×10^{-7} µCi/ml of ^{137}Cs.[9]

In the event that there is no detectable gamma activity in the effluent or if the value of $\left\{ \left(\sum C_g \right) \div SF \right\}$ is less than the background of the monitor, then the monitor setpoint will be set at twice the current background of the monitor.

As previously stated, the monitor's response is dependent on the gamma emitting radionuclide distribution of the effluent. Accordingly, a database conversion factor is calculated for each release based upon the results of the gamma spectrometric analysis of the effluent sample and the measured response of the monitor to National Institute of Standards and Technology (NIST) traceable calibration sources:

$$DBCF_C = \left(\sum \left(C_g \right) \right) \div \left(CMR \right) x \left(ECF \right)$$

Eq. 6

---

[9] HPCI 9605, "Calculation of Maximum Background Value for HB-RE-18"

$DBCF_c$ is the monitor data base conversion factor which converts count rate into concentration (μCi/ml);

CMR is the calculated response of the radiation monitor to the liquid effluent;

ECF is the conversion factor for ^{137}Cs, which converts count rate into concentration (μCi/ml).

C_g is as previously defined.

The new value of the $DBCF_c$ is calculated and entered into the monitor data base prior to each discharge. A more complete discussion of the derivation and calculation of the CMR is given in HPCI 8710.

2.3. Liquid Effluent Concentration Measurements

Liquid batch releases are discharged as a discrete volume and each release is authorized based upon the sample analysis and the dilution flow rate existing in the discharge line at the time of release. To assure representative sampling, each liquid monitor tank is isolated and thoroughly mixed by recirculation of tank contents prior to sample collection. The methods for mixing, sampling, and analyzing each batch are outlined in applicable plant procedures. The allowable release rate limit is calculated for each batch based upon the pre-release analysis, dilution flow-rate, and other procedural conditions, prior to authorization for release. The liquid effluent discharge is monitored prior to entering the dilution discharge line and will automatically be terminated if the pre-selected alarm/trip setpoint is exceeded. Concentrations are determined primarily from the gamma isotopic and ^{3}H analyses of the liquid batch sample. For ^{89}Sr, ^{90}Sr, ^{55}Fe, ^{63}Ni, ^{237}Np, ^{238}Pu, $^{239/240}Pu$, ^{241}Pu, ^{241}Am, ^{242}Cm, & $^{243/244}Cm$, the measured concentrations from the previous quarterly composite analyses are used until laboratory results become available. Composite samples are collected for each batch release and analyzed in accordance with FSAR-SP Table 16.11-1.The dose from liquids discharged as continuous releases is calculated by utilizing the last measured values of samples in accordance with FSAR-SP Table 16.11-1.

2.4. Dose due to Liquid Effluents

2.4.1. The Maximum Exposed Individual

The cumulative dose determination considers the dose contributions from the maximum exposed individual's consumption of fish and potable water, as appropriate. Normally, the adult is considered to be the maximum exposed individual.[10]

The Callaway Plant's liquid effluents are discharged to the Missouri River. As there are no potable water intakes within 10 miles of the discharge point,[11,12] this pathway does not require routine evaluation. Therefore, the dose contribution from fish consumption is expected to account for more than 95% of the total man-rem dose from discharges to the Missouri River.

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[10] NUREG-0133, Section 4.3
[11] Environmental Report, OLS, Table 2.1-19
[12] FSAR-SA Section 11.2.3.3.4

Dose from recreational activities is expected to contribute the additional 5%, which is considered to be negligible.[13]

2.4.2. Calculation of Dose from Liquid Effluents

The dose contributions for the total time period $\sum_{l=1}^{m} \Delta t_l$ are calculated at least once each 31 days and a cumulative summation of the total body and individual organ doses is maintained for each calendar quarter. Dose is calculated for all radionuclides identified in liquid effluents released to Unrestricted Areas using the following expression:[14]

$$D_\tau = \sum_i \left[A_{i\tau} \sum_{l=1}^{m} \Delta t_l \; C_{il} \; F_l \right]$$

Eq. 7

Where:

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

Δt_l is the length of the l^{th} time period over which $C_{i,l}$ and F_l are averaged for all liquid releases, in hours. Δt_l corresponds to the actual duration of the release(s).

$C_{i,l}$ is the average measured concentration of radionuclide, i, in undiluted liquid effluent during the time period Δt_l from any liquid release, in (µCi/ml).

$A_{i\tau}$ is the site- related ingestion dose commitment factor to the total body or any organ τ for each identified principal alpha, gamma and beta emitter listed in FSAR-SP Table 16.11-1,in (mrem/hr) per (µCi/ml).

F_l is the near field average dilution factor for C_{il} during any liquid effluent release:

$$F_l = \frac{f_{max}}{(F + f_{max}) \cdot 89.77}$$

Eq. 8

Where:

F_{max} is the maximum undiluted effluent flow rate during the release;

F is the average dilution flow; and

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[13] FSAR-SA, Section 11.2.3.4.3
[14] NUREG-0133, Section 4.3

89.77 is site specific applicable factor for the mixing effect of the discharge structure.[15,16,17]

The term $C_{i,l}$ is the undiluted concentration of radioactive material in liquid waste at the common release point determined in accordance with REC 16.11.1.1, Table 16.11-1, "Radioactive Liquid Waste Sampling and Analysis Program". All dilution factors beyond the sample point(s) are included in the F_l term.

As there are currently no potable water intakes within 10 river miles of the discharge point, the drinking water pathway is not included in dose estimates to the maximally exposed individual. Should future potable water intakes be constructed within 10 river miles downstream of the discharge point, then this manual will be revised to include this pathway in dose estimates.[18]

The $A_{i\tau}$ values given in Table 1 were calculated according to:[19]

$$A_{i\tau} = k_0 (U_w/D_w + U_F BF_i + U_I BI_i) DF_i$$

Eq. 9

Since there are no drinking water pathways, and CEC is a freshwater site, the terms for drinking water consumption (U_w/D_w) and invertebrate consumption ($U_I BI_i$) go to zero and the equation simplifies to:

$$A_{i\tau} = k_0 U_F BF_i DF_i$$

Eq. 10

Where:

k_0 is a constant of units conversion, $1.14 \times 10^5 = (10^6$ pCi/µCi $\cdot$ 10^3 ml/kg / 8760 hr/yr)

U_F is the adult fish consumption, 21 kg/yr [20]

BF_i is the bioaccumulation factor for nuclide, i, in fresh water fish, pCi/kg per pCi/L.[21,22]

DF_i is the dose conversion factor for nuclide, i, for adults for organ, τ, in mrem/pCi.

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[15] NEO-54
[16] UOTH 83-58
[17] CAR 200700053- Attachments: Phase 1 final draft
[18] FSAR-SP, Section 11.2.3.3.4
[19] NUREG-0133, Section 4.3.1
[20] NUREG-0133, Section 4.3.1, pp. 16
[21] UCRL- 50564, Table 6
[22] NUREG/CR-4013, pp. 3.17

2.4.3. Summary, Calculation of Dose Due to Liquid Effluents

The dose contribution for the total time period $\sum_{l=1}^{m} \Delta t_l$ is determined by calculation at least once per 31 days and a cumulative summation of the total body and organ doses is maintained for each calendar quarter. The projected dose contribution from liquid effluents for which radionuclide concentrations are determined by periodic composite and grab sample analysis may be approximated by using the last measured value. Dose contributions are determined for all radionuclides identified in liquid effluents released to Unrestricted Areas. Nuclides which are not detected in the analyses are reported as "less than" the Minimum Detectable Activity (MDA) and are not reported as being present at the Lower Limit of Detection (LLD) for that nuclide. The "less than" values are not used in the dose calculations.

2.5. Liquid Radwaste Treatment System

The Liquid Radwaste Treatment System is described in FSAR-SP Chapter 11.2.

The Operability of the Liquid Radwaste Treatment System ensures this system will be available for use when liquids require treatment prior to their release to the environment. Operability is demonstrated through compliance with REC 16.11.1.1. and 16.11.1.2.

Projected doses due to liquid releases to Unrestricted Areas are determined each 31 days. The prior 31 day period is used to calculate compliance. This may be modified as appropriate to account for changes in radwaste treatment which may have a significant effect on the projected doses.

2.6. Liquid Effluents Dose Factors

The dose conversion factors provided in Table 1 were derived from the appropriate dose conversion factors of Regulatory Guide 1.109, Table 2.2 and other sources as necessary.[23,24]

3. Gaseous Effluents

3.1. Gaseous Effluent Monitors

Noble gas activity monitors are present on the containment building ventilation system, plant unit ventilation system, and radwaste building ventilation system.

The alarm/trip (alarm & trip) setpoint for any gaseous effluent radiation monitor is determined based on the instantaneous noble gas total body and skin dose rate limits of REC 16.11.2.1, at the Site Boundary location with the highest annual average X/Q value.

Each gaseous monitor channel is provided with a two level system which provides sequential alarms on increasing radioactivity levels. These setpoints are designated as alert setpoints and alarm/trip setpoints.[25]

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[23] HPCI 0406
[24] HPCI 1604

The radiation monitor alarm/trip setpoints for each release point are based on the radioactive noble gases in gaseous effluents. It is not considered practicable to apply instantaneous alarm/trip setpoints to integrating radiation monitors sensitive to radioiodines, radioactive materials in particulate form and radionuclides other than noble gases. The exception is GL-RE-202. The only effluent released from the Laundry Decon Facility Dryer Exhaust is in the particulate form. Conservative assumptions may be necessary in establishing setpoints to account for system variables, such as the measurement system efficiency and detection capabilities during normal, anticipated, and unusual operating conditions, variability in release flow and principal radionuclides, and the time lag between alarm/trip action and the final isolation of the radioactive effluent.[26] FSAR-SP Table 16.11-6 provides the instrument surveillance requirements, such as calibration, source checks, functional tests, and channel checks.

3.1.1. Continuous Release Gaseous Effluent Monitors

The radiation detection monitors associated with continuous gaseous effluent releases are:[27,28]

Monitor I.D.	Description
GT-RE-21	Unit Vent
GH-RE-10	Radwaste Building Vent
GL-RE-202	Laundry Decon Facility Dryer Exhaust Monitor

Each of the above continuously monitors gaseous radioactivity concentrations downstream of the last point of potential influent, and therefore measures effluents and not inplant concentrations.

The unit vent monitor continuously monitors the effluent from the unit vent for gaseous radioactivity. The unit vent, via ventilation exhaust systems, continuously purges various tanks and sumps normally containing low-level radioactive aerated liquids that can potentially generate airborne activity. The exhaust systems which supply air to the unit vent are from the fuel building, auxiliary building, the access control area, the containment purge, and the condenser air discharge.

The unit vent monitor provides alarm functions only, and does not terminate releases from the unit vent.

The Radwaste Building ventilation effluent monitor continuously monitors for gaseous radioactivity in the effluent duct downstream of the exhaust filter and fans. The flow path provides ventilation exhaust for all parts of the building structure and components within the building and provides a discharge path for the waste gas decay tank release line. These

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[25] FSAR-SP Section 11.5.2.1.2
[26] NUREG- 0133, section 5.1.1
[27] FSAR-SP Section 11.5.2.3.3.1
[28] FSAR-SP Section 11.5.2.3.3.2

components represent potential sources for the release of gaseous and air particulate and iodine activities in addition to the drainage sumps, tanks, and equipment purged by the waste processing system.

This monitor will isolate the waste gas decay tank discharge line upon a high gaseous radioactivity alarm.

The Laundry Decon Facility Dryer Exhaust Monitor continuously monitors the effluent of the dryer exhaust for particulate radioactivity during operation of the dryers. This effluent point is designed to release an insignificant quantity of radioactivity. The items to be placed in the dryers are typically washed before drying removing most of the radioactive material. The dryer effluent then passes through a HEPA filter before being sampled and released.

The Laundry Decon Facility Dryer Exhaust Monitor will secure the dryers and exhaust fans and isolate the dryer effluent upon a high radioactivity alarm or for a monitor failure.

The continuous Unit Vent and Radwaste Building Vent gaseous effluent monitor setpoints are established using the methodology described in Section 3.2. Since there are two continuous gaseous effluent release points, a fraction of the total dose rate limit (DRL) will be allocated to each release point. Neglecting the batch releases, the plant Unit Vent monitor has been allocated 0.7 DRL and the Radwaste Building Vent monitor has been allocated 0.3 DRL. These allocation factors may be changed as required to support plant operational needs, but shall not be allowed to exceed unity (i.e., 1.0). Therefore, a particular monitor reaching the setpoint would not necessarily mean the dose rate limit at the Site Boundary is being exceeded; the alarm only indicates that the specific release point is contributing a greater fraction of the dose rate limit than was allocated to the associated monitor, and will necessitate an evaluation of both systems.

For a loss of all isokinetic sampling and/or all heat tracing for the Unit Vent or Radwaste Building Vent grab samplers, one hour is allowed to restore a sampler to service. If sampling cannot be restored within one hour, all batch releases and ventilation not required for the operation of the plant should be secured. The best available sampling should be maintained during this period and normal sampling returned to service as soon as possible.

3.1.2. Batch Release Gaseous Effluent Monitors

The radiation monitors associated with batch release gaseous effluents are:[29,30,31]

Monitor I.D.	Description
GT-RE-22, GT-RE-33	Containment Purge System
GH-RE-10	Radwaste Building Vent

[29] FSAR-SP Section 11.5.2.3.3.2
[30] FSAR-SP Section 11.5.2.3.2.3
[31] FSAR-SP Section 11.5.2.3.2.2

The Containment Purge System continuously monitors the containment purge exhaust duct during purge operations for gaseous radioactivity. The primary purpose of these monitors is to isolate the containment purge system on high gaseous activity via the ESFAS.

The sample points are located outside the containment between the containment isolation dampers and the containment purge filter adsorber unit.

The Radwaste Building Vent monitor was previously described.

A pre-release isotopic analysis is performed for each batch release to determine the identity and quantity of the principal radionuclides. The alarm/trip setpoint(s) is adjusted accordingly to ensure that the limits of REC 16.11.2.1 are not exceeded.

3.2. Gaseous Effluent Monitor Setpoints

The alarm/trip setpoint for the Unit Vent and Radwaste Building Vent gaseous effluent monitors is determined based on the more restrictive of the total body dose rate (Eq. 11) and skin dose rate (Eq. 13) as calculated for the Site Boundary. In the event there is no noble gas activity in the sample, then the high alarm setpoint is set to the default value of 2.2E-02 µCi/cc. This corresponds to 50% of the 500 mrem/yr limit of REC 16.11.2.1.[32] Each monitor is allocated only 50% of the limit such that the sum total of the two monitors cannot exceed the limit.

The alarm/ trip setpoint for the Laundry Decon Facility Exhaust Monitor is set to less than or equal to 2,000 cpm above equilibrium background. The maximum allowed background is 2,000 cpm as discussed in HPCI 99-05.

3.2.1. Total Body Dose Rate Setpoint Calculations

To ensure that the limits of REC 16.11.2.1 are met, the alarm/trip setpoint based on the total body dose rate is calculated according to:

$$S_{tb} \leq D_{tb} R_{tb} F_s F_a$$

Eq. 11

Where:

S_{tb} is the alarm/trip setpoint based on the total body dose rate (µCi/cc);

D_{tb} is the REC 16.11.2.1 dose rate limit of 500 mrem/yr, conservatively interpreted as a continuous release over a one year period;

F_s is the safety factor; a conservative factor used to compensate for statistical fluctuations and errors of measurement. (For example, F_S = 0.5 corresponds to a 100% variation.) Default value is F_S = 0.1.

[32] HPCI 8403, page 9

F_a is the allocation factor which will modify the required dilution factor such that simultaneous gaseous releases may be made without exceeding the limits of REC 16.11.2.1.

R_{tb} is a factor used to convert dose rate to the effluent concentration as measured by the effluent monitor, in (μCi/cc) per (mrem/yr) to the total body, determined according to:

$$R_{tb} = C \div \left[\left(\overline{X/Q} \right) \sum_i (K_i Q_i) \right]$$

Eq. 12

Where:

C is the reading of a noble gas monitor corresponding to the sample radionuclide concentrations for the release. Concentrations are determined in accordance with FSAR-SP Table 16.11-4.The mixture of radionuclides determined via grab sampling of the effluent stream or source is correlated to a calibration factor to determine monitor response. The monitor response is based on concentration, not release rate, and is in units of (μCi/cc);

$\overline{X/Q}$ is the highest calculated annual average relative concentration for any area at or beyond the Site Boundary in (sec/m^3) (Table 10, Table 11, and Table 12);

K_i is the total body dose factor due to gamma emissions for each identified noble gas radionuclide, in (mrem/yr) per ($\mu Ci/m^3$) (Table 3); and

Q_i is the rate of release of noble gas radionuclide, i, in (μCi/sec).

Q_i is calculated as the product of the ventilation path flow rate and the measured activity of the effluent stream as determined by sampling.

3.2.2. Skin Dose Rate Setpoint Calculation

To ensure that the limits of REC 16.11.2.1 are met, the alarm/trip setpoint based on the skin dose rate is calculated according to:

$$S_s \leq D_s R_s F_s F_a$$

Eq. 13

Where:

F_s and **F_a** are as previously defined;

S_s is the alarm/trip setpoint based on the skin dose rate;

D_s is the REC 16.11.2.1 dose rate limit of 3000 mrem/yr, conservatively interpreted as a continuous release over a one year period; and

R_s is the factor used to convert dose rate to the effluent concentration as measured by the effluent monitor, in (μCi/cc) per (mrem/yr) to the skin, determined according to:

$$R_s = C \div \left[\left(\overline{X/Q}\right) \sum_i (L_i + 1.1 M_i)\, Q_i \right]$$

Eq. 14

Where:

L_i is the skin dose factor due to beta emissions for each identified noble gas radionuclide, in (mrem/yr) per (µCi/m³);

1.1 is a factor of units conversion; 1 mrad air dose = 1.1 mrem skin dose; and

M_i is the air dose factor due to gamma emissions for each identified noble gas radionuclide, in (mrad/yr) per (µCi/m³).

C, $\left(\overline{X/Q}\right)$, and Q_i are previously defined.

3.3. Calculation of Dose and Dose Rate from Gaseous Effluents

3.3.1. Dose Rate from Gaseous Effluents

The following methodology is applicable to the location (Site Boundary or beyond) characterized by the values of the parameter X/Q which results in the maximum total body or skin dose rate. In the event that the analysis indicates a different location for the total body and skin dose limitations, the location selected for consideration is that which minimizes the allowable release values.[33]

The factors **K_i**, **L_i**, and **M_i** relate the radionuclide airborne concentrations to various dose rates, assuming a semi-infinite cloud model.

3.3.1.1. Dose Rate from Noble Gases

The release rate limit for noble gases is determined according to the following general relationships:[34]

$$D_{tb} = \sum_i \left[K_i Q_i \left(\left(\overline{X/Q}\right) \right) \right] \le 500\ mrem/yr$$

Eq. 15

$$D_s = \sum_i \left[\left(L_i + 1.1\, M_i\right)\left(\left(\overline{X/Q}\right) Q_i \right) \right] \le 3000\ mrem/yr$$

Eq. 16

Where:

[33] NUREG-0133, Section 5.1.2
[34] NUREG-0133, Section 5.1.2

Q_i is the release rate of noble gas radionuclides, i, in gaseous effluents, from all vent releases in (μCi/sec); and

1.1 is a factor of units conversion factor; 1 mrad air dose = 1.1 mrem skin dose.

L_i, M_i, K_i, $\overline{(X/Q)}$, D_{tb} and D_s are as previously identified.

3.3.1.2. Dose Rate from Radionuclides Other than Noble Gases

The release rate limit for ^{131}I and ^{133}I, for ^{3}H, and for all radioactive materials in particulate form with half-lives greater than 8 days is determined according to:[35]

$$D_o = \sum_i R_i \left[\overline{X/Q} \right] Q_i \le 1500\ mrem/yr$$

Eq. 17

Where:

D_o is the dose rate to any critical organ, in (mrem/yr);

R_i is the dose parameter for radionuclides other than noble gases for the inhalation pathway for the child, based on the critical organ, in (mrem/yr) per (μCi/m^3); and

Q_i is the release rate of radionuclides other than noble gases, i, in gaseous effluents, from all vent releases in (μCi/sec).

$\overline{(X/Q)}$ is as previously defined.

The dose parameter (R_i) includes the internal dosimetry of radionuclide, i, and the receptor's breathing rate, which are functions of the receptor's age. The child age group has been selected as the limiting age group. All radiodines are assumed to be released in elemental form.[36]

R_i values were calculated according to:[37]

$$R_i = K'(BR)\, DFA_i$$

Eq. 18

Where:

K' is a factor of units conversion factor: 1×10^6 pCi/μCi;

BR is the breathing rate from Regulatory Guide 1.109, Table E-5 (m^3/yr);

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[35] NUREG-0133, Section 5.2.1
[36] NUREG-0133, Section 5.2.1
[37] NUREG-0133, Section 5.2.1.1

DFA$_i$ is the maximum organ inhalation dose factor for the ith radionuclide, in (mrem/pCi). The total body is considered as an organ in the selection of DFA$_i$.[38,39]

The results of periodic tritium, iodine and particulate samples of the Unit Vent and Radwaste Vent are used to verify the dose rate limit was not exceeded for the period during which the samples or composite samples were obtained.

3.3.2. Dose Due to Gaseous Effluents

3.3.2.1. Air Dose Due to Noble Gases

The air dose at the Site Boundary due to noble gases is calculated according to the following methodology:[40]

During any calendar quarter, for gamma radiation:

$$D_g = 3.17E\text{-}08 \sum_i \left[M_i \left(\overline{X/Q}\right) Q_i \right] \leq 5 \text{ mrad}$$

Eq. 19

During any calendar quarter, for beta radiation:

$$D_b = 3.17E\text{-}08 \sum_i \left[N_i \left(\overline{X/Q}\right) Q_i \right] \leq 10 \text{ mrad}$$

Eq. 20

During any calendar year, for gamma radiation:

$$D_g = 3.17E\text{-}08 \sum_i \left[M_i \left(\overline{X/Q}\right) Q_i \right] \leq 10 \text{ mrad}$$

Eq. 21

During any calendar year, for beta radiation:

$$D_b = 3.17E\text{-}08 \sum_i \left[N_i \left(\overline{X/Q}\right) Q_i \right] \leq 20 \text{ mrad}$$

Eq. 22

Where:

D_g is the air dose in mrad, from gamma radiation due to noble gases released in gaseous effluent;

D_b is the air dose in mrad, from beta radiation due to noble gases released in gaseous effluents;

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[38] Regulatory Guide 1.109, Appendix E, Table E-9
[39] ZZ-48
[40] NUREG-0133, Section 5.3.1

N_i is the air dose factor due to beta emissions for each identified noble gas radionuclide, i, in (mrad/yr) per (μCi/m^3);

Q_i is the releases of noble gas radionuclides, i, in gaseous effluents, for all gaseous releases in (μCi). Releases are cumulative over the calendar quarter or year as appropriate. Q_i is calculated as the product of the ventilation flow rate and the measured activity of the effluent stream as determined by sampling; and

$3.17x10^{-8}$ is the inverse of the number of seconds per year.

$\overline{X/Q}$ & **M_i** are as previously defined.

3.3.2.2. Dose Due to Radionuclides Other than Noble Gases

The dose to a Member of the Public from ^{131}I and ^{133}I, for ^{3}H, and all radionuclides in particulate form with half-lives greater than 8 days in gaseous effluents released to areas at and beyond the Site Boundary, is calculated according to the following expressions:

During any calendar quarter:

$$\sum_j D_{I,j} \leq 7.5 \ mrem$$

Eq. 23

During any calendar year:

$$\sum_j D_{I,j} \leq 15 \ mrem$$

Eq. 24

For each pathway, j, (i.e., for inhalation, ground plane, meat, cow- milk, goat- milk, and vegetation) $D_{I,j}$ is calculated according to the expression:

$$D_{I,j} = 3.17E-8 \sum_i R_{I,j,i} \left[W_j Q_i \right]$$

Eq. 25

Where:

$D_{I,j}$ is the dose in mrem, to a Member of the Public from radionuclides other than noble gases, from pathway j, received by organ I (including total body);

$R_{I,i,j}$ is the dose factor for each identified radionuclide, i, in m^2 (mrem/yr) per (μCi/sec) or (mrem/yr) per (μCi/m^3) as appropriate, for the pathway $_j$, and exposed organ I, appropriate to the age group of the critical Member of the Public receptor;

W_j is the $\overline{X/Q}$ for the inhalation and tritium pathways, in sec/m^3 and is the $\overline{D/Q}$ for the food and ground plane pathways, in meters^{-2}.

$\overline{D/Q}$ is the average relative deposition of the effluent at or beyond the Site Boundary, considering depletion of the plume during transport;

Q_i is the release of radioiodines, radioactive materials in particulate form, and radionuclides other than noble gases, i, in gaseous effluents, for all gaseous releases in μCi. Releases are cumulative over the calendar quarter or year as appropriate. Q_i is calculated as the product of ventilation flow rate and the measured activity of the effluent stream as determined by sampling; and

3.17×10^{-8} is the inverse of the number of seconds per year.

$\overline{X/Q}$ is as previously defined. Refer to Table 10, Table 11, and Table 12 for applicability;

Although the annual average relative concentration $\overline{X/Q}$ and the average relative deposition rate $\overline{D/Q}$ are generally considered to be at the approximate receptor location in lieu of the Site Boundary for these calculations, it is acceptable to consider the ingestion, inhalation, and ground plane pathways to coexist at the location of the nearest residence with the highest value of $\overline{X/Q}$.[41] The Total Body dose from ground plane deposition is added to the dose for each individual organ.[42]

3.4. Gaseous Radwaste Treatment System

The gaseous radwaste treatment system and the ventilation exhaust system are available for use whenever gaseous effluents require treatment prior to being released to the environment. The gaseous radwaste treatment system is designed to allow for the retention of all gaseous fission products to be discharged from the reactor coolant system. The retention system consists of eight (8) waste gas decay tanks. Normally, waste gases will be retained for at least 60 days prior to discharge. When practicable, waste gas decay tanks are discharged outside the growing season or at night such that ^{14}C released from the waste gas system will not be incorporated into the ingestion pathways and will result in a lower dose to the Member of the Public. For this purpose, the growing season is defined as April 1 through November 1.[43] These systems will provide reasonable assurance that the releases of radioactive materials in gaseous effluents will be kept ALARA.

The Operability of the gaseous radwaste treatment system ensures this system will be available for use when gases require treatment prior to their release to the environment. Operability is demonstrated through compliance with REC 16.11.2.1, 16.11.2.2, and 16.11.2.3.

Projected doses (gamma air, beta air, and organ dose) due to gaseous effluents at or beyond the Site Boundary are determined each 31 days. The prior 31 day period is used to calculate

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[41] NUREG-0133, Section 5.3.1
[42] Regulatory Guide 1.109, Appendix C, Section 1
[43] Hammer, Gregory, R., "Climate of Missouri", monograph available from the National Climatic Data Center (NCDC) of the National Oceanic and Atmospheric Administration (NOAA), January, 2006.

compliance. This may be modified as appropriate to account for changes in radwaste treatment which may have a significant effect on the projected doses.

3.5. Gaseous Effluents Dose Factors

The dose conversion factors were derived from the appropriate dose conversion factors in Regulatory Guide 1.109 and other sources as necessary.[44,45] Particulate nuclides with a half-life of less than 8 days are not considered.[46] ^{90}Y, ^{140}La, and ^{144}Pr are included because the parent half-life is greater than 8 days, and equilibrium is assumed.

4. Dose and Dose Commitment from Uranium Fuel Cycle Sources

4.1. Calculation of Dose and Dose Commitment from Uranium Fuel Cycle Sources

The annual dose or dose commitment to a Member of the Public for Uranium Fuel Cycle Sources is determined as:

- Dose to the total body and internal organs due to gamma ray exposure from submersion in a cloud of radioactive noble gases, ground plane exposure, and direct radiation from the Unit, onsite storage of low-level radioactive waste, and outside storage tanks;
- Dose to skin due to beta radiation from submersion in a cloud of radioactive noble gases, and ground plane exposure;
- Thyroid dose due to inhalation and ingestion of radioiodines; and
- Organ dose due to inhalation and ingestion of radioactive material.

It is assumed that total body dose from sources of gamma radiation irradiates internal body organs at the same numerical rate.[47]

The dose from gaseous effluents is considered to be the summation of the dose at the individual's residence and the dose to the individual from activities within the Site Boundary.

Since the doses via liquid releases are very conservatively evaluated, there is reasonable assurance that no real individual will receive a significant dose from radioactive liquid release pathways. Therefore, only doses to individuals via airborne pathways and doses resulting from direct radiation are considered in determining compliance to 40 CFR 190.[48]

There are no other Uranium Fuel Cycle Sources within 8 km of the Callaway Plant.

4.1.1. Identification of the Member of the Public

The Member of the Public is considered to be a real individual, including all persons not occupationally associated with the Callaway Plant, but who may use portions of the plant site

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[44] ZZ-78
[45] ZZ-250
[46] Inspection Report 50-483/92002 (DRSS)
[47] NUREG-0543, Section III, page 8
[48] NUREG-0543, Section IV, page 9

for recreational or other purposes not associated with the plant.[49] Accordingly, it is necessary to characterize this individual with respect to his utilization of areas both within and at or beyond the Site Boundary and identify, as far as possible, major assumptions which could be reevaluated if necessary to demonstrate continued compliance with 40 CFR 190 through the use of more realistic assumptions.[50,51]

The evaluation of Total Dose from the Uranium Fuel Cycle should consider the dose to two Critical Receptors: (a) The Nearest Resident, and (b) The Critical Receptor within the Site Boundary.

4.1.2. Total Dose to the Nearest Resident

The dose to the Nearest Resident is due to plume exposure from noble gases, ground plane exposure, and inhalation and ingestion pathways. It is conservatively assumed that each ingestion pathway (meat, milk, and vegetation) exists at the location of the Nearest Resident.

It is assumed that direct radiation dose from operation of the Unit and storage of radioactive material, and dose from gaseous effluents due to activities within the Site Boundary is negligible for the Nearest Resident. The total Dose from the Uranium Fuel Cycle to the Nearest Resident is calculated using the methodology discussed in Section 3, using concurrent meteorological data for the location of the Nearest Resident with the highest value of X/Q.

The location of the Nearest Resident in each meteorological sector is determined from the Annual Land Use Census conducted in accordance with the Requirements of REC 16.11.4.2.

4.1.3. Total Dose to the Critical Receptor within the Site Boundary

The Union Electric Company has entered into an agreement with the State of Missouri Department of Conservation for management of the residual lands surrounding the Callaway Plant, including some areas within the Site Boundary. Under the terms of this agreement, certain areas have been opened to the public for low intensity recreational uses (hunting, hiking, sightseeing, etc.) but recreational use is excluded in an area immediately surrounding the plant site (refer to Figure 4.1). Much of the residual lands within the Site Boundary are leased to area farmers by the Department of Conservation to provide income to support management and development costs. Activities conducted under these leases are primarily comprised of farming (animal feed), grazing, and forestry. Crops for human consumption are specifically prohibited by the lease.[52,53,54]

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[49] NUREG-0133, Section 3.8
[50] NUREG-0543, Section IV, page 9
[51] NUREG-0543, section III, page 6
[52] Environmental Report, OLS, Section 2.1.2.3
[53] Environmental Report, OLS, Section 2.1.3.3.4
[54] Management Agreement for the Public Use of Lands, Exhibit A.

Based on the utilization of areas within the Site Boundary, it is reasonable to assume that the critical receptor within the Site Boundary is a farmer, and that his dose from activities within the Site Boundary is due to exposure incurred while conducting his farming activities. The previous tenant estimated that he spent approximately 1100 hours per year working the farm plots of the Reform Conservation Area.[55]

Any reevaluation of assumptions should consider only real receptors and real pathways using realistic assumptions, and should include a reevaluation of the occupancy period at the locations of real exposure (e.g. a real individual would not simultaneously exist at each point of maximum exposure).

