

Callaway Energy Center
2019 Annual Radioactive Effluent Release Report
Revision 2

Callaway Energy Center 2019 Annual Radioactive Effluent Release Report

Renewed Facility Operating License NPF-30

Docket Numbers 50-483 and 72-1045



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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 Appendix A, Section 5.1.c. This report is for the period January 1, 2019 to December 31, 2019.

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

Abstract

The Annual Radioactive Effluent Release Report covers the operation of the Callaway Energy Center during the year 2019. 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.

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 1021106¹.

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.

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.

¹ *Estimation of Carbon- 14 in Nuclear Power Plant Gaseous Effluents*, Technical Report 1021106, 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.

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 was one abnormal release during the reporting period. This issue is documented in CRs 201905475 and 201905723. WGDT E leaked into WGDT D through a leaking rupture disc when the waste gas system was operating. The pressure increase in WGDT D began 8/5/2019 and peaked on 8/26/2019 at 26 psig. The release from WGDT D via leakage to the room through a leaking check valve began on 8/26/2019 when the system was opened to repair the leaking rupture disc.

On 8/26/2019, the system was opened to repair the leaking rupture disc. The job was stopped when the workers received a carbon monoxide (CO) alarm on their MX-4 gas monitor. It was later determined to be hydrogen leaking from WGDT D interfering with the MX-4. WGDT D leaked into room 7107 through a leaking check valve when the system was opened on 8/26/2019 to repair the leaking rupture disc. The building ventilation picked up the leaked gas and discharged it through the Radwaste Vent per design.

On 8/28/2019, WGDT D was at 6 psig and continuing to release hydrogen gas into room 7107 creating a hazardous working environment. In consideration of personnel safety, the remainder of WGDT D was discharged through the normal valve lineup directly through the Radwaste vent to stop the release of hydrogen into room 7107. This discharge started at 14:07 and ended at 18:35 with the tank at atmospheric pressure.

The discharge of WGDT D to room 7107 and then directly to the Radwaste vent meets the criteria for an unplanned release, i.e., an unintended discharge of radioactive material from a source as described in NRC Health Physics Position (HPPOS) #254, "Definition of Unplanned Release", Case 1. As an example, the HPPOS cites the inadvertent release of the contents of a waste gas decay tank through the plant vent. The release would be considered an unplanned release because the discharge of the waste gas decay tank was not planned.

There are two discharges for consideration: noble gases and ^{14}C . Each has its own special set of circumstances that must be considered.

Noble Gas Discharge

The WGDT D discharge, first by leaking into room 7107 and then discharge through the normal lineup, started on 8/26/2019 when the system was opened and ended on 8/28/2019 when WGDT D was at atmospheric pressure.

A sample of WGDT D taken on 8/23/2019 and analyzed in the Count Room showed there was no detectable noble gas activity in WGDT D.

The eDNA trend for Radwaste vent noble gas monitor GHRE10B indicates a slight increase in Radwaste vent activity corresponding to the time WGDT D was discharged through the normal lineup to the Radwaste vent (8/28/2019 14:07- 18:35). The net average concentration measured by GHRE10B during the direct discharge was $4.86\text{E-}08$ $\mu\text{Ci/cc}$. There was no discernable increase in activity discharged through the Radwaste vent prior to the discharge via the normal valve lineup; i.e., GHRE10B did not indicate an increase in the Radwaste vent during the period of leakage into room 7107. A noble gas sample of the Radwaste vent taken at approximately the midpoint of the WGDT D discharge (16:00 on 8/28/2019) showed no detectable activity.

Since WGDT E was the on- service tank, it was assumed the activity in WGDT D and thus the Radwaste vent was ^{133}Xe .

The Offsite Dose Calculation Manual (ODCM, APA-ZZ-01003, R024), Equations 19 and 20 were used to calculate the gamma air dose and beta air dose, respectively. The measured flow rate from the Radwaste vent is 12,948 cfm (HOA-ZZ-00100, Ventilation Flow Rates, R023). The gamma air dose factors and beta air dose factors are in ODCM Table 3 and the X/Q (decayed/undepleted) is in ODCM Table 10.

The calculated ^{133}Xe discharged based on the GHRE10B reading was $4.78\text{E-}03$ Ci. The calculated gamma air dose was $9.09\text{E-}08$ mrad and the beta air dose was $2.70\text{E-}07$ mrad.

^{14}C Discharge

The activity of ^{14}C produced and discharged and the calculated inhalation dose was previously reported in revision 0 of this report and will not be repeated here. The release from WGDT D during the period 8/26/2019- 8/28/2019 involved approximately 25 hours of daylight during the growing season. It was assumed the $^{14}\text{CO}_2$ released during these periods of photosynthesis would be incorporated into plant material and therefore into the food chain ingestion pathways. Appendix A to the ODCM, Methodology for Calculating Dose from ^{14}C in Gaseous Effluents, was used to construct a model for the $^{14}\text{CO}_2$ source term and to calculate the dose from the ingestion pathways.

^{14}C is produced in the reactor coolant system as CH_4 . The conversion of CH_4 to CO_2 is due to operation of the high temperature catalytic recombiners in the waste gas system. The recombiners were not used past 7/8/2019 and all waste gas added to WGDT E beyond that date was not CO_2 . Only CO_2 is incorporated into plant material therefore only the waste gas produced prior to 7/8/2019 would be available to the ingestion pathway. A sample of WGDT D taken on 8/23/2019 and analyzed in the Count Room showed there was no detectable noble gas activity in WGDT D, therefore it was assumed that the ^{14}C produced prior to 7/8/2019 was equally distributed among the 7 remaining waste gas decay tanks and that all of the $^{14}\text{CO}_2$ activity in WGDT E leaked into WGDT D and was subsequently released during the period 8/26/2019- 8/28/2019. The ingestion dose was calculated using the equations provided in Appendix A to the ODCM and the X/Q (decayed/undepleted) is in ODCM Table 10.

