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UNION ELECTRIC

CALLAWAY PLANT
OFF-SITE DOSE CALCULATION MANUAL

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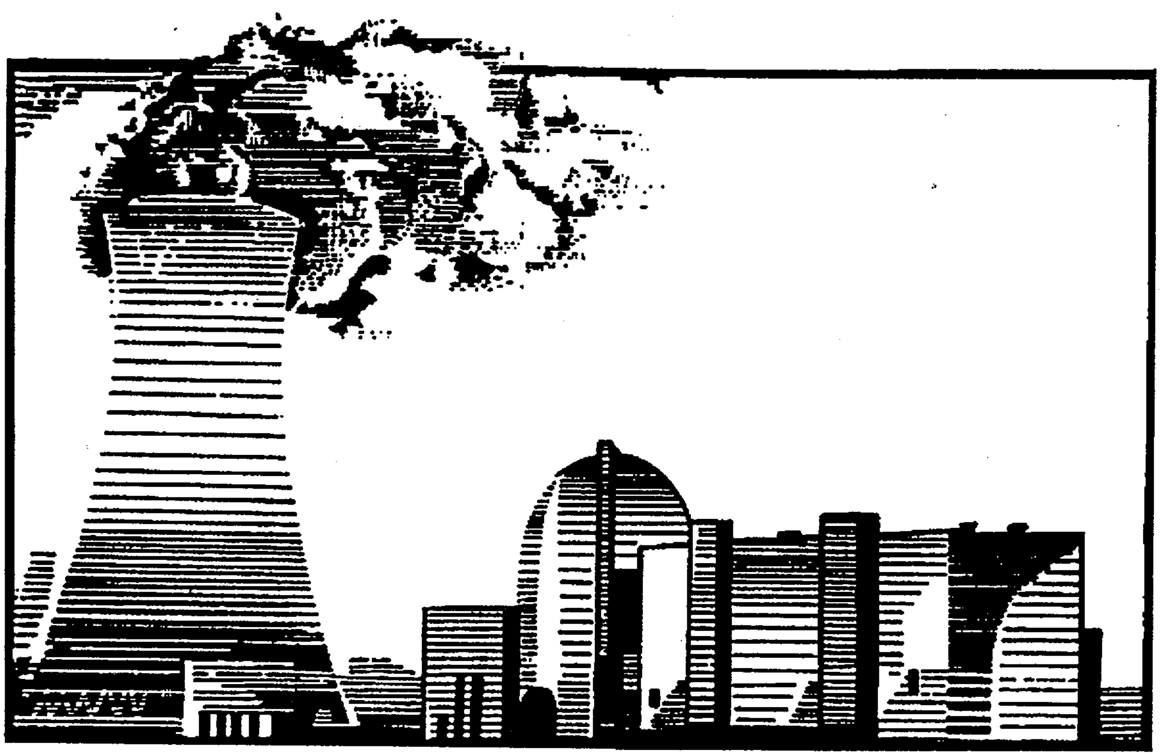

CALLAWAY PLANT

ADMINISTRATIVE PROCEDURE

APA-ZZ-01003

OFF-SITE DOSE CALCULATION MANUAL

RESPONSIBLE DEPARTMENT HEALTH PHYSICS

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This procedure contains the following:

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RECORD OF REVISIONS

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 ULNRC-803 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.

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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 as 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, OFF-SITE DOSE CALCULATION MANUAL.

Rev. No. 1 **Date: October, 1990**

Revise Action 41 of Table 9.2-A to allow continued purging for 24 hours as 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 as per Table 9.3-A, and the Callaway Plant NPDES permit (reissued March 15, 1991).

RECORD OF REVISIONS

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 & 23 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 SOS 94-1176).

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 C^{14}, P^{32}, Ni^{63}, Te^{125m}, and 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 Ag^{110m}, Np^{237}, Pu^{238}, $Pu^{239/240}$, Pu^{241}, Am^{241}, Cm^{242}, and $Cm^{234/244}$ 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 Y^{91m} and Tc^{99m} 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.

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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 H^3 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 SOS 95-2280). 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 SOS's 95-2055, 96-0167, 96-0961, 95-2280, and 96-0986).

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 SOS 97-166)

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.

RECORD OF REVISIONS

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 99-05. Tables 6.1, 6.2, 6.3: Updated values as calculated in HPCI 99-02. 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. Technical Specification 4.9.4.2 changed to FSAR SP 16.11.2.4.1.B. Technical Specification 6.8.4.F changed to FSAR SP 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 consistant with FSAR 16.11.5.2. Several changes were made throughout the procedure to correct typographical errors and have no technical impact.

OFF-SITE DOSE CALCULATION MANUAL

1 PURPOSE AND SCOPE

The OFF-SITE 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 AC 5.5.4** and **FSAR 16.11.4** , and descriptions of the information that should be included in the Annual Radiological Environmental Operating and Effluent Release Reports required by **T/S AC 5.6.2** and **T/S AC 5.6.3** .

Compliance with the Radiological Effluent Controls limits demonstrates compliance with the limits of 10 CFR 20.1301. (Ref. 11.1.1, 11.2.1, 11.23.3)

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

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:

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

Where:

C = The liquid effluent concentration value (ECV) implementing REC 16.11.1.1 for the site in (μCi/ml).

c = 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 = 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.

F = 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 $F + f \cong F$}.

(Ref. 11.8.1)

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:

$$c \leq \frac{C(F + f)}{f} \ (\mu\text{Ci} \ / \ \text{ml}) \qquad (2.2)$$

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.