4.1.3.1. Total Dose to the Farmer from Gaseous Effluents

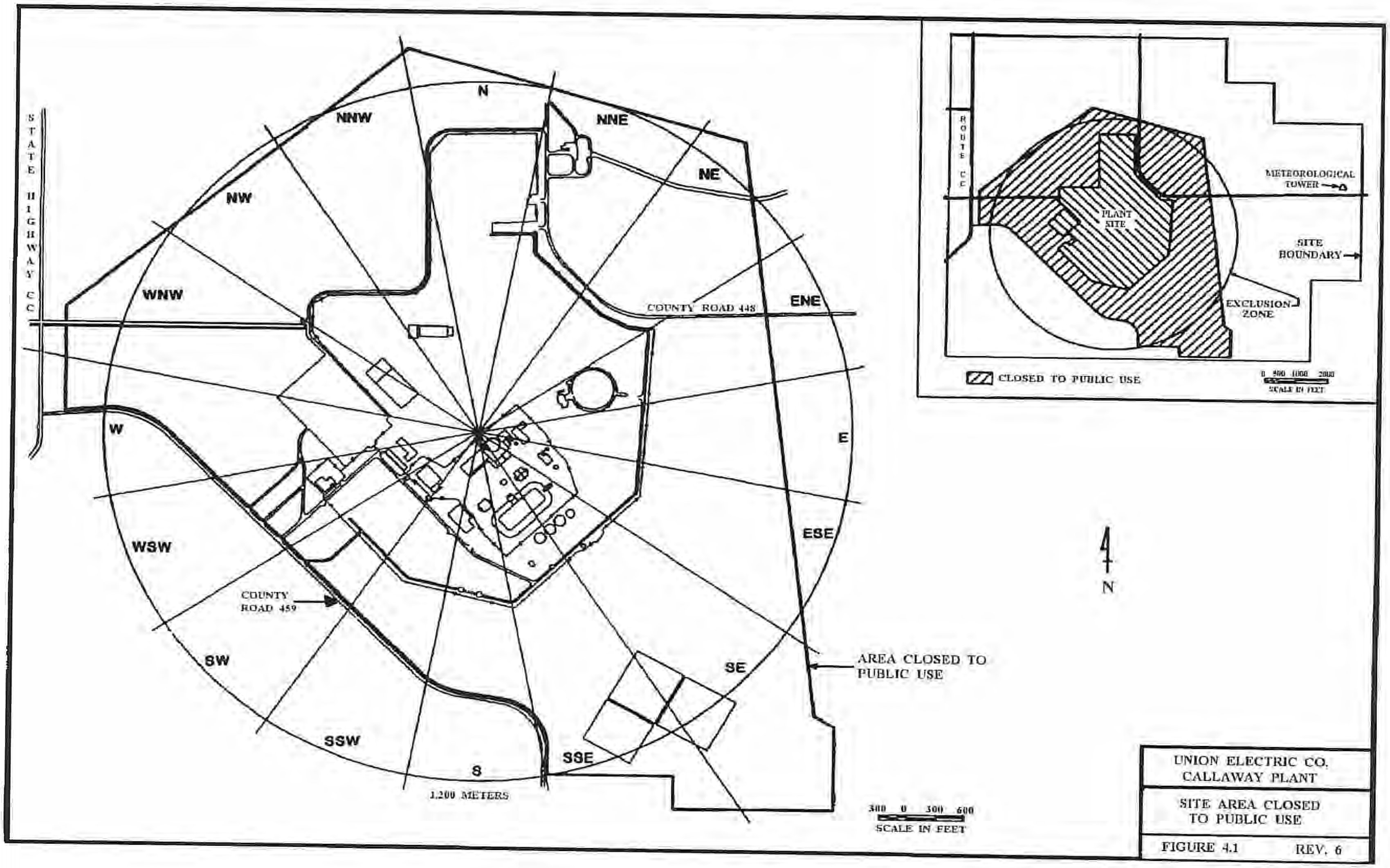
The Total Dose to the farmer from gaseous effluents is calculated for the adult age group using the methodology discussed in Section 3, utilizing historical meteorological data from Table 10 for activities within the Site Boundary. The Reform Conservation Area farm plots are leased to several different farmers therefore there is no dose calculation for the farmer's residence.

It is assumed that food ingestion pathways do not exist within the Site Boundary, therefore the gaseous effluents dose within the Site Boundary is due to plume exposure from Noble Gases and the ground plane and inhalation pathways.

4.1.3.1.1. Direct Radiation Dose

The direct radiation dose to the Member of Public due to activities within the Site Boundary is insignificant.[56,57]

[55] Private communication, H.C. Lindeman & B.F.Holderness, August 6, 1986
[56] HPCI 1206
[57] HPCI 1505



UNION ELECTRIC CO. CALLAWAY PLANT	
SITE AREA CLOSED TO PUBLIC USE	
FIGURE 4.1	REV. 6

5. Radiological Environmental Monitoring

5.1. Description Of The Radiological Environmental Monitoring Program

The Radiological Environmental Monitoring Program is intended to provide background data for pre- operation and to supplement the radiological effluent release monitoring program during plant operation. Radiation exposure to the public from the various specific pathways and direct radiation is evaluated by this program.

Some deviations from the sampling frequency may be necessary due to seasonal unavailability, hazardous conditions, or other legitimate reasons. Efforts are made to obtain all required samples within the required time frame. Any deviation(s) in sampling frequency or location is documented in the Annual Radiological Environmental Operating Report.

Sampling, reporting, and analytical requirements are given in FSAR-SP Tables 16.11-7, 16.11-8, and 16.11-9.

Airborne, waterborne, direct radiation, and ingestion samples collected under the monitoring program are analyzed by an independent, third-party laboratory. With the exception of direct radiation, the laboratory is required to participate in an Interlaboratory Analyses Program per Reg. Guide 4.15.[58] The laboratory participates in an Interlaboratory crosscheck program administered by Environmental Resources Associates (ERA), Mixed Analyte Performance Evaluation Program (MAPEP), or equivalent program. This participation includes all of the determinations (sample medium - radionuclide combination) that are both offered by ERA and/or MAPEP and are also included in the environmental monitoring program.

5.2. Performance Testing Of Environmental Thermoluminescence Dosimeters

Dosimeters used for monitoring of direct radiation dose in the Radiological Environmental Monitoring Program are tested for accuracy and precision to demonstrate compliance with the applicable portions of Regulatory Guide 4.13.

6. Annual Average Atmospheric Dispersion Parameters

6.1. Annual Atmospheric Dispersion Parameters

The dispersion values presented in Table 10 were determined through the analysis of five years of on-site meteorological data.[59] The straight-line Gaussian dispersion model XOQDOQ[60] was used for determination of the long-term atmospheric dispersion parameters. A more detailed discussion of the methodology and input data utilized to calculate these parameters can be found in HPCI 1503.

6.1.1. Determination of Dispersion Estimates for Special Receptor Locations

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[58] Regulatory Guide 4.15, rev. 1, section 6.3.2
[59] HPCI 1503
[60] NUREG/CR2919

XOQDOQ is utilized to obtain dispersion paramters for 22 standard distances. Dispersion parameters at the Site Boundary and at special receptor locations are estimated by logarithmic interpolation according to:[61]

$$X = X_1 \left(d/d_1\right)^B$$

Eq. 26

Where:

$$B = \frac{\ln\left(X_2/X_1\right)}{\ln\left(d_2/d_1\right)}$$

Eq. 27

X_1, X_2 are the atmospheric dispersion parameters at distance **d_1** and **d_2**, respectively, from the source. The distances d_1 and d_2 are selected such that they satisfy the relationship $d_1 < d < d_2$.

6.1.2. Atmospheric Dispersion Parameters for Farming Areas within the Site Boundary

The dispersion parameters for farming areas within the Site Boundary are intended for a narrow scope application; that of calculating the dose to the current farmer[62] from gaseous effluents while he conducts farming activities within the Site Boundary.

For the purpose of these calculations, it was assumed that all of the farmer's time, approximately 1100 hours per year, is spent on croplands of the Reform Conservation Area, including plots within the Site Boundary, and that his time is divided among the plots proportional to the acreage of each plot. Fractional acreage/time- weighted dispersion parameters were calculated for each plot as described in HPCI 1502. The weighted dispersion parameters for each plot were summed (according to type) in order to produce a composite value of the dispersion parameters which are presented in Table 10. These dispersion parameters therefore represent the distributed activities of the farmer within the Site Boundary and his estimated occupancy period.

6.2. Annual Meteorological Data Processing

The annual atmospheric dispersion parameters utilized in the calculation of doses for demonstration of compliance with the numerical dose objectives of 10 CFR 50, Appendix I, are determined using XOQDOQ.[63] Multiple sensors are utilized to ensure 90% valid data recovery for the wind speed, wind direction, and ambient air temperature parameters as required by Regulatory Guide 1.23. The selection hierarchy is presented in Table 13.

The input parameters to XOQDOQ are documented in HPCI 1503.

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[61] FSAR-SA 2.3.5.2.1.2

[62] The farming plots are leased by the Missouri Department of Conservation to multiple farmers through a bidding process. This represents a composite of those persons farming the plots within the Site Boundary.

[63] NUREG/CR-2919

A quality check of the meteorological data is performed prior to processing to ensure the validity of the calculated dispersion parameters.

7. Reporting Requirements

7.1. Annual Radiological Environmental Operating Report

The reporting requirements for the Annual Radiological Environmental Operating Report (AREOR) have been relocated to FSAR-SP 16.11.5.1.

7.2. Annual Radioactive Effluent Release Report

The reporting requirements for the Annual Radioactive Effluent Release Report (ARERR) have been relocated to FSAR-SP 16.11.5.2. The application of atmospheric dispersion parameters in the ARERR is presented in Table 12.

8. Radioactive Effluent Controls (REC)

The Radioactive Effluent Controls were relocated to FSAR-SP Chapter 16.11,"Offsite Dose Calculation Manual Radioactive Effluent Controls". The former ODCM REC numbers appear on each of the RECs in FSAR-SP Chapter 16.11, and may be used as a cross-reference between the previous and the current numbering system if necessary.

9. Administrative Controls

9.1. Major Changes to Liquid and Gaseous Radwaste Treatment Systems

A summary of Licensee-initiated major changes to the Radwaste Treatment Systems (liquid and gaseous) must be reported to the Commission in the Annual Radioactive Effluent Release Report (ARERR) for the period in which the evaluation was reviewed by the On-Site Review Committee (ORC). On site documentation must contain:

- A summary of the evaluation that led to the determination that the change could be made in accordance with 10 CFR 50.59;
- Sufficient detailed information to totally support the reason for the change without benefit of additional or supplemental information;
- A detailed description of the equipment, components and process involved and the interfaces with other plant systems;
- An evaluation of the change, which shows the predicted releases of radioactive materials in liquid and gaseous effluents that differ from those previously predicted in the License application and amendments thereto;
- An evaluation of the change, which shows the expected maximum exposures to a Member of the Public in the Unrestricted Area and to the general population that differ from those previously estimated in the License application and amendments thereto;

- A comparison of the predicted releases of radioactive materials, in liquid and gaseous effluents, to the actual releases for the period prior to when the changes are to be made;
- An estimate of the exposure to plant operating personnel as a result of the change; and
- Documentation of the fact that the change was reviewed and found acceptable by the ORC.

Changes to the Radwaste Treatment Systems shall become effective upon review and approval by the ORC.

9.2. Changes to the Offsite Dose Calculation Manual (ODCM)

All changes to the ODCM shall be performed pursuant to T/S AC 5.5.1

Review for each revision of the ODCM must include the Radiation Protection Department.

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Table 1: Ingestion Dose Commitment Values ($A_{i\tau}$) for Adult Age Group[1]

(mrem/hr) per (µCi/ml)

Nuclide	Bone	Liver	Total Body	Thyroid	Kidney	Lung	GI-LLI
^{3}H	0.00E+00	2.26E-01	2.26E-01	2.26E-01	2.26E-01	2.26E-01	2.26E-01
^{7}Be	1.31E-02	2.98E-02	1.45E-02	0.00E+00	3.15E-02	0.00E+00	5.17E+00
^{24}Na	4.07E+02	4.07E+02	4.07E+02	4.07E+02	4.07E+02	4.07E+02	4.07E+02
^{51}Cr	0.00E+00	0.00E+00	1.27E+00	7.61E-01	2.81E-01	1.69E+00	3.20E+02
^{54}Mn	0.00E+00	4.38E+03	8.35E+02	0.00E+00	1.30E+03	0.00E+00	1.34E+04
^{56}Mn	0.00E+00	1.10E+02	1.95E+01	0.00E+00	1.40E+02	0.00E+00	3.51E+03
^{55}Fe	6.58E+02	4.55E+02	1.06E+02	0.00E+00	0.00E+00	2.54E+02	2.61E+02
^{59}Fe	1.04E+03	2.44E+03	9.36E+02	0.00E+00	0.00E+00	6.82E+02	8.14E+03
^{57}Co	0.00E+00	2.09E+01	3.48E+01	0.00E+00	0.00E+00	0.00E+00	5.31E+02
^{58}Co	0.00E+00	8.92E+01	2.00E+02	0.00E+00	0.00E+00	0.00E+00	1.81E+03
^{60}Co	0.00E+00	2.56E+02	5.65E+02	0.00E+00	0.00E+00	0.00E+00	4.81E+03
^{63}Ni	3.11E+04	2.16E+03	1.04E+03	0.00E+00	0.00E+00	0.00E+00	4.50E+02
^{65}Ni	1.26E+02	1.64E+01	7.49E+00	0.00E+00	0.00E+00	0.00E+00	4.17E+02
^{64}Cu	0.00E+00	9.97E+00	4.68E+00	0.00E+00	2.51E+01	0.00E+00	8.50E+02
^{65}Zn	2.32E+04	7.37E+04	3.33E+04	0.00E+00	4.93E+04	0.00E+00	4.64E+04
^{69}Zn	4.93E+01	9.43E+01	6.56E+00	0.00E+00	6.13E+01	0.00E+00	1.42E+01
^{82}Br	0.00E+00	0.00E+00	2.27E+03	0.00E+00	0.00E+00	0.00E+00	2.60E+03
^{83}Br	0.00E+00	0.00E+00	4.04E+01	0.00E+00	0.00E+00	0.00E+00	5.82E+01
^{84}Br	0.00E+00	0.00E+00	5.24E+01	0.00E+00	0.00E+00	0.00E+00	4.11E-04
^{85}Br	0.00E+00	0.00E+00	2.15E+00	0.00E+00	0.00E+00	0.00E+00	1.01E-15
^{86}Rb	0.00E+00	1.01E+05	4.71E+04	0.00E+00	0.00E+00	0.00E+00	1.99E+04
^{88}Rb	0.00E+00	2.90E+02	1.54E+02	0.00E+00	0.00E+00	0.00E+00	4.00E-09
^{89}Rb	0.00E+00	1.92E+02	1.35E+02	0.00E+00	0.00E+00	0.00E+00	1.12E-11
^{89}Sr	2.21E+04	0.00E+00	6.35E+02	0.00E+00	0.00E+00	0.00E+00	3.55E+03
^{90}Sr	5.44E+05	0.00E+00	1.34E+05	0.00E+00	0.00E+00	0.00E+00	1.57E+04
^{91}Sr	4.07E+02	0.00E+00	1.64E+01	0.00E+00	0.00E+00	0.00E+00	1.94E+03
^{92}Sr	1.54E+02	0.00E+00	6.68E+00	0.00E+00	0.00E+00	0.00E+00	3.06E+03
^{90}Y	5.76E-01	0.00E+00	1.54E-02	0.00E+00	0.00E+00	0.00E+00	6.10E+03
^{91m}Y	5.44E-03	0.00E+00	2.11E-04	0.00E+00	0.00E+00	0.00E+00	1.60E-02
^{91}Y	8.44E+00	0.00E+00	2.26E-01	0.00E+00	0.00E+00	0.00E+00	4.64E+03
^{92}Y	5.06E-02	0.00E+00	1.48E-03	0.00E+00	0.00E+00	0.00E+00	8.86E+02
^{93}Y	1.60E-01	0.00E+00	4.43E-03	0.00E+00	0.00E+00	0.00E+00	5.09E+03
^{95}Zr	2.40E-01	7.70E-02	5.21E-02	0.00E+00	1.21E-01	0.00E+00	2.44E+02
^{97}Zr	1.33E-02	2.68E-03	1.22E-03	0.00E+00	4.04E-03	0.00E+00	8.30E+02
^{95}Nb	4.47E+02	2.48E+02	1.34E+02	0.00E+00	2.46E+02	0.00E+00	1.51E+06
^{99}Mo	0.00E+00	1.03E+02	1.96E+01	0.00E+00	2.34E+02	0.00E+00	2.39E+02
^{99m}Tc	8.87E-03	2.51E-02	3.19E-01	0.00E+00	3.81E-01	1.23E-02	1.48E+01

Table 1: Ingestion Dose Commitment Values (A_{it}) for Adult Age Group[1]

(mrem/hr) per (µCi/ml)

Nuclide	Bone	Liver	Total Body	Thyroid	Kidney	Lung	GI-LLI
^{101}Tc	9.12E-03	1.31E-02	1.29E-01	0.00E+00	2.37E-01	6.72E-03	3.95E-14
^{103}Ru	4.43E+00	0.00E+00	1.91E+00	0.00E+00	1.69E+01	0.00E+00	5.17E+02
^{105}Ru	3.69E-01	0.00E+00	1.46E-01	0.00E+00	4.76E+00	0.00E+00	2.26E+02
^{106}Ru	6.58E+01	0.00E+00	8.33E+00	0.00E+00	1.27E+02	0.00E+00	4.26E+03
^{109}Cd	0.00E+00	5.55E+02	1.94E+01	0.00E+00	5.31E+02	0.00E+00	5.60E+03
^{110m}Ag	8.85E-01	8.18E-01	4.86E-01	0.00E+00	1.61E+00	0.00E+00	3.34E+02
^{113}Sn	5.67E+04	1.61E+03	3.26E+03	9.19E+02	0.00E+00	0.00E+00	1.69E+05
^{117m}Sn	2.79E+03	1.62E+02	6.99E+02	5.21E+01	0.00E+00	0.00E+00	0.00E+00
^{122}Sb	5.48E-01	1.12E-02	1.66E-01	7.73E-03	0.00E+00	2.94E-01	0.00E+00
^{124}Sb	6.70E+00	1.27E-01	2.66E+00	1.63E-02	0.00E+00	5.22E+00	1.90E+02
^{125}Sb	4.29E+00	4.79E-02	1.02E+00	4.36E-03	0.00E+00	3.30E+00	4.72E+01
^{126}Sb	2.75E+00	5.59E-02	9.92E-01	1.68E-02	0.00E+00	1.68E+00	2.25E+02
^{127m}Te	6.48E+03	2.32E+03	7.90E+02	1.66E+03	2.63E+04	0.00E+00	2.17E+04
^{127}Te	1.05E+02	3.78E+01	2.28E+01	7.80E+01	4.29E+02	0.00E+00	8.31E+03
^{129m}Te	1.10E+04	4.11E+03	1.74E+03	3.78E+03	4.60E+04	0.00E+00	5.54E+04
^{129}Te	3.01E+01	1.13E+01	7.33E+00	2.31E+01	1.26E+02	0.00E+00	2.27E+01
^{131m}Te	1.66E+03	8.10E+02	6.75E+02	1.28E+03	8.21E+03	0.00E+00	8.04E+04
^{131}Te	1.89E+01	7.88E+00	5.96E+00	1.55E+01	8.26E+01	0.00E+00	2.67E+00
^{132}Te	2.41E+03	1.56E+03	1.47E+03	1.72E+03	1.50E+04	0.00E+00	7.38E+04
^{130}I	2.71E+01	8.01E+01	3.16E+01	6.79E+03	1.25E+02	0.00E+00	6.89E+01
^{131}I	1.49E+02	2.14E+02	1.22E+02	7.00E+04	3.66E+02	0.00E+00	5.64E+01
^{132}I	7.29E+00	1.95E+01	6.82E+00	6.82E+02	3.11E+01	0.00E+00	3.66E+00
^{133}I	5.14E+01	8.87E+01	2.70E+01	1.30E+04	1.55E+02	0.00E+00	7.97E+01
^{134}I	3.81E+00	1.03E+01	3.70E+00	1.79E+02	1.64E+01	0.00E+00	9.01E-03
^{135}I	1.59E+01	4.17E+01	1.54E+01	2.75E+03	6.68E+01	0.00E+00	4.70E+01
^{134}Cs	2.98E+05	7.09E+05	5.79E+05	0.00E+00	2.29E+05	7.61E+04	1.24E+04
^{136}Cs	3.12E+04	1.23E+05	8.86E+04	0.00E+00	6.85E+04	9.38E+03	1.40E+04
^{137}Cs	3.82E+05	5.22E+05	3.42E+05	0.00E+00	1.77E+05	5.89E+04	1.01E+04
^{138}Cs	2.64E+02	5.22E+02	2.59E+02	0.00E+00	3.84E+02	3.79E+01	2.23E-03
^{139}Ba	9.29E-01	6.62E-04	2.72E-02	0.00E+00	6.19E-04	3.75E-04	1.65E+00
^{140}Ba	1.94E+02	2.44E-01	1.27E+01	0.00E+00	8.30E-02	1.40E-01	4.00E+02
^{141}Ba	4.51E-01	3.41E-04	1.52E-02	0.00E+00	3.17E-04	1.93E-04	2.13E-10
^{142}Ba	2.04E-01	2.10E-04	1.28E-02	0.00E+00	1.77E-04	1.19E-04	2.87E-19
^{140}La	1.50E-01	7.54E-02	1.99E-02	0.00E+00	0.00E+00	0.00E+00	5.54E+03
^{142}La	7.66E-03	3.48E-03	8.68E-04	0.00E+00	0.00E+00	0.00E+00	2.54E+01
^{141}Ce	2.24E-02	1.52E-02	1.72E-03	0.00E+00	7.04E-03	0.00E+00	5.79E+01
^{143}Ce	3.95E-03	2.92E+00	3.23E-04	0.00E+00	1.29E-03	0.00E+00	1.09E+02

Table 1: Ingestion Dose Commitment Values ($A_{i\tau}$) for Adult Age Group[1]

(mrem/hr) per (µCi/ml)

Nuclide	Bone	Liver	Total Body	Thyroid	Kidney	Lung	GI-LLI
^{144}Ce	1.17E+00	4.88E-01	6.27E-02	0.00E+00	2.90E-01	0.00E+00	3.95E+02
^{143}Pr	5.51E-01	2.21E-01	2.73E-02	0.00E+00	1.27E-01	0.00E+00	2.41E+03
^{144}Pr	1.80E-03	7.48E-04	9.16E-05	0.00E+00	4.22E-04	0.00E+00	2.59E-10
^{147}Nd	3.76E-01	4.35E-01	2.60E-02	0.00E+00	2.54E-01	0.00E+00	2.09E+03
^{154}Eu	3.68E+01	4.52E+00	3.22E+00	0.00E+00	2.17E+01	0.00E+00	3.28E+03
^{181}Hf	4.00E-02	1.94E-01	1.80E-02	0.00E+00	4.18E-02	0.00E+00	2.21E+02
^{187}W	2.96E+02	2.47E+02	8.65E+01	0.00E+00	0.00E+00	0.00E+00	8.10E+04
^{237}Np	3.28E+04	2.85E+03	1.33E+03	0.00E+00	9.86E+03	0.00E+00	1.90E+03
^{239}Np	2.85E-02	2.80E-03	1.54E-03	0.00E+00	8.74E-03	0.00E+00	5.75E+02
^{238}Pu	5.70E+03	8.03E+02	1.43E+02	0.00E+00	6.13E+02	0.00E+00	6.12E+02
^{239}Pu*	6.59E+03	8.88E+02	1.60E+02	0.00E+00	6.80E+02	0.00E+00	5.68E+02
^{241}Pu	1.38E+02	7.07E+00	2.78E+00	0.00E+00	1.28E+01	0.00E+00	1.17E+01
^{241}Am	4.90E+04	1.72E+04	3.24E+03	0.00E+00	2.44E+04	0.00E+00	4.44E+03
^{242}Cm	1.23E+03	1.26E+03	8.20E+01	0.00E+00	3.72E+02	0.00E+00	4.74E+03
^{243}Cm**	3.82E+04	1.44E+04	2.24E+03	0.00E+00	1.05E+04	0.00E+00	4.67E+03

*Includes ^{240}Pu contribution

**Includes ^{244}Cm contribution

(1) UOTH 83-58, Calculation 88-002-00-F, ZZ-48, ZZ-57, ZZ-78, HPCI 8902, HPCI 0406, HPCI 1604, HPCI 1802.

Table 2: Bioaccumulation Factor (Bf_i) [a]

(pCi/kg) per (pCi/liter)

Element	Bf_i Fish (Freshwater)	Element	Bf_i Fish (Freshwater)
H	9.0 E - 01	Rh	1.0 E + 01
Be	2.0 E + 00	Ag	2.3 E + 00
Na	1.0 E + 02	Cd	2.0 E + 02
Cr	2.0 E + 02	Sn	3.0 E + 03
Mn	4.0 E + 02	Sb	1.0 E + 00
Fe	1.0 E + 02	Te	4.0 E + 02
Co	5.0 E + 01	I	1.5 E + 01
Ni	1.0 E + 02	Cs	2.0 E + 03
Cu	5.0 E + 01	Ba	4.0 E + 00
Zn	2.0 E + 03	La	2.5 E + 01
Br	4.2 E + 02	Ce	1.0 E + 00
Rb	2.0 E + 03	Pr	2.5 E + 01
Sr	3.0 E + 01	Nd	2.5 E + 01
Y	2.5 E + 01	Eu	2.5 E + 01
Zr	3.3 E + 00	Hf	3.3 E + 00
Nb	3.0 E + 04	W	1.2 E + 03
Mo	1.0 E + 01	Np	1.0 E + 01
Tc	1.5 E + 01	Pu	3.5 E + 00
Ru	1.0 E + 01	Am	2.5 E + 01
		Cm	2.5 E + 01

[a] Values from Regulatory Guide 1.109, Rev. 1, Table A-1 and HPCI 0406.

Table 3: Dose Factor for Exposure to a Semi- Infinite Cloud of Noble Gases

Radionuclide	Total Body Dose Factor K_i (mrem/yr) per (μCi/m³)	Skin Dose Factor L_i (mrem/yr) per (μCi/m³)	Gamma Air Dose Factor M_i (mrad/yr) per (μCi/m³)	Beta Air Dose Factor Ni (mrad/yr) per (μCi/m³)
^{83m}Kr	7.56 E-02	-----	1.93 E+01	2.88 E+02
^{85m}Kr	1.17E+03	1.46E+03	1.23 E+03	1.97 E+03
^{85}Kr	1.61 E+01	1.34 E+03	1.72 E+01	1.95 E+03
^{87}Kr	5.92 E+03	9.73 E+03	6.17 E+03	1.03 E+04
^{88}Kr	1.47 E+04	2.37 E+03	1.52 E+04	2.93 E+03
^{89}Kr	1.66 E+04	1.01 E+04	1.73 E+04	1.06 E+04
^{90}Kr	1.56 E+04	7.29 E+03	1.63 E+04	7.83 E+03
^{131m}Xe	9.15 E+01	4.76 E+02	1.56 E+02	1.11 E+03
^{133m}Xe	2.51 E+02	9.94 E+02	3.27 E+02	1.48 E+03
^{133}Xe	2.94 E+02	3.06 E+02	3.53 E+02	1.05 E+03
^{135m}Xe	3.12 E+03	7.11 E+02	3.36 E+03	7.39 E+02
^{135}Xe	1.81 E+03	1.86 E+03	1.92 E+03	2.46 E+03
^{137}Xe	1.42 E+03	1.22 E+04	1.51 E+03	1.27 E+04
^{138}Xe	8.83 E+03	4.13 E+03	9.21 E+03	4.75 E+03
^{41}Ar	8.84 E+03	2.69 E+03	9.30 E+03	3.28 E+03

Table 4: Ground Plane Pathway Dose Factors (R_i)

(m^2mrem/yr) per (µCi/sec)

Nuclide	Total Body	Skin	Nuclide	Total Body	Skin
^{3}H	0.00E+00	0.00E+00	^{113}Sn	1.43E+07	4.09E+07
^{7}Be	2.24E+07	3.21E+07	^{124}Sb	8.74E+08	1.23E+09
^{51}Cr	4.66E+06	5.51E+06	^{125}Sb	3.57E+09	5.19E+09
^{54}Mn	1.39E+09	1.63E+09	^{127m}Te	9.17E+04	1.08E+05
^{55}Fe	0.00E+00	0.00E+00	^{129m}Te	1.98E+07	2.31E+07
^{59}Fe	2.73E+08	3.21E+08	^{130}I	5.51E+06	6.69E+06
^{57}Co	2.98E+08	4.37E+08	^{131}I	1.72E+07	2.09E+07
^{58}Co	3.79E+08	4.44E+08	^{132}I	1.25E+06	1.47E+06
^{60}Co	2.15E+10	2.53E+10	^{133}I	2.45E+06	2.98E+06
^{63}Ni	0.00E+00	0.00E+00	^{134}I	4.47E+05	5.31E+05
^{65}Zn	7.47E+08	8.59E+08	^{135}I	2.53E+06	2.95E+06
^{86}Rb	8.99E+06	1.03E+07	^{134}Cs	6.85E+09	8.00E+09
^{89}Sr	2.16E+04	2.51E+04	^{136}Cs	1.51E+08	1.71E+08
^{90}Sr	0.00E+00	0.00E+00	^{137}Cs	1.03E+10	1.20E+10
^{90}Y	5.36E+06	6.32E+06	^{140}Ba	2.05E+07	2.35E+07
^{91}Y	1.07E+06	1.21E+06	^{140}La	1.47E+08	1.66E+08
^{95}Zr	2.45E+08	2.84E+08	^{141}Ce	1.37E+07	1.54E+07
^{95}Nb	2.50E+08	2.94E+08	^{144}Ce	6.96E+07	8.04E+07
^{103}Ru	1.08E+08	1.26E+08	^{143}Pr	0.00E+00	0.00E+00
^{106}Ru	4.22E+08	5.07E+08	^{144}Pr	4.35E+07	5.00E+07
^{110m}Ag	3.44E+09	4.01E+09	^{147}Nd	8.39E+06	1.01E+07
^{109}Cd	3.76E+07	1.54E+08	^{154}Eu	2.21E+10	3.15E+10
			^{181}Hf	1.97E+08	2.82E+08

Table 5: Child Inhalation Pathway Dose Factors (R_i)

(mrem/yr) per (µCi/m³)