The calculated release of $^{14}\text{CO}_2$ during periods of photosynthesis was $5.90\text{E-}02$ Ci. The calculated maximum organ dose was $7.21\text{E-}03$ mrem (bone) and $1.45\text{E-}03$ mrem (total body/ other organs).

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 1986³, therefore the associated action statement has been met since BM-RE-52 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.

At approximately 05:40 on 2/7/2019, the heat trace for GH-RE-10A and GH-RE-10B became non- functional, rendering the particulate and iodine (P&I) samplers for the Radwaste Building ventilation release pathway non- functional. These samplers are required by the Callaway ODCM. The ventilation system was secured in accordance with plant procedures approximately 78 minutes later, exceeding the 60 minutes allowed by plant procedures. 78 minutes is insignificant (<1%) with respect to the 7 day sampling period. This is documented in Condition Report 201900762.

The P&I samples were analyzed and there was no detectable radioactive material on the sampling media. Previous samples of the Radwaste Building ventilation release pathway showed no detectable P&I activity. The 2015, 2016, 2017, and 2018 Annual Radioactive Effluent Release Reports (ARERRs) show there was no detectable P&I activity discharged via the Radwaste Building ventilation release pathway for those years. It is therefore unlikely there was significant P&I activity in the Radwaste Building ventilation release pathway during the 78 minutes when the samplers were non- functional.

GT-RE-33, Containment Purge Exhaust Monitor, was non- functional for the last 24 days of 2019 for extensive troubleshooting and repair. During this time, the opposite train monitor and sampler, GT-RE-22 was functional and all requirements of the associated action statement were met. The period of non- functionality continued into 2020, and will be addressed in the 2020 ARERR. Refer to Condition Report 201907727 and EOSL entry 22771.

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). APA-ZZ-01003 was revised in 2019. A complete copy of APA-ZZ-01003, rev. 24 was submitted with revision 0 of this report.

There were no changes to FSAR-SP Chapter 16.11 (RECs).

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

6.7 Process Control Program Changes

There were no revisions to APA-ZZ-01011, "Process Control Program" during the reporting period.

6.8 Corrections to Previous Reports

This report constitutes revision 2 to the 2019 Annual Radioactive Effluent Release Report submitted under cover letter ULNRC-06594, dated July 28, 2020. Minor typographical errors were identified during routine use of the report (see CR202004032).

Changes in revision 2 are identified with revision bars in the margin.

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	1.19E-01	3.70E-02	5.31E-02 ⁵	7.83E-02	2.87E-01	20
<i>Average Release Rate</i>	μCi/s	1.51E-02	4.69E-03	6.73E-03 ⁵	9.93E-03	9.11E-03	
<i>% of Limit</i>	%	N/A	N/A	N/A	N/A	N/A	
¹³¹Iodine	Ci	ND*	ND*	ND*	ND*	ND*	N/A
<i>Average Release Rate</i>	μCi/s	N/A	N/A	N/A	N/A	N/A	
<i>% of Limit</i>	%	N/A	N/A	N/A	N/A	N/A	
Particulates	Ci	ND*	ND*	ND*	ND*	ND*	N/A
<i>Average Release Rate</i>	μCi/s	N/A	N/A	N/A	N/A	N/A	
<i>% of Limit</i>	%	N/A	N/A	N/A	N/A	N/A	
Gross Alpha	Ci	2.60E-07	2.84E-07	1.47E-07	2.96E-07	9.88E-07	
³H	Ci	4.70E+00	1.57E+01	9.69E+00	6.47E+00	3.65E+01	14
<i>Average Release Rate</i>	μCi/s	5.96E-01	1.99E+00	1.23E+00	8.20E-01	1.16E+00	
<i>% of Limit</i>	%	N/A	N/A	N/A	N/A	N/A	
¹⁴C⁶	Ci	2.84E+00	2.84E+00	2.84E+00	2.84E+00	1.14E+01	

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

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

⁵ Includes activity from CR201905723 event

⁶ ¹⁴C activity is estimated based on EPRI report TR-1021106, *Estimation of ¹⁴C 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	7.02E-02	1.94E-02	4.46E-02	4.64E-02	1.81E-01
⁸⁵ Kr	Ci	6.06E-03	0.00E+00	0.00E+00	1.07E-02	1.68E-02
¹³³ Xe	Ci	1.80E-06	1.54E-03	8.52E-03 ⁷	0.00E+00	1.01E-02
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	7.24E-02	3.30E-02	2.15E-01	2.09E-01	5.29E-01
Gross α	Ci	ND	ND	ND	ND	ND
¹⁴ C	Ci	2.78E-02	2.78E-02	2.78E-02	2.78E-02	1.11E-01

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

⁷ Includes activity from CR201905723 event

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
⁴¹ Ar	Ci	4.26E-02	0.00E+00	0.00E+00	2.12E-02	6.38E-02
¹³³ Xe	Ci	0.00E+00	1.60E-02	0.00E+00	0.00E+00	1.60E-02
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	4.63E+00	1.56E+01	9.48E+00	6.26E+00	3.60E+01
Gross α	Ci	2.60E-07	2.84E-07	1.47E-07	2.96E-07	9.88E-07
¹⁴ C	Ci	2.81E+00	2.81E+00	2.81E+00	2.81E+00	1.12E+01