2.1.1 Continuous Liquid Effluent Monitors

The radiation detection monitor associated with continuous liquid effluent releases is (Ref. 11.6.1, 11.6.2):

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 as per FSAR Table 16.11-1.

2.1.2 Radioactive Liquid Batch Release Effluent Monitors

The radiation monitor which is associated with the liquid effluent batch release system is (Ref. 11.6.4):

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 as per FSAR 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. (Ref. 11.8.1)

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 Table 16.11-1, and is used to calculate an ECV sum (ECVSUM):

$$\text{ECVSUM} = \left(\sum_{i = g,\, a,\, s,\, t,\, f} (C_i)/(ECV_i)\right) \qquad (2.3)$$

Where:

C_g = the concentration of each measured gamma emitting nuclide observed by gamma-ray spectroscopy of the waste sample.

C_a^* = the concentration of Np^{237}, Pu^{238}, $Pu^{239/240}$, Pu^{241}, Am^{241}, Cm^{242}, & $Cm^{243/244}$, in the quarterly composite sample.

C_s^* = the measured concentrations of Sr-89 and Sr-90 as determined by analysis of the quarterly composite sample.

C_t = the measured concentration of H-3 in the waste sample.

C_f^* = the measured concentration of Fe-55 as determined by analysis of the quarterly composite sample.

ECV_g, ECV_s, ECV_a, ECV_f, 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 $2\text{x}10^{-4}$ 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 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.

* Values for these concentrations are based on previous composite sample analyses as required by FSAR Table 16.11-1.

2.2.2 Calculation of the Maximum Permissible Liquid Effluent Discharge Flowrate

The maximum permissible liquid effluent discharge flowrate is calculated by:

$$f_{max} \leq (F + f_p)\,(SF)\,(N) \div (ECVSUM) \qquad (2.4)$$

Where:

f_{max} = maximum permissible liquid effluent discharge flowrate, (in gallons/minute);

f_p = the expected undiluted liquid effluent flowrate, in gpm.

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

SF = 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 flowrate (f_{max}). The value of SF should be ≤ 1.

F & 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 value of f_{max} 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:

$$c = BKG + (\Sigma (C_g) \div SF) = \mu Ci/ml \qquad (2.5)$$

Where:

c = the monitor setpoint as previously defined, in (μCi/ml);

BKG = the monitor background prior to discharge, in (μCi/ml);

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 (Ref. 11.21), the background must be maintained at a value of less than or equal to 9E-6 μCi/ml (relative to Cs-137) in order to detect a change of 4E-7 μCi/ml of Cs-137. (Ref. 11.25).

In the event that there is no detectable gamma activity in the effluent or if the value of ($\Sigma(C_g) \div SF$) 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 new 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:

$$DBCF_C = \left(\sum (C_g)\right) \div (CMR) \times (ECF) \qquad (2.6)$$

$DBCF_c$ = the monitor data base conversion factor which converts count rate into concentration (μ Ci/ml);

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

ECF = the conversion factor for Cs-137, 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 reference 11.14.7.

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 H-3 analyses of the liquid batch sample. For Sr^{89}, Sr^{90}, Fe^{55}, Np^{237}, Pu^{238}, $Pu^{239/240}$, Pu^{241}, Am^{241}, Cm^{242}, & $Cm^{243/244}$, 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 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 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. (Ref. 11.8.3)

The Callaway Plant's liquid effluents are discharged to the Missouri River. As there are no potable water intakes within 50 miles of the discharge point (Ref. 11.7.1, 11.6.6), 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. Dose from recreational activities is expected to contribute the additional 5%, which is considered to be negligible. (Ref. 11.6.7)

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 (Ref. 11.8.3):

$$D_\tau = \sum_i \left[A_{i\tau} \sum_{l=1}^{m} \Delta t_l \; C_{il} \; F_l \right] \qquad (2.12)$$

Where:

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

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

$A_{i\tau}$ = 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 Table 16.11-1, (in mrem/hr) per (μCi/ml). The calculation of the $A_{i\tau}$ values given in Table 2.1 are detailed in Ref. 11.14.12, 11.14.13, and 11.14.5.

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

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

Where:

f_{max} = maximum undiluted effluent flow rate during the release

F = average dilution flow

89.77 = site specific applicable factor for the mixing effect of the discharge structure. (Ref. 11.5.1)

The term C_{il} 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.

The nearest municipal potable water intake downstream from the liquid effluent discharge point into the Missouri River is located near the city of St. Louis, Missouri, approximately 78 miles downstream. As there are currently no potable water intakes within 50 river miles of the discharge point, the drinking water pathway is not included in dose estimates to the maximally exposed individual, or in dose estimates to the population. 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. (Ref. 11.6.6).

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 nuclide's Minimum Detectable Activity (MDA) and are not reported as being present at the Lower Level of Detection (LLD) level 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 Chapter 11.2 of the Callaway Plant FSAR.

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 DOSE FACTORS

The dose conversion factors provided in Table 2.1 were derived from the appropriate dose conversion factors of Regulatory Guide 1.109, Table 2.2 and other sources as necessary (Ref: 11.14.5, 11.14.13 and 11.14.12) Non-gamma emitting nuclides not listed in FSAR Table 16.11-1 are not considered.

