OFFSITE DOSE CALCULATION MANUAL

FORT CALHOUN STATION UNIT NO. 1

August, 1984

2. EFFLUENT MONITOR SETPOINTS

2.1 Liquid Effluent Radiation Monitors

2.1.1 Steam Generator Blowdown Monitors (RM-054A and B)

These process radiation detectors monitor the flow through the steam generator blowdown lines and automatically close the blowdown isolation valves if the monitor high alarm setpoint is reached. The high alarm setpoint calculations are based on controlling the outfall at 10 CFR Part 20 limits of 1.0E-07 μCi/cc for unrestricted areas, for unidentified isotopes.

The maximum allowable concentration in the blowdown line is calculated as follows:

$$A_o = \frac{(1.0E\text{-}07\ \mu Ci/cc)\ (X_o)}{Y_o}$$

where:

X_o = Dilution flow in the discharge tunnel (gpm).

(Normal flow is based on 1 circulating water pump at 120,000 gpm)

Y_o = Blowdown flow rate (gpm). (Normal blowdown flow rate is based on 2 transfer pumps with a design flow of 135 gpm each, 270 gpm total).

A_o = Maximum allowable blowdown line concentration (μCi/cc).

The high alarm setpoint (CPM) =

$$8.5E\text{-}01 \left[(S_F)\ \ (A_o) + B \right]$$

where:

8.5E-01 = Correction factor for instrument meter error.

S_F = Detector sensitivity factor (CPM/μCi/cc). (Sensitivity based on CS^{137})

A_o = Maximum allowable blowdown line activity (μCi/cc).

B = Background (CPM).

Setpoints may be recalculated based on adjusted dilution flow and adjusted blowdown flow.

2. EFFLUENT MONITOR SETPOINTS (Continued)

2.1.2 Overboard Discharge Header Monitor (RM-055 or RM-055A)

This process radiation monitor provides surveillance of the waste monitor tank effluent by monitoring the overboard header prior to its discharge into the circulating water discharge tunnel. The concentration of activity at the tunnel outfall is controlled below the 10 CFR Part 20 limit of 1.0E-07 μCi/cc for unrestricted areas for unidentified isotopes by the high alarm setpoint which also closes the overboard flow control valve.

The maximum allowable concentration in the overboard discharge header is:

$$A_o = \frac{(1.0E\text{-}07\ \mu Ci/cc)\ (X_o)}{Y_o}$$

where:

X_o = Dilution flow in the discharge tunnel (gpm).

(Normal flow is based on 1 circulating water pump at 120,000 gpm)

Y_o = Maximum monitor tank discharge flow rate (gpm).

A_o = Maximum allowable activity in discharge header (μCi/cc).

The high alarm setpoint (CPM) =

$$8.5E\text{-}01 \left[(S_F)\ \ (A_o) + B\right]$$

where:

8.5E-01 = Correction factor for instrument meter error.

S_F = Detector sensitivity factor (CPM/μCi/cc).
(Sensitivity based on CS^{137})

A_o = Maximum allowable concentration in discharge header (μCi/cc).

B = Background (CPM).

2. EFFLUENT MONITOR SETPOINTS (Continued)

2.2 Gaseous Effluent Radiation Monitors

2.2.1 Stack Particulate Monitors (RM-061/RM-050)

Either of these monitors may be used to measure airborne particulate activity in the ventilation stack. The detector is located adjacent to a section of moveable filter paper on a capstan drive which is set to move in a continuous mode. The monitor measures airborne particulate activity releases so that the unrestricted areas limits (of 1.0E-10 μCi/cc) for radionuclides with half-lives greater than 8 days are not exceeded at the site boundary. The Ventilation Isolation Actuation Signal (VIAS) is initiated when the high alarm setpoint is reached.