Nuclide	Bone	Liver	Total Body	Thyroid	Kidney	Lung	GI-LLI
^{3}H	0.00E+00	1.12E+03	1.12E+03	1.12E+03	1.12E+03	1.12E+03	1.12E+03
^{7}Be	8.47E+02	1.44E+03	9.25E+02	0.00E+00	0.00E+00	6.47E+04	2.55E+03
^{51}Cr	0.00E+00	0.00E+00	1.54E+02	8.55E+01	2.43E+01	1.70E+04	1.08E+03
^{54}Mn	0.00E+00	4.29E+04	9.51E+03	0.00E+00	1.00E+04	1.58E+06	2.29E+04
^{55}Fe	4.74E+04	2.52E+04	7.77E+03	0.00E+00	0.00E+00	1.11E+05	2.87E+03
^{59}Fe	2.07E+04	3.34E+04	1.67E+04	0.00E+00	0.00E+00	1.27E+06	7.07E+04
^{57}Co	0.00E+00	9.03E+02	1.07E+03	0.00E+00	0.00E+00	5.07E+05	1.32E+04
^{58}Co	0.00E+00	1.77E+03	3.16E+03	0.00E+00	0.00E+00	1.11E+06	3.44E+04
^{60}Co	0.00E+00	1.31E+04	2.26E+04	0.00E+00	0.00E+00	7.07E+06	9.62E+04
^{63}Ni	8.21E+05	4.63E+04	2.80E+04	0.00E+00	0.00E+00	2.75E+05	6.33E+03
^{65}Zn	4.25E+04	1.13E+05	7.03E+04	0.00E+00	7.14E+04	9.95E+05	1.63E+04
^{86}Rb	0.00E+00	1.98E+05	1.14E+05	0.00E+00	0.00E+00	0.00E+00	7.99E+03
^{89}Sr	5.99E+05	0.00E+00	1.72E+04	0.00E+00	0.00E+00	2.16E+06	1.67E+05
^{90}Sr	1.01E+08	0.00E+00	6.44E+06	0.00E+00	0.00E+00	1.48E+07	3.43E+05
^{90}Y	4.11E+03	0.00E+00	1.11E+02	0.00E+00	0.00E+00	2.62E+05	2.68E+05
^{91}Y	9.14E+05	0.00E+00	2.44E+04	0.00E+00	0.00E+00	2.63E+06	1.84E+05
^{95}Zr	1.90E+05	4.18E+04	3.70E+04	0.00E+00	5.96E+04	2.23E+06	6.11E+04
^{95}Nb	2.35E+04	9.18E+03	6.55E+03	0.00E+00	8.62E+03	6.14E+05	3.70E+04
^{103}Ru	2.79E+03	0.00E+00	1.07E+03	0.00E+00	7.03E+03	6.62E+05	4.48E+04
^{106}Ru	1.36E+05	0.00E+00	1.69E+04	0.00E+00	1.84E+05	1.43E+07	4.29E+05
^{110m}Ag	1.69E+04	1.14E+04	9.14E+03	0.00E+00	2.12E+04	5.48E+06	1.00E+05
^{109}Cd	0.00E+00	5.48E+05	2.59E+04	0.00E+00	4.96E+05	1.05E+06	2.78E+04
^{113}Sn	1.13E+05	3.12E+03	8.62E+03	2.33E+03	0.00E+00	1.46E+06	2.26E+05
^{124}Sb	5.74E+04	7.40E+02	2.00E+04	1.26E+02	0.00E+00	3.24E+06	1.64E+05
^{125}Sb	9.84E+04	7.59E+02	2.07E+04	9.10E+01	0.00E+00	2.32E+06	4.03E+04
^{127m}Te	2.49E+04	8.55E+03	3.02E+03	6.07E+03	6.36E+04	1.48E+06	7.14E+04
^{129m}Te	1.92E+04	6.85E+03	3.04E+03	6.33E+03	5.03E+04	1.76E+06	1.82E+05

Table 5: Child Inhalation Pathway Dose Factors (R_i)

(mrem/yr) per (µCi/m^3)

Nuclide	Bone	Liver	Total Body	Thyroid	Kidney	Lung	GI-LLI
^{130}I	8.18E+03	1.64E+04	8.44E+03	1.85E+06	2.45E+04	0.00E+00	5.11E+03
^{131}I	4.81E+04	4.81E+04	2.73E+04	1.62E+07	7.88E+04	0.00E+00	2.84E+03
^{132}I	2.12E+03	4.07E+03	1.88E+03	1.94E+05	6.25E+03	0.00E+00	3.20E+03
^{133}I	1.66E+04	2.03E+04	7.70E+03	3.85E+06	3.38E+04	0.00E+00	5.48E+03
^{134}I	1.17E+03	2.16E+03	9.95E+02	5.07E+04	3.30E+03	0.00E+00	9.55E+02
^{135}I	4.92E+03	8.73E+03	4.14E+03	7.92E+05	1.34E+04	0.00E+00	4.44E+03
^{134}Cs	6.51E+05	1.01E+06	2.25E+05	0.00E+00	3.30E+05	1.21E+05	3.85E+03
^{136}Cs	6.51E+04	1.71E+05	1.16E+05	0.00E+00	9.55E+04	1.45E+04	4.18E+03
^{137}Cs	9.07E+05	8.25E+05	1.28E+05	0.00E+00	2.82E+05	1.04E+05	3.62E+03
^{140}Ba	7.40E+04	6.48E+01	4.33E+03	0.00E+00	2.11E+01	1.74E+06	1.02E+05
^{140}La	6.44E+02	2.25E+02	7.55E+01	0.00E+00	0.00E+00	1.83E+05	2.26E+05
^{141}Ce	3.92E+04	1.95E+04	2.90E+03	0.00E+00	8.55E+03	5.44E+05	5.66E+04
^{144}Ce	6.77E+06	2.12E+06	3.61E+05	0.00E+00	1.17E+06	1.20E+07	3.89E+05
^{143}Pr	1.85E+04	5.55E+03	9.14E+02	0.00E+00	3.00E+03	4.33E+05	9.73E+04
^{144}Pr	5.96E-02	1.85E-02	3.00E-03	0.00E+00	9.77E-03	1.57E+03	1.97E+02
^{147}Nd	1.08E+04	8.73E+03	6.81E+02	0.00E+00	4.81E+03	3.28E+05	8.21E+04
^{154}Eu	1.01E+07	9.21E+05	8.40E+05	0.00E+00	4.03E+06	6.14E+06	1.10E+05
^{181}Hf	2.78E+04	1.01E+05	1.25E+04	0.00E+00	2.05E+04	1.06E+06	6.62E+04

Table 6: Child Grass- Cow – Milk Pathway Dose Factors (R_i)

(m^2mrem/yr) per (µCi/sec)

Nuclide	Bone	Liver	Total Body	Thyroid	Kidney	Lung	GI-LLI
^{3}H	0.00E+00	1.57E+03	1.57E+03	1.57E+03	1.57E+03	1.57E+03	1.57E+03
^{7}Be	7.50E+03	1.28E+04	8.20E+03	0.00E+00	1.25E+04	0.00E+00	7.12E+05
^{51}Cr	0.00E+00	0.00E+00	1.02E+05	5.66E+04	1.55E+04	1.03E+05	5.40E+06
^{54}Mn	0.00E+00	2.10E+07	5.59E+06	0.00E+00	5.89E+06	0.00E+00	1.76E+07
^{55}Fe	1.12E+08	5.94E+07	1.84E+07	0.00E+00	0.00E+00	3.36E+07	1.10E+07
^{59}Fe	1.20E+08	1.95E+08	9.70E+07	0.00E+00	0.00E+00	5.64E+07	2.03E+08
^{57}Co	0.00E+00	3.84E+06	7.78E+06	0.00E+00	0.00E+00	0.00E+00	3.15E+07
^{58}Co	0.00E+00	1.21E+07	3.72E+07	0.00E+00	0.00E+00	0.00E+00	7.08E+07
^{60}Co	0.00E+00	4.32E+07	1.27E+08	0.00E+00	0.00E+00	0.00E+00	2.39E+08
^{63}Ni	2.97E+10	1.59E+09	1.01E+09	0.00E+00	0.00E+00	0.00E+00	1.07E+08
^{65}Zn	4.14E+09	1.10E+10	6.86E+09	0.00E+00	6.95E+09	0.00E+00	1.94E+09
^{86}Rb	0.00E+00	8.78E+09	5.40E+09	0.00E+00	0.00E+00	0.00E+00	5.65E+08
^{89}Sr	6.63E+09	0.00E+00	1.89E+08	0.00E+00	0.00E+00	0.00E+00	2.57E+08
^{90}Sr	1.12E+11	0.00E+00	2.84E+10	0.00E+00	0.00E+00	0.00E+00	1.51E+09
^{90}Y	3.38E+03	0.00E+00	9.05E+01	0.00E+00	0.00E+00	0.00E+00	9.62E+06
^{91}Y	3.91E+04	0.00E+00	1.04E+03	0.00E+00	0.00E+00	0.00E+00	5.20E+06
^{95}Zr	3.84E+03	8.43E+02	7.51E+02	0.00E+00	1.21E+03	0.00E+00	8.80E+05
^{95}Nb	3.72E+05	1.45E+05	1.03E+05	0.00E+00	1.36E+05	0.00E+00	2.68E+08
^{103}Ru	4.29E+03	0.00E+00	1.65E+03	0.00E+00	1.08E+04	0.00E+00	1.11E+05
^{106}Ru	9.25E+04	0.00E+00	1.15E+04	0.00E+00	1.25E+05	0.00E+00	1.44E+06
^{110m}Ag	2.09E+08	1.41E+08	1.13E+08	0.00E+00	2.63E+08	0.00E+00	1.68E+10
^{109}Cd	0.00E+00	3.86E+06	1.79E+05	0.00E+00	3.45E+06	0.00E+00	1.25E+07
^{113}Sn	6.11E+08	1.26E+07	3.48E+07	9.29E+08	0.00E+00	0.00E+00	4.32E+08
^{124}Sb	1.09E+08	1.41E+06	3.81E+07	2.40E+05	0.00E+00	6.03E+07	6.80E+08
^{125}Sb	8.71E+07	6.72E+05	1.83E+07	8.07E+04	0.00E+00	4.86E+07	2.08E+08
^{127m}Te	2.08E+08	5.61E+07	2.47E+07	4.98E+07	5.94E+08	0.00E+00	1.69E+08
^{129m}Te	2.72E+08	7.59E+07	4.22E+07	8.76E+07	7.98E+08	0.00E+00	3.31E+08

Table 6: Child Grass- Cow – Milk Pathway Dose Factors (R_i)

(m^2mrem/yr) per (µCi/sec)

Nuclide	Bone	Liver	Total Body	Thyroid	Kidney	Lung	GI-LLI
^{130}I	1.73E+06	3.50E+06	1.80E+06	3.85E+08	5.23E+06	0.00E+00	1.64E+06
^{131}I	1.30E+09	1.31E+09	7.46E+08	4.34E+11	2.15E+09	0.00E+00	1.17E+08
^{132}I	6.92E-01	1.27E+00	5.85E-01	5.90E+01	1.95E+00	0.00E+00	1.50E+00
^{133}I	1.72E+07	2.13E+07	8.05E+06	3.95E+09	3.54E+07	0.00E+00	8.57E+06
^{134}I	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
^{135}I	5.41E+04	9.74E+04	4.61E+04	8.63E+06	1.49E+05	0.00E+00	7.42E+04
^{134}Cs	2.27E+10	3.72E+10	7.84E+09	0.00E+00	1.15E+10	4.14E+09	2.00E+08
^{136}Cs	1.01E+09	2.78E+09	1.80E+09	0.00E+00	1.48E+09	2.21E+08	9.78E+07
^{137}Cs	3.23E+10	3.09E+10	4.56E+09	0.00E+00	1.01E+10	3.62E+09	1.93E+08
^{140}Ba	1.17E+08	1.03E+05	6.84E+06	0.00E+00	3.34E+04	6.12E+04	5.94E+07
^{140}La	1.78E+02	6.23E+01	2.10E+01	0.00E+00	0.00E+00	0.00E+00	1.74E+06
^{141}Ce	2.19E+04	1.09E+04	1.62E+03	0.00E+00	4.79E+03	0.00E+00	1.36E+07
^{144}Ce	1.62E+06	5.09E+05	8.67E+04	0.00E+00	2.82E+05	0.00E+00	1.33E+08
^{143}Pr	7.19E+02	2.16E+02	3.57E+01	0.00E+00	1.17E+02	0.00E+00	7.76E+05
^{144}Pr	5.04E+00	1.56E+00	2.53E-01	0.00E+00	8.24E-01	0.00E+00	3.35E+03
^{147}Nd	4.45E+02	3.61E+02	2.79E+01	0.00E+00	1.98E+02	0.00E+00	5.71E+05
^{154}Eu	9.43E+04	8.48E+03	7.75E+03	0.00E+00	3.73E+04	0.00E+00	1.97E+06
^{181}Hf	6.44E+02	2.35E+03	2.91E+02	0.00E+00	4.76E+02	0.00E+00	8.66E+05

Table 7: Child Grass- Goat – Milk Pathway Dose Factors (R_i)

(m^2mrem/yr) per (µCi/sec)

Nuclide	Bone	Liver	Total Body	Thyroid	Kidney	Lung	GI-LLI
^{3}H	0.00E+00	3.20E+03	3.20E+03	3.20E+03	3.20E+03	3.20E+03	3.20E+03
^{7}Be	9.00E+02	1.53E+03	9.84E+02	0.00E+00	1.50E+03	0.00E+00	8.55E+04
^{51}Cr	0.00E+00	0.00E+00	1.22E+04	6.79E+03	1.85E+03	1.24E+04	6.48E+05
^{54}Mn	0.00E+00	2.52E+06	6.71E+05	0.00E+00	7.06E+05	0.00E+00	2.11E+06
^{55}Fe	1.45E+06	7.72E+05	2.39E+05	0.00E+00	0.00E+00	4.36E+05	1.43E+05
^{59}Fe	1.56E+06	2.53E+06	1.26E+06	0.00E+00	0.00E+00	7.34E+05	2.64E+06
^{57}Co	0.00E+00	4.61E+05	9.33E+05	0.00E+00	0.00E+00	0.00E+00	3.78E+06
^{58}Co	0.00E+00	1.46E+06	4.46E+06	0.00E+00	0.00E+00	0.00E+00	8.50E+06
^{60}Co	0.00E+00	5.19E+06	1.53E+07	0.00E+00	0.00E+00	0.00E+00	2.87E+07
^{63}Ni	3.56E+09	1.91E+08	1.21E+08	0.00E+00	0.00E+00	0.00E+00	1.28E+07
^{65}Zn	4.97E+08	1.32E+09	8.23E+08	0.00E+00	8.34E+08	0.00E+00	2.32E+08
^{86}Rb	0.00E+00	1.05E+09	6.48E+08	0.00E+00	0.00E+00	0.00E+00	6.78E+07
^{89}Sr	1.39E+10	0.00E+00	3.97E+08	0.00E+00	0.00E+00	0.00E+00	5.39E+08
^{90}Sr	2.35E+11	0.00E+00	5.95E+10	0.00E+00	0.00E+00	0.00E+00	3.16E+09
^{90}Y	4.06E+02	0.00E+00	1.09E+01	0.00E+00	0.00E+00	0.00E+00	1.15E+06
^{91}Y	4.69E+03	0.00E+00	1.25E+02	0.00E+00	0.00E+00	0.00E+00	6.25E+05
^{95}Zr	4.60E+02	1.01E+02	9.01E+01	0.00E+00	1.45E+02	0.00E+00	1.06E+05
^{95}Nb	4.46E+04	1.74E+04	1.24E+04	0.00E+00	1.63E+04	0.00E+00	3.21E+07
^{103}Ru	5.14E+02	0.00E+00	1.98E+02	0.00E+00	1.29E+03	0.00E+00	1.33E+04
^{106}Ru	1.11E+04	0.00E+00	1.38E+03	0.00E+00	1.50E+04	0.00E+00	1.73E+05
^{110m}Ag	2.51E+07	1.69E+07	1.35E+07	0.00E+00	3.15E+07	0.00E+00	2.01E+09
^{109}Cd	0.00E+00	4.64E+05	2.15E+04	0.00E+00	4.14E+05	0.00E+00	1.50E+06
^{113}Sn	7.33E+07	1.51E+06	4.18E+06	1.11E+08	0.00E+00	0.00E+00	5.18E+07
^{124}Sb	1.30E+07	1.69E+05	4.57E+06	2.88E+04	0.00E+00	7.24E+06	8.16E+07
^{125}Sb	1.05E+07	8.06E+04	2.19E+06	9.68E+03	0.00E+00	5.83E+06	2.50E+07
^{127m}Te	2.50E+07	6.73E+06	2.97E+06	5.98E+06	7.13E+07	0.00E+00	2.02E+07
^{129m}Te	3.26E+07	9.10E+06	5.06E+06	1.05E+07	9.57E+07	0.00E+00	3.98E+07

Table 7: Child Grass- Goat – Milk Pathway Dose Factors (R_i)

(m^2mrem/yr) per (µCi/sec)

Nuclide	Bone	Liver	Total Body	Thyroid	Kidney	Lung	GI-LLI
^{130}I	2.08E+06	4.20E+06	2.16E+06	4.62E+08	6.27E+06	0.00E+00	1.96E+06
^{131}I	1.57E+09	1.57E+09	8.95E+08	5.21E+11	2.58E+09	0.00E+00	1.40E+08
^{132}I	8.30E-01	1.53E+00	7.02E-01	7.08E+01	2.34E+00	0.00E+00	1.80E+00
^{133}I	2.06E+07	2.55E+07	9.66E+06	4.74E+09	4.25E+07	0.00E+00	1.03E+07
^{134}I	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
^{135}I	6.49E+04	1.17E+05	5.53E+04	1.04E+07	1.79E+05	0.00E+00	8.90E+04
^{134}Cs	6.80E+10	1.12E+11	2.35E+10	0.00E+00	3.46E+10	1.24E+10	6.01E+08
^{136}Cs	3.04E+09	8.35E+09	5.40E+09	0.00E+00	4.45E+09	6.63E+08	2.93E+08
^{137}Cs	9.68E+10	9.27E+10	1.37E+10	0.00E+00	3.02E+10	1.09E+10	5.80E+08
^{140}Ba	1.41E+07	1.23E+04	8.21E+05	0.00E+00	4.01E+03	7.35E+03	7.13E+06
^{140}La	2.14E+01	7.47E+00	2.52E+00	0.00E+00	0.00E+00	0.00E+00	2.08E+05
^{141}Ce	2.63E+03	1.31E+03	1.95E+02	0.00E+00	5.75E+02	0.00E+00	1.63E+06
^{144}Ce	1.95E+05	6.11E+04	1.04E+04	0.00E+00	3.38E+04	0.00E+00	1.59E+07
^{143}Pr	8.63E+01	2.59E+01	4.28E+00	0.00E+00	1.40E+01	0.00E+00	9.31E+04
^{144}Pr	6.05E-01	1.87E-01	3.04E-02	0.00E+00	9.89E-02	0.00E+00	4.03E+02
^{147}Nd	5.34E+01	4.33E+01	3.35E+00	0.00E+00	2.37E+01	0.00E+00	6.85E+04
^{154}Eu	1.13E+04	1.02E+03	9.29E+02	0.00E+00	4.47E+03	0.00E+00	2.37E+05
^{181}Hf	7.73E+01	2.81E+02	3.49E+01	0.00E+00	5.72E+01	0.00E+00	1.04E+05

Table 8: Child Meat Pathway Dose Factors (R_i)

(m^2mrem/yr) per (μCi/sec)

Nuclide	Bone	Liver	Total Body	Thyroid	Kidney	Lung	GI-LLI
^{3}H	0.00E+00	2.34E+02	2.34E+02	2.34E+02	2.34E+02	2.34E+02	2.34E+02
^{7}Be	7.38E+03	1.26E+04	8.07E+03	0.00E+00	1.23E+04	0.00E+00	7.00E+05
^{51}Cr	0.00E+00	0.00E+00	8.80E+03	4.88E+03	1.33E+03	8.92E+03	4.67E+05
^{54}Mn	0.00E+00	8.02E+06	2.14E+06	0.00E+00	2.25E+06	0.00E+00	6.73E+06
^{55}Fe	4.58E+08	2.43E+08	7.52E+07	0.00E+00	0.00E+00	1.37E+08	4.50E+07
^{59}Fe	3.77E+08	6.10E+08	3.04E+08	0.00E+00	0.00E+00	1.77E+08	6.35E+08
^{57}Co	0.00E+00	5.92E+06	1.20E+07	0.00E+00	0.00E+00	0.00E+00	4.85E+07
^{58}Co	0.00E+00	1.64E+07	5.03E+07	0.00E+00	0.00E+00	0.00E+00	9.59E+07
^{60}Co	0.00E+00	6.94E+07	2.05E+08	0.00E+00	0.00E+00	0.00E+00	3.84E+08
^{63}Ni	2.92E+10	1.56E+09	9.92E+08	0.00E+00	0.00E+00	0.00E+00	1.05E+08
^{65}Zn	3.76E+08	1.00E+09	6.23E+08	0.00E+00	6.31E+08	0.00E+00	1.76E+08
^{86}Rb	0.00E+00	5.77E+08	3.55E+08	0.00E+00	0.00E+00	0.00E+00	3.71E+07
^{89}Sr	4.82E+08	0.00E+00	1.38E+07	0.00E+00	0.00E+00	0.00E+00	1.87E+07
^{90}Sr	1.04E+10	0.00E+00	2.64E+09	0.00E+00	0.00E+00	0.00E+00	1.40E+08
^{90}Y	1.93E+05	0.00E+00	5.16E+03	0.00E+00	0.00E+00	0.00E+00	5.49E+08
^{91}Y	1.80E+06	0.00E+00	4.82E+04	0.00E+00	0.00E+00	0.00E+00	2.40E+08
^{95}Zr	2.67E+06	5.86E+05	5.22E+05	0.00E+00	8.39E+05	0.00E+00	6.11E+08
^{95}Nb	4.26E+06	1.66E+06	1.18E+06	0.00E+00	1.56E+06	0.00E+00	3.07E+09
^{103}Ru	1.55E+08	0.00E+00	5.96E+07	0.00E+00	3.90E+08	0.00E+00	4.01E+09
^{106}Ru	4.44E+09	0.00E+00	5.54E+08	0.00E+00	6.00E+09	0.00E+00	6.91E+10
^{110m}Ag	8.40E+06	5.67E+06	4.53E+06	0.00E+00	1.06E+07	0.00E+00	6.75E+08
^{109}Cd	0.00E+00	1.91E+06	8.84E+04	0.00E+00	1.70E+06	0.00E+00	6.18E+06
^{113}Sn	2.18E+09	4.48E+07	1.24E+08	3.31E+09	0.00E+00	0.00E+00	1.54E+09
^{124}Sb	2.93E+07	3.80E+05	1.03E+07	6.46E+04	0.00E+00	1.62E+07	1.83E+08
^{125}Sb	2.85E+07	2.20E+05	5.97E+06	2.64E+04	0.00E+00	1.59E+07	6.81E+07
^{127m}Te	1.78E+09	4.78E+08	2.11E+08	4.25E+08	5.07E+09	0.00E+00	1.44E+09
^{129m}Te	1.79E+09	5.00E+08	2.78E+08	5.78E+08	5.26E+09	0.00E+00	2.19E+09

Table 8: Child Meat Pathway Dose Factors (R_i)

(m^2mrem/yr) per (μCi/sec)

Nuclide	Bone	Liver	Total Body	Thyroid	Kidney	Lung	GI-LLI
^{130}I	3.06E-06	6.18E-06	3.18E-06	6.80E-04	9.23E-06	0.00E+00	2.89E-06
^{131}I	1.66E+07	1.67E+07	9.47E+06	5.51E+09	2.74E+07	0.00E+00	1.48E+06
^{132}I	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
^{133}I	5.70E-01	7.05E-01	2.67E-01	1.31E+02	1.17E+00	0.00E+00	2.84E-01
^{134}I	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
^{135}I	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
^{134}Cs	9.23E+08	1.51E+09	3.20E+08	0.00E+00	4.69E+08	1.68E+08	8.17E+06
^{136}Cs	1.62E+07	4.46E+07	2.89E+07	0.00E+00	2.38E+07	3.54E+06	1.57E+06
^{137}Cs	1.33E+09	1.28E+09	1.89E+08	0.00E+00	4.16E+08	1.50E+08	8.00E+06
^{140}Ba	4.39E+07	3.85E+04	2.56E+06	0.00E+00	1.25E+04	2.29E+04	2.22E+07
^{140}La	3.33E+02	1.17E+02	3.93E+01	0.00E+00	0.00E+00	0.00E+00	3.25E+06
^{141}Ce	2.22E+04	1.11E+04	1.65E+03	0.00E+00	4.86E+03	0.00E+00	1.38E+07
^{144}Ce	2.32E+06	7.27E+05	1.24E+05	0.00E+00	4.02E+05	0.00E+00	1.89E+08
^{143}Pr	3.34E+04	1.00E+04	1.66E+03	0.00E+00	5.43E+03	0.00E+00	3.61E+07
^{144}Pr	5.63E+02	1.74E+02	2.83E+01	0.00E+00	9.21E+01	0.00E+00	3.75E+05
^{147}Nd	1.17E+04	9.48E+03	7.34E+02	0.00E+00	5.20E+03	0.00E+00	1.50E+07
^{154}Eu	1.12E+07	1.01E+06	9.20E+05	0.00E+00	4.43E+06	0.00E+00	2.34E+08
^{181}Hf	4.77E+06	1.74E+07	2.15E+06	0.00E+00	3.53E+06	0.00E+00	6.41E+09

Table 9: Child Vegetation Pathway Dose Factors (R_i)

(m^2mrem/yr) per (µCi/sec)

Nuclide	Bone	Liver	Total Body	Thyroid	Kidney	Lung	GI-LLI
^{3}H	0.00E+00	4.01E+03	4.01E+03	4.01E+03	4.01E+03	4.01E+03	4.01E+03
^{7}Be	3.38E+05	5.76E+05	3.70E+05	0.00E+00	5.65E+05	0.00E+00	3.21E+07
^{51}Cr	0.00E+00	0.00E+00	1.17E+05	6.50E+04	1.78E+04	1.19E+05	6.21E+06
^{54}Mn	0.00E+00	6.65E+08	1.77E+08	0.00E+00	1.86E+08	0.00E+00	5.58E+08
^{55}Fe	8.01E+08	4.25E+08	1.32E+08	0.00E+00	0.00E+00	2.40E+08	7.87E+07
^{59}Fe	3.98E+08	6.43E+08	3.20E+08	0.00E+00	0.00E+00	1.87E+08	6.70E+08
^{57}Co	0.00E+00	2.99E+07	6.04E+07	0.00E+00	0.00E+00	0.00E+00	2.45E+08
^{58}Co	0.00E+00	6.44E+07	1.97E+08	0.00E+00	0.00E+00	0.00E+00	3.76E+08
^{60}Co	0.00E+00	3.78E+08	1.12E+09	0.00E+00	0.00E+00	0.00E+00	2.10E+09
^{63}Ni	3.95E+10	2.11E+09	1.34E+09	0.00E+00	0.00E+00	0.00E+00	1.42E+08
^{65}Zn	8.13E+08	2.17E+09	1.35E+09	0.00E+00	1.36E+09	0.00E+00	3.80E+08
^{86}Rb	0.00E+00	4.52E+08	2.78E+08	0.00E+00	0.00E+00	0.00E+00	2.91E+07
^{89}Sr	3.60E+10	0.00E+00	1.03E+09	0.00E+00	0.00E+00	0.00E+00	1.39E+09
^{90}Sr	1.24E+12	0.00E+00	3.15E+11	0.00E+00	0.00E+00	0.00E+00	1.67E+10
^{90}Y	3.01E+06	0.00E+00	8.04E+04	0.00E+00	0.00E+00	0.00E+00	8.56E+09
^{91}Y	1.86E+07	0.00E+00	4.99E+05	0.00E+00	0.00E+00	0.00E+00	2.48E+09
^{95}Zr	3.86E+06	8.48E+05	7.55E+05	0.00E+00	1.21E+06	0.00E+00	8.85E+08
^{95}Nb	7.48E+05	2.91E+05	2.08E+05	0.00E+00	2.74E+05	0.00E+00	5.39E+08
^{103}Ru	1.53E+07	0.00E+00	5.90E+06	0.00E+00	3.86E+07	0.00E+00	3.97E+08
^{106}Ru	7.45E+08	0.00E+00	9.30E+07	0.00E+00	1.01E+09	0.00E+00	1.16E+10
^{110m}Ag	3.21E+07	2.17E+07	1.73E+07	0.00E+00	4.04E+07	0.00E+00	2.58E+09
^{109}Cd	0.00E+00	2.45E+08	1.14E+07	0.00E+00	2.18E+08	0.00E+00	7.94E+08
^{113}Sn	1.58E+09	3.25E+07	9.00E+07	2.40E+09	0.00E+00	0.00E+00	1.12E+09
^{124}Sb	3.52E+08	4.57E+06	1.23E+08	7.77E+05	0.00E+00	1.95E+08	2.20E+09
^{125}Sb	4.99E+08	3.85E+06	1.05E+08	4.63E+05	0.00E+00	2.78E+08	1.19E+09
^{127m}Te	1.32E+09	3.56E+08	1.57E+08	3.16E+08	3.77E+09	0.00E+00	1.07E+09
^{129m}Te	8.41E+08	2.35E+08	1.31E+08	2.71E+08	2.47E+09	0.00E+00	1.03E+09

Table 9: Child Vegetation Pathway Dose Factors (R_i)

(m^2mrem/yr) per (µCi/sec)

Nuclide	Bone	Liver	Total Body	Thyroid	Kidney	Lung	GI-LLI
^{130}I	6.16E+05	1.24E+06	6.41E+05	1.37E+08	1.86E+06	0.00E+00	5.82E+05
^{131}I	1.43E+08	1.44E+08	8.17E+07	4.76E+10	2.36E+08	0.00E+00	1.28E+07
^{132}I	9.23E+01	1.70E+02	7.80E+01	7.87E+03	2.60E+02	0.00E+00	2.00E+02
^{133}I	3.53E+06	4.37E+06	1.65E+06	8.12E+08	7.28E+06	0.00E+00	1.76E+06
^{134}I	1.56E-04	2.89E-04	1.33E-04	6.65E-03	4.42E-04	0.00E+00	1.92E-04
^{135}I	6.26E+04	1.13E+05	5.33E+04	9.98E+06	1.73E+05	0.00E+00	8.59E+04
^{134}Cs	1.60E+10	2.63E+10	5.55E+09	0.00E+00	8.15E+09	2.93E+09	1.42E+08
^{136}Cs	8.24E+07	2.27E+08	1.47E+08	0.00E+00	1.21E+08	1.80E+07	7.96E+06
^{137}Cs	2.39E+10	2.29E+10	3.38E+09	0.00E+00	7.46E+09	2.68E+09	1.43E+08
^{140}Ba	2.77E+08	2.43E+05	1.62E+07	0.00E+00	7.90E+04	1.45E+05	1.40E+08
^{140}La	3.36E+04	1.18E+04	3.96E+03	0.00E+00	0.00E+00	0.00E+00	3.28E+08
^{141}Ce	6.56E+05	3.27E+05	4.86E+04	0.00E+00	1.43E+05	0.00E+00	4.08E+08
^{144}Ce	1.27E+08	3.98E+07	6.78E+06	0.00E+00	2.21E+07	0.00E+00	1.04E+10
^{143}Pr	1.46E+05	4.37E+04	7.23E+03	0.00E+00	2.37E+04	0.00E+00	1.57E+08
^{144}Pr	7.88E+03	2.44E+03	3.97E+02	0.00E+00	1.29E+03	0.00E+00	5.25E+06
^{147}Nd	7.15E+04	5.79E+04	4.48E+03	0.00E+00	3.18E+04	0.00E+00	9.17E+07
^{154}Eu	1.66E+08	1.50E+07	1.37E+07	0.00E+00	6.57E+07	0.00E+00	3.48E+09
^{181}Hf	4.90E+05	1.79E+06	2.21E+05	0.00E+00	3.63E+05	0.00E+00	6.59E+08

Table 10: Highest Annual Average Atmospheric Dispersion Parameters

Location[(b)]	Meteorological Sector	Distance (meters)	X/Q Undecayed/ undepleted (sec/m^3)	X/Q Decayed/ Undepleted (sec/m^3)	X/Q Decayed/ Depleted (sec/m^3)	D/Q (m^{-2})
Site Boundary[64]	SSW	1400	1.8E-6	1.7E-6	1.6E-6	4.5E-9
Nearest Residence[65,66]	NNW	2900	1.1E-6	1.0E-6	9.0E-7	3.0E-9
Farming Areas within the Site Boundary[67,68]	N/A	N/A	1.6E-6	1.6E-6	1.4E-6	5.5E-9

[64] Dispersion parameters from HPCI 1503
[65] Dispersion parameters from HPCI 1504
[66] All ingestion dose pathways are assumed to exist at the location of the nearest resident
[67] Dispersion parameters from HPCI 1502
[68] These values were derived for a narrow scope application. Extreme caution should be exercised when determining their suitability for use in other applications

Table 11: Application of Atmospheric Dispersion Parameters for Release Permits

Dose Pathway	Dispersion Parameter	Controlling Age Group	REC	Controlling Location
Noble Gas, Beta Air & Gamma Air	X/Q, decayed/undepleted (2.26 day half-life)	N/A	16.11.2.2	Site Boundary
Noble Gas, Total Body & Skin	X/Q, decayed/undepleted (2.26 day half-life)	N/A	16.11.2.1	Site Boundary
Inhalation	X/Q, decayed/depleted (8 day half-life)	Child	16.11.2.1 16.11.2.3	Nearest Resident Site Boundary
Ground Plane Deposition	D/Q	N/A	16.11.2.3	Nearest Resident
Ingestion pathways	D/Q*	Child	16.11.2.3	Nearest Resident

*For ^{3}H, X/Q decayed/depleted is used instead of D/Q.[69]

[69] Regulatory Guide 1.109, Appendix C, Section 3.a

Table 12: Application of Atmospheric Dispersion Parameters Annual Radioactive Effluent Release Report				
Dose Pathway	**Dispersion Parameter**	**Controlling Age Group**	**Dispersion Values[70]**	**Controlling Location**
Noble Gas, Beta Air & Gamma Air Dose	X/Q, decayed/undepleted (2.26 day half-life)	N/A	Concurrent	Site Boundary Nearest Resident
Noble Gas, Total Body & Skin Dose	X/Q, decayed/undepleted (2.26 day half-life)	N/A	Concurrent	Site Boundary Nearest Resident
			Historical	Inside Site Boundary
Ground Plane Deposition Dose	D/Q	N/A	Concurrent	Site Boundary Nearest Resident
			Historical	Inside Site Boundary
Inhalation Dose	X/Q, decayed/depleted (8 day half-life)	Child	Concurrent	Site Boundary Nearest Resident
		Adult	Concurrent	Nearest Residence
			Historical	Inside Site Boundary
Ingestion Dose Pathways	D/Q (For H^3, X/Q, decayed/depleted is used instead of D/Q.)[71]	Child	Concurrent	Site Boundary Nearest Resident
^{14}C All Dose Pathways[72]	X/Q, undecayed/undepleted	Child	Concurrent	Nearest Resident
		Adult	Historical	Inside Site Boundary

[70] Historical, i.e., 5 year average, dispersion parameters for activities inside the Site Boundary are provided in Table 10.
[71] Regulatory Guide 1.109, Appendix C, Section 3.a
[72] See Appendix A

Table 13: Meteorological Data Selection Hierarchy

Parameter	Primary	First Alternate	Second Alternate	Third Alternate
Wind Speed	10m A	10m B	60m A	60m B
Wind Direction	10m A	10m B	60m A	60m B
Air Temperature	10m A	10m B		
Wind Variability	10m A	10m B	60m A	60m B
Temp Difference	60-10m A	60-10m B		
Dew point/Relative Humidity	10m A	60m B		
Precipitation	1m			

(a) 'A' indicates Alpha train meteorological instrumentation.