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

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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 (%) ⁸
Fission and Activation Products⁹	Ci	8.48E-03	2.45E-02	8.65E-03	2.05E-03	4.36E-02	20
<i>Avg Diluted Conc</i>	μCi/ml	3.37E-08	1.08E-07	5.18E-08	1.75E-08	5.72E-08	
<i>% of Limit</i>	%	N/A	N/A	N/A	N/A	N/A	
³ H	Ci	7.41E+02	1.56E+02	8.99E+00	9.39E+00	9.15E+02	14
<i>Avg Diluted Conc</i>	μCi/ml	2.95E-03	6.86E-04	5.38E-05	8.03E-05	1.20E-03	
<i>% of Limit</i>	%	N/A	N/A	N/A	N/A	N/A	
Dissolved & Entrained Gases	Ci	5.65E-04	6.78E-05	0.00E+00	0.00E+00	6.33E-04	27
<i>Avg Diluted Conc</i>	μCi/ml	2.25E-09	2.99E-10	0.00E+00	0.00E+00	8.31E-10	
<i>% of Limit</i>	%	N/A	N/A	N/A	N/A	N/A	
Gross α	Ci	4.02E-05	8.06E-05	2.47E-04	1.17E-04	4.85E-04	29
<i>Avg Diluted Conc</i>	μCi/ml	1.60E-10	3.55E-10	1.48E-09	1.00E-09	6.36E-10	
Vol Liquid Effluent¹⁰	Liters	4.71E+06	7.57E+06	5.42E+06	3.69E+06	2.14E+07	
Dilution Volume¹¹	Liters	2.47E+08	2.19E+08	1.62E+08	1.13E+08	7.41E+08	
Avg river flow¹²	m ³ /s	4.24E+03	7.90E+03	6.11E+03	5.18E+03	5.86E+03	
Time period for releases	hrs	1.72E+02	1.56E+02	1.11E+02	7.69E+01	5.16E+02	

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

⁸ Safety Analysis calculation 87-063-00, January 6, 1988

⁹ Excludes ³H, noble gases, and gross alpha.

¹⁰ Primary system liquid effluent plus secondary liquid effluent, prior to dilution.

¹¹ Does not include Missouri River dilution.

¹² 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	0.00E+00	1.25E-04	0.00E+00	0.00E+00	1.25E-04
⁵⁷ Co	Ci	8.68E-06	0.00E+00	0.00E+00	0.00E+00	8.68E-06
⁵⁸ Co	Ci	7.37E-04	2.23E-03	2.17E-03	4.52E-05	5.18E-03
⁶⁰ Co	Ci	6.19E-03	1.97E-03	1.57E-03	6.69E-04	1.04E-02
⁶³ Ni	Ci	6.28E-04	1.58E-03	2.38E-03	5.25E-04	5.11E-03
^{117m} Sn	Ci	0.00E+00	1.74E-05	0.00E+00	0.00E+00	1.74E-05
¹²² Sb	Ci	0.00E+00	3.59E-05	0.00E+00	0.00E+00	3.59E-05
¹²⁴ Sb	Ci	0.00E+00	3.52E-03	1.92E-04	0.00E+00	3.72E-03
¹²⁵ Sb	Ci	8.35E-04	1.48E-02	2.03E-03	7.97E-04	1.85E-02
¹²⁶ Sb	Ci	0.00E+00	1.80E-05	0.00E+00	0.00E+00	1.80E-05
¹³⁷ Cs	Ci	7.63E-05	1.14E-04	3.03E-04	9.01E-06	5.02E-04
¹³⁸ Cs	Ci	0.00E+00	9.96E-06	0.00E+00	0.00E+00	9.96E-06
Total	Ci	8.48E-03	2.45E-02	8.65E-03	2.05E-03	4.36E-02
Dissolved & Entrained Gases	Units	Quarter 1	Quarter 2	Quarter 3	Quarter 4	Total for the year
¹³³ Xe	Ci	5.65E-04	6.78E-05	0.00E+00	0.00E+00	6.33E-04
Total	Ci	5.65E-04	6.78E-05	0.00E+00	0.00E+00	6.33E-04
³ H	Ci	7.41E+02	1.56E+02	8.99E+00	9.39E+00	9.15E+02
Gross α	Ci	4.02E-05	8.06E-05	2.47E-04	1.17E-04	4.85E-04

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

Table A-3: Low-Level Waste Shipped for 2019

Resins, Filters, And Evaporator Bottoms			
Waste Class	Volume		Curies Shipped
	ft³	m³	
A	1.17E+03	3.31E+01	8.25E-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	1.17E+03	3.31E+01	8.25E-01
Major Nuclides for the Above Table: H-3, C-14, Mn-54, Fe-55, Co-58, Co-60, Ni-63, Sr-90, Tc-99, Sb-125, 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	1.41E+04	3.99E+02	2.34E-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	1.41E+04	3.99E+02	2.34E-01
Major Nuclides for the Above Table: H-3, C-14, Cr-51, Mn-54, Fe-55, Co-58, Co-60, Ni-63, Zn-65, Sr-90, Zr-95, Nb-95, Tc-99, Ru-106, Sb-125, I-129, Cs-137, Pu-238, Pu-239, 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 for 2019 (continued)			
Other Waste			
Waste Class	Volume		Curies Shipped
	ft ³	m ³	
A	5.53E+02	1.57E+01	6.06E-02
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	5.53E+02	1.57E+01	6.06E-02
Major Nuclides for the Above Table: H-3, C-14, Fe-55, Co-60, Ni-59, Tc-99, Ru-106, I-129, Cs-137			
Sum Of All Low-Level Waste Shipped From Site			
Waste Class	Volume		Curies Shipped
	ft ³	m ³	
A	1.58E+04	4.48E+02	1.12E+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	1.58E+04	4.48E+02	1.12E+00
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-95, Tc-99, Ru-106, Sb-125, I-129, Cs-137, Pu-238, Pu-239, Pu-241, 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.