The maximum allowable release rate:

$$\frac{(1.0E\text{-}10\ \mu Ci/cc)}{(1.5E\text{-}05\ sec/m^3)} \times (1.0E{+}06\ cc/m^3) = 6.67E00\ \mu Ci/sec$$

where:

1.0E-10 μCi/cc = Limiting activity at site boundary for unidentified isotopes with half lives greater than 8 days.

1.5E-05 sec/m³ = Annual average dispersion factor at the site boundary.

The high alarm setpoint (CPM):

$$8.5E\text{-}01\left[\frac{(6.67E00)\ (S_F)\ \ (F_s)\ (T)}{(F_v)} + B\right]$$

where:

8.5E-01 = Correction for instrument meter error.

S_F = Detector sensitivity factor (CPM/μCi). (Sensitivity based on CS^{137})

F_s = Monitor sample flow rate (SCFM).

T = Effective monitor response time (sec).

F_v = Vent stack flow rate (SCFM).

B = Background (CPM).

2. EFFLUENT MONITOR SETPOINTS (Continued)

2.2.2 Stack Gaseous Activity Monitors (RM-062/RM-051)

Either of these monitors may be used to measure gaseous activity in the ventilation stack. The gas is monitored after passing through a particulate filter. The monitor controls gaseous activity releases so that the unrestricted area limits of 3.0E-07 μCi/cc for noble gases are not exceeded at the site boundary. The Ventilation Isolation Actuation Signal is initiated when the high alarm setpoint is reached.

The maximum allowable release rate:

$$\frac{3.0\text{E-}07\ \mu\text{Ci/cc}}{1.5\text{E-}05\ \text{sec/m}^3} \times 1.0\text{E+}06\ \text{cc/m}^3 = 2.0\text{E+}04\ \mu\text{Ci/sec}$$

where:

3.0E-07 μCi/cc = Limiting gaseous activity at site boundary (based upon XE-133).

1.5E-05 sec/m^3 = Annual average dispersion factor at the site boundary.

The high alarm setpoint (CPM):

$$8.5\text{E-}01\left[\frac{(2.00\text{E+}04)\ (S_F)\ \ (60)}{(F_V)\ (28316)} + B\right]$$

$$= 8.5\text{E-}01\left[\frac{(4.24\text{E+}01)\ (S_F)}{(F_V)} + B\right]$$

where:

8.5E-01 = Correction for instrument meter error.

S_F = Detector sensitivity factor (CPM/μCi/cc). (Sensitivity based on CS^{137})

60 = Conversion (seconds to minutes).

28316 = Conversion factor (ft^3 to cc).

F_V = Vent stack flow rate (ft^3/min).

B = Background (CPM).

2. EFFLUENT MONITOR SETPOINTS (Continued)

2.2.3 Stack Iodine Monitor (RM-060)

RM-060 monitors the gaseous waste discharged from the stack for iodine (I-131) activity by continuously counting a charcoal filter cartridge through which a sample of ventilation stack air is passing at a known rate. The monitor alarm setpoint initiates the Ventilation Isolation Actuation Signal, when reached, and prevents the concentration of iodine activity, at the site boundary, from exceeding 10 CFR Part 20 limits for unrestricted areas.

The maximum allowable release rate:

$$\frac{(1.0E\text{-}10\ \mu Ci/cc)}{(1.5E\text{-}05\ sec/m^3)} \times (1.0E{+}06\ cc/m^3) = 6.67E00\ \mu Ci/sec$$

where:

1.0E-10 µCi/cc = Limiting activity at site boundary for I-131.

The high alarm setpoint (CPM):

$$8.5E\text{-}01 \left[\frac{(6.67E00)\ (S_F)\ \ (F_s)\ (T)\ (E)}{(F_v)} + B \right]$$

where:

8.5E-01 = Correction factor for instrument meter error.

S_F = Detector sensitivity factor (CPM/µCi). (Sensitivity based on I^{131})

F_s = Monitor sample flow rate (SCFM).

T = Effective monitor response time (sec).

F_v = Vent stack flow rate (SCFM).