TABLE 2.1

INGESTION DOSE COMMITMENT FACTOR ($A_{i\tau}$) FOR ADULT AGE GROUP

(mrem/hr) per (µCi/ml)

Nuclide	Bone	Liver	Total Body	Thyroid	Kidney	Lung	GI-LLI
H-3	No Data	2.26E-01	2.26E-01	2.26E-01	2.26E-01	2.26E-01	2.26E-01
Be-7	1.30E-02	2.98E-02	1.45E-02	No Data	3.15E-02	No Data	5.16E+00
Na-24	4.07E+02	4.07E+02	4.07E+02	4.07E+02	4.07E+02	4.07E+02	4.07E+02
Cr-51	No Data	No Data	1.27E+00	7.62E-01	2.81E-01	1.69E+00	3.20E+02
Mn-54	No Data	4.38E+03	8.35E+02	No Data	1.30E+03	No Data	1.34E+04
Mn-56	No Data	1.10E+02	1.95E+01	No Data	1.40E+02	No Data	3.52E+03
Fe-55	6.57E+02	4.54E+02	1.06E+02	No Data	No Data	2.53E+02	2.61E+02
Fe-59	1.04E+03	2.44E+03	9.34E+02	No Data	No Data	6.81E+02	8.13E+03
Co-57	No Data	2.09E+01	3.48E+01	No Data	No Data	No Data	5.31E+02
Co-58	No Data	8.94E+01	2.00E+02	No Data	No Data	No Data	1.81E+03
Co-60	No Data	2.57E+02	5.66E+02	No Data	No Data	No Data	4.82E+03
Ni-65	1.26E+02	1.64E+01	7.48E+00	No Data	No Data	No Data	4.16E+02
Cu-64	No Data	1.00E+01	4.69E+00	No Data	2.52E+01	No Data	8.52E+02
Zn-65	2.32E+04	7.38E+04	3.33E+04	No Data	4.93E+04	No Data	4.65E+04
Zn-69	4.93E+01	9.44E+01	6.56E+00	No Data	6.13E+01	No Data	1.42E+01
Br-82	No Data	No Data	2.27E+03	No Data	No Data	No Data	2.60E+03
Br-83	No Data	No Data	4.04E+01	No Data	No Data	No Data	5.81E+01
Br-84	No Data	No Data	5.26E+01	No Data	No Data	No Data	4.13E-04
Br-85	No Data	No Data	2.15E+00	No Data	No Data	No Data	0
Rb-86	No Data	1.01E+05	4.71E+04	No Data	No Data	No Data	1.99E+04
Rb-88	No Data	2.90E+02	1.54E+02	No Data	No Data	No Data	4.00E-09
Rb-89	No Data	1.92E+02	1.35E+02	No Data	No Data	No Data	0
Sr-89	2.21E+04	No Data	6.35E+02	No Data	No Data	No Data	3.55E+03
Sr-90	5.44E+05	No Data	1.34E+05	No Data	No Data	No Data	1.57E+04
Sr-91	4.07E+02	No Data	1.64E+01	No Data	No Data	No Data	1.94E+03
Sr-92	1.54E+02	No Data	6.68E+00	No Data	No Data	No Data	3.06E+03
Y-90	5.75E-01	No Data	1.54E-02	No Data	No Data	No Data	6.10E+03
Y-91M	5.44E-03	No Data	2.10E-04	No Data	No Data	No Data	1.60E-02
Y-91	8.43E+00	No Data	2.25E-01	No Data	No Data	No Data	4.64E+03
Y-92	5.05E-02	No Data	1.48E-03	No Data	No Data	No Data	8.85E+02
Y-93	1.60E-01	No Data	4.42E-03	No Data	No Data	No Data	5.08E+03
Zr-95	2.40E-01	7.70E-02	5.21E-02	No Data	1.21E-01	No Data	2.44E+02
Zr-97	1.33E-02	2.68E-03	1.22E-03	No Data	4.04E-03	No Data	8.30E+02
Nb-95	4.47E+02	2.48E+02	1.34E+02	No Data	2.46E+02	No Data	1.51E+06
Mo-99	No Data	1.03E+02	1.96E+01	No Data	2.33E+02	No Data	2.39E+02
Tc-99M	8.87E-03	2.51E-02	3.19E-01	No Data	3.81E-01	1.23E-02	1.48E+01
Tc-101	9.11E-03	1.31E-02	1.29E-01	No Data	2.36E-01	6.70E-03	0

TABLE 2.1 (Cont'd)

INGESTION DOSE COMMITMENT FACTOR ($A_{i\tau}$) FOR ADULT AGE GROUP

(mrem/hr) per (μCi/ml)