(b) 'B' indicates Bravo train meteorological instrumentation.

Appendix A: Methodology for Calculating Dose from ^{14}C in Gaseous Effluents

1) Introduction

The purpose of this Appendix is to provide methodology and parameters for calculating (1) the quantity of ^{14}C released in gaseous effluents, (2) the dose to the Member of the Public at the nearest receptor location due to ^{14}C released in gaseous effluents, and (3) the dose from ^{14}C released in gaseous effluents to the Member of the Public due to activities within the Site Boundary.

The quantity of ^{14}C discharged can be estimated[73] by sample measurements, or by use of a normalized ^{14}C source term and scaling factors based on power generation,[74] or by use of the GALE code,[75] or by use of the EPRI site specific or proxy methodologies.[76] *Any of these methodologies is acceptable for estimating the ^{14}C discharged in gaseous effluents.*

2) Assumptions

a. The total quantity of ^{14}C produced during the year is assumed to be released during the year in which it was produced.

b. The quantity of ^{14}C produced is determined using the methodology in EPRI TR-1021106.

c. For conservatism, it is assumed that all ^{14}C produced is released in gaseous effluents.

d. The dose contribution of ^{14}C from liquid effluents is much less than that contributed by gaseous effluents, therefore evaluation of ^{14}C in liquid effluents is not required.[77]

e. The dose to the Member of the Public is determined in accordance with the methodology and parameters in Regulatory Guide 1.109.

f. ^{14}C has a long half- life with respect to the plume transit time. ^{14}C is discharged as CH_4 or CO_2 gas and does not deplete or undergo chemical change before it reaches the receptor location. Therefore the appropriate dispersion parameter is X/Q (undecayed and undepleted).

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[73] Regulatory Guide 1.21, rev. 2, Section 1.9
[74] NCRP Report 81
[75] NUREG- 0017
[76] EPRI TR-1021106, Section 4
[77] Regulatory Guide 1.21, rev. 2, Section 1.9

g. The inhalation pathway is assumed to exist at the Nearest Residence location with the highest value of X/Q, undecayed/ undepleted as determined by the annual Land Use Census.

h. The ingestion pathways are assumed to exist at the nearest receptor location with the highest value of X/Q, undecayed/ undepleted as determined by the annual Land Use Census. For conservatism, the Nearest Residence location may be considered the highest nearest receptor location for the ingestion pathways.

i. The appropriate dispersion parameters for activities within the Site Boundary is provided in Table 10.

j. ^{14}C is not a gamma- emitting nuclide; therefore the ground plane pathway is negligible.

k. As a first approximation, it is assumed that the child age group exists at the Nearest Residence and ingestion pathway locations.

l. Only $^{14}CO_2$ discharged during periods of photosynthesis is considered for the ingestion pathways.

m. All of the ^{14}C produced is assumed to contribute to the inhalation dose pathway, regardless of chemical form.

3) Applicable Dose Limits

10 CFR 50, Appendix I, states, "The calculated annual total quantity of all radioactive iodine and radioactive material in particulate form above background to be released from each light-water-cooled nuclear power reactor in effluents to the atmosphere will not result in an estimated annual dose or dose commitment from such *radioactive iodine and radioactive material in particulate form* for any individual in an unrestricted area from all pathways of exposure in excess of 15 millirems to any organ."[78] Radiological Effluent Control (REC) 16.11.2.3 limits the annual dose to the Member of the Public from *^{131}I, ^{133}I, ^{3}H, and particulates* with half-lives greater than 8 days released in gaseous effluents to 15 mrem to any organ.[79] ^{14}C is released as a gas in the form of CH_4 or CO_2 and is not a radioiodine, tritium, or particulate, therefore the design objectives in 10 CFR 50, Appendix I and the limits of REC 16.11.2.3 do not apply to ^{14}C.

10 CFR 20.1301(a)(1) limits the annual TEDE dose to the Member of the Public to 100 mrem.

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[78] 10 CFR 50, Appendix I, section II, paragraph C
[79] NUREG-1301, REC 3.11.2.3

40 CFR 190.10(a) limits the total annual dose from the uranium fuel cycle to the Member of the Public to 25 mrem to the whole body or any organ. 40 CFR 190 is implemented by REC 16.11.3.1. This limit includes dose from the release of gaseous effluents to areas at or beyond the Site Boundary, the dose from gaseous effluents due to activities within the Site Boundary, and the dose from direct radiation. The methodology for calculating the total annual dose from the uranium fuel cycle is provided in Section 4.

10 CFR 72.104 requires that the annual dose equivalent to any real individual who is located beyond the controlled area must not exceed 25 mrem to the whole body, 75 mrem to the thyroid and 25 mrem to any other critical organ as a result of exposure to planned discharges of radioactive materials and direct radiation from Independent Spent Fuel Storage Installation (ISFSI) operations. There are no radioactive effluents from the ISFSI. The HI-STORM UMAX Canister Storage System does not create any radioactive materials or have any radioactive waste treatment systems. COC Specification 3.1.1, "Multi-Purpose Canister (MPC)", provides assurance that there are no radioactive effluents from the ISFSI.[80] ^{14}C is a weak beta emitter and does not contribute to direct radiation dose.

4) Estimation of ^{14}C in Gaseous Effluents

^{14}C exists in all PWR systems, and any location or system that contains tritium most likely also will contain ^{14}C in some chemical form. Measurements of ^{14}C concentrations in various liquid systems have been performed, and some of the reported data are included in EPRI TR-1021106.[81] As a general rule, ^{14}C in the primary coolant is essentially all organic with a significant fraction as a gaseous species. If the RCS liquid or gas is exposed to an oxidizing environment, such as during the forced oxidation during the shutdown evolution and during refueling outages, a slow transformation from an organic to an inorganic chemical form can occur.

Dissolved nitrogen gas and ammonia in the RCS could contribute to the ^{14}C source term. The dissolved nitrogen could become significant in the latter stages of the fuel cycle due to the introduction of increased quantities of non-borated water for boron dilution. Callaway maintains a hydrogen gas overpressure on the RCS which effectively eliminates dissolved nitrogen gas and ammonia in the RCS, therefore the RCS ammonia concentration is assumed to be 0.[82]

In general, ^{14}C is produced in light water moderated nuclear power reactors by $^{14}N(n,p)^{14}C$ reactions with nitrogen impurities in the coolant and by $^{17}O(n,\alpha)^{14}C$ reactions in the coolant. ^{14}C produced in a nuclear power reactor can be released directly to the environment from the coolant in a gaseous form or in much smaller quantities as liquid

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[80] Certificate of Compliance No. 1040, Appendix A, Specification 5.1.

[81] EPRI TR-1021106, Section 4.1

[82] CDP-ZZ-00200, Appendix B, Table 1.1, " Reactor Coolant System-MODES 1, 2, 3, and 4", page 6 of 23

effluents.[83] Kunz estimated the fraction of ^{14}C in liquid and solid wastes at <5% of that in gaseous discharges[84]. Regulatory Guide 1.21 states that the dose contribution from ^{14}C in liquid discharges is insignificant and evaluation of ^{14}C released in liquid effluents is not required.[85]

The release and removal pathways from the primary coolant include VCT venting, boron dilution, inventory buildup on the letdown demineralizers and filters, and reactor coolant leakage. Letdown system removal is approximately 1 Ci/yr.[86] The ^{14}C production balance is shown in Figure 1.

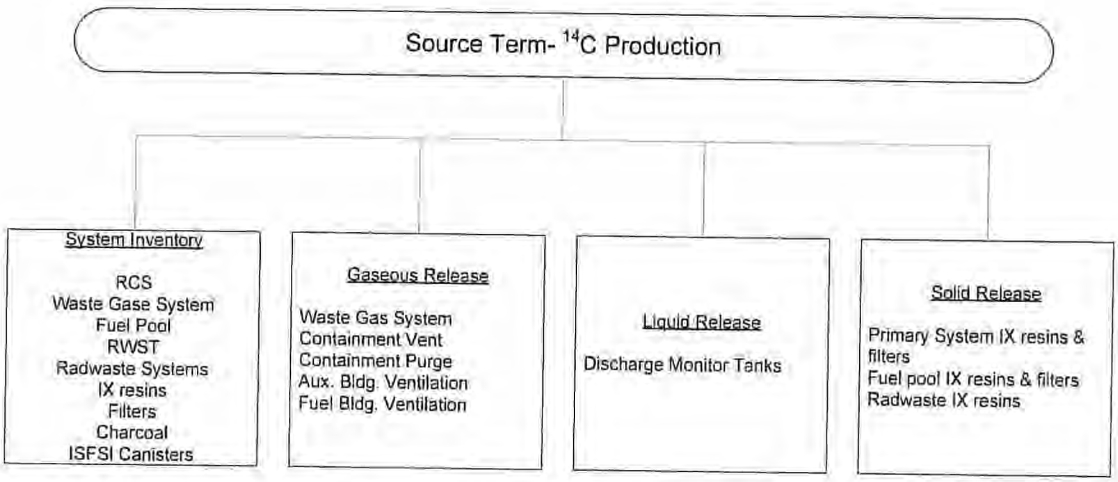

Figure 1: ^{14}C Production Balance

5) Chemical Form of ^{14}C in Gaseous Effluents

Since the PWR operates with a reducing chemical environment, most, if not all, of the ^{14}C species initially produced are in the reduced, i.e., organic, form and contain only a single carbon atom. Possible species include methane ($^{14}CH_4$), methanol ($^{14}CH_3OH$), formaldehyde ($H_2{}^{14}C{=}O$ or the *gem*-diol $H_2{}^{14}C(OH)_2$), and formic acid ($H^{14}COOH$). In theory, the only ionic species produced will be formic acid ($H^{14}CO_2H$) , and some or all of the formic acid will be removed by the letdown demineralizers. Formaldehyde is soluble in water and may partially be chemisorbed on the ion exchange resin. A quasi-equilibrium is established in the coolant between the initially produced species and other possible species in the reactor coolant. The most chemically reduced species and probably the most prevalent species is $^{14}CH_4$ which partitions between the liquid and gas phases in the VCT and pressurizer.[87] The airborne ^{14}C released from PWRs is predominantly hydrocarbons (75–95%), mainly methane (CH_4), with only a small fraction

[83] IAEA Report 421, Section 3.1.3
[84] Kunz, 1985
[85] Regulatory Guide 1.21, rev. 2, section 1.09
[86] EPRI TR-1021106, Section 4.1
[87] EPRI TR-1021106, Section 4.1

in the form of CO_2.[88,89] Regulatory Guide 1.21 states that ^{14}C releases in PWRs occur primarily as a mix of organic carbon and CO_2 in gaseous waste from the waste gas system.[90] NUREG-0017[91] concludes that 16.4% of the ^{14}C produced in a PWR will be released via the waste gas processing system, and the remainder, 83.6%, from the Reactor Building and the Auxiliary Building.

Due to the presence of high temperature hydrogen recombiners in the Callaway waste gas system, 100% of the ^{14}C released through the waste gas system is assumed to be released from the waste gas decay tanks in the oxidized, i.e., inorganic form as CO_2. The ^{14}C released from the unit vent is assumed to be in the reduced (organic) form as CH_4, therefore 16.4% of the ^{14}C produced is released through the Waste Gas Decay tanks (WGDT) as CO_2, and 83.6% is released via the Unit Vent as CH_4.

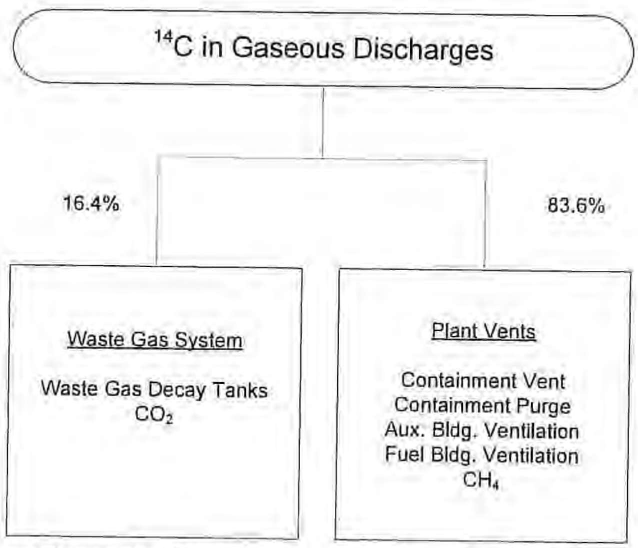

Figure 2: ^{14}C Gaseous Discharge Balance

6) ^{14}C Source Term Estimation

The neutron absorption cross section for the $^{17}O(n,\alpha)^{14}C$ reaction is shown in Figure 3. The $^{17}O(n,\alpha)^{14}C$ reaction has a 1/v region and a significant high energy neutron cross section. Given a constant neutron flux and target concentration, the rate of production of a species, N_a, in atoms per second is given by:

$$N_a = N_T \bullet \{(\sigma_t \bullet \varphi_t) + (\sigma_e \bullet \varphi_e) + (\sigma_f \bullet \varphi_f)\}$$

Where:

N_a is the rate of production, atoms/sec

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88 IAEA Report 421, Section 3.1.3
89 Neeb, section 4.2.4
90 Regulatory Guide 1.21, rev. 2, section 1.09
91 NUREG-0017, Section 2.2.25.2

NT is the number of ^{17}O or ^{14}N target atoms per kg of coolant

$\boldsymbol{\sigma_t}$ is the effective neutron cross section for thermal neutron absorption, cm^2

$\boldsymbol{\varphi_t}$ is the thermal neutron flux, n/cm^2-sec

$\boldsymbol{\sigma_e}$ is the effective neutron cross section for epithermal energy neutron absorption, cm^2

$\boldsymbol{\varphi_e}$ is the epithermal neutron flux, n/cm^2-sec

$\boldsymbol{\sigma_f}$ is the effective neutron cross section for fast neutron absorption, cm^2

$\boldsymbol{\varphi_f}$ is the fast neutron flux, n/cm^2-sec

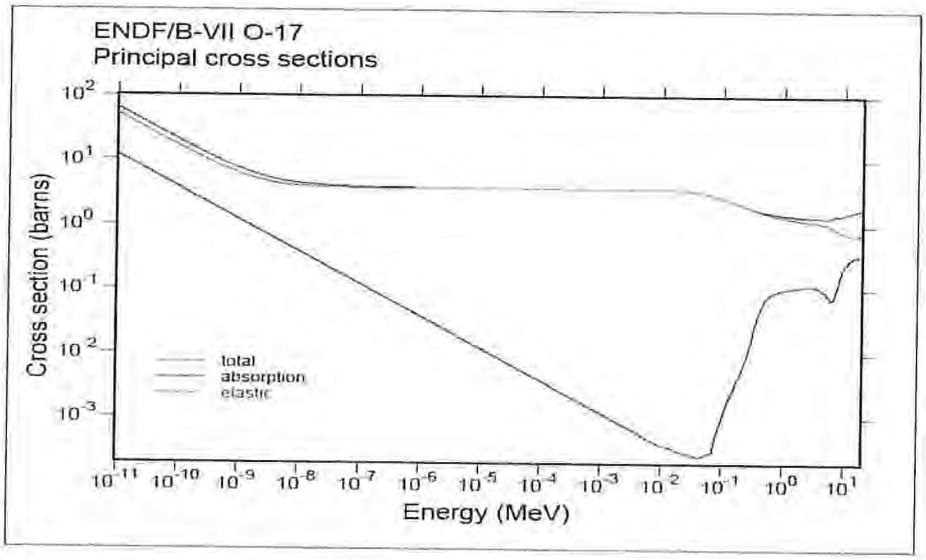

Figure 3: ENDF/B VII Cross Sections for ^{17}O

Table 14: Effective Cross Section for the $^{17}O(n,\alpha)^{14}C$ Reaction in the PWR as a Function of Neutron Energy[92]		
Neutron Group	Group Energy	Effective Cross Section
Thermal	≤0.625 eV	0.121 barns
Epithermal (E)	>0.625 eV - <1 MeV	0.0291 barns
Fast (F)	≥1 MeV	0.1124 barns

The source term of each species A_i, is given by:

$$A_a\ (dps) = N_a \cdot \lambda_a$$

[92] EPRI TR-1021106, Section 4.3.2.2

$$A_a(\mu Ci) = \frac{N_a \cdot \lambda_a}{3.7E4}$$

Where A_a is the activity of species a, N_a is the number of atoms of species a, λ_a is the decay constant of species a, in seconds. The ^{14}C production rate from the $^{17}O(n,\alpha)^{14}C$ reaction is calculated for the three group flux distribution according to:[93]

$$^{14}C\ production\ rate = \frac{(1E\text{-}24 \cdot \lambda \cdot N \cdot \{(\sigma_t \varphi_t) + (\sigma_e \varphi_e) + (\sigma_f \varphi_f)\}}{3.7E4}$$

Where:

^{14}C Production rate is ^{14}C rate of production, µCi/sec- kg

N is the number of target atoms per unit mass of coolant (1.27E22 atoms ^{17}O/ kg H_2O);

$\boldsymbol{\sigma_t}$ is the effective neutron cross section for thermal neutron absorption, in barns;

$\boldsymbol{\varphi_t}$ is the thermal neutron flux, n/cm^2-sec;

$\boldsymbol{\sigma_e}$ is the effective neutron cross section for epithermal energy neutron absorption, in barns;

$\boldsymbol{\varphi_e}$ is the epithermal neutron flux, n/cm^2-sec;

$\boldsymbol{\sigma_f}$ is the effective neutron cross section for fast neutron absorption, in barns;

$\boldsymbol{\varphi_f}$ is the fast neutron flux, n/cm^2-sec;

1.0E-24 is a units conversion factor, 1.0E-24 cm^2/barn;

$\boldsymbol{\lambda}$ is the ^{14}C decay constant, 3.833E-12/sec; and

3.7E4 is a units conversion factor, 3.7E4 d/(sec- µCi).

The activity of ^{14}C produced is thus the product of the production rate, the coolant mass in the active core region, and time:

$$A_C = \text{Production rate} \cdot \text{coolant mass} \cdot \text{time}$$

Where:

$\boldsymbol{A_C}$ is the activity of ^{14}C produced, in µCi;

The ***coolant mass*** is the mass of water in the active core region, in kg, corrected for core average temperature and pressure;

The ***time*** is the time period of reactor operation, in sec;

The Callaway reactor is a Westinghouse Model F, four loop Pressurized Water Reactor (PWR) rated at 3565 MW_{th}. The fuel is Westinghouse Vantage+ OFA with 193 fuel

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[93] EPRI TR-1021106, Section 4.3.2.1

assemblies. The mass of coolant in the active core region is 12,925 kg.[94] The hydrogen gas overpressure in the Volume Control Tank (VCT) effectively eliminates N_2 and NH_3 in the RCS, therefore ^{14}C production from the $^{14}N(n,p)^{14}C$ reaction is insignificant.

The core average neutron flux, the Effective Full Power Years (EFPY), and the fuel burnup are specific to the reactor operation for the period.

7) Inhalation Dose at the Nearest Residence Location from ^{14}C

The child age group is the critical age group for an airborne release of ^{14}C due to higher inhalation dose factors and higher ingestion dose factors.[95] The inhalation dose for the child age group, D, is calculated according to the expression[96]:

$$D_j = 3.17E4 \cdot R_a \cdot DFA_j \cdot Q_i \cdot X/Q$$

Where:

D is the dose in mrem, to a member of the public from ^{14}C, from the inhalation pathway, received by organ j;

3.17 E4 is the number of pCi/Ci divided by the number of sec/yr;

$\boldsymbol{R_a}$ is the breathing rate for the child age group (3700 m^3/yr);[97]

$\boldsymbol{DFA_j}$ is the ^{14}C inhalation pathway dose factor for organ *j*, appropriate to the child age group (mrem/pCi). For ^{14}C, the limiting organ is the bone. The DFA_{bone} for the child age group is 9.70E-6 mrem/pCi, and the $DFA_{total\ body}$ for the child age group is 1.82E-6;[98]

$\boldsymbol{Q_i}$ is the quantity of ^{14}C produced during the year (Ci/yr); and

X/Q is the highest calculated annual average concentration at the nearest receptor location (sec/m^3).

The inhalation dose to the bone for the child age group at the Nearest Residence location is:

$$D_{bone} = 1138 \cdot Q_i \cdot X/Q$$

The inhalation dose to the total body for the child age group at the Nearest Residence location is:

$$D_{total\ body} = 213 \cdot Q_i \cdot X/Q$$

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[94] Westinghouse Calculation Note CN-TA-02-135, "Callaway (SCP) RSG IGOR/RETRAN Base Deck", May 16, 2003
[95] Regulatory Guide 1.109, Table E-9, and Table E-13
[96] Regulatory Guide 1.109, equations C-3 and C-4.
[97] Regulatory Guide 1.109, Table E-5
[98] Regulatory Guide 1.109, Table E-9.

8) Dose from ^{14}C in Fresh Leafy Vegetation

The concentration of ^{14}C in leafy vegetation is calculated by assuming that the ^{14}C ratio to the natural carbon in the vegetation is the same as the ratio of ^{14}C to natural carbon in the atmosphere surrounding the vegetation.[99]

Only ^{14}C released in the oxide form (CO or CO_2) is incorporated into the plant material.[100] All ^{14}C released from the waste gas decay tanks is assumed to be in the organic form, as CO_2. The inorganic form, e.g., CH_4, is not incorporated into plant material, therefore, only the organic form, e.g., CO_2 contributes to the ingestion dose pathway. $^{14}CO_2$ released outside the growing season or at night is not incorporated into plant material and does not contribute to the dose from the ingestion pathway. $^{14}CO_2$ released during the growing season in the daytime is assumed to be incorporated into the plant material and contributes to the ingestion dose pathway. The growing season in mid- Missouri is approximately April 1- November 1.[101]

The concentration of ^{14}C in leafy vegetation is given by:[102]

$$Conc_v = \frac{3.17E7 \cdot Q_i \cdot X/Q \cdot 0.11}{0.16}$$

Where:

$Conc_V$ is the concentration of ^{14}C in leafy vegetation grown at the nearest receptor location (pCi/kg);

3.17E7 is equal to (1E12pCi/C)(1E3g/kg)/(3.15E7 sec/yr);

Q_i is the quantity of ^{14}C released as CO_2 during periods of photosynthesis (Ci/yr);

X/Q is the highest calculated annual average concentration at the nearest receptor location (sec/m^3);

0.11 is the fraction of total plant mass that is natural carbon, dimensionless; and

0.16 is the concentration of natural carbon in the atmosphere (g/m^3).

Substitution of constants yields:

$$Conc_v = 2.2E7 \cdot Q_i \cdot X/Q$$

The leafy vegetation ingestion dose for the Child age group at the nearest receptor location is given by:[103]

$$D = DFI \cdot f_l \cdot U_a \cdot Conc_v$$

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[99] Regulatory Guide 1.109, Appendix C
[100] Regulatory Guide 1.109, Appendix C
[101] Hammer, G. R.
[102] Regulatory Guide 1.109, equation C-8
[103] Regulatory Guide 1.109, equation C-13

Where:

D is the annual dose to the bone or total body for the child age group from ingestion of fresh leafy vegetation, (mrem/yr);

DFI is the ingestion dose conversion factor for the maximum exposed organ. For the child age group, the bone is the maximum exposed organ. The $\mathbf{DFI_{bone}}$ is 1.21E-5 mrem/pCi ingested and the $\mathbf{DFI_{total\ body}}$ is 2.42E-6 mrem/pCi ingested;[104]

f_l is the fraction of leafy vegetation grown in the garden at the nearest receptor location. $f_l = 1.0$;[105] and

U_a is the ingestion rate of leafy vegetation. For the child age group, $U_a = 26$ kg/yr.[106]

9) Dose from ^{14}C in Milk

The concentration of ^{14}C in milk is determined as[107]:

$$Conc_{milk} = F_m \cdot Conc_v \cdot Q_F \cdot e^{-\lambda t_f}$$

Where:

$Conc_{milk}$ is the concentration of ^{14}C in milk, in pCi/L;

F_m is the average fraction of the animal's daily intake of ^{14}C which appears in each liter of milk, in days/L. For cow milk, F_m is 1.2E-2 days/L.[108] For goat milk, F_m is 0.10 days/L;[109]

$Conc_V$ is the concentration of ^{14}C in leafy vegetation grown at the receptor location (pCi/kg), as described above;

Q_F is the amount of feed consumed by the animal per day, in kg/day. For cows, Q_F is equal to 50 kg/day and for goats Q_F is equal to 6 kg/day;[110]

t_f is the average transport time of the ^{14}C from the feed into the milk and to the receptor (a value of 2 days is assumed): and

λ is the radiological decay constant for ^{14}C, 3.32E-7 days^{-1}.

The dose from ^{14}C in milk is determined as:

$$D = DFI \cdot U_a \cdot Conc_{milk}$$

Where:

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[104] Regulatory Guide 1.109, Table E-13
[105] Regulatory Guide 1.109, Table E-15
[106] Regulatory Guide 1.109, Table E-5
[107] Regulatory Guide 1.109, equation C-10
[108] Regulatory Guide 1.109, Table E-1
[109] Regulatory Guide 1.109, Table E-2
[110] Regulatory Guide 1.109, Table E-3

D is the annual dose to the bone or total body for the child age group from milk ingestion, (mrem/yr);

DFI is the ingestion dose conversion factor for the maximum exposed organ. For the child age group, the bone is the maximum exposed organ. The $\mathbf{DFI_{bone}}$ is 1.21E-5 mrem/pCi ingested and the $\mathbf{DFI_{total\ body}}$ is 2.42E-6 mrem/pCi ingested;[111] and

$\boldsymbol{U_a}$ is the ingestion rate for milk. For the child age group, U_a =330 L/yr (for both cow and goat milk).[112]

10) Dose from ^{14}C in Meat

The concentration of ^{14}C in meat is determined as[113]:

$$Conc_{meat} = 3.1E\text{-}2 \cdot Conc_v \cdot 50 \cdot e^{-(20 \cdot 3.32E-7)}$$

Where:

$\boldsymbol{Conc_{meat}}$ is the concentration of ^{14}C in meat, in pCi/kg;

3.1E-02 is the stable element transfer factor, in days/kg, for beef[114]

$\boldsymbol{Conc_V}$ is the concentration of ^{14}C in leafy vegetation grown at the receptor location (pCi/kg), as described above;

50 kg/day is the amount of feed consumed by the beef animal per day;[115]

20 days is the average time from slaughter to consumption[116]: and

3.32E-7 days^{-1} is the radiological decay constant for ^{14}C.

The dose from ^{14}C in meat is determined as:

$$D = DFI \cdot U_a \cdot Conc_{meat}$$

Where:

D is the annual dose to the bone or total body for the child age group from milk ingestion, (mrem/yr);

DFI is the ingestion dose conversion factor for the maximum exposed organ. For the child age group, the bone is the maximum exposed organ. The $\mathbf{DFI_{bone}}$ is 1.21E-5 mrem/pCi ingested and the $\mathbf{DFI_{total\ body}}$ is 2.42E-6 mrem/pCi ingested;[117] and

$\boldsymbol{U_a}$ is the ingestion rate for meat. For the child age group, U_a =41 kg/yr.[118]

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[111] Regulatory Guide 1.109, Table E-13
[112] Regulatory Guide 1.109, Table E-5
[113] Regulatory Guide 1.109, equation C-12
[114] Regulatory Guide 1.109, Table E-1
[115] Regulatory Guide 1.109, Table E-3
[116] Regulatory Guide 1.109, Table E-15
[117] Regulatory Guide 1.109, Table E-13
[118] Regulatory Guide 1.109, Table E-5

11) Dose to the Member of the Public from Activities within the Site Boundary

The Member of the Public performing activities within the Site Boundary is described in Section 4. The ingestion dose pathways do not exist within the Site Boundary. ^{14}C is not a gamma- emitting nuclide; therefore the ground plane pathway is negligible.

The inhalation dose, D, is calculated according to the expression[119]:

$$D_j = 3.17E4 \cdot R_a \cdot DFA_j \cdot Q_i \cdot X/Q \cdot 1.26E\text{-}1$$

Where:

D is the dose in mrem, to a member of the public from ^{14}C, from the inhalation pathway, received by organ j;

3.17 E4 is the number of pCi/Ci divided by the number of sec/yr;

$\boldsymbol{R_a}$ is the breathing rate for the adult age group (8000 m^3/yr);[120]

$\boldsymbol{DFA_j}$ is the ^{14}C inhalation pathway dose factor for organ *j*, appropriate to the adult age group (mrem/pCi). For ^{14}C, the limiting organ is the bone. The DFA_{bone} for the adult age group is 2.27E-6 mrem/pCi, and the $DFA_{total\ body}$ and $DFA_{thyroid}$ is 4.26E-7 mrem/pCi.[121]

$\boldsymbol{Q_i}$ is the quantity of ^{14}C produced during the year (Ci/yr)

X/Q is the highest calculated annual average concentration for activities within the Site Boundary, as shown in Table 10.

1.26E-1 is the fraction of the year the farmer performs activities within the Site Boundary (1100 hrs/8760 hrs), dimensionless.