E = Charcoal filter collection efficiency.

B = Background (CPM).

2. EFFLUENT MONITOR SETPOINTS (Continued)

2.2.4 Condenser Air Ejector Monitor (RM-057)

This monitor is located in the turbine building and monitors the condenser off-gases. The purpose of this monitor is to monitor gaseous releases so that the 10 CFR Part 20 limits for unrestricted areas are not exceeded.

The maximum allowable release rate:

$$\frac{3.0E\text{-}07\ \mu Ci/cc}{1.5E\text{-}05\ sec/m^3} \times 1.0E\text{+}06\ cc/m^3 = 2.0E\text{+}04\ \mu Ci/sec$$

where:

3.0E-07 μCi/cc = Limiting gaseous activity at site boundary (based upon XE-133).

1.5E-05 sec/m^3 = Annual average dispersion factor at the site boundary.

The high alarm setpoint (CPM):

$$8.5E\text{-}01 \left[\frac{(2.0E\text{+}04)\ (S_F)\ \ (60)}{(F_v)\ (28316)} + B\right]$$

$$= 8.5E\text{-}01 \left[\frac{(4.24E\text{+}01)\ (S_F)}{(F_v)} + B\right]$$

where:

8.5E-01 = Correction for instrument meter error.

S_F = Detector sensitivity factor (CPM/μCi/cc). (Sensitivity based on CS^{137})

60 = Conversion (seconds to minutes).

28316 = Conversion factor (cubic feet to cc).

F_v = Condenser vent system flow rate (ft^3/min).

4. DOSE CONTRIBUTIONS FROM LIQUID EFFLUENTS

The cumulative dose contributions to the total body and any organ of an individual will be calculated on a quarterly basis based on the total nuclides released from the plant to unrestricted areas during the previous calendar quarter. These dose contributions will be calculated using the following expression:

$$D_\tau = \Sigma_i A_{i\tau} \Sigma(\Delta t\ a_i \cdot \frac{f}{F})$$
$$= \Sigma_i A_{i\tau} \Sigma(\Delta t\ C_i)$$

where:

D_τ is the cumulative dose commitment to the total body or any organ, τ, from the liquid effluents for the total time period, in mrem.

$A_{i\tau}$ is the ingestion dose commitment factor to the total body or any organ, τ, for each identified principal gamma and beta emitter listed in Table 3-11 of the Technical Specifications, in mrem/hr per μCi/ml.

Δt is the length of time period over which C_i, f, and F are averaged for all liquid releases, in hours.

a_i, C_i, f, F are as defined under Section 3. of this manual.

The cumulative dose contributions to the total body and any organ will be reviewed quarterly to verify satisfaction to the design objectives and the actions of Technical Specification 2.9.1 (1) determined.

4.1 Ingestion Dose Commitment Factors

The above equation for calculating the dose contributions requires the use of an ingestion dose commitment factor, $A_{i\tau}$, for each nuclide, i, which embodies the dose factors, and dilution factors for the points of pathway origin (only drinking water and fish consumption are considered the major pathways of exposure due to liquid effluents). The adult total body dose factor and the adult critical organ (liver) dose factor for each radionuclide are obtained from Regulatory Guide 1.109, Revision 1. The ingestion dose commitment factor can be calculated from the following expression:

$$A_{i\tau} = 1.14\text{ E+05}\left[\frac{730}{D_w} e^{-\lambda_i t_p} + 21\ BF_i\ e^{-\lambda_i t_s}\right] DF_i$$

4. DOSE CONTRIBUTIONS FROM LIQUID EFFLUENTS (Continued)

where:

D_w - Dilution factor from the near field area of the release point to the drinking water facility 19 miles downstream.

λ_i - Radioactive decay constant of nuclide, i, in ($days^{-1}$).

t_p - The average transit time from the point of release to the drinking water facility including the time through the purification plant and the water distribution system, in days.

t_f - The time for radionuclide decay during transit through the aquatic food chain, in days.