Nuclide	Bone	Liver	Total Body	Thyroid	Kidney	Lung	GI-LLI
Ru-103	4.42E+00	No Data	1.90E+00	No Data	1.69E+01	No Data	5.17E+02
Ru-105	3.68E-01	No Data	1.45E-01	No Data	4.76E+00	No Data	2.25E+02
Ru-106	6.57E+01	No Data	8.32E+00	No Data	1.27E+02	No Data	4.25E+03
Cd-109	No Data	5.54E+02	1.94E+01	No Data	5.31E+02	No Data	5.59E+03
Ag-110m	8.83E-01	8.17E-01	4.85E-01	No Data	1.61E+00	No Data	3.33E+02
Sn-113	5.66E+04	1.61E+03	3.26E+03	9.18E+02	No Data	No Data	1.69E+05
Sb-124	6.69E+00	1.26E-01	2.65E+00	1.62E-02	No Data	5.21E+00	1.90E+02
Sb-125	4.28E+00	4.78E-02	1.02E+00	4.35E-03	No Data	3.30E+00	4.71E+01
Te-127m	6.47E+03	2.32E+03	7.90E+02	1.66E+03	2.63E+04	No Data	2.17E+04
Te-127	1.05E+02	3.78E+01	2.28E+01	7.80E+01	4.29E+02	No Data	8.30E+03
Te-129M	1.10E+04	4.11E+03	1.74E+03	3.78E+03	4.60E+04	No Data	5.54E+04
Te-129	3.01E+01	1.13E+01	7.33E+00	2.31E+01	1.26E+02	No Data	2.27E+01
Te-131M	1.66E+03	8.09E+02	6.75E+02	1.28E+03	8.21E+03	No Data	8.03E+04
Te-131	1.89E+01	7.88E+00	5.96E+00	1.55E+01	8.25E+01	No Data	2.67E+00
Te-132	2.41E+03	1.56E+03	1.47E+03	1.72E+03	1.50E+04	No Data	7.38E+04
I-130	2.71E+01	8.01E+01	3.16E+01	6.79E+03	1.25E+02	No Data	6.89E+01
I-131	1.49E+02	2.14E+02	1.22E+02	7.00E+04	3.66E+02	No Data	5.64E+01
I-132	7.29E+00	1.95E+01	6.82E+00	6.82E+02	3.11E+01	No Data	3.66E+00
I-133	5.10E+01	8.87E+01	2.70E+01	1.30E+04	1.55E+02	No Data	7.97E+01
I-134	3.81E+00	1.03E+01	3.70E+00	1.79E+02	1.64E+01	No Data	9.01E-03
I-135	1.59E+01	4.16E+01	1.54E+01	2.75E+03	6.68E+01	No Data	4.70E+01
Cs-134	2.98E+05	7.09E+05	5.80E+05	No Data	2.29E+05	7.62E+04	1.24E+04
Cs-136	3.12E+04	1.23E+05	8.86E+04	No Data	6.85E+04	9.39E+03	1.40E+04
Cs-137	3.82E+05	5.22E+05	3.42E+05	No Data	1.77E+05	5.89E+04	1.01E+04
Cs-138	2.64E+02	5.22E+02	2.59E+02	No Data	3.84E+02	3.79E+01	2.23E-03
Ba-139	9.29E-01	6.62E-04	2.72E-02	No Data	6.19E-04	3.76E-04	1.65E+00
Ba-140	1.94E+02	2.44E-01	1.27E+01	No Data	8.31E-02	1.40E-01	4.00E+02
Ba-141	4.50E-01	3.40E-04	1.52E-02	No Data	3.16E-04	1.93E-04	2.12E-10
Ba-142	2.04E-01	2.09E-04	1.28E-02	No Data	1.77E-04	1.19E-04	0
La-140	1.50E-01	7.53E-02	1.99E-02	No Data	No Data	No Data	5.53E+03
La-142	7.65E-03	3.48E-03	8.66E-04	No Data	No Data	No Data	2.54E+01
Ce-141	2.24E-02	1.51E-02	1.72E-03	No Data	7.03E-03	No Data	5.78E+01
Ce-143	3.94E-03	2.92E+00	3.23E-04	No Data	1.28E-03	No Data	1.09E+02
Ce-144	1.17E+00	4.88E-01	6.26E-02	No Data	2.89E-01	No Data	3.94E+02
Pr-143	5.50E-01	2.21E-01	2.73E-02	No Data	1.27E-01	No Data	2.41E+03
Nd-147	3.76E-01	4.35E-01	2.60E-02	No Data	2.54E-01	No Data	2.09E+03
Eu-154	3.67E+01	4.52E+00	3.21E+00	No Data	2.16E+01	No Data	3.27E+03
Hf-181	3.99E-02	1.94E-01	1.80E-02	No Data	4.17E-02	No Data	2.21E+02
W-187	2.96E+02	2.47E+02	8.64E+01	No Data	No Data	No Data	8.09E+04

TABLE 2.1 (Cont'd)

INGESTION DOSE COMMITMENT FACTOR ($A_{i\tau}$) FOR ADULT AGE GROUP

(mrem/hr) per (μCi/ml)

Nuclide	Bone	Liver	Total Body	Thyroid	Kidney	Lung	GI-LLI
Np-237	3.27E+04	2.84E+03	1.32E+03	No Data	9.85E+03	No Data	1.90E+03
Np-239	2.84E-02	2.80E-03	1.54E-03	No Data	8.72E-03	No Data	5.74E+02
Pu-238	5.69E+03	8.01E+02	1.43E+02	No Data	6.12E+02	No Data	6.11E+02
Pu-239*	6.58E+03	8.87E+02	1.60E+02	No Data	6.78E+02	No Data	5.67E+02
Pu-241	1.38E+02	7.06E+00	2.78E+00	No Data	1.28E+01	No Data	1.17E+01
Am-241	4.89E+04	1.72E+04	3.23E+03	No Data	2.43E+04	No Data	4.43E+03
Cm-242	1.23E+03	1.25E+03	8.19E+01	No Data	3.72E+02	No Data	4.73E+03
Cm-243**	3.82E+04	1.44E+04	2.24E+03	No Data	1.05E+04	No Data	4.67E+03

*Includes Pu-240 contribution
**Includes Cm-244 contribution

TABLE 2.2

BIOACCUMULATION FACTOR (Bf_i) [a]

(pCi/kg) per (pCi/liter)

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

[a] Values from Regulatory Guide 1.109, Rev. 1, Table A-1 and References 11.14.4, 11.14.8, and 11.14.13.

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. (Ref. 11.6.3)

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, the variability in release flow and principal radionuclides, and the time lag between alarm/trip action and the final isolation of the radioactive effluent. (Ref. 11.8.5) FSAR Table 16.11-6 provides the instrument surveillance requirements, such as calibration, source checking, functional testing, and channel checking.