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)	1.50E-03	5.92E-04	8.12E-04	4.50E-05	2.95E-03
% Limit	0.10%	0.04%	0.05%	0.00%	0.10%
Liquid Effluent Dose Limit, Maximum Organ (mrem)	5	5	5	5	10
Maximum Organ Dose (mrem)	1.60E-03	7.55E-04	1.41E-03	1.45E-04	3.64E-03
% Limit	0.03%	0.02%	0.03%	0.00%	0.04%
Gaseous Effluent Dose Limit, Gamma Air (mrad)	5	5	5	5	10
Gamma Air Dose (mrad)	4.92E-05	8.77E-06	1.96E-05 ¹³	2.95E-05	1.07E-04
% Limit	0.00%	0.00%	0.00%	0.00%	0.00%
Gaseous Effluent Dose Limit, Beta Air (mrad)	10	10	10	10	20
Beta Air Dose (mrad)	1.79E-05	3.85E-06	7.28E-06 ¹⁴	1.14E-05	4.04E-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 ¹⁵ (mrem)	1.24E-03	4.14E-03	2.56E-03	1.71E-03	9.66E-03
% Limit	0.02%	0.06%	0.03%	0.02%	0.06%
¹⁴C Maximum organ dose (mrem)¹⁶	3.55E-03	3.55E-03	1.08E-02 ¹⁷	3.55E-03	2.15E-02

¹³ Includes dose from CR201905723 event

¹⁴ Includes dose from CR201905723 event

¹⁵ Iodine, ³H, and particulates with greater than an 8 day half- life.

¹⁶ Not included in above totals

¹⁷ Includes dose from CR201905723 event



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	1.61E-02	1.61E-02	3.45E-02
% Limit	0.06%	0.02%	0.14%

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Appendix B
***Meteorological Dispersion Parameters and Joint Frequency Tables; Totals of Hours
at Each Wind Speed & Direction for the period January 1, 2019- December 31, 2019***

Meteorological Dispersion Parameters for the Reporting Period

Nearest Resident Dispersion Parameters

Direction: NNW

Distance: 2913 meters

X/Q, Undecayed and Undepleted: 9.90E-07

X/Q Decayed and Undepleted: 9.73E-07

X/Q Decayed and Depleted: 8.23E-07

D/Q Deposition rate: 2.87E-09

Site Boundary Dispersion Parameters

Direction: SSW

Distance: 1400 meters

X/Q, Undecayed and Undepleted: 1.50E-06

X/Q Decayed and Undepleted: 1.48E-06

X/Q Decayed and Depleted: 1.32E-06

D/Q Deposition rate: 5.13E-09

Meteorological Data Recovery Rate

10 meters elevation Hours of valid data: 8701
Total hours in period: 8760
Recovery rate: 99%

60 meters elevation Hours of valid data: 8701
Total hours in period: 8760
Recovery rate: 99%

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Joint Frequency Distribution: Hours at Wind Speed and Direction												
January- December, 2019												
All Stabilities												
Elevations: Winds 10m Stability 60m												
Wind Direction Sector	Wind Speed Range (m/s)											Total
	<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	
N	2	32	54	75	142	116	93	35	37	8	0	594
NNE	0	34	61	69	207	96	36	5	0	0	0	508
NE	2	35	70	48	138	56	14	7	4	0	0	374
ENE	3	33	48	50	117	52	20	13	2	0	0	338
E	0	24	45	52	110	78	40	8	2	0	0	359
ESE	2	32	56	75	114	86	45	29	1	0	0	440
SE	0	48	102	154	261	104	31	12	1	0	0	713
SSE	2	31	87	140	416	194	77	31	8	2	0	988
S	0	26	43	73	258	203	123	55	27	1	0	809
SSW	1	25	60	64	190	170	82	26	13	0	0	631
SW	1	27	32	63	158	97	54	22	10	5	0	469
WSW	4	30	46	57	92	46	38	19	21	8	1	362
W	1	23	52	63	113	70	55	49	48	12	2	488
WNW	3	35	62	61	114	96	61	47	35	0	0	514
NW	1	39	74	97	134	96	52	29	7	0	0	529
NNW	3	26	49	84	149	129	64	49	11	1	0	565
Tot	25	500	941	1225	2713	1689	885	436	227	37	3	8681
Hours of Calm	20											
Hours of Variable Direction	0											
Hours of Valid Data	8701											
Hours of Missing Data	59											
Hours in Period	8760											

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Joint Frequency Distribution: Hours at Wind Speed and Direction												
January- December, 2019												
Class A Extremely Unstable based on lapse rate												
Elevations: Winds 10m Stability 60m												
Wind Direction Sector	Wind Speed Range (m/s)											Total
	<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	
N	0	0	0	0	1	0	1	0	0	0	0	2
NNE	0	0	0	0	2	0	0	0	0	0	0	2
NE	0	0	0	0	2	0	0	0	0	0	0	2
ENE	0	0	0	0	0	3	1	0	0	0	0	4
E	0	0	0	0	0	1	0	0	0	0	0	1
ESE	0	0	0	0	0	0	3	2	0	0	0	5
SE	0	0	0	1	3	3	5	2	0	0	0	14
SSE	0	0	0	2	5	9	2	1	0	0	0	19
S	0	0	0	0	5	3	3	2	1	0	0	14
SSW	0	0	0	0	3	10	13	7	3	0	0	36
SW	0	0	0	0	0	15	12	6	4	0	0	37
WSW	0	0	0	0	1	3	1	1	7	0	0	13
W	0	0	0	0	1	3	1	6	2	0	0	13
WNW	0	0	0	0	1	8	7	1	6	0	0	23
NW	0	0	0	0	0	2	3	5	0	0	0	10
NNW	0	0	0	0	0	1	1	0	0	0	0	2
Tot	0	0	0	3	24	61	53	33	23	0	0	197
Hours of Calm	0											
Hours of Variable Direction	0											
Hours of Valid Data	197											
Hours of Missing Data	59											
Hours in Period	8760											