BF_i - Bioaccumulation factor for nuclide, i, in fish for fresh water site, in pCi/kg per pCi/l.

DF_i - Dose conversion factor for nuclide, i, for adults, in mrem/pCi.

1.14E+05 - Unit Conversion Factor (1.0E+06 pCi/μCi x 1.0E+03 $\frac{ml}{kg}$ ÷ 8760 hr/yr)

Tabulated below are the appropriate values and other references:

Parameter	Value
D_w	30.8 (dimensionless)
t_p	0.75 day
t_f	1 day
BF_i	Table A-1 of Regulatory Guide 1.109
DF_i	Table E-11 of Regulatory Guide 1.109

Resolution of the units yields:

$$A_{i\tau} = 2.40E+06 \left[1.13\ e^{-0.75\lambda_i} + BF_i\ e^{-\lambda_i} \right] DF_i$$

The values for ingestion dose commitment factor, $A_{i\tau}$, for the adult total body, and critical organ (liver), are presented in Table 1.

5. LIQUID RADWASTE TREATMENT SYSTEM

The major equipment or subsystem(s) of the liquid radwaste treatment system are comprised of waste filters, and evaporator. This equipment, including associated pumps, valves and piping, is used in different combinations on an as-needed basis in order to process the liquid effluent to provide compliance with the as low as is reasonably achievable philosophy and the applicable sections of 10 CFR Part 20. The liquid radwaste treatment system is fully described, in Section 11.1.2 of the USAR. For effluent release points and monitor locations refer to P&IDs 11405-M-100, M-9 and M-8.

Waste filters (WD-17A and WD-17B) are used only on those occasions when considered necessary, otherwise the flows from the low activity fluids may bypass the filters. No credit for decontamination factors (iodines, Cs, Rb, others) was taken for these filters during the Appendix I dose design objective evaluation; therefore, the inoperability of these filters does not affect the dose contributions to any individual in the unrestricted areas via liquid pathways. The inoperability of waste filters will not be considered a reportable event in accordance with Specification 2.9.1(1)c.

Every effort will be made to process all liquid waste, except from the hotel waste tanks, through the evaporator before entering the monitor tanks. If the radioactive liquid waste was discharged without processing through the evaporator a special report shall be submitted to the Commission, pursuant to Specification 2.9.1(1)c.

The quantity of radioactive material contained in each unprotected outdoor liquid holdup tank shall not exceed 10 curies, excluding tritium and dissolved or entrained noble gases.

TABLE 2

Dose Factors for Noble Gases

Nuclide	Gamma Air Dose Factor DF_i^{γ} (mrad/sec per $\mu Ci/m^3$)	Beta Air Dose Factor DF_i^{β} (mrad/sec per $\mu Ci/m^3$)
AR-41	2.9E-04	1.0E-04
KR-85M	3.9E-05	6.2E-05
KR-85	5.4E-07	6.2E-05
KR-87	2.0E-04	3.3E-04
KR-88	4.8E-04	9.3E-05
XE-131M	4.9E-06	3.5E-05
XE-133M	1.0E-05	4.7E-05
XE-133	1.1E-05	3.3E-05
XE-135M	1.1E-04	2.3E-05
XE-135	6.1E-05	7.8E-05
XE-138	2.9E-04	1.5E-04

TABLE 5

Dose Factors for I-131, H-3 and Radioactive Particulates Via Ground and Food Pathways*
(m^2-mrem/yr per μCi/sec) R_i (Child)

Nuclide	Total Body	Thyroid
H-3	5.8E+03**	5.8E+03**
CR-51	4.8E+06	3.8E+04
MN-54	1.5E+09	0.0
FE-59	8.2E+08	0.0
CO-58	6.3E+08	0.0
CO-60	2.3E+10	0.0
ZN-65	6.8E+09	0.0
SR-89	1.2E+09	0.0
SR-90	3.4E+11	0.0
ZR-95	2.5E+08	0.0
I-131	4.8E+08	2.7E+11
CS-134	1.8E+10	0.0
CS-136	1.2E+09	0.0
CS-137	1.7E+10	0.0
BA-140	4.2E+07	0.0

*Food pathways for "Child" are milk, meat, and vegetation.
**Units for H-3 are mrem/yr per μCi/m^3.