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[119] Regulatory Guide 1.109, equations C-3 and C-4
[120] Regulatory Guide 1.109, Table E-5
[121] Regulatory Guide 1.109, Table E-7

12) Alternate Methodologies

Regulatory Guide 1.21 states that the following methods are acceptable for estimating the production of ^{14}C:[122]

- Sampling and analysis of effluent streams
- Use of normalized ^{14}C source term and scaling factors based on power generation, e.g., NCRP Report 81[123]
- Use of the PWR GALE code[124]

Callaway Plant effluents have not been sampled for ^{14}C. NCRP Report 81, Table 3.3 states that the total ^{14}C production rate for a PWR without reactor coolant nitrogen is 6 Ci/GW_e-yr. Assuming a conversion of 0.34 GW_e/GW_{th}, the expected ^{14}C production rate is 2 Ci/GW_{th}-yr or 7.2 Ci/EFPY for Callaway, which is significantly lower than the quantity of ^{14}C calculated using the EPRI methodology. The PWR GALE code does not calculate the quantity of ^{14}C produced, but instead assigns a value of 7.3 Ci/yr for every PWR without regard for power level, reactor coolant nitrogen concentration, or waste gas system design and operation. Again, this is significantly lower than the quantity of ^{14}C calculated using the EPRI methodology. For example, using the EPRI methodology and the neutron flux distribution for Cycle 18, the ^{14}C production for Callaway is 13.2 Ci/EFPY.[125] The ^{14}C production calculated using the EPRI methodology is therefore conservative with respect to the methodologies mentioned in Regulatory Guide 1.21, rev. 2.

The EPRI methodology also provides for a PWR proxy calculation. The average ^{14}C production rate for Westinghouse PWRs is 3.4 Ci/ GW_{th}- yr[126]. Callaway is rated at 3.565 GW_{th} (3565 MW_{th}), therefore, the ^{14}C production rate based on the proxy PWR is 12.1 Ci/ EFPY. The ^{14}C production calculated using the EPRI proxy methodology is therefore conservative with respect to the acceptable methodologies described in Regulatory Guide 1.21, rev. 2.

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[122] Regulatory Guide 1.21, Section 1.9
[123] NCRP Report 81
[124] NUREG-0017
[125] HPCI 1102
[126] EPRI TR-1021106, Section 4.8 and Appendix D

Appendix B: Record of Revisions[127]

Rev. No. 0 Date: March 1983

Rev. No. 1 Date: November, 1983

Revised to support the current RETS submittal and to incorporate NRC Staff comments.

Rev. No. 2 Date: March, 1984

Revised to incorporate NRC Staff comments

Rev. No. 3 Date: June, 1985

Revised to incorporate errata identified by ULNRC00803 and changes to the Environmental Monitoring Program. Incorporate results of 1984 Land Use Census.

Rev. No. 4 Date: February, 1987

Minor clarifications, incorporated 31-day projected dose methodology. Change in the utilization of areas within the Site Boundary.

Rev. No. 5 Date: January, 1988

Minor clarifications, revised descriptions of liquid and gaseous rad monitors, revised liquid setpoint methodology to incorporate monitor background, revised dose calculations for 40CFR190 requirements, Revised Table 6 and Figures 5.1A and 5.1B to refine descriptions of environmental TLD stations, incorporated description of environmental TLD testing required by Reg. Guide 4.13, revised Tables 1, 2, 4 and 5 to add additional nuclides, deleted redundant material from Chapter 6.

Rev. No. 6 Date: May, 1989

Revised methodology for calculating maximum permissible liquid effluent discharge rates and liquid effluent discharge rates and liquid effluent monitor setpoints, provided methodology for calculating liquid effluent monitors response correction factors, provided an enhanced description of controls on liquid monitor background limits, provided additional liquid and gaseous dose conversion factors and bioaccumulation factors (Tables 1, 2, 4 & 5), provided description of the use of the setpoint required by Technical Specification 4.9.4.2 during Core Alterations, added discussion of gaseous and liquid monitor setpoint selection in the event that the sample contains no detectable activity, added minimum holdup requirements for Waste Gas Decay tanks, revised dispersion parameters and accompanying description per FSAR Change Notice 88-42.

APA-ZZ-01003

Rev. No. 0 Date: August, 1989

Radiological Effluent Technical Specifications were moved from the Callaway Plant Technical Specifications to Section 9.0, Radioactive Effluent Controls, of the ODCM per NRC Generic Letter 89-01. At the same time, in order to formalize control of the entire ODCM, it was converted to APA-ZZ-01003, Offsite Dose Calculation Manual.

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[127] Section numbers, table numbers, etc. refer to the numbering schema used in the particular revision.

Rev. No. 1 Date: October, 1990

Revise Action 41 of Table 9.2-A to allow continued purging for 24 hours per Amendment 20 to operating license, issued 4/10/87.

Rev. No. 2 Date: May, 1991

Section 2.4.2: Changed gross alpha analysis frequency from "each batch" to a monthly composite per Table 9.3-A, and the Callaway Plant NPDES permit (reissued March 15, 1991).

Rev. No. 3 Date: June, 1993

Deleted HF-RE-45 and LE-RE-59 as effluent monitors. Revised table numbering for consistency with those in Section 9.0, deleted redundant material, incorporated 1992 Land Use Census results, moved LLD description to Attachment 1, moved REC Bases to Attachment 2. Deleted reporting requirements for solid radwaste, which are described in APA-ZZ-01011, Process Control Program. Addressed compliance with 10 CFR 20.1301. Revised the dilution flow rate to allow values other than 5000 gpm, based on dilution flow monitor setpoint. Revised "MPC" terminology to "ECV". Added Action 46 to REC 9.2 to clarify actions for inoperable mid and high range WRGM Channels. Revised references to be consistent with the revised 10 CFR 20. Added Appendix A. Revised Action 41 of Rec 9.2 and the operability requirements of GT-RE-22/33. Incorporated the revised R_i values in Tables 3.2 and 3.3. Added Section 6.2 and Table 6.5.

Rev. No. 4 Date: September, 1994

Increased the minimum channels OPERABLE requirement of REC 9.2 for GT-RE-22 & 33 from 1 channel to 2 channels. Revised Action 41 and the Bases for REC 9.2 accordingly. Incorporated the operability requirements from Tech Spec 3.9.9 into the Action statement for clarity. (Refer to CARS 199401176).

Rev. No. 5 Date: February, 1995

Removed the REMP station locations. Removed particulate nuclides with a half-life of less than 8 days from Tables 3.2-3.4 and removed ^{14}C, ^{32}P, ^{63}Ni, and ^{125m}Te from Tables 2.1, 2.2, 3.2, 3.3, and 3.4. Changed the reporting frequency of the Effluent Release Report from semiannual to annual. Removed the meat, milk and vegetable pathway dispersion parameters from Tables 6.1, 6.2, and 6.3, and clarified the applicability of the dispersion parameters and dose locations in Table 6.4. Relocated REC 9.1 and 9.2 to the FSAR. Revised footnotes 3 and 7 of Table 16.11-4 to require additional sampling of the Unit Vent in the event of a reactor power transient, only if the Unit Vent noble gas activity increases by a factor of 3 or greater. Added Section 4.1.3.1.3 for determination of dose due to the on-site storage of low level radioactive waste.

Rev. No. 6 Date September, 1996

Section 2: Added dose factors (A_{it})for ^{110m} Ag, ^{237}Np, ^{238}Pu, $^{239/240}Pu$, ^{241}Pu, ^{241}Am, ^{242}Cm, and $^{234/244}Cm$ to Table 2.1, and Bioaccumulation Factors (Bf_i) for Ag, Pu, Am, and Cm to Table 2.2 due to a change in the liquid radwaste treatment process. Revised the description of the methodology for performing the 31 day dose projection in Section 2.5. Revised the maximum allowable background for HB-RE-18. Section 3: Eliminated ^{91m}Y and ^{99m}Tc from Table 3.4 (Meat Pathway) due to a half-life of < 8 days. Substituted the phrase "more restrictive" in lieu of "lesser" in Section 3.2. Revised the definition of F_a in equation 3.1. Added description of use of samples to verify dose rates in Section 3.3.1.2. Augmented the definition of q_i in Section 3.3.2.1. Edited equations 3.13 and 3.14 and added equation 3.15 to clarify dose calculations. Revised the methodology for performing the 31 day dose projection in Section 3.4. Section 4: Strengthened the discussion of the reevaluation of assumptions in Section 4.1.3. Section 6: Added new Table 6.6 to describe the selection and use of dispersion parameters during the preparation of the Effluent Release Report. Updated Tables 6.1 and 6.2 to reference the 1995 Land Use Census. There were no changes in the receptor locations. Section 8: Replaced the reference to HDP-ZZ-04500 to a more generic reference to the plant operating procedures, due to change in organizational structure and responsibilities. Section 9: (1) Eliminated 9.0.1 and 9.0.2 due to redundancy with Technical Specifications 3.0.1 and 3.0.2; (2) Revised Table 9.3-A to incorporate sampling and analysis requirements for TRU nuclides in liquid effluents; (3) Eliminated sampling of Fuel Building Exhaust from Table 16.11-4 and the associated footnotes due to redundancy with Unit Vent sampling; revised the continuous sampling requirements for the gaseous batch release points consistent with plant design; revised the ^{3}H analysis frequency for Purges from weekly to "prior to each purge"; and, (4) Revised the air sampling station location criteria on Table 9.11-A and footnote # 1, and eliminated footnote #3 in order to be less generic and more descriptive of the parameters used in determining the station locations (See CARS 199502280).Revised the location requirements for milk and vegetables. Revised description of use of baseline samples to trigger gamma isotopic analysis in footnote #4, revised requirement for location of downstream sample station in footnote #6. Revised Surveillance Requirement 9.10.2.1 to eliminate liquid effluents from the surveillance. (5) Revised REC 9.5 and REC 9.9 to eliminate exceptions for partially tested effluents being released in excess of the respective limit. Section 11: Added reference 11.14.13.Attachment 2: Revised the Bases for REC 9.10 to support the elimination of liquid effluents from Surveillance 9.10.2.1.The remaining changes are editorial in nature and have no technical impact.(This revision implements CARS 199502055, CARS 199600167, CARS 199600961, CARS 199502280, and CARS 199600986).

Rev. No. 7 Date February, 1997

Section 9: (1) REC 9.5, "Liquid Radwaste Treatment System", Action statement: Eliminated reference to COMN 1161. (2) Table 9.11-A, items 4a (milk) and 4c (vegetation): revised to required control stations in the least prevalent wind direction. (See CARS 199700166) Appendix A: revised the discussion relative to the appropriate gross alpha Effluent Concentration Value.

Rev. No. 8 Date May, 1997

Section 1: The Purpose and Scope was revised to describe the split of the ODCM into two sections Per FSAR Change Notice 95-058. Section 2: Sections 2.2 and 2.3 were revised to clarify the use of nuclide- specific alpha activity vice gross alpha activity for setpoint determination. Section 2.5 was revised to delete the description of the Liquid Radwaste Treatment System. Section 6: Tables 6.1, 6.2, and 6.3 were revised to reflect the results of the 1996 Annual Land Use Census. Section 7: The reporting requirements for the Annual Radiological Environmental Operating Report and the Effluent Release Report were relocated to the FSAR Per FSAR Change Notice 95-058. Section 9: REC's and the supporting Attachments 1 and 2 were relocated to the FSAR Per FSAR Change Notice 95-058. Appendix A: Appendix A was deleted. Editorial changes were made throughout the ODCM reflecting the relocation of the REC's to the FSAR.

Rev. No. 9 Date March, 1998

Section 2.5: Revised projected liquid dose calculation to use previous 31 day cumulative doses. Section 3.1.1: Added GL-RE-202, Laundry Decon Facility Dryer Exhaust Monitor. Added action to be taken when the particulate and/or iodine grab sampler is not operable. Section 3.2: Added setpoint calculation for GL-RE-202. Section 3.2.1 and 3.3.2.2: Changes were made to correct typographical errors and have no technical impact. Section 3.4: Revised projected gas dose calculation to use previous 31 day cumulative doses. Section 3.5: Removed the word secular from "secular equilibrium" since the equilibrium mode could be secular or transient depending on the isotope. Table 6.2: Added Laundry Decon Facility Dryer Exhaust to title of table since these will be the dispersion factors used for this release point.

Rev. No. 10 Date December 20, 1999

Section 3.1: Added explanation that GL-RE-202 only monitors particulate. Section 3.2: Changed Laundry Decon Facility Exhaust Monitor setpoint to less than or equal to 2000 cpm above equilibrium background with a maximum allowed background of 2000 cpm as calculated in HPCI 9905. Tables 6.1, 6.2, 6.3: Updated values as calculated in HPCI 9902. Section 5.1: Defined how REMP sample locations were determined. Removed reference to Plant Operating manual since it no longer exists.

Rev. No. 11 Date December 22, 1999

Changes required to go from old Technical Specifications to Improved Technical Specifications (ITS). Technical Specification 4.9.4.2 changed to FSAR 16.11.2.4.1. Technical Specification 6.8.4.F changed to FSAR 16.11.4. Technical Specification 6.8.1.F changed to Improved Technical Specification 5.4.1. Technical Specification 6.14 changed to Improved Technical Specification 5.5.1. Technical Specification 6.8.4.E changed to Improved Technical Specification 5.5.4. Technical Specification 6.9.1.6 changed to Improved Technical Specification 5.6.2. Technical Specification 6.9.1.7 changed to Improved Technical Specification 5.6.3. Changed name of Annual Radiological Effluent Release Report to Effluent Release Report as stated in ITS. Added liquid releases are limited to 10 times the Appendix B, Table 2, Column 2 limits Per FSAR CN 98-041 supporting implementation of ITS.

Rev. No. 12 Date December 01, 2000

Section 2.1 and 2.2.1: Updated 10CFR20, Appendix B, Table II, Column 2 reference to the new 10CFR20 format. Corrected typo for "f", flow setpoint should be undiluted waste flow rate. Section 3.2.1: Corrected typo, default value for safety factor should be 0.1. Section 5.1: Updated crosscheck program used to EML since EPA program is no longer available. Section 6.2: Added vertical height of highest adjacent building used to perform concurrent year annual average atmospheric dispersion (X/Q) calculations and reference for this value. This information should be documented in the ODCM. Added responsibility for validation of meteorological data, since responsibility has changed from engineering to HPTS. Section 10.1.1: Revised to require a summary of Major Radwaste System changes to be included in the annual report. This was done to be consistent with FSAR 16.11.5.2.Several changes were made throughout the procedure to correct typographical errors and have no technical impact.

Rev. No. 13 Date September 19, 2002

Section 3.2: Revised to implement the approved OL 1218, Rev. 1; License Amendment no. 152 allowing equipment hatch and emergency air lock to remain open during refueling activities (FSAR CN-01-030 and CN-02-049). The amendment eliminated FSAR 16.11.2.4.1B and subsequently deleted the core alteration setpoint value 5.0 E-3 µCi/cc for Containment Purge Monitors GT-RE-22 and GT-RE-33. The alarm setpoints for the Containment Purge Monitors will be based on the methodology described in Section 3 of the ODCM.

Rev. No. 14 Date June 17, 2003

Revised Table 2.1 (Ingestion Dose Commitment Factor for Adult Age Group) to include dose factors for Pr-144. (CARS 200303251).Revised Section 4.1.3.1 to adjust the Farmer's residence (critical receptor) from 3830 meters in the SE sector to 2897 meters in the NNW sector. The Farmer's residence (critical receptor) was changed in 2002 to a location directly across the street from the Nearest residence. For conservatism and ease in calculation, Table 6.1 and 6.2 were revised making the distances and dispersion parameters for the Farmer's residence (critical receptor) and the Nearest residence the same. Revised section 7.2 to reference Table 6.6. Revised section 10.2.2 to remove the requirement for QA department review of the ODCM for reach revision (CARS 200304509). Added a reference to 11.14.14, Calculation HPCI 0304 (Rev. 0), "Calculation of Liquid Effluent Dose Commitment factor for Pr-144 ($A_{i\tau}$) for the Adult Age Group", June, 2003.

Rev. No. 15 Date December 9, 2004

Reformatted references to FSAR-SP Chapter 16.11 in section 1, 2.1.1, 2.1.2, 2.2.1, 2.3, 2.4.2, 2.5, 2.6, 3.1, 3.2.1, 3.5, 5.1, 7.1, 7.2, and 9. References to ^{63}Ni were added to section 2.2.1 for the calculation of ECVSUM, section 2.3, and described in section 2.6 since it is an exception to non- gamma emitters not listed in FSAR-SP Table 16.11-1. ^{63}Ni was added to the ODCM based on previous 10 CFR 61 sample results and 2nd quarter liquid composite analyses. Consolidated references listed in section 2.4.2 and 2.6 for the site related ingestion dose commitment factors ($A_{i\tau}$ of Table 2.1 into HPCI 0406, Revision 1. References to HPCI 9504 (Ref: 11.14.13) and HPCI 0304 (Ref: 11.14.14) were deleted and replaced with HPCI 0406, Revision 1 which is now listed as Ref: 11.14.13. Added ^{63}Ni and ^{122}Sb to Table 2.1- INGESTION DOSE COMMITMENT FACTOR ($A_{i\tau}$) FOR ADULT AGE GROUP. Revised the reference for Table 2.1 to 11.14.13. Corrected a typo in section 3.1.2 referring to the Radwaste Building Vent system designator as GT vs. GH (CAR 200406851). References 11.19 and 11.20 were deleted in section 4.1.3.1.1. Reference 11.18 was changed to MicroShield (Grove Engineering, Inc.) vs. ISOSHLD. Reference 11.24 in section 4.1.3.1.3 was corrected to 11.18. Section 5.1 and 5.2 were revised to indicate that the Radiological Environmental Monitoring Program TLDs will be processed and provided by a vendor laboratory beginning in the first quarter of 2005. Section 5.2 was revised to delete reference 11.14.10 which refers to HPCI 8808, "Performance Testing of the Environment TLD System at Callaway Plant", August 1989. Reference 11.14.7 was corrected with HPCI 8710 vice HPCI 8810. Revised Table 6.1, Note (c) to reference FSAR Table 2.3-83 vs. Table 2.3-82. Revised Table 6.1 and 6.2 Note (b) to reference data is from the 2002 Land Use Census. Changed and/or corrected the Skin dose factor (L_i) units in Table 3.1 (Dose Factor for exposure to a Semi-Infinite Cloud of Noble Gases) to mrem/yr per uCi/m^3. Revised section 3.3.1.2: Added units for the term BR in m^3/yr. Removed paragraph in section 3.3.2.2 that describes actions for implementing the use of appropriate $R_{i,l,j}$ values. This paragraph was taken directly from section 5.3.1 of NUREG 0133, U.S. Nuclear Regulatory Commission, "Preparation of Radiological Effluent Technical Specification for Nuclear Power Plants", USNRC NUREG-0133, Washington, D.C. 20555, October, 1978. This paragraph does not apply since the use of pathways is already considered as described in sections 4.1.2 and 4.1.3.1. Revised note (c) of Table 6.1 to reference FSAR-SA Table 2.3-83. Revised note (a) from Table 6.1 to reference FSAR-SA Table 2.3-82. In addition, revised Note (b) from Table 6.1 to reference data taken from the 2002 Land Use

Census. Revised Notes (a) and (c) from Table 6.2 to reference FSAR-SA Table 2.3-84 and 2.3-81 respectively. Added a 0.95 conservatism factor to section 2.2.3 *Calculation of Liquid Effluent Monitor Setpoint*. This will conservatively reduce the liquid monitor setpoint to further ensure the section 4.4.1 of NUREG 0133, U.S. Nuclear Regulatory Commission, "Preparation of Radiological Effluent Technical Specification for Nuclear Power Plants", USNRC NUREG-0133, Washington, D.C. 20555, October, 1978 which states the alarm and trip setpoints for each instrument channel listed in Table 3.3-11 should be provided and should correspond to a value(s) which represents a safe margin of assurance that the instantaneous liquid release limit of 10 CFR Part 20 is not exceeded. A determination was made IAW T/S 5.5.1 that the associated changes with Revision 15 maintain the levels of radioactive effluent control required by 10 CFR 20.1302, 40 CFR 190, 10 CFR 50.36a, and 10 CFR 50 Appendix I, and not adversely impact the accuracy or reliability of effluent, dose, or setpoint calculations.

Rev. No. 16 Date December 1, 2005

Section 5.1 was revised to remove an invalid requirement that a third-party laboratory performing analysis specifically state the Interlaboratory Comparison (crosscheck) requirements for the Radiological Environmental Monitoring Program (REMP) contract lab. Reference 11.14.14 to Reg. Guide 4.15, Quality Assurance for Radiological Monitoring Programs (Normal Operations)- Effluent Streams and the Environment, was added to provide supporting documentation for contract lab Interlaboratory Comparison requirements. Additional information on REMP contract lab participation in Interlaboratory Comparisons was also added in section 5.1. (CAR 200500891) Revised reference 11.14.7 by adding normalization and standardization factors for radionuclides listed in Table 2.1 of the ODCM that were not included in the original calculation. Added section 4.1.3.1.4 to describe direct dose to a Member of the Public from the Old Steam Generator Storage Facility (OSGSF). Reworded step 4.1.2 to describe the sources of direct radiation from "outside storage tanks" to "storage of radioactive material". Revised section 4.1.3.1.2 to include and describe direct dose calculations in support of Modification 03-1008, Equipment Hatch Platform and Missile Shield Modification. Reference 11.14.10 was added to reference direct dose calculation to the Member of the Public from Modification 03-1008. Revised section 4.1.3.1.3 to include and describe direct dose calculations from the Radwaste Yard RAM storage and Stores II. Reference 11.19 and 11.20 were added to reference direct dose calculations to the Member of the Public from RAM storage at Stores II and the Radwaste Yard. A determination was made IAW T/S 5.5.1 that the associated changes with Revision 16 maintain the levels of radioactive effluent control required by 10 CFR 20.1302, 40 CFR 190, 10 CFR 50.36a, and 10 CFR 50 Appendix I, and not adversely impact the accuracy or reliability of effluent, dose, or setpoint calculations.

Rev. No. 17 Date March 14, 2007

Section 2.4.1 was revised Per CAR 200701309 to state that no potable water intakes exist within 10 miles of the plant discharge point. This is due to the fact that the Annual Land Use Census ensures no newly developed potable water intakes within 10 miles of the plant discharge Per FSAR-SP Chapter 16.11.4.2c. Section 2.4.2 was revised to add reference 11.6.18 to CAR 200700053 which provides documentation of an evaluation of the site specific mixing factor for liquid effluents. Modification 06-0061 reconfigured the plant discharge terminus at the Missouri River. The modification was completed in January 2007.

Rev. No. 18 Date October 11, 2007

Revised Table 6.5 was revised to reflect upgrade/replacement of the primary meteorological tower instrumentation as per Modification Package 04-1020. Section 2.4.2 was revised to remove the discussion of the nearest municipal potable water intake downstream from the liquid effluent discharge point as being located near the city of St. Louis, Missouri, approximately 78 miles downstream. Since the Land Use Census annually verifies no potable water intakes within 10 miles – this discussion was deemed inappropriate in describing methodology for calculating dose to the public from liquid effluents. In addition, the distance referenced as not having potable water intakes downstream of the plant discharge was changed for consistency with section 2.4.1 and the Land Use Census.

Rev. No. 19 Date August, 2012

Converted to Word 2010, including appropriate formatting changes and cross-referencing for the conversion. Deleted all references to the obsolete Commitment Tracking System (COMN) and all hidden text for the obsolete hidden text referencing system. Added level of use. (CAR 201104163, Action 1) Section 3.4- Added dose reduction controls for discharge of ^{14}C from the waste gas system and defined the growing season. Section 3.5- Deleted statement that non- gamma emitting nuclides not listed in the FSAR-SP Table 16.11.4 are not considered in dose calculations. Eliminated Sections 4.1.3.1.1, 4.1.3.1.2, 4.1.3.1.3, and 4.1.3.1.4- direct radiation dose is negligible; refer to HPCI 1206. Section 5.2- changed to allow use of dosimeters other than TLDs. Section 6.1- Deleted discussion of short- term X/Q processing and the slope factor and deleted the associated table of 'S' factors. Section 6.2- Deleted designation of responsibilities for met data review. (CAR 201104163, Action 1) Section 10.2- changed to align with T/S 5.5.1. CAR 201104163, Action 2) Corrected the department title to align with organizational structure. (CAR 201104163, Action 1). Table 10 and Table 11- The dispersion parameters for the Farmer's residence were removed. As a first approximation, the dispersion parameters for the Nearest Residence will be used for the Farmer's residence. Appendix A- Appendix A was added to describe the calculation of the production of ^{14}C and the calculation of dose from ^{14}C in gaseous effluents. (CAR 201104163) ^{63}Ni was added to the gaseous effluent inhalation pathway and ingestion pathways dose factor tables. Values for ^{63}Ni are from APA-ZZ-01003, rev. 4. (CAR 201104197). Adult ingestion dose factors removed. Ingestion dose pathway removed from Table 13 for activities inside the Site Boundary.

Rev. No. 20 Date April, 2015

Revised Table 10 to implement the recalculated dispersion parameters using 2009- 2013 meteorology. Deleted Table 11 as described in HPCI1503. Added HPCI1502, HPCI1503, HPCI1504, & HPCI1505 as references. Deleted reference to ZZ-67. Added ISFSI to Appendix A, Figure 1. Revised Section 6 to describe the recalculation of the long- term dispersion parameters. Deleted Section 8; following sections were renumbered accordingly.

Rev. No. 21 Date May, 2015

Revised Table 10 to correct the dispersion parameters for the Site Boundary and Nearest Resident locations and edited to two significant digits for consistency with the remainder of Table 10. (CAR 201502908)

Rev. No. 22 Date March, 2017

The following changes implement CR's 201604927, 201602733, 201603668, and 201602733: The methodology used to calculate the A_{i_t} values was added to section 2.4.2. Default setpoint values for GTRE21B and GHRE10B were added to section 3.2. Deleted the specific years of the meteorological data in section 6.1 and instead stated the dispersion parameters represent five years of on- site data to eliminate a potential error trap. The HPCI referenced in section 6.1 provides the necessary level of detail, including the years represented by the data. A footnote was added to section 6.1.2 to clarify that the farmer is a composite and not an actual person. Section 6.2 was revised to clarify the quality check of the meteorological data prior to processing. Section 10, "Bibliography" was revised to add new references and to update the revision level of CDP-ZZ-00200. ^{126}Sb was added to Table 1. Table 12 was revised to change the "Farmer's Residence" to the "Nearest Resident" because the farming plots are now leased to multiple farmers and it is not feasible to calculate dose to multiple farmers' residences. The footnote in Table 12 regarding ^{3}H dispersion parameters was moved into the table. ^{14}C was added to Table 12. Appendix A was reformatted for better readability. Appendix A, Section 2, "Assumptions" was revised to clarify the assumptions, principally dispersion parameter use and the dose pathways and locations. Appendix A, Section 3, "Applicable Dose Limits", was revised to add 10 CFR 72.104. Appendix A, Section 11, "Dose to the Member of the Public from Activities Within the Site Boundary", was revised to eliminate the value of the X/Q for activities within the Site Boundary and to instead refer to Table 10 as the source for the X/Q. The three condensed form equations were likewise eliminated. This eliminated an error trap in that the X/Q could be revised and it may not be recognized that the specific value was stated in the text of Appendix A, Section 11. Appendix A, Section 12 was edited for readability.

Rev. No. 23 Date June, 2018

- Section 5.1 was revised to delete the phrase referring to HPCI 9901 because HPCI 9901 is obsolete. HPCI 1506, rev. 1, superseded portions of of HPCI 9901, the remainder is superseded by HTP-ZZ-DTI-REMP-SMPL-SCHED, REMP Sample Locations and Analysis Schedule". (CR 201705399)
- Section 10, "Bibliography", was revised to update the revision level of CDP-ZZ-00200, Appendix B, ANSI N42.18-2004 (redesignation of ANSI N13.10-1974), and HPCI 1604.
- Table 1 was revised to add the Dose Commitment Factors for ^{117m}Sn. (CR 201706108)
- Format changes are not marked with revision bars.

16.11 (ODCM 9.0) OFFSITE DOSE CALCULATION MANUAL RADIOACTIVE EFFLUENT CONTROLS

16.11.1 LIQUID EFFLUENT

16.11.1.1 LIQUID EFFLUENTS CONCENTRATION LIMITING CONDITION FOR OPERATION

(ODCM 9.3.1)

The concentration of radioactive material released in liquid effluents to UNRESTRICTED AREAS (see Figure 16.11-1) shall be limited to 10 times the concentration values in Appendix B, Table 2, Column 2 to 10 CFR 20.1001-20.2402, for radionuclides other than dissolved or entrained noble gases. For dissolved or entrained noble gases, the concentration shall be limited to 2 x 10^{-4} microCurie/ml total activity.

APPLICABILITY: At all times.

ACTION:

With the concentration of radioactive material released in liquid effluents to UNRESTRICTED AREAS exceeding the above limits, immediately restore the concentration to within the above limits.

16.11.1.1.1 SURVEILLANCE REQUIREMENTS

(ODCM 9.3.2)

16.11.1.1.1.a

Radioactive liquid wastes shall be sampled and analyzed according to the sampling and analysis program of Table 16.11-1.

16.11.1.1.1.b

The results of the radioactivity analysis shall be used in accordance with the methodology and parameters in the ODCM to assure that the concentrations at the point of release are maintained within the limits of Section 16.11.1.1.

16.11.1.1.2 BASES

This section is provided to ensure that the concentration of radioactive materials released in liquid waste effluents to UNRESTRICTED AREAS will be less than 10 times the concentration in Appendix B, Table 2, Column 2 to 10 CFR 20.1001-20.2402. This limitation provides additional assurance that the levels of radioactive materials in bodies of water in UNRESTRICTED AREAS will result in exposures within: (1) the Section II.A design objectives of Appendix I, 10 CFR Part 50, to a MEMBER OF THE PUBLIC, and

(2) the limits of 10 CFR Part 20.1301 to the population. The concentration limit for dissolved or entrained noble gases is based upon the assumption that Xe-135 is the controlling radioisotope and its MPC in air (submersion) was converted to an equivalent concentration in water using the methods described in International Commission on Radiological Protection (ICRP) Publication 2.

The required detection capabilities for radioactive materials in liquid waste samples are tabulated in terms of the lower limits of detection (LLD's).

16.11.1.2 DOSE FROM LIQUID EFFLUENTS LIMITING CONDITION FOR OPERATION

(ODCM 9.4.1)

The dose or dose commitment to a MEMBER OF THE PUBLIC from radioactive materials in liquid effluents released, from each unit, to UNRESTRICTED AREAS (see Figure 16.11-1) shall be limited:

a. During any calendar quarter to less than or equal to 1.5 mrems to the whole body and to less than or equal to 5 mrems to any organ, and

b. During any calendar year to less than or equal to 3 mrems to the whole body and to less than or equal to 10 mrems to any organ.

APPLICABILITY: At all times.

ACTION:

With the calculated dose from the release of radioactive materials in liquid effluents exceeding any of the above limits, prepare and submit to the Commission within 30 days a Special Report that identifies the cause(s) for exceeding the limit(s) and defines the corrective actions that have been taken to reduce the releases and the proposed corrective actions to be taken to assure that subsequent releases will be in compliance with the above limits. This Special Report shall also include: (1) the results of radiological analyses of the drinking water source, and (2) the radiological impact on finished drinking water supplies with regard to the requirements of 40 CFR Part 141, Clean Drinking Water Act.*

16.11.1.2.1 SURVEILLANCE REQUIREMENTS

(ODCM 9.4.2)

Cumulative dose contributions from liquid effluents for the current calendar quarter and the current calendar year shall be determined in accordance with the methodology and parameters in the ODCM at least once per 31 days.

16.11.1.2.2 BASES

This section is provided to implement the requirements of Sections II.A and IV.A of Appendix I, 10 CFR Part 50. The Limiting Condition for Operation implements the guides set forth in Section II.A of Appendix I. The ACTION statements provide the required

* The requirements of ACTION a.(1) and (2) are applicable only if drinking water supply is taken from the receiving water body within 3 miles of the plant discharge. In the case of river-sited plants this is 3 miles downstream only.

operating flexibility and at the same time implement the guides set forth in Section IV.A of Appendix I to assure that the releases of radioactive material in liquid effluents to UNRESTRICTED AREAS will be kept "as low as is reasonably achievable".