3.1.1 Continuous Release Gaseous Effluent Monitors

The radiation detection monitors associated with continuous gaseous effluent releases are (Ref. 11.6.8, 11.6.9):

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 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 Monitors

The radiation monitors associated with batch release gaseous effluents are (Ref. 11.6.9, 11.6.10, 11.6.11):

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

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 Unit Vent and Radwaste Building Vent gaseous effluent monitors is determined based on the more restrictive of the total body dose rate (equation 3.1) and skin dose rate (equation 3.3), as calculated for the SITE BOUNDARY.

The alarm trip setpoint for the Laundry Decon Facility Exhaust Monitor is set to less then or equal to 2,000 cpm above equilibrium background. The maximum allowed background is 2,000 cpm as discussed in reference 11.27.

During core alterations, the setpoint for the Containment Purge Monitors, GT-RE-22 and GT-RE-33 is set at a value of less than or equal to 5E-3 μCi/cc, as required by **FSAR 16.11.2.4.1.B** . The actual setpoint value will be reduced according to the Instrument Loop Uncertainty Estimate (ILUE). This value will also be utilized in the event that there is no detectable noble gas activity in the containment atmosphere sample analyzed in accordance with REC 16.11.2.1. The full derivation of this value is discussed in reference 11.14.6.

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:

$$S_{tb} \leq D_{tb} R_{tb} F_s F_a \qquad (3.1)$$

Where:

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

D_{tb} = REC 16.11.2.1 limit of 500 mrem/yr, conservatively interpreted as a continuous release over a one year period.

F_s = 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 $F_s = 0.1$.

F_a = 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} = 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:

$$R_{tb} = C \div \left[(\overline{X/Q}) \sum_i K_i Q_i \right] \qquad (3.2)$$

Where:

C = monitor reading of a noble gas monitor corresponding to the sample radionuclide concentrations for the release. Concentrations are determined in accordance with FSAR 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 concentrations, not release rate, and is in units of (μCi/cc).

$\overline{X/Q}$ = the highest calculated annual average relative concentration for any area at or beyond the SITE BOUNDARY in (sec/m^3). Refer to Tables 6.1, 6.2 and 6.4.

K_i = the total body dose factor due to gamma emissions for each identified noble gas radionuclide, in (mrem/yr) per (μCi/m^3). (Table 3.1)

Q_i = 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:

$$S_s \leq D_s R_s F_s F_a \qquad (3.3)$$

Where:

F_s and F_a are as previously defined.

S_s = the alarm/trip setpoint based on the skin dose rate.

D_s = REC 16.11.2.1 limit of 3000 mrem/yr, conservatively interpreted as a continuous release over a one year period.

R_s = 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:

$$R_s = C \div \left[\left(\overline{X/Q}\right) \sum_i \left(L_i + 1.1 M_i\right) Q_i \right] \qquad (3.4)$$

Where:

L_i = the skin dose factor due to beta emissions for each identified noble gas radionuclide, in (mrem/yr) per (μCi/m^3).

1.1 = conversion factor: 1 mrad air dose = 1.1 mrem skin dose.

M_i = the air dose factor due to gamma emissions for each identified noble gas radionuclide, in (mrad/yr) per (μCi/m^3).

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. (Ref. 11.8.6)

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 (Ref. 11.8.6):

$$D_{tb} = \sum_i \left[K_i \left(\left(\overline{X/Q}\right) Q_i\right)\right] \leq 500 \text{mrem/yr} \qquad (3.5)$$

$$D_s = \sum_i \left[\left(L_i + 1.1\, M_i\right)\left(\left(\overline{X/Q}\right) Q_i\right)\right] \leq 3000 \text{ mrem/yr} \qquad (3.6)$$

Where:

Q_i = The release rate of noble gas radionuclides, i, in gaseous effluents, from all vent releases in (μCi/sec).

1.1 = Units conversion factor; 1 mrad air dose = 1.1 mrem skin dose.

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

3.3.1.2 Dose Rate from Radionuclides Other than Noble Gases

The release rate limit for Iodine-131 and Iodine-133, for tritium, and for all radioactive materials in particulate form with half lives greater than 8 days is determined according to (Ref. 11.8.7):

$$D_o = \sum_i R_i \left[\overline{X/Q} \right] Q_i \leq 1500 \text{ mrem/yr} \qquad (3.7)$$

Where:

D_o = Dose rate to any critical organ, in (mrem/yr).

R_i = 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).

Q_i = 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 (ref. 11.8.7).

R_i values were calculated according to (Ref. 11.8.8):

$$R_i = K' \text{ (BR) } DFA_i \qquad (3.8)$$

Where:

K' = Units conversion factor: 1E06 pCi/μCi

BR = The breathing rate. (Regulatory Guide 1.109, Table E-5).

DFA_i = 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. (Ref. 11.11.5 and 11.14.4)

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 (Ref. 11.8.9):

During any calendar quarter, for gamma radiation:

$$D_g = 3.17E\text{-}08 \sum_i \left[M_i \left(\overline{X/Q}\right) q_i\right] \leq 5 \text{ mrad} \qquad (3.9)$$

During any calendar quarter, for beta radiation:

$$D_b = 3.17E\text{-}08 \sum_i \left[N_i \left(\overline{X/Q}\right) q_i\right] \leq 10 \text{ mrad} \qquad (3.10)$$

During any calendar year, for gamma radiation:

$$D_g = 3.17E\text{-}08 \sum_i \left[M_i \left(\overline{X/Q}\right) q_i\right] \leq 10 \text{ mrad} \qquad (3.11)$$

During any calendar year, for beta radiation:

$$D_b = 3.17E\text{-}08 \sum_i \left[N_i \left(\overline{X/Q}\right) q_i\right] \leq 20 \text{ mrad} \qquad (3.12)$$

Where:

D_g = Air dose in mrad, from gamma radiation due to noble gases released in gaseous effluent.