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Joint Frequency Distribution: Hours at Wind Speed and Direction												
January- December, 2019												
Class B Moderately Unstable based on lapse rate												
Elevations: Winds 10m Stability 60m												
Wind Direction Sector	Wind Speed Range (m/s)											Total
	<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	
N	0	0	0	0	2	0	3	0	0	2	0	7
NNE	0	0	0	0	4	6	0	0	0	0	0	10
NE	0	0	0	0	8	1	2	0	0	0	0	11
ENE	0	0	0	0	3	1	4	0	0	0	0	8
E	0	0	0	0	0	2	3	0	0	0	0	5
ESE	0	0	1	0	4	4	4	1	0	0	0	14
SE	0	0	0	3	4	11	2	0	1	0	0	21
SSE	0	0	0	2	8	10	1	2	1	0	0	24
S	0	0	2	0	15	14	7	7	1	0	0	46
SSW	0	0	0	5	20	25	12	2	4	0	0	68
SW	0	0	1	0	5	12	11	4	1	0	0	34
WSW	0	0	0	0	2	4	3	0	0	0	0	9
W	0	0	0	0	6	8	3	0	2	0	0	19
WNW	0	0	0	0	3	11	6	4	1	0	0	25
NW	0	0	0	0	2	11	4	5	0	0	0	22
NNW	0	0	0	1	6	10	2	2	0	1	0	22
Tot	0	0	4	11	92	130	67	27	11	3	0	345
Hours of Calm	0											
Hours of Variable Direction	0											
Hours of Valid Data	345											
Hours of Missing Data	59											
Hours in Period	8760											

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Joint Frequency Distribution: Hours at Wind Speed and Direction												
January- December, 2019												
Class C Slightly Unstable based on lapse rate												
Elevations: Winds 10m Stability 60m												
Wind Direction Sector	Wind Speed Range (m/s)											Total
	<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	
N	0	0	0	2	13	10	4	0	2	1	0	32
NNE	0	0	0	4	13	12	4	1	0	0	0	34
NE	0	0	1	0	10	0	0	0	0	0	0	11
ENE	0	0	0	2	8	1	3	0	0	0	0	14
E	0	0	0	2	8	2	2	1	0	0	0	15
ESE	0	0	1	2	4	10	1	3	0	0	0	21
SE	0	0	6	9	14	10	1	0	0	0	0	40
SSE	0	0	1	10	20	13	2	2	0	0	0	48
S	0	0	2	2	17	11	14	4	2	0	0	52
SSW	0	0	2	7	18	22	16	4	3	0	0	72
SW	0	0	0	3	17	16	7	1	1	0	0	45
WSW	0	0	1	3	6	4	2	3	1	0	0	20
W	0	0	1	3	10	8	7	4	3	0	0	36
WNW	0	0	0	2	14	10	3	6	5	0	0	40
NW	0	0	0	4	12	8	1	3	0	0	0	28
NNW	0	0	0	4	16	14	3	2	0	0	0	39
Tot	0	0	15	59	200	151	70	34	17	1	0	547
Hours of Calm	0											
Hours of Variable Direction	0											
Hours of Valid Data	547											
Hours of Missing Data	59											
Hours in Period	8760											

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Joint Frequency Distribution: Hours at Wind Speed and Direction												
January- December, 2019												
Class D Neutral based on lapse rate												
Elevations: Winds 10m Stability 60m												
Wind Direction Sector	Wind Speed Range (m/s)											Total
	<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	
N	0	4	16	26	82	81	75	34	34	5	0	357
NNE	0	4	14	24	129	69	30	4	0	0	0	274
NE	1	4	18	20	82	42	11	5	4	0	0	187
ENE	1	2	10	22	68	39	11	13	2	0	0	168
E	0	3	20	24	64	63	35	7	2	0	0	218
ESE	0	6	14	25	57	59	33	22	1	0	0	217
SE	0	5	12	38	106	56	19	10	0	0	0	246
SSE	0	1	17	15	74	33	21	11	3	2	0	177
S	0	2	9	14	42	52	45	17	18	1	0	200
SSW	0	3	11	19	43	49	27	11	1	0	0	164
SW	0	4	12	20	57	30	18	7	1	5	0	154
WSW	2	6	16	16	38	22	17	12	11	6	0	146
W	0	3	15	20	44	26	28	28	39	12	2	217
WNW	0	2	17	30	33	48	41	33	23	0	0	227
NW	0	7	18	40	59	64	36	14	7	0	0	245
NNW	0	6	17	42	78	79	47	42	11	0	0	322
Tot	4	62	236	395	1056	812	494	270	157	31	2	3519
Hours of Calm												1
Hours of Variable Direction												0
Hours of Valid Data												3520
Hours of Missing Data												59
Hours in Period												8760