TABLE 6

Dose Factors for I-131, H-3 and Radioactive Particulates
Via Ground and Food Pathway*
(m^2-mrem/yr per μCi/sec) R_i (Infant)

Nuclide	Total Body	Thyroid
H-3	2.4E+03**	2.4E+03**
CR-51	4.8E+06	5.5E+04
MN-54	1.3E+09	0.0
FE-59	3.6E+08	0.0
CO-58	4.2E+08	0.0
CO-60	2.2E+10	0.0
ZN-65	6.3E+09	0.0
SR-89	2.0E+08	0.0
SR-90	2.1E+10	0.0
ZR-95	2.5E+08	0.0
I-131	7.3E+08	5.3E+11
CS-134	1.1E+10	0.0
CS-136	1.2E+09	0.0
CS-137	1.3E+10	0.0
BA-140	2.7E+07	0.0

*Food pathways for "Infant" is milk only.
**Units for H-3 are mrem/yr per μCi/m^3.

8. GASEOUS RADWASTE TREATMENT SYSTEM

The waste gases at Fort Calhoun Station are collected in the vent header where the gas compressor(s) takes suction, compresses the gas and then delivers it to one of the four gas decay tanks. The waste gases are primarily treated in these gas decay tanks by holding the gases for radioactive decay prior to final controlled release to the environs. In order to provide conformance with the dose design objectives, gas decay tanks are normally stored for approximately 17 days with earlier release allowed to support plant operation only and thus achieve decay of short half-life radioactive materials, e.g., I-131, XE-133. If the radioactive gaseous wastes from the gas decay tank(s) were discharged without processing in accordance with the above conditions, a special report shall be submitted to the Commission pursuant to Specification 2.9.1(2)c.

The radioactive effluents from the controlled access area of the auxiliary building are filtered by the HEPA filters in the auxiliary building ventilation system. If the radioactive gaseous wastes were discharged without the HEPA filters, a special report shall be submitted to the NRC pursuant to specification 2.9.1(2)c.

The discharge from the gas decay tanks is routed through charcoal and HEPA filter unit VA-82. No credit was taken for the operation of hydrogen purge filters during the Appendix I dose design evaluation and doses through the gaseous pathways were well below the design objectives. The unavailability of hydrogen purge filters will not be considered a reportable event as per Specification 2.9.1(2)c.

The containment air is processed through at least one of the redundant containment HEPA and charcoal filters in the Containment Air Cooling and Filtering Units prior to purging. If the containment purges were made without processing through one of the Containment Air Cooling and Filtering Units, a special report shall be submitted to the Commission pursuant to Specification 2.9.1(2)c.

The gaseous radwaste treatment system is described in Section 11.1.3 of the USAR. For effluent release points and monitor locations refer to P&IDs 11405-M-1 and M-261.

TABLE 9 (Continued)

Where:

LLD is the lower limit of detection as defined above, as microcuries per unit mass or volume,

s_b is the standard deviation of the background counting rate of of the counting rate of a blank sample as appropriate, as counts per minute,

E is the counting efficiency, as counts per disintegration,

V is the sample size in units of mass or volume,

2.22×10^6 is the number of disintegrations per minutes per microcurie,

Y is the fractional radiochemical yield, when applicable,

λ is the radioactive decay constant for the particular radionuclide, and

Δt for the environmental samples is the elapsed time between the sample collection or end of the sample collection period, and time of counting.

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

It should be recognized that the LLD is defined as before the fact limit representing the capability of a measurement system and not as after the fact limit for a particular measurement.