D_b = Air dose in mrad, from beta radiation due to noble gases released in gaseous effluents.

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

q_i = The releases of noble gas radionuclides, i, in gaseous effluents, for all gaseous releases in (μ Ci). 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.

3.17E-08 = 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 Iodine-131 and 133, tritium, 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:

$$\Sigma_j D_{I,j} \leq 7.5 \text{ mrem} \quad (3.13)$$

During any calendar year:

$$\Sigma_j D_{I,j} \leq 15 \text{ mrem} \quad (3.14)$$

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:

$$D_{I,j} = 3.17E\text{-}8\ \Sigma_i R_{I,i,j} [W_j q_i] \quad (3.15)$$

Where:

$D_{I,j}$	=	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).
$R_{I,i,j}$	=	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	=	$(\overline{X/Q})$ for the inhalation and tritium pathways, in (sec/m^3). Refer to Tables 6.1, 6.2, and 6.4 for applicability.
W_j	=	$(\overline{D/Q})$ for the food and ground plane pathways, in (meters^{-2}). Refer to Tables 6.1, 6.2 and 6.4 for applicability.
$\overline{(D/Q)}$	=	the average relative deposition of the effluent at or beyond the SITE BOUNDARY, considering depletion of the plume during transport.
q_i	=	The releases 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.
3.17 E-08	=	The inverse of the number of seconds per year.

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

For the direction sectors with existing pathways within 5 miles from the site, the appropriate $R_{I,i,j}$ values are used. If no real pathway exists within 5 miles from the center of the building complex, the cow-milk $R_{I,i,j}$ value is used, and it is assumed that this pathway exists at the 4.5 to 5.0 mile distance in the limiting-case sector. If the $R_{I,i,j}$ for an existing pathway within 5 miles is less than a cow-milk $R_{I,i,j}$ at 4.5 to 5.0 miles, then the value of the cow-milk $R_{I,i,j}$ at 4.5 to 5.0 miles is used. (Ref. 11.8.9)

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 $(\overline{X/Q})$. (Ref. 11.8.9) The Total Body dose from ground plane deposition is added to the dose for each individual organ. (Ref. 11.11.3)

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. 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 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 DOSE FACTORS

The dose conversion factors provided in the following tables were derived from the appropriate dose conversion factors in Regulatory Guide 1.109 and other sources as necessary (Ref: 11.14.9 and 11.14.11). Per USNRC guidance, particulate nuclides with a half-life of less than 8 days are not considered (Ref: 11.24). Y-90, La-140, and Pr-144 are included because the parent half-life is greater than 8 days, and equilibrium is assumed. Non-gamma emitting nuclides not listed in FSAR Table 16.11-4 are also not considered. **(COMN 43121)**

TABLE 3.1

DOSE FACTOR FOR EXPOSURE TO A SEMI-INFINITE CLOUD OF NOBLE GASES

Radionuclide	Total Body Dose Factor K_i (mrem/yr) per (μCi/m^3)	Skin Dose Factor L_i (mrad/yr) per (μCi/m^3)	Gamma Air Dose Factor M_i (mrad/yr) per (μCi/m^3)	Beta Air Dose Factor Ni (mrad/yr per (μCi/m^3)
Kr-83m	7.56 E-02	-----	1.93 E+01	2.88 E+02
Kr-85m	1.17E+03	1.46E+03	1.23 E+03	1.97 E+03
Kr-85	1.61 E+01	1.34 E+03	1.72 E+01	1.95 E+03
Kr-87	5.92 E+03	9.73 E+03	6.17 E+03	1.03 E+04
Kr-88	1.47 E+04	2.37 E+03	1.52 E+04	2.93 E+03
Kr-89	1.66 E+04	1.01 E+04	1.73 E+04	1.06 E+04
Kr-90	1.56 E+04	7.29 E+03	1.63 E+04	7.83 E+03
Xe-131m	9.15 E+01	4.76 E+02	1.56 E+02	1.11 E+03
Xe-133m	2.51 E+02	9.94 E+02	3.27 E+02	1.48 E+03
Xe-133	2.94 E+02	3.06 E+02	3.53 E+02	1.05 E+03
Xe-135m	3.12 E+03	7.11 E+02	3.36 E+03	7.39 E+02
Xe-135	1.81 E+03	1.86 E+03	1.92 E+03	2.46 E+03
Xe-137	1.42 E+03	1.22 E+04	1.51 E+03	1.27 E+04
Xe-138	8.83 E+03	4.13 E+03	9.21 E+03	4.75 E+03
Ar-41	8.84 E+03	2.69 E+03	9.30 E+03	3.28 E+03

TABLE 3.2
PATHWAY DOSE FACTORS (R_I) FOR RADIONUCLIDES OTHER THAN NOBLE GASES
Ground Plane Pathway
(m^2mrem/yr) per (μCi/sec)