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Joint Frequency Distribution: Hours at Wind Speed and Direction												
January- December, 2019												
Class E Slightly Stable based on lapse rate												
Elevations: Winds 10m Stability 60m												
Wind Direction Sector	Wind Speed Range (m/s)											Total
	<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	
N	1	5	17	24	34	24	9	1	1	0	0	116
NNE	0	8	21	31	44	8	2	0	0	0	0	114
NE	0	8	14	19	28	13	1	2	0	0	0	85
ENE	0	9	18	22	36	8	1	0	0	0	0	94
E	0	3	17	20	37	10	0	0	0	0	0	87
ESE	1	10	23	33	49	13	4	1	0	0	0	134
SE	0	17	32	67	109	24	4	0	0	0	0	253
SSE	0	5	17	35	148	92	49	15	4	0	0	365
S	0	3	5	23	96	104	51	25	5	0	0	312
SSW	0	6	20	20	74	56	14	2	2	0	0	194
SW	0	5	12	28	61	23	6	3	3	0	0	141
WSW	0	9	13	29	37	13	15	3	2	2	1	124
W	1	8	20	31	43	24	16	11	2	0	0	156
WNW	1	5	19	22	48	19	4	3	0	0	0	121
NW	1	12	30	25	43	11	8	2	0	0	0	132
NNW	1	6	11	15	40	25	11	3	0	0	0	112
Tot	6	119	289	444	927	467	195	71	19	2	1	2540
Hours of Calm												2
Hours of Variable Direction												0
Hours of Valid Data												2542
Hours of Missing Data												59
Hours in Period												8760

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Joint Frequency Distribution: Hours at Wind Speed and Direction												
January- December, 2019												
Class F Moderately Stable based on lapse rate												
Elevations: Winds 10m Stability 60m												
Wind Direction Sector	Wind Speed Range (m/s)											Total
	<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	
N	0	11	13	19	10	1	1	0	0	0	0	55
NNE	0	12	11	10	15	1	0	0	0	0	0	49
NE	0	8	24	8	5	0	0	0	0	0	0	45
ENE	0	15	15	4	2	0	0	0	0	0	0	36
E	0	11	7	6	1	0	0	0	0	0	0	25
ESE	0	10	17	15	0	0	0	0	0	0	0	42
SE	0	17	47	28	23	0	0	0	0	0	0	115
SSE	0	12	28	53	118	32	2	0	0	0	0	245
S	0	8	11	22	74	17	3	0	0	0	0	135
SSW	0	8	18	10	31	8	0	0	0	0	0	75
SW	1	11	7	11	17	1	0	1	0	0	0	49
WSW	2	10	15	9	8	0	0	0	0	0	0	44
W	0	8	12	7	9	1	0	0	0	0	0	37
WNW	1	19	19	5	14	0	0	0	0	0	0	58
NW	0	8	18	17	16	0	0	0	0	0	0	59
NNW	1	5	11	17	9	0	0	0	0	0	0	43
Tot	5	173	273	241	352	61	6	1	0	0	0	1112
Hours of Calm												4
Hours of Variable Direction												0
Hours of Valid Data												1116
Hours of Missing Data												59
Hours in Period												8760

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Joint Frequency Distribution: Hours at Wind Speed and Direction												
January- December, 2019												
Class G Extremely Stable based on lapse rate												
Elevations: Winds 10m Stability 60m												
Wind Direction Sector	Wind Speed Range (m/s)											Total
	<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	
N	1	12	8	4	0	0	0	0	0	0	0	25
NNE	0	10	15	0	0	0	0	0	0	0	0	25
NE	1	15	13	1	3	0	0	0	0	0	0	33
ENE	2	7	5	0	0	0	0	0	0	0	0	14
E	0	7	1	0	0	0	0	0	0	0	0	8
ESE	1	6	0	0	0	0	0	0	0	0	0	7
SE	0	9	5	8	2	0	0	0	0	0	0	24
SSE	2	13	24	23	43	5	0	0	0	0	0	110
S	0	13	14	12	9	2	0	0	0	0	0	50
SSW	1	8	9	3	1	0	0	0	0	0	0	22
SW	0	7	0	1	1	0	0	0	0	0	0	9
WSW	0	5	1	0	0	0	0	0	0	0	0	6
W	0	4	4	2	0	0	0	0	0	0	0	10
WNW	1	9	7	2	1	0	0	0	0	0	0	20
NW	0	12	8	11	2	0	0	0	0	0	0	33
NNW	1	9	10	5	0	0	0	0	0	0	0	25
Tot	10	146	124	72	62	7	0	0	0	0	0	421
Hours of Calm											13	
Hours of Variable Direction											0	
Hours of Valid Data											434	
Hours of Missing Data											59	
Hours in Period											8760	

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Joint Frequency Distribution: Hours at Wind Speed and Direction												
January- December, 2019												
All Stabilities												
Elevations: Winds 60m Stability 60m												
Wind Direction Sector	Wind Speed Range (m/s)											Total
	<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	
N	1	3	5	19	63	78	119	84	72	34	7	485
NNE	0	2	6	21	83	192	180	118	61	5	0	668
NE	0	4	16	32	85	152	127	85	33	3	2	539
ENE	0	6	13	25	68	76	100	47	31	6	1	373
E	0	6	13	9	64	75	84	70	24	5	0	350
ESE	0	4	6	18	51	86	122	86	44	5	0	422
SE	0	9	20	49	209	188	124	46	17	0	0	662
SSE	0	7	17	19	111	154	143	139	139	15	4	748
S	0	2	8	21	63	94	151	228	238	44	4	853
SSW	0	3	7	17	73	93	130	196	219	27	2	767
SW	0	2	5	9	41	62	109	122	127	26	14	517
WSW	1	2	9	16	29	53	77	44	63	44	34	372
W	0	2	5	10	38	49	80	73	111	62	41	471
WNW	0	1	10	15	39	50	79	97	160	58	28	537
NW	0	3	9	11	68	85	66	85	110	32	8	477
NNW	0	2	8	13	76	64	89	69	115	20	4	460
Tot	2	58	157	304	1161	1551	1780	1589	1564	386	149	8701
Hours of Calm												0
Hours of Variable Direction												0
Hours of Valid Data												8701
Hours of Missing Data												59
Hours in Period												8760