Also, for fresh water sites with drinking water supplies that can be potentially affected by plant operations, there is reasonable assurance that the operation of the facility will not result in radionuclide concentrations in the finished drinking water that are in excess of the requirements of 40 CFR Part 141. The dose calculation methodology and parameters in the ODCM implement the requirements in Section III.A of Appendix I which specify that conformance with the guides of Appendix I be shown by calculational procedures based on models and data, such that the actual exposure of a MEMBER OF THE PUBLIC through appropriate pathways is unlikely to be substantially underestimated. The equations specified in the ODCM for calculating the doses due to the actual release rates of radioactive materials in liquid effluents are consistent with the methodology provided in Regulatory Guide 1.109, "Calculations of Annual Doses to Man from Routine Releases of Reactor Effluents with 10 CFR Part 50, Appendix I", Revision 1, October 1977 and Regulatory Guide 1.113, "Estimating Aquatic and Dispersion of Effluents from accidental and Routine Reactor Releases for the Purpose of Implementing Appendix I", April 1977.

The reporting requirements of Action(a) implement the requirements of 10CFR20.2203.

16.11.1.3 RADIOACTIVE LIQUID EFFLUENT MONITORING INSTRUMENTATION LIMITING CONDITION FOR OPERATION

(ODCM 9.1.1)

The radioactive liquid effluent monitoring instrumentation channels shown in Table 16.11-2 shall be FUNCTIONAL with their Alarm/Trip Setpoints set to ensure that the limits of Section 16.11.1.1 are not exceeded. The Alarm/Trip Setpoints of these channels shall be determined and adjusted in accordance with the methodology and parameters in the ODCM.

APPLICABILITY: At all times.

ACTION:

a. With a radioactive liquid effluent monitoring instrumentation channel Alarm/Trip Setpoint less conservative than required by the above, immediately suspend the release of radioactive liquid effluents monitored by the affected channel, or declare the channel non-functional.

b. With less than the minimum number of radioactive liquid effluent monitoring instrumentation channels FUNCTIONAL, take the ACTION shown in Table 16.11-2. Restore the non-functional instrumentation to FUNCTIONAL status within 30 days and, if unsuccessful, explain in the next Radioactive Effluent Release Report, pursuant to Technical Specification 5.6.3, why this non-functionality was not corrected within the time specified.

16.11.1.3.1 SURVEILLANCE REQUIREMENTS

(ODCM 9.1.2)

Each radioactive liquid effluent monitoring instrumentation channel shall be demonstrated FUNCTIONAL by performance of the CHANNEL CHECK, SOURCE CHECK, CHANNEL CALIBRATION and CHANNEL OPERATIONAL TEST at the frequencies shown in Table 16.11-3.

16.11.1.3.2 BASES

The radioactive liquid effluent monitoring instrumentation is provided to monitor and control, as applicable, the releases of radioactive materials in liquid effluents during actual or potential releases of liquid effluents. The Alarm/Trip Setpoints for these instruments shall be calculated and adjusted in accordance with the methodology and parameters in the ODCM to ensure that the alarm/trip will occur prior to exceeding the limits of 10 CFR Part 20. The FUNCTIONALITY and use of this instrumentation is consistent with the requirements of General Design Criteria 60, 63, and 64 of Appendix A to 10 CFR Part 50.

16.11.1.4 LIQUID RADWASTE TREATMENT SYSTEM LIMITING CONDITION FOR OPERATION

(ODCM 9.5.1)

The Liquid Radwaste Treatment System shall be FUNCTIONAL and appropriate portions of the system shall be used to reduce releases of radioactivity when the projected doses due to the liquid effluent, from each unit, to UNRESTRICTED AREAS (see Figure 16.11-1) would exceed 0.06 mrem to the whole body or 0.2 mrem to any organ in a 31 day period.

APPLICABILITY: At all times.

ACTION:

With radioactive liquid waste being discharged in excess of the above limits and the Liquid Radwaste Treatment Systems are not being fully utilized, prepare and submit to the Commission within 30 days a Special Report that includes the following information:

1) Explanation of why liquid radwaste was being discharged without treatment, identification of any inoperable equipment or subsystems, and the reason for the inoperability.

2) Action(s) taken to restore the inoperable equipment to OPERABLE status, and

3) Summary description of action(s) taken to prevent a recurrence.

16.11.1.4.1 SURVEILLANCE REQUIREMENTS

(ODCM 9.5.2)

16.11.1.4.1.a

Doses due to liquid releases from each unit to UNRESTRICTED AREAS shall be projected at least once per 31 days in accordance with the methodology and parameters in the ODCM.

16.11.1.4.1.b

The installed Liquid Radwaste Treatment System shall be considered FUNCTIONAL by meeting Sections 16.11.1.1 and 16.11.1.2.

16.11.1.4.2 BASES

The FUNCTIONALITY of the Liquid Radwaste Treatment System ensures that this system will be available for use whenever liquid effluents require treatment prior to release to the environment. The requirement that the appropriate portions of this system be used when specified provides assurance that the releases of radioactive materials in liquid effluents will be kept "as low as is reasonably achievable". This section implements the requirements of 10 CFR Part 50.36a, General Design Criterion 60 of Appendix A to 10 CFR Part 50 and the design objective given in Section II.D of Appendix I to 10 CFR Part 50. The specified limits governing the use of appropriate portions of the Liquid Radwaste Treatment System were specified as a suitable fraction of the dose design objectives set forth in Section II.A of Appendix I, 10 CFR Part 50, for liquid effluents.

16.11.1.5 LIQUID HOLDUP TANKS
LIMITING CONDITION FOR OPERATION

The quantity of radioactive material contained in each of the following unprotected outdoor tanks shall be limited to less than or equal to 150 Curies, excluding tritium and dissolved or entrained noble gases:

a. Reactor Makeup Water Storage Tank,

b. Refueling Water Storage Tank,

c. Condensate Storage Tank, and

d. Outside temporary tanks, excluding demineralizer vessels and the liner being used to solidify radioactive waste.

APPLICABILITY: At all times.

ACTION:

With the quantity of radioactive material in any of the above listed tanks exceeding the above limit, immediately suspend all additions of radioactive material to the tank, within 48 hours reduce the tank contents to within the limit, and describe the events leading to this condition in the next Radioactive Effluent Release Report, pursuant to Technical Specification 5.6.3.

e.

16.11.1.5.1 SURVEILLANCE REQUIREMENTS

(4.11.1.4)

The quantity of radioactive material contained in each of the above listed tanks shall be determined to be within the above limit by analyzing a representative sample of the tank's contents at least once per 7 days when radioactive materials are being added and within 7 days following any addition of radioactive material to the tank. The provisions of Sections 16.0.2.2 and 16.0.2.3 are applicable, however the allowed surveillance interval extension beyond 25% shall not be exceeded. These tanks are also covered by Administrative Controls Section 5.5.12 of the plant Technical Specifications.

16.11.1.5.2 BASES

The tanks listed above include all those outdoor radwaste tanks that are not surrounded by liners, dikes, or walls capable of holding the tank contents and that do not have tank overflows and surrounding area drains connected to the Liquid Radwaste Treatment System.

Restricting the quantity of radioactive material contained in the specified tanks provides assurance that in the event of an uncontrolled release of the tanks' contents, the resulting concentrations would be less than the limits of 10 CFR Part 20.1-20.602, Appendix B, Table II, Column 2, (redesignated at 56FR23391, May 21, 1991) at the nearest potable water supply and the nearest surface water supply in an UNRESTRICTED AREA.

16.11.2 GASEOUS EFFLUENTS

16.11.2.1 GASEOUS EFFLUENTS DOSE RATE LIMITING CONDITION OF OPERATION

(ODCM 9.6.1)

The dose rate due to radioactive materials released in gaseous effluents from the site to areas at and beyond the SITE BOUNDARY (see Figure 16.11-2) shall be limited to the following:

a. For noble gases: Less than or equal to 500 mrems/yr to the whole body and less than or equal to 3000 mrems/yr to the skin, and

b. For Iodine-131 and 133, for tritium, and for all radionuclides in particulate form with half-lives greater than 8 days: Less than or equal to 1500 mrems/yr to any organ.

APPLICABILITY: At all times.

ACTION:

With the dose rate(s) exceeding the above limits, immediately restore the release rate to within the above limit(s).

16.11.2.1.1 SURVEILLANCE REQUIREMENTS

(ODCM 9.6.2)

16.11.2.1.1.a

The dose rate due to noble gases in gaseous effluents shall be determined to be within the above limits in accordance with the methodology and parameters in the ODCM.

16.11.2.1.1.b

The dose rate due to Iodine-131 and 133, tritium and all radionuclides in particulate form with half-lives greater than 8 days in gaseous effluents shall be determined to be within the above limits in accordance with the methodology and parameters in the ODCM by obtaining representative samples and performing analyses in accordance with the sampling and analysis program specified in Table 16.11-4.

16.11.2.1.2 BASES

This section is provided to ensure that the dose at any time at and beyond the SITE BOUNDARY from gaseous effluents from all units on the site will be within the annual dose limits of 10 CFR Part 20 to UNRESTRICTED AREAS. The dose rate limits are the doses associated with the concentrations of 10 CFR Part 20.1-20.601, Appendix B, Table II, Column 1. These limits provide reasonable assurance that radioactive material discharged in gaseous effluents will not result in the exposure of a MEMBER OF THE PUBLIC in an UNRESTRICTED AREA, either within or outside the SITE BOUNDARY, to annual average concentrations exceeding the dose limits specified in 10 CFR Part 20 10 CFR 20.1301. For MEMBERS OF THE PUBLIC who may at times be within the SITE BOUNDARY, the occupancy of that MEMBER OF THE PUBLIC will usually be sufficiently low to compensate for any increase in the atmospheric diffusion factor above that for the SITE BOUNDARY. Examples of calculations for such MEMBERS OF THE PUBLIC, with the appropriate occupancy factors, shall be given in the ODCM. The specified release rate limits restrict, at all times, the corresponding gamma and beta dose rates above background to a MEMBER OF THE PUBLIC at or beyond the SITE BOUNDARY to less than or equal to 500 mrem/year to the whole body or to less than or equal to 3000 mrems/year to the skin. These release rate limits also restrict, at all times, the corresponding thyroid dose rate above background to a child via the inhalation pathway to less than or equal to 1500 mrems/year.

The required detection capabilities for radioactive materials in gaseous waste samples are tabulated in terms of the lower limits of detection (LLD's).

The requirement for additional sampling of the Unit Vent following a reactor power transient is provided to ensure that the licensee is aware of and properly accounts for any increases in the release of gaseous effluents due to spiking which may occur as a result of the power transient. Monitoring the Unit Vent for increased noble gas activity is appropriate because it is the release point for any increased activity which may result from the power transient.

Since the escape rate coefficients for the noble gas nuclides is equal to or greater than the escape rate coefficient for iodine and the particulate nuclides*,** , it is reasonable to assume that the RCS spiking behavior of the noble gas nuclides is similar to that of the particulate and iodine nuclides. Considering the effects of iodine and particulate partitioning, plateout on plant and ventilation system surfaces, and the 99% efficiency of the Unit Vent HEPA filters and charcoal absorbers, it is reasonable to assume that the relative concentrations of the noble gas nuclides will be much greater than those of the iodine and particulate nuclides. Therefore, an increase in the iodine and particulate RCS activity is not an appropriate indicator of an increase in the Unit Vent activity, and it is appropriate to monitor the Unit Vent effluent activity as opposed to the RCS activity as an indicator of the need to perform post-transient sampling. In addition, it is appropriate to monitor the noble gas activity due to its relatively greater concentration in the Unit Vent.

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* Cohen, Paul, Water Coolant Technology of Power Reactors, Table 5.19, page 198. American Nuclear Society. 1980.

** NUREG-0772, "Technical Bases for Estimating Fission Product Behavior During LWR Accidents", Silberberg, M., editor, USNRC; Figure 4.3, page 4.22. June, 1981.

16.11.2.2 DOSE - NOBLE GASES LIMITING CONDITION OF OPERATION (ODCM 9.7.1)

The air dose due to noble gases released in gaseous effluents, from each unit, to areas at and beyond the SITE BOUNDARY (see Figure 16.11-2) shall be limited to the following:

During any calendar quarter: Less than or equal to 5 mrads for gamma radiation and less than or equal to 10 mrads for beta radiation, and

During any calendar year: Less than or equal to 10 mrads for gamma radiation and less than or equal to 20 mrads for beta radiation.

APPLICABILITY: At all times.

ACTION:

With the calculated air dose from radioactive noble gases in gaseous effluents exceeding any of the above limits, prepare and submit to the Commission within 30 days a Special Report that identifies the cause(s) for exceeding the limit(s) and defines the corrective actions that have been taken to reduce the releases and the proposed corrective actions to be taken to assure that subsequent releases will be in compliance with the above limits.

16.11.2.2.1 SURVEILLANCE REQUIREMENTS (ODCM 9.7.2)

Cumulative dose contributions for the current calendar quarter and current calendar year for noble gases shall be determined in accordance with the methodology and parameters in the ODCM at least once per 31 days.

16.11.2.2.2 BASES

This section is provided to implement the requirements of Sections II.B, III.A, and IV.A of Appendix I, 10 CFR Part 50. The Limiting Condition for Operation implements the guides set forth in Section II.B of Appendix I. The ACTION statement provides the required operating flexibility and at the same time implement the guides set forth in Section IV.A of Appendix I to assure that the releases of radioactive material in gaseous effluents to UNRESTRICTED AREAS will be kept "as low as is reasonably achievable".

The Surveillance Requirements implement the requirements in Section III.A of Appendix I that conformance with the guides of Appendix I be shown by calculational procedures based on models and data such that the actual exposure of a MEMBER OF THE PUBLIC through appropriate pathways is unlikely to be substantially underestimated. The dose calculation methodology and parameters established in the ODCM for calculating the doses due to the actual release rates of radioactive noble gases in gaseous effluents are consistent with the methodology provided in Regulatory Guide 1.109, "Calculation of Annual Doses to Man from Routine Releases on Reactor Effluents for the Purpose of Evaluating Compliance with 10 CFR Part 50, Appendix I", Revision 1, October 1977 and Regulatory Guide 1.111, "Methods for Estimating Atmospheric Transport and Dispersion of Gaseous Effluents in Routine Releases from Light-Water Cooled Reactors", Revision 1, July 1977. The ODCM equations provided for determining the air doses at and beyond the SITE BOUNDARY are based upon the historical average atmospheric conditions.

The reporting requirements of Action(a) implement the requirements of 10CFR20.2203.

16.11.2.3 DOSE - IODINE-131 AND 133, TRITIUM, AND RADIOACTIVE MATERIAL IN PARTICULATE FORM LIMITING CONDITION OF OPERATION

(ODCM 9.8.1)

The dose to a MEMBER OF THE PUBLIC from Iodine-131 and 133, tritium, and all radionuclides in particulate form with half-lives greater than 8 days in gaseous effluents released, from each unit, to areas at and beyond the SITE BOUNDARY (see Figure 16.11-2) shall be limited to the following:

a. During any calendar quarter: Less than or equal to 7.5 mrems to any organ, and

b. During any calendar year: Less than or equal to 15 mrems to any organ.

APPLICABILITY: At all times.

ACTION:

a. With the calculated dose from the release of Iodine-131 and 133, tritium, and radionuclides in particulate form with half-lives greater than 8 days, in gaseous effluents exceeding any of the above limits, prepare and submit to the Commission within 30 days a Special Report that identifies the cause(s) for exceeding the limits and defines the corrective actions that have been taken to reduce the releases and the proposed corrective actions to be taken to assure that subsequent releases will be in compliance with the above limits.

b. The provisions of Sections 16.0.1.3 and 16.0.1.4 are not applicable.

16.11.2.3.1 SURVEILLANCE REQUIREMENTS

(ODCM 9.8.2)

Cumulative dose contributions for the current calendar quarter and current calendar year for Iodine-131 and 133, tritium, and radionuclides in particulate form with half-lives greater than 8 days shall be determined in accordance with the methodology and parameters in the ODCM at least once per 31 days.

16.11.2.3.2 BASES

This section is provided to implement the requirements of Sections II.C, III.A, and IV.A of Appendix I, 10 CFR Part 50. The Limiting Conditions for Operation are the guides set forth in Section II.C of Appendix I. The ACTION statements provide the required operating flexibility and at the same time implement the guides set forth in Section IV.A of Appendix I to assure that the release of radioactive material in gaseous effluents to UNRESTRICTED AREAS will be kept "as low as reasonably achievable". The ODCM calculational methods specified in the Surveillance Requirements implement the requirements in Section III.A of Appendix I that conformance with the guides of Appendix

I be shown by calculational procedures based on models and data such that the actual exposure of a MEMBER OF THE PUBLIC through appropriate pathways is unlikely to be substantially underestimated. The ODCM calculational methodology and parameters for calculating the doses due to the actual release rates of the subject materials are consistent with the methodology provided in Regulatory Guide 1.109, "Calculation of Annual Doses to Man from Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10 CFR Part 50, Appendix I", Revision 1, October 1977 and Regulatory Guide 1.111, "Methods for Estimating Atmospheric Transport and Dispersion of Gaseous Effluents in Routine Releases from Light-Water Cooled Reactors", Revision 1, July 1977. These equations also provide for determining the actual doses based upon the historical average atmospheric conditions. The release rate controls for Iodine-131, and 133, tritium, and radionuclides in particulate form with half-lives greater than 8 days are dependent upon the existing radionuclide pathways to man, in the areas at and beyond the SITE BOUNDARY. The pathways that were examined in the development of these calculations were: (1) individual inhalation of airborne radionuclides, (2) deposition of radionuclides onto green leafy vegetation with subsequent consumption by man, (3) deposition of radionuclides onto grassy areas where milk animals and meat-producing animals graze with consumption of the milk and meat by man, and (4) deposition on the ground with subsequent exposure of man.

The reporting requirements of Action(a) implement the requirements of 10CFR20.2203.

16.11.2.4 RADIOACTIVE GASEOUS EFFLUENT MONITORING INSTRUMENTATION LIMITING CONDITION FOR OPERATION

(ODCM 9.2.1)

The radioactive gaseous effluent monitoring instrumentation channels shown in Table 16.11-5 shall be FUNCTIONAL with their Alarm/Trip Setpoints set to ensure that the limits of Section 16.11.2.1 are not exceeded. The Alarm/Trip Setpoints of these channels meeting Section 16.11.2.1 shall be determined and adjusted in accordance with the methodology and parameters in the ODCM.

APPLICABILITY: As shown in Table 16.11-5.

ACTION:

a. With a radioactive gaseous effluent monitoring instrumentation channel Alarm/Trip Setpoint less conservative than required by the above, immediately declare the channel non-functional.

b. With less than the minimum number of radioactive gaseous effluent monitoring instrumentation channels FUNCTIONAL, take the ACTION shown in Table 16.11-5. Restore the non-functional instrumentation to FUNCTIONAL status within the time specified in the ACTION, or explain in the next Radioactive Effluent Release Report, pursuant to Technical Specification 5.6.3, why this non-functionality was not corrected within the time specified.

16.11.2.4.1 SURVEILLANCE REQUIREMENTS

(ODCM 9.2.2)

Each radioactive gaseous effluent monitoring instrumentation channel shall be demonstrated FUNCTIONAL by performance of the CHANNEL CHECK, SOURCE CHECK, CHANNEL CALIBRATION and CHANNEL OPERATIONAL TEST at the frequencies shown in Table 16.11-6.

16.11.2.4.2 BASES

The radioactive gaseous effluent monitoring instrumentation is provided to monitor and control, as applicable, the releases of radioactive materials in gaseous effluents during actual or potential releases of gaseous effluents. The Alarm/Trip Setpoints for these instruments shall be calculated and adjusted in accordance with the methodology and parameters in the ODCM to ensure that the alarm/trip will occur prior to exceeding the limits of 10 CFR Part 20. The FUNCTIONALITY and use of this instrumentation is consistent with the requirements of General Design Criteria 60, 63, and 64 of Appendix A to 10 CFR Part 50. The sensitivity of any noble gas activity monitor used to show compliance with the gaseous effluent release requirements of Section 16.11.2.1 shall be such that concentrations as low as 1×10^{-6} μCi/cc are measurable.

The monitors GT-RE-22 and GT-RE-33 are only required for automatic containment purge isolation in MODES 1 through 4. For plant conditions during CORE ALTERATIONS and during movement of irradiated fuel within containment, the function of the monitors is to alarm only and the trip signals for automatic actuation of CPIS may be bypassed. Based on the guidance provided in Regulatory Guide 1.97 concerning monitoring requirements for containment or purge effluent, the monitors GT-RE-22 and GT-RE-33 do not need to meet the single failure criterion for an Alarm function only during CORE ALTERATIONS or during movement of irradiated fuel in containment. One instrumentation channel at a minimum is required for the alarm only function during refueling activities.

In the event that the containment mini-puge supply and exhaust valves have been closed to satisfy Action 41 of Table 16.11-5 due to non-functionality of GTRE0022 and/or GTRE0033, an allowance is provided in Action 41 to open the containment mini-purge supply and exhaust valves under administrative controls for the purpose of equalizing containment pressure. The administrative controls consist of designating a control room operator to rapidly close the valves when a need for system isolation is indicated.

16.11.2.5 GASEOUS RADWASTE TREATMENT SYSTEM LIMITING CONDITION OF OPERATION

(ODCM 9.9.1)

The VENTILATION EXHAUST TREATMENT SYSTEM and the WASTE GAS HOLDUP SYSTEM shall be FUNCTIONAL and appropriate portions of these systems shall be used to reduce releases of radioactivity when the projected doses in 31 days due to gaseous effluent releases, from each unit, to areas at and beyond the SITE BOUNDARY (see Figure 16.11-2) would exceed:

a. 0.2 mrad to air from gamma radiation, or

b. 0.4 mrad to air from beta radiation, or

c. 0.3 mrem to any organ of a MEMBER OF THE PUBLIC.

APPLICABILITY: At all times

ACTION:

With radioactive gaseous waste being discharged without treatment and in excess of the above limits, prepare and submit to the Commission within 30 days a Special Report that includes the following information:

1) Identification of any non-functional equipment or subsystems, and the reason for the non-functionality,

2) Action(s) taken to restore the non-functional equipment to FUNCTIONAL status, and

3) Summary description of action(s) taken to prevent a recurrence.

16.11.2.5.1 SURVEILLANCE REQUIREMENTS

(ODCM 9.9.2)

16.11.2.5.1.a

Doses due to gaseous releases to areas at and beyond the SITE BOUNDARY shall be projected at least once per 31 days in accordance with the methodology and parameters in the ODCM.

16.11.2.5.1.b

The installed VENTILATION EXHAUST TREATMENT SYSTEM and the WASTE GAS HOLDUP SYSTEMS shall be considered FUNCTIONAL by meeting Sections 16.11.2.1 and 16.11.2.2 or 16.11.2.3.

16.11.2.5.2 BASES

The FUNCTIONALITY of the WASTE GAS HOLDUP SYSTEM and the VENTILATION EXHAUST TREATMENT SYSTEM ensures that the system will be available for use whenever gaseous effluents require treatment prior to release to the environment. The requirement that the appropriate portions of these systems be used, when specified, provides reasonable assurance that the releases of radioactive materials in gaseous effluents will be kept "as low as is reasonably achievable." This control implements the requirements of 10 CFR Part 50.36a, General Design Criterion 60 of Appendix A to 10 CFR Part 50, and the design objectives given in Section II.D of Appendix I to 10 CFR Part 50. The specified limits governing the use of appropriate portions of the systems were specified as a suitable fraction of the dose design objectives set forth in Sections II.B and II.C of Appendix I, 10 CFR Part 50, for gaseous effluents.

16.11.2.6 EXPLOSIVE GAS MIXTURE LIMITING CONDITION FOR OPERATION

The concentration of oxygen in the WASTE GAS HOLDUP SYSTEM shall be limited to less than or equal to 3% by volume whenever the hydrogen concentration exceeds 4% by volume.

APPLICABILITY: At all times.

ACTION:

a. With the concentration of oxygen in the WASTE GAS HOLDUP SYSTEM greater than 3% by volume but less than or equal to 4% by volume, reduce the oxygen concentration to the above limit within 48 hours.

b. With the concentration of oxygen in the WASTE GAS HOLDUP SYSTEM greater than 4% by volume and the hydrogen concentration greater than 4% by volume, immediately suspend all additions of waste gases to the system and reduce the concentration on oxygen to less than or equal to 4% by volume, then take ACTION a. above.

16.11.2.6.1 SURVEILLANCE REQUIREMENTS

The concentrations of hydrogen and oxygen in the WASTE GAS HOLDUP SYSTEM shall be determined to be within the above limits by continuously monitoring the waste gases in the WASTE GAS HOLDUP SYSTEM with the hydrogen and oxygen monitors required FUNCTIONAL by Section 16.11.2.7. This system is covered by Technical Specification 5.5.12 which governs surveillance test frequencies and missed surveillances.

16.11.2.6.2 BASES

This Requirement is provided to ensure that the concentration of potentially explosive gas mixtures contained in the WASTE GAS HOLDUP SYSTEM is maintained below the flammability limits of hydrogen and oxygen. Automatic control features are included in the system to prevent the hydrogen and oxygen concentrations from reaching these flammability limits. These automatic control features include isolation of the source of hydrogen and/or oxygen. Maintaining the concentration of hydrogen and oxygen below their flammability limits provides assurance that the releases of radioactive materials will be controlled in conformance with the requirements of General Design Criterion 60 of Appendix A to 10 CFR Part 50.

16.11.2.7 WASTE GAS HOLDUP SYSTEM RECOMBINER EXPLOSIVE GAS MONITORING INSTRUMENTATION LIMITING CONDITION FOR OPERATION

At least one hydrogen and both the inlet and outlet oxygen explosive gas monitoring instrument channels for each WASTE GAS HOLDUP SYSTEM recombiner shall be FUNCTIONAL with their Alarm/Trip Setpoints (with the exception of the "FEED H2 4%/ FEED O2 3%" and "FEED H2 4%/FEED O2 4%" alarms) set to ensure that the limits of Section 16.11.2.6 are not exceeded.

APPLICABILITY: During WASTE GAS HOLDUP SYSTEM operation.

ACTION:

a. With an outlet oxygen monitor channel non-functional, operation of the system may continue provided grab samples are taken and analyzed at least once per 24 hours.

b. With both oxygen or both hydrogen channels or both the inlet oxygen and inlet hydrogen monitor channels for one recombiner non-functional, suspend oxygen supply to the recombiner. Addition of waste gas to the system may continue provided grab samples are taken and analyzed at least: 1) once per 4 hours during mechanical or chemical degassing in preparation for plant shutdown, and 2) once per 24 hours during other operations.

c. With the inlet oxygen analyzer non-functional, operation of the system may continue provided the inlet hydrogen is maintained less than 4%. If inlet hydrogen is greater than 4%, suspend oxygen to the recombiner. Addition of waste gas to the system may continue provided grab samples are taken and analyzed at least: 1) once per 4 hours during mechanical or chemical degassing operations in preparation for plant shutdown, and 2) once per 24 hours during other operations.

16.11.2.7.1 SURVEILLANCE REQUIREMENTS

This system is covered by Technical Specification 5.5.12 which governs surveillance test frequencies and missed surveillances.

Each waste gas holdup system recombiner explosive gas monitoring instrumentation channel shall be demonstrated FUNCTIONAL by performance of:

a. A CHANNEL CHECK at least once per 24 hours,

b. Not used

c. A CHANNEL CALIBRATION at least once per 92 days with the use of standard gas samples containing a nominal:

1) One volume percent hydrogen, balance nitrogen and four volume percent hydrogen, balance nitrogen for the hydrogen monitor, and

2) One volume percent oxygen, balance nitrogen, and four volume percent oxygen, balance nitrogen for the inlet oxygen monitor, and

3) 10 ppm by volume oxygen, balance nitrogen and 80 ppm by volume oxygen, balance nitrogen for the outlet oxygen monitor.

16.11.2.7.2 BASES

Mechanical 'degassing operation' is defined as the transfer of gas from the Volume Control Tank (VCT) to the Waste Gas Holdup System when establishing a nitrogen blanket on the VCT in preparation for a plant shutdown. Chemical 'degassing operation' is the process of adding hydrogen peroxide to the RCS after the VCT hydrogen blanket has been replaced with nitrogen per the mechanical degassification process and the RCS has been reduced to less than 180°F. Both mechanical and chemical degassification may lead to an explosive gas mixture in the Waste Gas Holdup System, thus requiring the more restrictive 4-hour sampling. Other operations require 24-hour sampling.

The "FEED H2 4%/FEED O2 3%" AND "FEED H2 4%/FEED O2 4%" alarms are not required to be FUNCTIONAL. These alarms result from the combination of inlet hydrogen and inlet oxygen analyzer outputs while the FSAR only addresses FUNCTIONALITY of each separate analyzer. Only the individual alarms and control functions associated with each analyzer are to be used to determine its functionality. These alarms and control functions are sufficient to ensure that the limits of Section 16.11.2.6 are not exceeded.

The CHANNEL CALIBRATION includes triggering the following alarms at the analyzer and verifying that the required control board annunciators and control functions actuate:

1) Feed Gas High H_2

2) HARC-1104 OAIC-1112 Hi Hi H_2/O_2 O_2 Shutdown

3) H_2 Reactor High Oxygen O_2 Limit

4) Product Gas High H_2

5) Product Gas High Oxygen

6) Product Gas Hi Hi O_2 Shutdown

This surveillance verifies the FUNCTIONALITY of the analyzers' output relays, all interposing relays, and the annunciators. Setpoint verification consists of verifying that the correct setpoint values are entered in the analyzers' database.

16.11.2.8 GAS STORAGE TANKS LIMITING CONDITION FOR OPERATION

The quantity of radioactivity contained in each gas storage tank shall be limited to less than or equal to 2.5 x 10^5 Curies of noble gases (considered as Xe-133 equivalent).

APPLICABILITY: At all times.

ACTION:

With the quantity of radioactive material in any gas storage tank exceeding the above limit, immediately suspend all additions of radioactive material to the tank and, within 48 hours, reduce the tank contents to within the limit, and describe the events leading to this condition in the next Radioactive Effluent Release Report, pursuant to Technical Specification 5.6.3.

16.11.2.8.1 SURVEILLANCE REQUIREMENTS

The provisions of Sections 16.0.2.2 and 16.0.2.3 are applicable, however the allowed surveillance interval extension beyond 25% shall not be exceeded. This system is also covered by Administrative Controls Section 5.5.12 of the plant Technical Specifications.

The quantity of radioactive material contained in each gas storage tank shall be determined to be within the above limit at least once per 18 months.

16.11.2.8.2 BASES

The tanks included in this Requirement are those tanks for which the quantity of radioactivity contained is not limited directly or indirectly by another Requirement. Restricting the quantity of radioactivity contained in each gas storage tank provides assurance that in the event of an uncontrolled release of the tank's contents, the resulting whole body exposure to a MEMBER OF THE PUBLIC at the nearest SITE BOUNDARY will not exceed 0.5 rem. This is consistent with Standard Review Plan 11.3, Branch Technical Position ETSB 11-5, "Postulated Radioactive Releases Due to a Waste Gas System Leak or Failure," in NUREG-0800, July 1981. The determination of Xe-133 equivalent uses the effective dose conversion factors for air submersion listed in Table III.1 of EPA Federal Guidance Report No. 12, EPA-402-R-93-081, "External Exposure to Radionuclides in Air, Water, and Soil," 1993.

16.11.3 TOTAL DOSE

16.11.3.1 TOTAL DOSE LIMITING CONDITION FOR OPERATION

(ODCM 9.10.1)

The annual (calendar year) dose or dose commitment to any MEMBER OF THE PUBLIC due to releases of radioactivity and to radiation from uranium fuel cycle sources shall be limited to less than or equal to 25 mrems to the whole body or any organ, except the thyroid, which shall be limited to less than or equal to 75 mrem.