NUCLIDE	TOTAL BODY	SKIN
Be-7	2.24E+07	3.21E+07
Cr-51	4.66E+06	5.51E+06
Mn-54	1.39E+09	1.63E+09
Fe-59	2.73E+08	3.21E+08
Co-57	2.98E+08	4.37E+08
Co-58	3.79E+08	4.44E+08
Co-60	2.15E+10	2.53E+10
Zn-65	7.47E+08	8.59E+08
Rb-86	8.99E+06	1.03E+07
Sr-89	2.16E+04	2.51E+04
Y-90	5.36E+06	6.32E+06
Y-91	1.07E+06	1.21E+06
Zr-95	2.45E+08	2.84E+08
Nb-95	2.50E+08	2.94E+08
Ru-103	1.08E+08	1.26E+08
Ru-106	4.22E+08	5.07E+08
Ag-110m	3.44E+09	4.01E+09
Cd-109	3.76E+07	1.54E+08
Sn-113	1.43E+07	4.09E+07
Sb-124	8.74E+08	1.23E+09
Sb-125	3.57E+09	5.19E+09
Te-127m	9.17E+04	1.08E+05
Te-129m	1.98E+07	2.31E+07

TABLE 3.2
PATHWAY DOSE FACTORS (R_I) FOR RADIONUCLIDES OTHER THAN NOBLE GASES

Ground Plane Pathway
(m^2mrem/yr) per (μCi/sec)

NUCLIDE	TOTAL BODY	SKIN
I-130	5.51E+06	6.69E+06
I-131	1.72E+07	2.09E+07
I-132	1.25E+06	1.47E+06
I-133	2.45E+06	2.98E+06
I-134	4.47E+05	5.31E+05
I-135	2.53E+06	2.95E+06
Cs-134	6.85E+09	8.00E+09
Cs-136	1.51E+08	1.71E+08
Cs-137	1.03E+10	1.20E+10
Ba-140	2.05E+07	2.35E+07
La-140	1.47E+08	1.66E+08
Ce-141	1.37E+07	1.54E+07
Ce-144	6.96E+07	8.04E+07
Pr-144	4.35E+07	5.00E+07
Nd-147	8.39E+06	1.01E+07
Eu-154	2.21E+10	3.15E+10
Hf-181	1.97E+08	2.82E+08

TABLE 3.3
CHILD PATHWAY DOSE FACTORS (R_I) FOR RADIONUCLIDES OTHER THAN NOBLE GASES
Inhalation Pathway
(mrem/yr) per (μCi/m^3)

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

TABLE 3.3
CHILD PATHWAY DOSE FACTORS (R_I) FOR RADIONUCLIDES OTHER THAN NOBLE GASES
Inhalation Pathway
(mrem/yr) per ($\mu Ci/m^3$)

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

TABLE 3.3
CHILD PATHWAY DOSE FACTORS (R_I) FOR RADIONUCLIDES OTHER THAN NOBLE GASES

Meat Pathway
(m^2mrem/yr) per (µCi/sec)

Nuclide	Bone	Liver	Total Body	Thyroid	Kidney	Lung	GI-LLI
H-3	ND	2.34E+02	2.34E+02	2.34E+02	2.34E+02	2.34E+02	2.34E+02
Be-7	7.38E+03	1.26E+04	8.07E+03	0.00E+00	1.23E+04	0.00E+00	7.00E+05
Cr-51	0.00E+00	0.00E+00	8.80E+03	4.88E+03	1.33E+03	8.92E+03	4.67E+05
Mn-54	0.00E+00	8.02E+06	2.14E+06	0.00E+00	2.25E+06	0.00E+00	6.73E+06
Fe-55	4.58E+08	2.43E+08	7.52E+07	0.00E+00	0.00E+00	1.37E+08	4.50E+07
Fe-59	3.77E+08	6.10E+08	3.04E+08	0.00E+00	0.00E+00	1.77E+08	6.35E+08
Co-57	0.00E+00	5.92E+06	1.20E+07	0.00E+00	0.00E+00	0.00E+00	4.85E+07
Co-58	0.00E+00	1.64E+07	5.03E+07	0.00E+00	0.00E+00	0.00E+00	9.59E+07
Co-60	0.00E+00	6.94E+07	2.05E+08	0.00E+00	0.00E+00	0.00E+00	3.84E+08
Zn-65	3.76E+08	1.00E+09	6.23E+08	0.00E+00	6.31E+08	0.00E+00	1.76E+08
Rb-86	0.00E+00	5.77E+08	3.55E+08	0.00E+00	0.00E+00	0.00E+00	3.71E+07
Sr-89	4.82E+08	0.00E+00	1.38E+07	0.00E+00	0.00E+00	0.00E+00	1.87E+07
Sr-90	1.04E+10	0.00E+00	2.64E+09	0.00E+00	0.00E+00	0.00E+00	1.40E+08
Y-90	1.93E+05	0.00E+00	5.16E+03	0.00E+00	0.00E+00	0.00E+00	5.49E+08
Y-91	1.80E+06	0.00E+00	4.82E+04	0.00E+00	0.00E+00	0.00E+00	2.40E+08
Zr-95	2.67E+06	5.86E+05	5.22E+05	0.00E+00	8.39E+05	0.00E+00	6.11E+08
Nb-95	4.26E+06	1.66E+06	1.18E+06	0.00E+00	1.56E+06	0.00E+00	3.07E+09
Ru-103	1.55E+08	0.00E+00	5.96E+07	0.00E+00	3.90E+08	0.00E+00	4.01E+09
Ru-106	4.44E+09	0.00E+00	5.54E+08	0.00E+00	6.00E+09	0.00E+00	6.91E+10
Ag-110m	8.40E+06	5.67E+06	4.53E+06	0.00E+00	1.06E+07	0.00E+00	6.75E+08
Cd-109	0.00E+00	1.91E+06	8.84E+04	0.00E+00	1.70E+06	0.00E+00	6.18E+06
Sn-113	2.18E+09	4.48E+07	1.24E+08	3.31E+09	0.00E+00	0.00E+00	1.54E+09
Sb-124	2.93E+07	3.80E+05	1.03E+07	6.46E+04	0.00E+00	1.62E+07	1.83E+08
Sb-125	2.85E+07	2.20E+05	5.97E+06	2.64E+04	0.00E+00	1.59E+07	6.81E+07
Te-127m	1.78E+09	4.78E+08	2.11E+08	4.25E+08	5.07E+09	0.00E+00	1.44E+09
Te-129m	1.79E+09	5.00E+08	2.78E+08	5.78E+08	5.26E+09	0.00E+00	2.19E+09
I-130	3.06E-06	6.18E-06	3.18E-06	6.80E-04	9.23E-06	0.00E+00	2.89E-06