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Joint Frequency Distribution: Hours at Wind Speed and Direction												
January- December, 2019												
Class A Extremely Unstable based on lapse rate												
Elevations: Winds 60m Stability 60m												
Wind Direction Sector	Wind Speed Range (m/s)											Total
	<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	
N	0	0	0	0	0	1	0	1	0	0	0	2
NNE	0	0	0	0	0	2	0	0	2	0	0	4
NE	0	0	0	0	0	3	0	7	4	0	0	14
ENE	0	0	0	0	1	0	2	0	0	0	0	3
E	0	0	0	0	0	1	0	0	0	0	0	1
ESE	0	0	0	0	0	0	0	1	0	0	0	1
SE	0	0	0	0	3	2	4	0	2	0	0	11
SSE	0	0	0	0	2	3	8	4	1	0	0	18
S	0	0	0	0	4	3	5	2	3	0	0	17
SSW	0	0	0	0	0	2	4	9	16	6	0	37
SW	0	0	0	0	0	0	4	11	13	3	2	33
WSW	0	0	0	0	0	0	2	2	1	6	3	14
W	0	0	0	0	0	0	1	1	2	5	1	10
WNW	0	0	0	0	0	0	1	3	9	3	4	20
NW	0	0	0	0	0	0	2	2	5	2	0	11
NNW	0	0	0	0	0	0	0	1	0	0	0	1
Tot	0	0	0	0	10	17	33	44	58	25	10	197
Hours of Calm	0											
Hours of Variable Direction	0											
Hours of Valid Data	197											
Hours of Missing Data	59											
Hours in Period	8760											

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Joint Frequency Distribution: Hours at Wind Speed and Direction												
January- December, 2019												
Class B Moderately Unstable based on lapse rate												
Elevations: Winds 60m Stability 60m												
Wind Direction Sector	Wind Speed Range (m/s)											Total
	<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	
N	0	0	0	0	3	0	0	3	0	0	1	7
NNE	0	0	0	0	2	6	3	0	0	0	0	11
NE	0	0	0	3	4	6	6	8	0	0	0	27
ENE	0	0	0	0	0	6	4	3	2	0	0	15
E	0	0	0	0	0	0	0	3	0	0	0	3
ESE	0	0	0	0	2	2	4	1	1	0	0	10
SE	0	0	0	0	4	2	7	0	0	0	0	13
SSE	0	0	0	1	6	6	9	1	2	2	0	27
S	0	0	0	2	7	10	11	7	10	0	0	47
SSW	0	0	0	0	8	14	12	18	8	4	0	64
SW	0	0	0	0	1	1	12	6	11	3	1	35
WSW	0	0	0	0	0	0	0	2	5	1	0	8
W	0	0	0	0	0	2	4	5	4	2	0	17
WNW	0	0	0	0	1	2	5	4	10	6	0	28
NW	0	0	0	0	0	6	3	3	2	4	0	18
NNW	0	0	0	0	0	4	5	1	3	0	2	15
Tot	0	0	0	6	38	67	85	65	58	22	4	345
Hours of Calm	0											
Hours of Variable Direction	0											
Hours of Valid Data	345											
Hours of Missing Data	59											
Hours in Period	8760											

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Joint Frequency Distribution: Hours at Wind Speed and Direction												
January- December, 2019												
Class C Slightly Unstable based on lapse rate												
Elevations: Winds 60m Stability 60m												
Wind Direction Sector	Wind Speed Range (m/s)											Total
	<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	
N	0	0	0	0	11	2	9	3	1	2	1	29
NNE	0	0	1	2	6	12	9	5	1	0	0	36
NE	0	0	0	0	13	8	4	3	1	0	0	29
ENE	0	0	0	2	8	3	1	1	1	0	0	16
E	0	0	1	0	6	0	2	0	0	0	0	9
ESE	0	0	0	2	1	7	5	1	3	1	0	20
SE	0	0	0	3	16	9	5	1	0	0	0	34
SSE	0	0	2	4	19	13	6	3	2	0	0	49
S	0	0	1	3	11	10	8	10	7	2	0	52
SSW	0	0	0	3	16	11	11	16	13	3	0	73
SW	0	0	1	1	8	6	7	9	11	2	1	46
WSW	0	0	0	0	2	4	3	1	5	3	0	18
W	0	0	0	1	6	5	8	5	10	2	3	40
WNW	0	0	0	0	4	9	6	5	5	8	3	40
NW	0	0	0	0	10	8	3	6	3	2	0	32
NNW	0	0	0	0	3	10	6	3	2	0	0	24
Tot	0	0	6	21	140	117	93	72	65	25	8	547
Hours of Calm	0											
Hours of Variable Direction	0											
Hours of Valid Data	547											
Hours of Missing Data	59											
Hours in Period	8760											

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Joint Frequency Distribution: Hours at Wind Speed and Direction												
January- December, 2019												
Class D Neutral based on lapse rate												
Elevations: Winds 60m Stability 60m												
Wind Direction Sector	Wind Speed Range (m/s)											Total
	<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	
N	0	3	3	15	39	48	75	42	51	31	5	312
NNE	0	1	4	14	39	109	76	38	23	2	0	306
NE	0	3	12	20	32	80	56	24	11	2	1	241
ENE	0	5	10	16	38	43	36	16	18	6	1	189
E	0	3	7	5	42	38	32	29	23	5	0	184
ESE	0	2	4	12	24	31	52	41	34	4	0	204
SE	0	4	5	19	63	65	45	25	13	0	0	239
SSE	0	2	5	11	48	47	25	16	19	1	4	178
S	0	1	3	8	19	26	28	45	39	17	1	187
SSW	0	2	4	8	30	28	30	34	38	9	0	183
SW	0	1	3	6	24	31	31	26	20	10	7	159
WSW	1	0	4	13	12	17	27	8	21	18	25	146
W	0	1	5	6	20	22	16	19	44	37	36	206
WNW	0	0	7	14	26	23	26	30	75	34	21	256
NW	0	0	9	7	39	44	34	32	62	18	8	253
NNW	0	2	6	9	53	34	44	42	67	18	2	277
Tot	1	30	91	183	548	686	633	467	558	212	111	3520
Hours of Calm												0
Hours of Variable Direction												0
Hours of Valid Data												3520
Hours of Missing Data												59
Hours in Period												8760