APPLICABILITY: At all times.

ACTION:

With the calculated doses from the release of radioactive materials in gaseous effluents exceeding twice the limits of Section 16.11.2.2a, 16.11.2.2b, 16.11.2.3a, or 16.11.2.3b, calculations should be made including direct radiation contributions from the units and from outside storage tanks to determine whether the above limits of Section 16.11.3.1 have been exceeded. If such is the case, prepare and submit to the Commission within 30 days a Special Report that defines the corrective action to be taken to reduce subsequent release to prevent recurrence of exceeding the above limits and includes the schedule for achieving conformance with the above limits. This Special Report, as defined in 10 CFR 20.2203, shall include an analysis that estimates the radiation exposure (dose) to a MEMBER OF THE PUBLIC from uranium fuel cycle sources, including all effluent pathways and direct radiation, for the calendar year that includes the release(s) covered by this report. It shall also describe levels of radiation and concentrations of radioactive material involved, and the cause of the exposure levels or concentrations. If the estimated dose(s) exceeds the above limits, and if the release condition resulting in violation of 40 CFR Part 190 has not already been corrected, the Special Report shall include a request for a variance in accordance with the provisions of 40 CFR Part 190. Submittal of the report is considered a timely request, and a variance is granted until staff action on the request is complete.

16.11.3.1.1 SURVEILLANCE REQUIREMENTS

(ODCM 9.10.2)

16.11.3.1.1.a

Cumulative dose contributions from gaseous effluents shall be determined in accordance with Sections 16.11.2.2.1, and 16.11.2.3.1, and in accordance with the methodology and parameters in the ODCM.

16.11.3.1.1.b

Cumulative dose contributions from direct radiation from the units and from radwaste storage tanks shall be determined in accordance with the methodology and parameters in the ODCM. This requirements is applicable only under conditions set forth in ACTION a. of Section 16.11.3.1.

16.11.3.1.2 BASES

This Requirement is provided to meet the dose limitations of 40 CFR Part 190 that have been incorporated into 10 CFR Part 20.1301. The control requires the preparation and submittal of a Special Report whenever the calculated doses due to releases of radioactivity and the radiation from uranium fuel cycle sources exceed 25 mrems to the whole body or any organ except the thyroid, which shall be limited to less than or equal to 75 mrems. For sites containing up to four reactors, it is highly unlikely that the resultant dose to a MEMBER OF THE PUBLIC will exceed the dose limits of 40 CFR Part 190 if the individual reactors remain within twice the dose design objectives of Appendix I, and if direct radiation doses from the reactor units and from outside storage tanks are kept small. The Special Report will describe a course of action that should result in the limitation of the annual dose to a MEMBER OF THE PUBLIC to within the 40 CFR Part 190 limits.

For the purposes of the Special Report, it may be assumed that the dose commitment to the MEMBER OF THE PUBLIC from other uranium fuel cycle sources is negligible, with the exception that dose contributions from other nuclear fuel cycle facilities at the same site or within a radius of 8 km must be considered. If the dose to any MEMBER OF THE PUBLIC is estimated to exceed the requirements of 40 CFR Part 190, the Special Report with a request for a variance (provided the release conditions resulting in violation of 40 CFR Part 190 have not already been corrected), in accordance with the provisions of 40 CFR Part 190.11 and 10 CFR 20.2203, is considered to be a timely request and fulfills the requirements of 40 CFR Part 190 until NRC staff action is completed. The variance only relates to 40 CFR Part 190, and does not apply in any way to the other requirements for dose limitation of 10 CFR Part 20, as addressed in Sections 16.11.1.1 and 16.11.2.1. An individual is not considered a MEMBER OF THE PUBLIC during any period in which he/she is engaged in carrying out any operation that is part of the nuclear fuel cycle.

There are three defined effluent release categories: 1.) Releases directly to the hydrosphere; 2.) noble gas releases to the atmosphere; 3.) radioiodine and particulate releases to the atmosphere. For each effluent release category, it is assumed in the dose calculations that an individual with the highest dose potential is the receptor. In general, the adult is considered to be the critical age group for liquid effluents, and the child age group is the most limiting for radioiodine and particulates in gaseous effluents. Thus, it is highly unlikely or impossible for the same individual to simultaneously receive the highest dose via all three effluent categories. For most reactor sites, it is also unlikely that all different potential dose pathways would contribute to the dose to a single real individual. Since it is difficult or impossible to continually determine actual food use patterns and critical age group, for calculational purposes, assumptions are made which tend to maximize doses. Any refinement in the assumptions would have the effect of reducing the estimated dose. For radionuclides released to the hydrosphere, the degree of overestimation in most situations is such that no individual will receive a significant dose. These conservative assumptions generally result in an overestimation of dose by one or two orders of magnitude. Since these assumptions are reflected in the Radiological Effluent Controls limiting radionuclide releases to design objective individual doses, no offsite individual is likely to actually receive a significant dose. Since the doses from liquid releases are very conservatively evaluated, there is reasonable assurance that no real individual will receive a significant dose from radioactive liquid release pathway. Therefore, only doses to individuals via airborne pathways and dose resulting from direct radiation need to be considered in determining potential compliance to 40 CFR 190*.

The reporting requirements of Action(a) implement the requirements of 10CFR20.2203.

* NUREG-0543, "Methods for Demonstrating LWR compliance with the EPA Uranium Fuel Cycle Standard (40 CFR 190)", Congel, F. J., Office of Nuclear Reactor Regulation, USNRC. January, 1980. pp. 5-8.

16.11.4 RADIOLOGICAL ENVIRONMENTAL MONITORING

16.11.4.1 MONITORING PROGRAM LIMITING CONDITION OF OPERATION (ODCM 9.11.1)

The Radiological Environmental Monitoring Program shall be conducted as specified in Table 16.11-7.

APPLICABILITY: At all times.

ACTION:

a. With the Radiological Environmental Monitoring Program not being conducted as specified in Table 16.11-7, prepare and submit to the Commission, in the Annual Radiological Environmental Operating Report required by Technical Specification 5.6.2, a description of the reasons for not conducting the program as required and the plans for preventing a recurrence.

b. With the level of radioactivity as the result of plant effluents in an environmental sampling medium at a specified location exceeding the reporting levels of Table 16.11-8 when averaged over any calendar quarter, prepare and submit to the Commission within 30 days a Special Report that identifies the cause(s) for exceeding the limit(s) and defines the corrective actions to be taken to reduce radioactive effluents so that the potential annual dose* to a MEMBER OF THE PUBLIC is less than the calendar year limits of Sections 16.11.1.2, 16.11.2.2, or 16.11.2.3. When more than one of the radionuclides in Table 16.11-8 are detected in the sampling medium, this report shall be submitted if:

$$\frac{\text{concentration (1)}}{\text{reporting level (1)}} + \frac{\text{concentration (2)}}{\text{reporting (2)}} + \ldots \geq 1.0$$

When radionuclides other than those in Table 16.11-8 are detected and are the result of plant effluents, this report shall be submitted if the potential annual dose* to A MEMBER OF THE PUBLIC from all radionuclides is equal to or greater than the calendar year limits of Sections 16.11.1.2, 16.11.2.2 or 16.11.2.3. This report is not required if the measured level of radioactivity was not the result of plant effluents; however, in such an event, the condition shall be reported and described in the Annual Radiological Environmental Operating Report, required by Technical Specification 5.6.2.

c. With milk or fresh leafy vegetable samples unavailable from one or more of the sample locations required by Table 16.11-7, identify specific locations for

* The methodology and parameters used to estimate the potential annual dose to a MEMBER OF THE PUBLIC shall be indicated in this report.

obtaining replacement samples and add them within 30 days to the Radiological Environmental Monitoring Program*. The specific locations from which samples were unavailable may then be deleted from the monitoring program. In the next Annual Radiological Environmental Operating Report include the revised figure(s) and tables reflecting the new sample location(s) with supporting information identifying the cause of the unavailability of samples and justifying the selection of new location(s) for obtaining samples.

d. When LLDs specified in Table 16.11-9 are unachievable due to uncontrollable circumstances such as background fluctuations, unavailable small sample sizes, the presence of interfering nuclides, etc., the contributing factors shall be identified and described in the Annual Radiological Environmental Operating Report.

16.11.4.1.1 SURVEILLANCE REQUIREMENTS

(ODCM 9.11.2)

The radiological environmental monitoring samples shall be collected pursuant to Table 16.11-7 and shall be analyzed pursuant to the requirements of Table 16.11-7 and the detection capabilities required by Table 16.11-9.

16.11.4.1.2 BASES

The Radiological Environmental Monitoring Program provides representative measurements of radiation and of radioactive materials in those exposure pathways and for those radionuclides that lead to the highest potential radiation exposures of MEMBERS OF THE PUBLIC resulting from the station operation. This monitoring program implements Section IV.B.2 of Appendix I to 10 CFR Part 50 and thereby supplements the Radiological Effluent Monitoring Program by verifying that the measurable concentrations of radioactive materials and levels of radiation are not higher than expected on the basis of the effluent measurements and the modeling of the environmental exposure pathways. Guidance for the initial monitoring program was provided by the Radiological Assessment Branch Technical Position on Environmental Monitoring, Revision 1, November 1979.

The required detection capabilities for environmental sample analyses are tabulated in terms of the lower limits of detection (LLD's). The LLD's required by Table 16.11-9 are considered optimum for routine environmental measurements in industrial laboratories.

* Excluding short term or temporary unavailability.

16.11.4.2 LAND USE CENSUS LIMITING CONDITION OF OPERATION (ODCM 9.12.1)

A Land Use Census shall be conducted and shall identify within a distance of 8 km (5 miles) the location in each of the 16 meteorological sectors of the nearest milk animal, the nearest residence and the nearest garden* of greater than 50 m^2 (500 ft^2) producing broad leaf vegetation. The Land Use Census shall identify water intakes constructed within 10 river miles downstream of the plant discharge point.

APPLICABILITY: At all times.

ACTION:

a. With a Land Use Census identifying a location(s) that yields a calculated dose or dose commitment greater than the values currently being calculated by Section 16.11.2.3.1, identify the new location(s) in the next Radioactive Effluent Release Report, pursuant to Technical Specification 5.6.3.

b. With a Land Use Census identifying a location(s) that yields a calculated dose or dose commitment (via the same exposure pathway) 20% greater than at a location from which samples are currently being obtained in accordance with Section 16.11.4.1, add the new location(s) within 30 days to the Radiological Environmental Monitoring Program except for vegetation samples which shall be added to the program before the next growing season. The sampling location(s), excluding the control station location, having the lowest calculated dose or dose commitment(s), via the same exposure pathway, may be deleted from this monitoring program after October 31 of the year in which this Land Use Census was conducted. In the next Annual Radiological Environmental Operating Report include the revised figure(s) and tables reflecting the new sample location(s) with information supporting the change in sample location.

c. With a Land Use Census identifying a water intake within 10 river miles downstream of the plant discharge point, implement the appropriate waterborne or ingestion sampling required by Table 16.11-7.

* Broad leaf vegetation sampling of at least three different kinds of vegetation may be performed at the SITE BOUNDARY in each to two different direction sectors with the highest predicted D/Q's in lieu of the garden census. Requirements for broad leaf vegetation sampling in Table 16.11-7, Part 4.c shall be followed, including analysis of control samples.

16.11.4.2.1 SURVEILLANCE REQUIREMENTS

(ODCM 9.12.2)

The Land Use Census shall be conducted during the growing season at least once per 12 months using that information which will provide the best results, such as, but not limited to, door-to-door survey, aerial survey, or by consulting local agriculture authorities and/or residents. The results of the Land Use Census shall be included in the Annual Radiological Environmental Operating Report pursuant to Technical Specification 5.6.2.

16.11.4.2.2 BASES

This Requirement is provided to ensure that changes in the use of areas at and beyond the SITE BOUNDARY are identified and that modifications to the Radiological Environmental Monitoring Program given in the ODCM are made if required by the results of this census. Information that will provide the best results, such as door-to-door survey, aerial survey, or consulting with local agricultural authorities, shall be used. This census satisfies the requirements of Section IV.B.3 of Appendix I to 10 CFR Part 50. Restricting the census to gardens of greater than 50 m^2 provides assurance that significant exposure pathways via leafy vegetables will be identified and monitored since a garden of this size is the minimum required to produce the quantity (26 kg/year) of leafy vegetables assumed in Regulatory Guide 1.109 for consumption by a child. To determine this minimum garden size, the following assumptions were made: (1) 20% of the garden was used for growing broad leaf vegetation (i.e., similar to lettuce and cabbage), and (2) a vegetation yield of 2 kg/m^2.

16.11.4.3 INTERLABORATORY COMPARISON PROGRAM LIMITING CONDITION OF OPERATION

(ODCM 9.13.1)

Analyses shall be performed on radioactive materials supplied as part of an Interlaboratory Comparison Program that has been approved by the USNRC.

APPLICABILITY: At all times.

ACTION:

With analyses not being performed as required above, report the corrective actions taken to prevent a recurrence to the Commission in the Annual Radiological Environmental Operating Report pursuant to Technical Specification 5.6.2.

16.11.4.3.1 SURVEILLANCE REQUIREMENTS

(ODCM 9.13.2)

The Interlaboratory Comparison Program shall be described in the plant procedures. A summary of the results obtained as part of the above required Interlaboratory Comparison Program shall be included in the Annual Radiological Environmental Operating Report pursuant to Technical Specification 5.6.2.

16.11.4.3.2 BASES

The requirement for participation in an approved Interlaboratory Comparison Program is provided to ensure that independent checks on the precision and accuracy of the measurements of radioactive material in environmental sample matrices are performed as part of the quality assurance program for environmental monitoring in order to demonstrate that the results are valid for the purpose of Section IV.B.2 of Appendix I to 10 CFR Part 50.

16.11.5 ADMINISTRATIVE CONTROLS

16.11.5.1 ANNUAL RADIOLOGICAL ENVIRONMENTAL OPERATING REPORT (ODCM 7.1)

Routine Annual Radiological Environmental Operating Report covering the operation of the unit during the previous calendar year shall be submitted prior to May 1 of each year.

The Annual Radiological Environmental Operating Report shall include summaries, interpretations, and an analysis of trends of the results of the radiological environmental surveillance activities for the report period, including a comparison with preoperational studies, with operational controls and with previous environmental surveillance reports, and an assessment of the observed impacts of the plant operation on the environment. The reports shall include the results of Land Use Census required by Section 16.11.4.2. It shall also include a listing of new locations for environmental monitoring identified by the Land Use Census pursuant to Section 16.11.4.2.

The Annual Radiological Environmental Operating Report shall include the results of analysis of all radiological environmental samples and of all environmental radiation measurements taken during the period pursuant to Section 16.11.4.1, as well as summarized tabulated results of these analyses and measurements in the format of the table in the Radiological Assessment Branch Technical Position, Revision 1, November 1979. In the event that some individual results are not available for inclusion with the report, the report shall be submitted noting and explaining the reasons for the missing results. The missing data shall be submitted as soon as possible in a supplementary report. The reports shall also include the following: a summary description of the radiological environmental monitoring program; at least two legible maps* covering all sampling locations keyed to a table giving distances and directions from the midpoint between the two reactors; the results of licensee participation in the Interlaboratory Comparison Program and the corrective action being taken if the specified program is not being performed as required by Section 16.11.4.3; reasons for not conducting the Radiological Environmental Monitoring Program as required by Section 16.11.4.1 and discussion of all deviations from the sampling schedule of Table 16.11-7, discussion of environmental sample measurements that exceed the reporting levels of Table 16.11-8, but are not the result of the plant effluents, pursuant to Section 16.11.4.1; and discussion of all analyses in which the LLD required by Table 16.11-9 was not achievable.

16.11.5.1.1 BASES

The reporting requirement for the Annual Radiological Environmental Operating Report is provided to ensure compliance with Technical Specification 5.6.2. This requirement was relocated from the Offsite Dose Calculation Manual to FSAR Chapter 16.

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* One map shall cover stations near the SITE BOUNDARY; a second shall include the more distant stations.

16.11.5.2 RADIOACTIVE EFFLUENT RELEASE REPORT

(ODCM 7.2)

Routine Radioactive Effluent Release Reports covering the operation of the unit during the previous calendar year shall be submitted prior to May 1 of each year.

The Radioactive Effluent Release Report shall include a summary of the quantities of radioactive liquid and gaseous effluents released from the unit as outlined in Regulatory Guide 1.21, "Measuring, Evaluating, and Reporting Radioactivity in Solid Wastes and Releases Gaseous Effluents from Light-Water-Cooled Nuclear Power Plants, "Revision 1, June 1974, with data summarized on a quarterly basis in a format acceptable to the NRC.

The Radioactive Effluent Release Report shall include an annual summary of hourly meteorological data collected over the previous calender year. This annual summary may be either in the form of an hour-by-hour listing on magnetic tape of wind speed, wind direction, atmospheric stability, and precipitation (if measured), or in the form of joint frequency distribution of wind speed, wind direction, and atmospheric stability* .

This report shall also include an assessment of the radiation doses due to the radioactive liquid and gaseous effluents released from the unit during the previous calendar year. This report shall also include an assessment of the radiation doses from radioactive liquid and gaseous effluents to MEMBERS OF THE PUBLIC due to their activities inside the SITE BOUNDARY (Figures 16.11-1 and 16.11-2) during the report period using historical average atmospheric conditions. All assumptions used in making these assessments, i.e., specific activity, exposure time and location, shall be included in these reports. The meteorological conditions concurrent with the time of release of radioactive materials in gaseous effluents, as determined by sampling frequency and measurement, shall be used for determining the gaseous pathway doses. Assessment of radiation doses shall be performed in accordance with the methodology and parameters in the OFFSITE DOSE CALCULATION MANUAL (ODCM).

The Radioactive Effluent Release Report shall include an assessment of radiation doses to the most likely exposed MEMBER OF THE PUBLIC from reactor releases and other nearby uranium fuel cycle sources, including doses from primary effluent pathways and direct radiation, for the previous calendar year to show conformance with 40 CFR Part 190, "Environmental Radiation Protection Standards for Nuclear Power Operation." Doses to the MEMBER OF THE PUBLIC shall be calculated using the methodology and parameters of the ODCM.

* In lieu of submission with the Annual Radioactive Effluent Release Report, Union Electric has the option of retaining this summary of required meteorological data on site in a file that shall be provided to the NRC upon request.

As required by 10 CFR 72.44(d)(3), an annual report shall be submitted to the Commission in accordance with 10 CFR 72.4, specifying the quantity of each of the principal radionuclides released to the environment in liquid and in gaseous effluents during the previous 12 months of operation. The report must be submitted within 60 days after the end of the 12-month monitoring period.

The Radioactive Effluent Release Report shall include a list and description of unplanned releases from the site to UNRESTRICTED AREAS of radioactive materials in gaseous and liquid effluents made during the reporting period.

The Radioactive Effluent Release Report shall include a summary description of any major changes made during the year to any Liquid or Gaseous Treatment Systems, pursuant to Offsite Dose Calculation Manual. It shall also include a listing of new locations for dose calculations identified by the Land Use Census pursuant to Section 16.11.4.2.

Reporting requirements for changes to Solid Waste Treatment Systems are addressed in APA-ZZ-01011, PROCESS CONTROL PROGRAM (PCP).

The Radioactive Effluent Release Report shall also include the following information: An explanation as to why the liquid or gaseous effluent monitoring instrumentation was not restored to service within the time specified, and a description of the events leading the liquid holdup tanks or gas storage tanks exceeding the limits of Section 16.11.1.5 or 16.11.2.8.

The Radioactive Effluent Release Report shall include as part of or submitted concurrent with, a complete and legible copy of all revisions of the ODCM that occurred during the year pursuant to Technical Specification 5.5.1.

Solid Waste reporting is addressed in APA-ZZ-01011, PROCESS CONTROL PROGRAM (PCP).

16.11.5.2.1 BASES

The reporting requirement for the Radioactive Effluent Release Report is provided to ensure compliance with Technical Specification 5.6.3. This requirement was relocated from the Offsite Dose Calculation Manual implementing procedure to FSAR Chapter 16.

In addition to the above reporting requirement, an annual report shall also be submitted in compliance with the HI-STORM UMAX Certificate of Compliance (CoC), Appendix A, Section 5.1

TABLE 16.11-1 RADIOACTIVE LIQUID WASTE SAMPLING AND ANALYSIS PROGRAM

1. Discharge Monitor Tanks (Batch Release) (2)			
SAMPLING FREQUENCY(7)	MINIMUM ANALYSIS FREQUENCY	TYPE OF ACTIVITY ANALYSIS	LLD (1) (µCi/ml)
Prior to Each Batch	Prior to Each Batch	Principal Gamma Emitters (3)	5E-7
		I-131	1E-6
		Dissolved and Entrained Gases (Gamma Emitters)	1E-5
		H-3	1E-5
	Monthly Composite (4)	Gross Alpha	1E-7
	Quarterly Composite (4)	Sr-89, Sr-90	5E-8
		Fe-55	1E-6
		Ni-63	5E-8
		Np-237	5E-9
		Pu-238	5E-9
		Pu-239/240	5E-9
		Pu-241	5E-7
		Am-241	5E-9
		Cm-242	5E-9
		Cm-243/244	5E-9

2. Steam Generator Blowdown (Continuous Release) (5)			
SAMPLING FREQUENCY(7)	MINIMUM ANALYSIS FREQUENCY	TYPE OF ACTIVITY ANALYSIS	LLD (1) (µCi/ml)
Daily Grab Sample (6)	Daily	Principal Gamma Emitters (3)	5E-7
		I-131	1E-6
		Dissolved and Entrained Gases (Gamma Emitters)	1E-5
		H-3	1E-5
	MonthlyComposite (4)	Gross Alpha	1E-7
	Quarterly Composite (4)	Sr-89, Sr-90	5E-8
		Fe-55	1E-6

TABLE NOTATIONS

(1) The LLD is defined, for purposes of these Requirements, as the smallest concentration of radioactive material in a sample that will yield a net count, above system background, that will be detected with 95% probability with only 5% probability of falsely concluding that a blank observation represents a "real" signal.

For a particular measurement system, which may include radiochemical separation:

$$LLD = \frac{4.66\ S_b}{E \times V \times 2.22E6 \times Y \times \exp(-\lambda \Delta t)}$$

Where:

- LLD = the "a priori" lower limit of detection (microCuries per unit mass or volume),
- S_b = the standard deviation of the background counting rate or of the counting rate of a blank sample as appropriate (counts per minute),
- E = the counting efficiency (counts per disintegration),
- V = the sample size (units of mass or volume),
- 2.22E6= the number of disintegrations per minute per microCurie,
- Y = the fractional radiochemical yield, when applicable,
- λ = the radioactive decay constant for the particular radionuclide (sec-1), and

TABLE 16.11-1 (Sheet 2)

Δt = the elapsed time between the midpoint of the sample collection period, and the time of counting (sec). For batch releases, $\Delta t=0$.

Typical values of E, V, Y, and Δt should be used in the calculation.

It should be recognized that the LLD is defined as a "a priori" (before the fact) limit representing the capability of a measurement system and not as an "a posteriori" (after the fact) limit for a particular measurement. Analyses shall be performed in such a manner that the stated LLD's will be achieved under routine conditions.

(2) A batch release is the discharge of liquid wastes of a discrete volume. Prior to sampling for analyses, each batch shall be isolated, and then thoroughly mixed by a method described in the ODCM to assure representative sampling.

(3) The principal gamma emitters for which the LLD control applies include the following radionuclides: Mn-54, Fe-59, Co-58, Co-60, Zn-65, Mo-99, Cs-134, Cs-137, Ce-141, and Ce-144. This list does not mean that only these nuclides are to be considered. Other gamma peaks that are identifiable, together with those of the above nuclides, shall also be analyzed and reported in the Radioactive Effluent Release Report pursuant to Technical Specification 5.6.3, in the format outlined in Regulatory Guide 1.21, Appendix B, Revision 1, June 1974.

(4) A composite sample is one in which the quantity of liquid sampled is proportional to the quantity of liquid waste discharged and in which the method of sampling employed results in a specimen that is representative of the liquids released. Prior to analysis, all samples taken for the composite shall be thoroughly mixed in order for the composite samples to be representative of the effluent release.

(5) A continuous release is the discharge of liquid wastes of a nondiscrete volume, e.g., from a volume of a system that has an input flow during the continuous release.

(6) Samples shall be taken at the initiation of effluent flow and at least once per 24 hours thereafter while the release is occurring. To be representative of the liquid effluent, the sample volume shall be proportioned to the effluent stream discharge volume. The ratio of sample volume to effluent discharge volume shall be maintained constant for all samples taken for the composite sample.

(7) Samples shall be representative of the effluent release.

TABLE 16.11-2 RADIOACTIVE LIQUID EFFLUENT MONITORING INSTRUMENTATION

	INSTRUMENT	MINIMUM CHANNELS FUNCTIONAL	ACTION
1.	Radioactivity Monitors Providing Alarm and Automatic Termination of Release		
	a. Liquid Radwaste Discharge Monitor (HB-RE-18)	1	31
	b. Steam Generator Blowdown Discharge Monitor (BM-RE-52)	1	32
2.	Flow Rate Measurement Devices		
	a. Liquid Radwaste Blowdown Discharge Line (HB-FE-2017)	1	34
	b. Steam Generator Blowdown Discharge Line (BM-FE-0054)	1	34
	c. Cooling Tower Blowdown and Bypass Flow Totalizer (FYDB1017A)	1	34
3.	Discharge Monitoring Tanks (DMT's) Level		
	a. DMT A (HB-LI-2004)	1	33
	b. DMT B (HB-LI-2005)	1	33

ACTION STATEMENTS

ACTION 31 - With the number of channels FUNCTIONAL less than required by the Minimum Channels FUNCTIONAL requirement, effluent releases via this pathway may continue provided that prior to initiating a release:

a. At least two independent samples are analyzed in accordance with Section 16.11.1.1.1, and

b. At least two technically qualified members of the facility staff independently verify the release rate calculations and discharge line valving.

Otherwise, suspend release of radioactive effluents via this pathway.

TABLE 16.11-2 (Sheet 2)

ACTION STATEMENTS

ACTION 32 - With the number of channels FUNCTIONAL less than required by the Minimum Channels FUNCTIONAL requirement, effluent releases via this pathway may continue provided grab samples are analyzed for principal gamma emitters and I-131 at a lower limit of detection as specified in Table 16.11-1:

a. At least once per 12 hours when the specific activity of the secondary coolant is greater than 0.01 micro-Curie/gram DOSE EQUIVALENT I-131, or

b. At least once per 24 hours when the specific activity of the secondary coolant is less than or equal to 0.01 micro-Curie/gram DOSE EQUIVALENT I-131.

ACTION 33 - With the number of channels FUNCTIONAL less than required by the Minimum Channels FUNCTIONAL requirement, effluent releases via this pathway may continue provided the volume discharged is determined by alternate means.

ACTION 34 - With the number of channels FUNCTIONAL less than required by the Minimum Channels FUNCTIONAL requirement, effluent releases via this pathway may continue provided the flow rate is estimated at least once per 4 hours during actual releases. Pump performance curves generated in place may be used to estimate flow.

TABLE 16.11-3 RADIOACTIVE LIQUID EFFLUENT MONITORING INSTRUMENTATION SURVEILLANCE REQUIREMENTS

INSTRUMENT	CHANNEL CHECK	SOURCE CHECK	CHANNEL CALIBRATION	CHANNEL OPERATIONAL TEST
1. Radioactivity Monitors Providing Alarm and Automatic Termination of Release				
a. Liquid Radwaste Discharge Monitor (HB-RE-18)	D	P	R(2)	Q(1)
b. Steam Generator Blowdown Discharge Monitor (BM-RE-52)	D	M	R(2)	Q(1)
2. Flow Rate Measurement Devices				
a. Liquid Radwaste Blowdown Discharge Line (HB-FE-2017)	D(3)	N.A.	R	N.A.
b. Steam Generator Blowdown Discharge Line (BM-FE-0054)	D(3)	N.A.	R	N.A.
c. Cooling Tower Blowdown and Bypass Flow Totalizer (FYDB1017A)	D(3)	N.A.	R	N.A.
3. Discharge Monitoring Tanks (DMT's) Level				
a. DMT A(HB-LI-2004)	Prior to release (4)	N.A.	R	N.A.
b. DMT B(HB-LI-2005)	Prior to release (4)	N.A.	R	N.A.

TABLE 16.11-3 (Sheet 2)

TABLE NOTATIONS

1. The CHANNEL OPERATIONAL TEST shall also demonstrate that automatic isolation of this pathway and control room alarm annunciation occur as appropriate if any of the following conditions exists:

   a. Instrument indicates measured levels above the Alarm/Trip Setpoint (isolation and alarm), or

   b. Circuit failure (alarm only), or

   c. Instrument indicates a downscale failure (alarm only), or

   d. Instrument controls not set in operate mode (alarm only).

2. The initial CHANNEL CALIBRATION shall be performed using one or more of the reference (gas or liquid and solid) standards obtained from the National Institute of Standards and Technology (NIST) or using standards that have been obtained from suppliers that participate in measurement assurance activities with NIST. These standards shall permit calibrating the system over its intended range of energy, measurement range, and establish monitor response to a solid calibration source. For subsequent CHANNEL CALIBRATION, NIST traceable standard (gas, liquid, or solid) may be used; or a gas, liquid, or solid source that has been calibrated by relating it to equipment that was previously (within 30 days) calibrated by the same geometry and type of source standard traceable to NIST.

3. CHANNEL CHECK shall consist of verifying indication of flow during periods of release. CHANNEL CHECK shall be made at least once per 24 hours on days on which continuous, periodic, or batch releases are made.

4. CHANNEL CHECK shall consist of verifying indication of tank level during periods of release. CHANNEL CHECK shall be made at least once per 24 hours on days on which continuous, periodic, or batch releases are made from the DMT.

TABLE 16.11-4 RADIOACTIVE GASEOUS EFFLUENTS SAMPLING AND ANALYSIS PROGRAM

1. Waste Gas Decay Tank			
SAMPLING FREQUENCY (9)	MINIMUM ANALYSIS FREQUENCY	TYPE OF ACTIVITY ANALYSIS	LLD (1) (µCi/ml)
Prior to each release- grab sample	Prior to each tank	Principal Gamma Emitters- particulate, iodine, noble gas (2)	1E-4
Continuous	See footnote 8		

2. Containment Purge or Vent			
SAMPLING FREQUENCY (9)	MINIMUM ANALYSIS FREQUENCY	TYPE OF ACTIVITY ANALYSIS	LLD (1) (µCi/ml)
Prior to each release- grab sample	Prior to each release	Principal Gamma Emitters- particulate, iodine, noble gas (2) H-3(oxide)	1E-4 1E-6
Continuous	See footnote 8		

3. Unit Vent (3)			
SAMPLING FREQUENCY (9)	MINIMUM ANALYSIS FREQUENCY	TYPE OF ACTIVITY ANALYSIS	LLD (1) (µCi/ml)
Monthly- grab sample (3)(4)	Monthly (3)(4)	Principal Gamma Emitters- noble gas (2) H-3(oxide)	1E-4 1E-6
Continuous (6)	Weekly (7)	I-131 I-133 Principal Gamma Emitters- particulate nuclides only (2)	1E-12 1E-10 1E-11
	MonthlyComposite	Gross Alpha	1E-11
	Quarterly Composite	Sr-89, Sr-90, Ni-63, Fe-55	1E-11

4. Radwaste Building Vent			
SAMPLING FREQUENCY (9)	MINIMUM ANALYSIS FREQUENCY	TYPE OF ACTIVITY ANALYSIS	LLD (1) (µCi/ml)
Monthly- grab sample	Monthly	Principal Gamma Emitters- noble gas (2)	1E-4
Continuous (6)	Weekly (7)	I-131 I-133 Principal Gamma Emitters- particulate nuclides only (2)	1E-12 1E-10 1E-11
	Monthly Composite	Gross Alpha	1E-11
	Quarterly Composite	Sr-89, Sr-90, Ni-63, Fe-55	1E-11

5. Laundry Decontamination Facility Dryer Exhaust			
SAMPLING FREQUENCY (9)	MINIMUM ANALYSIS FREQUENCY	TYPE OF ACTIVITY ANALYSIS	LLD (1) (µCi/ml)
Continuous (6)	Weekly (7)	Principal Gamma Emitters- particulate nuclides only (2)	1E-11
	Monthly (10) Composite	Gross Alpha	1E-11
	Quarterly (10) Composite	Sr-89, Sr-90, Ni-63, Fe-55	1E-11

TABLE 16.11-4 (Sheet 2)

6. Containment ILRT Depressurization (Post-test Vent)			
SAMPLING FREQUENCY (9)	MINIMUM ANALYSIS FREQUENCY	TYPE OF ACTIVITY ANALYSIS	LLD (1) (μCi/ml)
Prior to each release- grab sample	Prior to each release	Principal Gamma Emitters- particulate, iodine, noble gas (2) H-3(oxide)	1E-4 1E-6

TABLE NOTATIONS

(1) The LLD is defined, for purposes of these Requirements, as the smallest concentration of radioactive material in a sample that will yield a net count, above system background, that will be detected with 95% probability with only 5% probability of falsely concluding that a blank observation represents a "real" signal.

For a particular measurement system, which may include radiochemical separation:

$$LLD = \frac{4.66\ S_b}{E \times V \times 2.22E6 \times Y \times \exp(-\lambda\Delta t)}$$

Where:

LLD = the "a priori" lower limit of detection (microCuries per unit mass or volume),

S_b = the standard deviation of the background counting rate or of the counting rate of a blank sample as appropriate (counts per minute),

E = the counting efficiency (counts per disintegration),

V = the sample size (units of mass or volume),

2.22E6= the number of disintegrations per minute per microCurie,

Y = the fractional radiochemical yield, when applicable,

λ = the radioactive decay constant for the particular radionuclide (sec^{-1}), and

Δt = the elapsed time between the midpoint of the sample collection period, and the time of counting (sec).

Typical values of E, V, Y, and Δt should be used in the calculation.

It should be recognized that the LLD is defined as a "a priori" (before the fact) limit representing the capability of a measurement system and not as an "a posteriori" (after the fact) limit for a particular measurement. Analyses shall be performed in such a manner that the stated LLD's will be achieved under routine conditions.

(2) The principal gamma emitters for which the LLD Requirement applies include the following radionuclides: Kr-87, Kr-88, Xe-133, Xe-133m, Xe-135, and Xe-138 in noble gas releases and Mn-54, Fe-59, Co-58, Co-60, Zn-65, I-131, Cs-134, Cs-137, Ce-141, and Ce-144 in iodine and particulate releases. This list does not mean that only these nuclides are to be considered. Any nuclide which is identified in the sample and which is also listed in the ODCM gaseous effluents dose factor tables, shall be analyzed and reported in the Radioactive Effluent Release Report.

(3) If the Unit Vent noble gas monitor (GT-RE-21B) shows that the effluent activity has increased (relative to the pre-transient activity) by more than a factor of 3 following a reactor shutdown, startup, or a thermal power change which exceeds 15% of the rated thermal power within a 1 hour period, samples shall be obtained and analyzed for noble gas, particulates and iodines. This sampling shall continue to be performed at least once per 24 hours for a period of 7 days or until the Unit Vent noble gas monitor no longer indicates a factor of 3 increase in Unit Vent noble gas activity, whichever comes first.

(4) Tritium grab samples shall be taken and analyzed at least once per 24 hours when the refueling canal is flooded.

(5) Deleted.

(6) The ratio of the sample flow rate to the sampled stream flow rate shall be known for the time period covered by each dose or dose rate calculation made in accordance with Sections 16.11.2.1, 16.11.2.2, and 16.11.2.3.

(7) Samples shall be changed at least once per 7 days and analyses shall be completed within 48 hours after changing, or removal from the sampler. When sampling is performed in accordance with footnote 3 (above), then the LLD may be increased by a factor of 10.

(8) Continuous sampling of this batch release pathway is included in the continuous sampling performed for the corresponding continuous release pathway.

(9) Samples shall be representative of the effluent release.

(10) Required only if Mn-54, Fe-59, Co-58, Co-60, Zn-65, Cs-134, Cs-137, Ce-141, or Ce-144 are detected in principle gamma emitter analyses.

TABLE 16.11-5 RADIOACTIVE GASEOUS EFFLUENT MONITORING INSTRUMENTATION

INSTRUMENT	MINIMUM CHANNELS FUNCTIONAL	APPLICABILITY	ACTION
1. Unit Vent System			
a. Noble Gas Activity Monitor - Providing Alarm (GT-RE-21)	1	At all times	40,46
b. Iodine Sampler	1	At all times	43
c. Particulate Sampler	1	At all times	43
d. Unit Vent Flow Rate	1	At all times	45
e. Particulate and Radioiodine Sampler Flow Rate Monitor	1	At all times	43
2. Containment Purge System			
a. Noble Gas Activity Monitor			
- Providing Alarm and Automatic Termination of Release (GT-RE-22, GT-RE-33)	2	MODES 1,2,3, and 4.	41
- Providing Alarm function only	1	During CORE ALTERATIONS or movement of irradiated fuel within the containment	42
b. Iodine Sampler	1	MODES 1,2,3,4 and during CORE ALTERATIONS or movement of irradiated fuel within the containment	43
c. Particulate Sampler	1	MODES 1,2,3,4 and during CORE ALTERATIONS or movement of irradiated fuel within the containment	43
d. Containment Purge Ventilation Flow Rate	N/A	N/A	N/A

TABLE 16.11-5 (Sheet 2)

e. Particulate and Radioiodine Sampler Flow Rate Monitor	1	MODES 1,2,3,4 and during CORE ALTERATIONS or movement of irradiated fuel within the containment	43
3. Radwaste Building Vent System			
a. Noble Gas Activity Monitor-Providing Alarm and Automatic Termination of Release (GH-RE-10)	1	At all times	38,40
b. Iodine Sampler	1	At all times	43
c. Particulate Sampler	1	At all times	43
d. Radwaste Building Vent Flow Rate	N/A	N/A	N/A
e. Particulate and Radioiodine Sampler Flow Rate Monitor	1	At all times	43
4. Laundry Decontamination Faciliy Dryer Exhaust			
a. Particulate Monitor	1	When the dryers are operating	47
b. Particulate Monitor Flow Rate Meter	1	When the dryers are operating	47
c. Dryer Exhaust Ventilation Flow Rate	NA	NA	NA

ACTION STATEMENTS

ACTION 38 - With the number of low range channels FUNCTIONAL less than required by the Minimum Channels FUNCTIONAL requirement, the contents of the tank(s) may be released to the environment for up to 14 days provided that prior to initiating the release:

a. At least two independent samples of the tank's contents are analyzed, and

b. At least two technically qualified members of the facility staff independently verify the release rate calculations and discharge valve lineup.

TABLE 16.11-5 (Sheet 3)

Otherwise, suspend release of radioactive effluents via this pathway.

ACTION 39 - Deleted.

ACTION 40 - With the number of low range channels FUNCTIONAL less than required by the Minimum Channels FUNCTIONAL requirement, effluent releases via this pathway may continue for up to 30 days provided grab samples are taken at least once per 12 hours and these samples are analyzed for radioactivity within 24 hours.

ACTION 41 - With the number of channels FUNCTIONAL one less than required by the Minimum Channels FUNCTIONAL requirement, restore the affected channel to FUNCTIONAL status within 4 hours. If the non-functional channel is not restored within 4 hours or with no channels FUNCTIONAL, immediately suspend the release of radioactive effluents via this pathway.

Containment mini-purge supply and exhaust valves that have been closed to satisfy this Action may be opened under administrative controls provided either:

a. one channel is FUNCTIONAL, or

b. the requirements for Table 16.11-5 Function 1.a are met and the requirements for minimum channels FUNCTIONAL for the Unit Vent Noble Gas Monitor (GT-RE-21) specified in Table 16.3-7 Function 3 are met.

The administrative controls consist of designating a control room operator to rapidly close the valves when a need for system isolation is indicated.

ACTION 42 - With the number of channels FUNCTIONAL less than required by the Minimum Channels FUNCTIONAL requirement, and if the containment equipment hatch is open, then immediately suspend CORE ALTERATIONS and movement of irradiated fuel assemblies within containment. If the containment equipment hatch is not open, then suspend the release of radioactive effluents via this pathway or immediately suspend CORE ALTERATIONS and movement of irradiated fuel assemblies within containment.

ACTION 43 - With the number of channels FUNCTIONAL less than required by the Minimum Channels FUNCTIONAL requirement, effluent releases via the affected pathway may continue for up to 30 days provided samples are continuously collected with auxiliary sampling equipment as required in Table 16.11-4.

TABLE 16.11-5 (Sheet 4)

ACTION 44 - Deleted.

ACTION 45 - Flow rate for this system shall be based on fan status and operating curves or actual measurements.

ACTION 46 - For midrange and high range channels only - with the number of FUNCTIONAL channels less than required by the Minimum Channels FUNCTIONAL requirement, take the action specified in Section 16.3.3.4, ACTION C.

ACTION 47 - With the number of channels FUNCTIONAL less than required by the Minumum Channels FUNCTIONAL requirement, immediately suspend the release of radioactivite effluents via this pathway.

TABLE 16.11-6 RADIOACTIVE GASEOUS EFFLUENT MONITORING INSTRUMENTATION SURVEILLANCE REQUIREMENTS

INSTRUMENT	CHANNEL CHECK	SOURCE CHECK	CHANNEL CALIBRATION	CHANNEL OPERATIONAL TEST	MODES FOR WHICH SURVEILLANCE IS REQUIRED
1. Unit Vent System					
a. Noble Gas Activity Monitor - Providing Alarm (GT-RE-21)	D	M	R(3)	Q(2)	At all times
b. Iodine Sampler	W	N.A.	N.A.	N.A.	At all times
c. Particulate Sampler	W	N.A.	N.A.	N.A.	At all times
d. Unit Vent Flow Rate	N.A.	N.A.	R(4)	Q	At all times
e. Particulate and Radioiodine Sampler Flow Rate Monitor	D	N.A.	R	Q	At all times
2. Containment Purge System					
a. Noble Gas Activity Monitor - Providing Alarm and Automatic Termination of Release (GT-RE-22, GT-RE-33)	N.A.	P	N.A.	N.A.	MODES 1,2,3,4 and during CORE ALTERATIONS or movement of irradiated fuel within the containment
b. Iodine Sampler	W	N.A.	N.A.	N.A.	MODES 1,2,3,4 and during CORE ALTERATIONS or movement of irradiated fuel within the containment
c. Particulate Sampler	W	N.A.	N.A.	N.A.	MODES 1,2,3,4 and during CORE ALTERATIONS or movement of irradiated fuel within the containment
d. Containment Purge Ventilation Flow Rate	N.A.	N.A.	R(4)	N.A.	MODES 1,2,3,4 and during CORE ALTERATIONS or movement of irradiated fuel within the containment

TABLE 16.11-6 (Sheet 2)

INSTRUMENT	CHANNEL CHECK	SOURCE CHECK	CHANNEL CALIBRATION	CHANNEL OPERATIONAL TEST	MODES FOR WHICH SURVEILLANCE IS REQUIRED
e. Particulate and Radioiodine Sampler Flow Rate Monitor	D	N.A.	R	N.A.	MODES 1,2,3,4 and during CORE ALTERATIONS or movement of irradiated fuel within the containment
3. Radwaste Building Vent System					
a. Noble Gas Activity Monitor - Providing Alarm and Automatic Termination of Release (GH-RE-10)	D,P	M,P	R(3)	Q(1)	At all times
b. Iodine Sampler	W	N.A.	N.A.	N.A.	At all times
c. Particulate Sampler	W	N.A.	N.A.	N.A.	At all times
d. Radwaste Building Vent Flow Rate	N.A.	N.A.	R(4)	N.A.	At all times
e. Particulate and Radioiodine Sampler Flow Rate Monitor	D	N.A.	R	N.A.	At all times
4. Laundry Decontamination Facility Dryer Exhaust					
a. Particulate Monitor	NA	D	A	Q(5)	When the dryers are operating
b. Particulate Monitor Flow Rate Meter	D	NA	A	NA	When the dryers are operating
c. Dryer Exhaust Ventilation Flow Rate	NA	NA	R(4)	NA	When the dryers are operating

TABLE 16.11-6 (Sheet 3)

1. The CHANNEL OPERATIONAL TEST shall also demonstrate that automatic isolation of this pathway and control room alarm annunciation occur as appropriate if any of the following conditions exists:

   a. Instrument indicates measured levels above the Alarm/Trip Setpoint (isolation and alarm), or

   b. Circuit failure (alarm only), or

   c. Instrument indicates a downscale failure (alarm only), or

   d. Instrument controls not set in operate mode (alarm only).

2. The CHANNEL OPERATIONAL TEST shall also demonstrate that control room alarm annunciation occurs if any of the following conditions exists:

   a. Instrument indicates measured levels above the Alarm Setpoint, or

   b. Circuit failure, or

   c. Instrument indicates a downscale failure, or

   d. Instrument controls not set in operate mode.

3. The initial CHANNEL CALIBRATION shall be performed using one or more of the reference (gas or liquid and solid) standards certified by the National Institute of Standards & Technology (NIST) or using standards that have been obtained from suppliers that participate in measurement assurance activities with NIST. These standards shall permit calibrating the system over its intended range of energy, measurement range, and establish monitor response to a solid calibration source. For subsequent CHANNEL CALIBRATION, NIST traceable standard (gas, liquid, or solid) may be used; or a gas, liquid, or solid source that has been calibrated by relating it to equipment that was previously (within 30 days) calibrated by the same geometry and type of source standard traceable to NIST.

4. If flow rate is determined by exhaust fan status and fan performance curves, the following surveillance operations shall be performed at least once per 18 months:

   a. The specific vent flows by direct measurement, or

   b. The differential pressure across the exhaust fan and vent flow established by the fan's "flow-ΔP" curve, or

   c. The fan motor horsepower measured and vent flow established by the fan's "flow-horsepower" curve.

5. The CHANNEL OPERATIONAL TEST shall also demonstrate that automatic isolation of this pathway and the shutdown of the dryers occur as appropriate if any of the following conditions exists:

   a. Instrument indicates measured levels above the Alarm/Trip Setpoint, or

   b. Monitor failure.

TABLE 16.11-7 RADIOLOGICAL ENVIRONMENTAL MONITORING PROGRAM'

EXPOSURE PATHWAY AND/OR SAMPLE	NUMBER OF REPRESENTATIVE SAMPLES AND SAMPLE LOCATIONS (1)	SAMPLING AND COLLECTION FREQUENCY	TYPE AND FREQUENCY OF ANALYSIS
1. Direct Radiation(2)	Forty routine monitoring stations either with two or more dosimeters or with one instrument for measuring and recording dose rate continuously, placed as follows: An inner ring of sixteen stations, one in each meteorological sector in the general area of the SITE BOUNDARY; Four of the stations shall be placed to monitor for gamma and neutron dose from the ISFSI; An outer ring of stations, one in each meteorological sector in the 6- to 8-km (3 to 5 mile) range from the site; and Eight stations to be placed in special interest areas such as population centers, nearby residences, schools, and in one or two areas to serve as control stations.	Quarterly	Gamma dose for each sample. Neutron dose for the four samples monitoring ISFSI direct radiation.
2. Airborne Radioiodine and Particulates	Samples from five locations; Three samples from close to the SITE BOUNDARY locations, in different sectors, with high calculated annual average ground level D/Qs. One sample from the vicinity of a community located near the plant with a high calculated annual average ground level D/Q. One sample from a location in the vicinity of Fulton, MO.	Continuous sampler operation with sample collection weekly, or more frequently if required by dust loading.	Radioiodine Canister: I-131 analysis for each sample. Gamma isotopic analysis(5) for each sample.

TABLE 16.11-7 (Sheet 2)

EXPOSURE PATHWAY AND/OR SAMPLE	NUMBER OF REPRESENTATIVE SAMPLES AND SAMPLE LOCATIONS (1)	SAMPLING AND COLLECTION FREQUENCY	TYPE AND FREQUENCY OF ANALYSIS
3. Waterborne			
a. Surface (6) (river)	One sample upstream One sample downstream	Composite sample over 1-month period (7).	Gamma Isotopic(5) and tritium analysis for each sample.
b. Surface (onsite ponds)	Water sample from on site ponds forming a ring around the plant, suitable for monitoring for plant storm water runoff and washout from plant gaseous effluents, placed as follows: Each settling pond receiving plant storm water runoff. One of the in-service sludge lagoons. Two additional on site ponds most likely to be affected by washout of radioactivity released in gaseous effluents.	Semiannually	Gamma isotopic(5) and tritium analyses for each sample. If contaminated with gamma emitting nuclides of plant origin, analyze for HTD nuclides(11).
c. Groundwater (non-drinking water)	Groundwater samples from non-drinking water shallow and deep(12) monitoring wells located as follows: Samples from one deep well located upgradient of the plant power block and one deep well located downgradient of the sludge lagoons. Samples from seven shallow wells or groundwater sumps in locations suitable to monitor for subsurface leakage from power block structures and components.	Quarterly	Gamma isotopic(5) and tritium analyses for each sample. If contaminated with gamma emitting nuclides of plant origin, analyze for HTD nuclides(11).

TABLE 16.11-7 (Sheet 3)

EXPOSURE PATHWAY AND/OR SAMPLE	NUMBER OF REPRESENTATIVE SAMPLES AND SAMPLE LOCATIONS (1)	SAMPLING AND COLLECTION FREQUENCY	TYPE AND FREQUENCY OF ANALYSIS
c. Groundwater (non-drinking water) (continued)	Samples from three shallow wells in locations suitable to monitor for migrations of contaminated groundwater from the power block area to areas outside the Owner Controlled Area fence (one well upgradient of the plant power block and two wells in areas likely to be affected.) Samples from one shallow well located immediately downgradient of the sludge ponds. Samples from five shallow wells located along the discharge pipeline corridor in the alluvial plain. Samples from three shallow wells near the property boundary located to monitor for migration of contaminated groundwater from the discharge pipeline to the nearest potable water well. Samples from one deep well near the property boundary located to monitor for migration of contaminated groundwater from the discharge pipeline to the nearest potable water well.		

TABLE 16.11-7 (Sheet 4)

EXPOSURE PATHWAY AND/OR SAMPLE	NUMBER OF REPRESENTATIVE SAMPLES AND SAMPLE LOCATIONS (1)	SAMPLING AND COLLECTION FREQUENCY	TYPE AND FREQUENCY OF ANALYSIS
d. Drinking (river water)	One sample of each of one to three of the nearest water supplies within 10 miles downstream that could be affected by its discharge.	Composite sample over 2-week period(7) when I-131 analysis is performed, monthly composite otherwise.	I-131 analysis on each composite when the dose calculated for the consumption of the water is greater than 1 mrem per year(9). Composite for gross beta and gamma isotopic analyses(5) monthly. Composite for tritium analysis quarterly.
	One sample from a control location.		

As there are no drinking water intakes within 10 miles downstream of the discharge point, the drinking water pathway is currently not included as part of the Callaway Plant Radiological Environmental Monitoring Program. Should the annual Land Use Census identify water intakes within 10 river miles downstream of the discharge point, the program will be revised to include this pathway.

EXPOSURE PATHWAY AND/OR SAMPLE	NUMBER OF REPRESENTATIVE SAMPLES AND SAMPLE LOCATIONS (1)	SAMPLING AND COLLECTION FREQUENCY	TYPE AND FREQUENCY OF ANALYSIS
e. Drinking (potable well water)	Samples of potable well water appropriate for monitoring for radioactivity in drinking water supplies in areas most likely to be affected by a spill or leak.	Quarterly	Gamma isotopic(5) and tritium analyses for each sample. If contaminated with nuclides of plant origin, analyze for HTD nuclides(11).
	Two samples of potable well water from the community of Portland, MO.		
	One sample of Callaway Plant potable water.		
	One sample of potable well water from each resident bordering plant property along Mud Creek and Logan Creek.		
f. Sediment from river shoreline	One sample from downstream area with existing or potential recreational value	Semiannually	Gamma isotopic analysis(5) for each sample
	One sample from upstream control location.		

TABLE 16.11-7 (Sheet 5)

EXPOSURE PATHWAY AND/OR SAMPLE	NUMBER OF REPRESENTATIVE SAMPLES AND SAMPLE LOCATIONS (1)	SAMPLING AND COLLECTION FREQUENCY	TYPE AND FREQUENCY OF ANALYSIS
g. Shoreline sediment from sludge ponds	Shoreline sediment from each on site sludge pond most likely to be affected. One sample from each in-service sludge pond. One sample from each wetlands pond.	Annually	Gamma isotopic(5) analysis for each sample.
4. Ingestion			
a. Milk	Samples from milking animals in three different meteorological sectors within 5 km (3 mile) distance having the highest dose potential. If there are none, then one sample from milking animals in each of three different meteorological sectors between 5 to 8 km (3 to 5 mile) distance where doses are calculated to be greater than 1 mrem per yr.(9) One sample from milking animals at a control location, 15 to 30 km (10 to 20 mile) distance and in the least prevalent wind direction.	Semimonthly when animals are on pasture, monthly at other times	Gamma isotopic(5) and I-131 analyses for each sample
Due to the lack of milking animals which satisfy these requirements, the milk pathway is currently not included as part of the Callaway Plant Radiological Environmental Monitoring Program. Should the Annual Land Use Census identify the existence of milking animals in locations which satisfy these requirements, then the program will be revised to include this pathway.			
b. Fish	One sample of each commercially and recreationally important species in vicinity of plant discharge area. One sample of same species in areas not influenced by plant discharge.	Sample in season, or semiannually if they are not seasonal	Gamma isotopic analysis(5) on edible portions for each sample

TABLE 16.11-7 (Sheet 6)

EXPOSURE PATHWAY AND/OR SAMPLE	NUMBER OF REPRESENTATIVE SAMPLES AND SAMPLE LOCATIONS (1)	SAMPLING AND COLLECTION FREQUENCY	TYPE AND FREQUENCY OF ANALYSIS
c. Food Products	One sample of each principal class of food products from any area that is irrigated by water in which liquid plant wastes have been discharged.	At time of harvest(10)	Gamma isotopic analysis(5) on edible portion for each sample
As there are no areas irrigated by water in which liquid plant wastes have been discharged within 50 miles downstream of the discharge point, this sample type is not currently included as part of the Callaway Plant Radiological Environmental Monitoring Program. Should the annual Land Use Census identify irrigation water intakes within 10 river miles downstream of the discharge point, the program will be revised to include this sample type.			
	Samples of three different kinds of broad leaf vegetation if available grown nearest each of two different offsite locations of highest predicted annual average ground level D/Q if milk sampling is not performed	Monthly when available	Gamma isotopic (5) and I-131 analyses
	One sample of each of the similar broad leaf vegetation grown 15 to 30 km (10 to 20 mile) distant in the least prevalent wind direction if milk sampling is not performed	Monthly when available	Gamma isotopic (5) and I-131 analyses
5. Soil	Surface soil samples suitable for monitoring for ground deposition if radioactivity in gaseous effluents as follows: Four ecology plots located in four quadrants surrounding the plant. One control location from an area not likely to be influenced by plant gaseous effluents.	Annually	Gamma isotopic(5) analysis for each sample.

TABLE 16.11-7 (Sheet 7)

EXPOSURE PATHWAY AND/OR SAMPLE	NUMBER OF REPRESENTATIVE SAMPLES AND SAMPLE LOCATIONS (1)	SAMPLING AND COLLECTION FREQUENCY	TYPE AND FREQUENCY OF ANALYSIS
6. Farm crops(13)	Farm crops from areas most likely to be affected by a break or leak in the discharge pipeline, located as follows: Three samples of each type of farm crop along the discharge pipeline corridor between manhole 8 and Katy Trail. Three samples of each type of farm crop along the discharge pipeline corridor between manhole 5 and manhole 3B. Three samples of each type of farm crop along the discharge pipeline easement between Hwy 94 and the barge loading dock access road. One sample of each type of crop sampled above, from a control location unlikely to be influenced by plant operations.	At time of harvest(10)	Gamma isotopic(5) and tritium analyses for each sample

TABLE NOTATIONS

1. Specific parameters of distance and direction sector from the centerline of one unit, and additional description where pertinent, shall be provided for each and every sample location in Table 16.11-7 in a table and figure(s) in the appropriate plant procedures. Deviations are permitted from the required sampling schedule if specimens are unobtainable due to hazardous conditions, seasonal unavailability, malfunction of automatic sampling equipment, and other legitimate reasons. If specimens are unobtainable due to sampling equipment malfunction, every effort shall be made to complete corrective action prior to the end of the next sampling period. All deviations from the sampling schedule shall be documented in the Annual Radiological Environmental Operating Report pursuant to Technical Specification 5.6.2.

   It is recognized that, at times, it may not be possible or practicable to continue to obtain samples of the media of choice at the most desired location or time. In these instances suitable specific alternative media and locations may be chosen for the particular pathway in question and appropriate substitutions made within 30 days in the Radiological Environmental Monitoring Program. Submit in the next Annual Radiological Environmental Operating Report documentation for a change including the revised figure(s) and table reflecting the new location(s) with supporting information identifying the cause of the unavailability of samples for that pathway and justifying the selection of the new location(s) for obtaining samples.

TABLE 16.11-7 (Sheet 8)

The selection of sample locations should consider accessibility of sample site, availability of power, wind direction frequency, sector population, equipment security, and the presence of potentially adverse environmental conditions (such as unusually dusty conditions, etc.).

2. One or more instruments, such as a pressurized ion chamber, for measuring and recording dose rate continuously may be used in place of, or in addition to, integrating dosimeters. For the purposes of this table, a thermoluminescent dosimeter (TLD) and/or an optically stimulated luminescent dosimeter (OSLD), are considered to be one phosphor; two or more phosphors in a packet are considered as two or more dosimeters. Film badges shall not be used as dosimeters for measuring direct radiation. The number of direct radiation monitoring stations may be reduced according to geographical limitations; e.g., at an ocean site, some sectors will be over water so that the number of dosimeters may be reduced accordingly. The frequency of analysis or readout for TLD systems will depend upon the characteristics of the specific system used and should be selected to obtain optimum dose information with minimal fading.

3. Deleted.

4. Deleted.

5. Gamma isotopic analysis means the identification and quantification of gamma-emitting radionuclides that may be attributable to the effluents from the facility.

6. The "upstream sample" shall be taken at a distance beyond significant influence of the discharge. The "downstream" sample shall be taken in an area near the downstream edge of the mixing zone.

7. In this program, composite sample aliquots shall be collected at time intervals that are very short (e.g., hourly) relative to the compositing period (e.g., monthly) in order to assure obtaining a representative sample.

8. Groundwater samples shall be taken when this source is tapped for drinking or irrigation purposes in areas where the hydraulic gradient or recharge properties are suitable for contamination.

9. The dose shall be calculated for the maximum organ and age group, using the methodology and parameters in the ODCM.

10. If harvest occurs more than once a year, sampling shall be performed during each discrete harvest. If harvest occurs continuously, sampling shall be monthly. Attention shall be paid to including samples of tuberous and root food products.

11. In this program, HTD nuclides are defined as ^{89}Sr, ^{90}Sr, ^{55}Fe, ^{63}Ni, ^{237}Np, ^{238}Pu, ^{241}Am, ^{242}Cm, and $^{243/244}Cm$.

12. In this program, a shallow well is defined as a well which extracts groundwater from the vadose zone. A deep well is defined as a well which extracts groundwater from the saturated zone.

13. Edible and non-edible farm crops from areas that could be affected by a break or leak in the discharge pipeline (including the retired discharge pipeline.)

TABLE 16.11-8 REPORTING LEVELS FOR RADIOACTIVITY CONCENTRATIONS IN ENVIRONMENTAL SAMPLES

REPORTING LEVELS

ANALYSIS	WATER (pCi/l)[a]	AIRBORNE PARTICULATE OR GASES (pCi/m^3)	FISH (pCi/kg, wet)[b]	MILK (pCi/l)[a]	FOOD PRODUCTS pCi/kg, wet)[b]
H-3	20,000*				
Mn-54	1,000		30,000		
Fe-59	400		10,000		
Co-58	1,000		30,000		
Co-60	300		10,000		
Zn-65	300		20,000		
Zr-Nb-95**	400				
I-131	2	0.9		3	100
Cs-134	30	10	1,000	60	1,000
Cs-137	50	20	2,000	70	2,000
Ba-La-140**	200			300	

(a) Multiply the values in this table by 1E-9 to convert to units of μCi/ml.
(b) Multiply the values in this table by 1E-9 to convert to units of μCi/g.

* For drinking water samples. This is 40 CFR Part 141 value. For surface water samples, a value of 30,000 pCi/l may be used.

** Total activity, parent plus daughter activity.

TABLE 16.11-9 DETECTION CAPABILITITES FOR ENVIRONMENTAL SAMPLE ANALYSIS

LOWER LIMIT OF DETECTION (LLD) (1), (2), (3)

ANALYSIS	SURFACE WATER (pCi/l)[a]	DRINKING WATER (pCi/l)[a]	AIRBORNE PARTICULATE OR GASES (pCi/m^3)	FISH (pCi/kg, wet)[b]	MILK (pCi/l)[a]	FOOD PRODUCTS (pCi/kg, wet)[b]	SEDIMENT (pCi/kg, dry)[b]
Gross Beta	4	4	0.01				
H-3	3000	2000					
Mn-54	15	15		130			
Fe-59	30	30		260			
Co-58,60	15	15		130			
Zn-65	30	30		260			
Zr-Nb-95*	15	15					
I-131	**	1	0.07		1	60	
Cs-134	15	15	0.05	130	15	60	150
Cs-137	18	18	0.06	150	18	80	180
Ba-La-140*	15	15			15		

(a) Multiply the values in this table by 1E-9 to convert to units of μCi/ml.
(b) Multiply the values in this table by 1E-9 to convert to units of μCi/g.

* Total activity, parent plus daughter activity.

** For surface water samples, the LLD of gamma isotopic analysis may be used.

TABLE 16.11-9 (Sheet 2)

TABLE NOTATIONS

1. This list does not mean that only these nuclides are to be considered. Other peaks that are identifiable, together with those of the listed nuclides, shall also be analyzed and reported in the Annual Radiological Environmental Operating Report.

2. Required detection capabilities for thermoluminescent dosimeters used for environmental measurements shall be in accordance with the recommendations of Regulatory Guide 4.13, Revision 1, July 1977.

3. The LLD is defined, for purposes of these Requirements, as the smallest concentration of radioactive material in a sample that will yield a net count, above system background, that will be detected with 95% probability with only 5% probability of falsely concluding that a blank observation represents a "real" signal.

   For a particular measurement system, which may include radiochemical separation:

$$LLD = \frac{4.66S_b}{E \times V \times 2.22E6 \times Y \times \exp(-\lambda\Delta t)}$$

   Where:

   LLD = the "a priori" lower limit of detection (microCuries per unit mass or volume),

   S_b = the standard deviation of the background counting rate or of the counting rate of a blank sample as appropriate (counts per minute),

   E = the counting efficiency (counts per disintegration),

   V = the sample size (units of mass or volume),

   2.22E6 = the number of disintegrations per minute per microCurie,

   Y = the fractional radiochemical yield, when applicable,

   λ = the radioactive decay constant for the particular radionuclide (sec^{-1}), and

   Δt = the elapsed time between the end of the sample collection period, and the time of counting (sec).

   Typical values of E, V, Y, and Δt should be used in the calculation.

   It should be recognized that the LLD is defined as a "a priori" (before the fact) limit representing the capability of a measurement system and not as an "a posteriori" (after the fact) limit for a particular measurement. Analyses shall be performed in such a manner that the stated LLD's will be achieved under routine conditions.