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Joint Frequency Distribution: Hours at Wind Speed and Direction												
January- December, 2019												
Class E Slightly Stable based on lapse rate												
Elevations: Winds 60m Stability 60m												
Wind Direction Sector	Wind Speed Range (m/s)											Total
	<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	
N	0	0	1	4	8	18	27	22	18	1	0	99
NNE	0	1	1	3	23	46	58	38	17	1	0	188
NE	0	0	4	4	22	35	39	22	8	1	0	135
ENE	0	1	2	5	15	17	22	10	5	0	0	77
E	0	1	1	2	8	22	28	24	1	0	0	87
ESE	0	2	2	2	11	24	45	27	6	0	0	119
SE	0	1	4	11	72	80	50	12	1	0	0	231
SSE	0	2	4	2	13	52	56	78	78	11	0	296
S	0	0	1	2	10	18	41	90	128	22	3	315
SSW	0	1	3	3	12	21	35	66	84	5	2	232
SW	0	1	0	0	6	19	32	44	47	7	3	159
WSW	0	0	2	1	7	19	32	23	25	15	6	130
W	0	1	0	2	9	13	37	31	40	16	1	150
WNW	0	0	0	0	2	11	24	42	39	7	0	125
NW	0	3	0	3	14	14	17	33	26	6	0	116
NNW	0	0	1	3	9	8	20	14	26	2	0	83
Tot	0	14	26	47	241	417	563	576	549	94	15	2542
Hours of Calm	0											
Hours of Variable Direction	0											
Hours of Valid Data	2542											
Hours of Missing Data	59											
Hours in Period	8760											

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Joint Frequency Distribution: Hours at Wind Speed and Direction												
January- December, 2019												
Class F Moderately Stable based on lapse rate												
Elevations: Winds 60m Stability 60m												
Wind Direction Sector	Wind Speed Range (m/s)											Total
	<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	
N	0	0	0	0	2	6	6	9	2	0	0	25
NNE	0	0	0	1	11	15	25	29	16	2	0	99
NE	0	1	0	5	12	12	16	15	9	0	1	71
ENE	0	0	1	2	3	5	20	8	3	0	0	42
E	0	1	3	0	4	9	14	10	0	0	0	41
ESE	0	0	0	0	8	13	11	15	0	0	0	47
SE	0	0	5	11	42	24	11	7	1	0	0	101
SSE	0	1	0	0	15	23	35	30	35	1	0	140
S	0	0	1	2	8	16	37	54	38	3	0	159
SSW	0	0	0	0	2	13	29	38	50	0	0	132
SW	0	0	0	1	0	3	16	21	21	1	0	63
WSW	0	1	0	2	5	5	9	8	6	1	0	37
W	0	0	0	1	1	5	11	10	11	0	0	39
WNW	0	0	1	0	2	5	14	11	18	0	0	51
NW	0	0	0	1	4	9	3	5	10	0	0	32
NNW	0	0	1	0	7	4	9	6	10	0	0	37
Tot	0	4	12	26	126	167	266	276	230	8	1	1116
Hours of Calm	0											
Hours of Variable Direction	0											
Hours of Valid Data	1116											
Hours of Missing Data	59											
Hours in Period	8760											

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Joint Frequency Distribution: Hours at Wind Speed and Direction												
January- December, 2019												
Class G Extremely Stable based on lapse rate												
Elevations: Winds 60m Stability 60m												
Wind Direction Sector	Wind Speed Range (m/s)											Total
	<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	
N	1	0	1	0	0	3	2	4	0	0	0	11
NNE	0	0	0	1	2	2	9	8	2	0	0	24
NE	0	0	0	0	2	8	6	6	0	0	0	22
ENE	0	0	0	0	3	2	15	9	2	0	0	31
E	0	1	1	2	4	5	8	4	0	0	0	25
ESE	0	0	0	2	5	9	5	0	0	0	0	21
SE	0	4	6	5	9	6	2	1	0	0	0	33
SSE	0	2	6	1	8	10	4	7	2	0	0	40
S	0	1	2	4	4	11	21	20	13	0	0	76
SSW	0	0	0	3	5	4	9	15	10	0	0	46
SW	0	0	1	1	2	2	7	5	4	0	0	22
WSW	0	1	3	0	3	8	4	0	0	0	0	19
W	0	0	0	0	2	2	3	2	0	0	0	9
WNW	0	1	2	1	4	0	3	2	4	0	0	17
NW	0	0	0	0	1	4	4	4	2	0	0	15
NNW	0	0	0	1	4	4	5	2	7	0	0	23
Tot	1	10	22	21	58	80	107	89	46	0	0	434
Hours of Calm	0											
Hours of Variable Direction	0											
Hours of Valid Data	434											
Hours of Missing Data	59											
Hours in Period	8760											

Appendix C

Changes to the Callaway Energy Center Offsite Dose Calculation Manual for the year 2019

APA-ZZ-01003, "Off-Site Dose Calculation Manual," was revised in 2019. A complete copy of the revised document was submitted with revision 0 of this report.