TABLE 3.3
CHILD PATHWAY DOSE FACTORS (R_I) FOR RADIONUCLIDES OTHER THAN NOBLE GASES
Meat Pathway
(m^2mrem/yr) per (µCi/sec)

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

TABLE 3.3
CHILD PATHWAY DOSE FACTORS (R_I) FOR RADIONUCLIDES OTHER THAN NOBLE GASES

Grass-Cow-Milk Pathway
(m^2mrem/yr) per (µCi/sec)

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

TABLE 3.3
CHILD PATHWAY DOSE FACTORS (R_I) FOR RADIONUCLIDES OTHER THAN NOBLE GASES
Grass-Cow-Milk Pathway
(m^2mrem/yr) per (μCi/sec)

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

TABLE 3.3
CHILD PATHWAY DOSE FACTORS (R_I) FOR RADIONUCLIDES OTHER THAN NOBLE GASES
Grass-Goat-Milk Pathway
(m^2mrem/yr) per (µCi/sec)

Nuclide	Bone	Liver	Total Body	Thyroid	Kidney	Lung	GI-LLI
H-3	0.00E+00	3.20E+03	3.20E+03	3.20E+03	3.20E+03	3.20E+03	3.20E+03
Be-7	9.00E+02	1.53E+03	9.84E+02	0.00E+00	1.50E+03	0.00E+00	8.55E+04
Cr-51	0.00E+00	0.00E+00	1.22E+04	6.79E+03	1.85E+03	1.24E+04	6.48E+05
Mn-54	0.00E+00	2.52E+06	6.71E+05	0.00E+00	7.06E+05	0.00E+00	2.11E+06
Fe-55	1.45E+06	7.72E+05	2.39E+05	0.00E+00	0.00E+00	4.36E+05	1.43E+05
Fe-59	1.56E+06	2.53E+06	1.26E+06	0.00E+00	0.00E+00	7.34E+05	2.64E+06
Co-57	0.00E+00	4.61E+05	9.33E+05	0.00E+00	0.00E+00	0.00E+00	3.78E+06
Co-58	0.00E+00	1.46E+06	4.46E+06	0.00E+00	0.00E+00	0.00E+00	8.50E+06
Co-60	0.00E+00	5.19E+06	1.53E+07	0.00E+00	0.00E+00	0.00E+00	2.87E+07
Zn-65	4.97E+08	1.32E+09	8.23E+08	0.00E+00	8.34E+08	0.00E+00	2.32E+08
Rb-86	0.00E+00	1.05E+09	6.48E+08	0.00E+00	0.00E+00	0.00E+00	6.78E+07
Sr-89	1.39E+10	0.00E+00	3.97E+08	0.00E+00	0.00E+00	0.00E+00	5.39E+08
Sr-90	2.35E+11	0.00E+00	5.95E+10	0.00E+00	0.00E+00	0.00E+00	3.16E+09
Y-90	4.06E+02	0.00E+00	1.09E+01	0.00E+00	0.00E+00	0.00E+00	1.15E+06
Y-91	4.69E+03	0.00E+00	1.25E+02	0.00E+00	0.00E+00	0.00E+00	6.25E+05
Zr-95	4.60E+02	1.01E+02	9.01E+01	0.00E+00	1.45E+02	0.00E+00	1.06E+05
Nb-95	4.46E+04	1.74E+04	1.24E+04	0.00E+00	1.63E+04	0.00E+00	3.21E+07
Ru-103	5.14E+02	0.00E+00	1.98E+02	0.00E+00	1.29E+03	0.00E+00	1.33E+04
Ru-106	1.11E+04	0.00E+00	1.38E+03	0.00E+00	1.50E+04	0.00E+00	1.73E+05
Ag-110m	2.51E+07	1.69E+07	1.35E+07	0.00E+00	3.15E+07	0.00E+00	2.01E+09
Cd-109	0.00E+00	4.64E+05	2.15E+04	0.00E+00	4.14E+05	0.00E+00	1.50E+06
Sn-113	7.33E+07	1.51E+06	4.18E+06	1.11E+08	0.00E+00	0.00E+00	5.18E+07
Sb-124	1.30E+07	1.69E+05	4.57E+06	2.88E+04	0.00E+00	7.24E+06	8.16E+07
Sb-125	1.05E+07	8.06E+04	2.19E+06	9.68E+03	0.00E+00	5.83E+06	2.50E+07
Te-127m	2.50E+07	6.73E+06	2.97E+06	5.98E+06	7.13E+07	0.00E+00	2.02E+07
Te-129m	3.26E+07	9.10E+06	5.06E+06	1.05E+07	9.57E+07	0.00E+00	3.98E+07
I-130	2.08E+06	4.20E+06	2.16E+06	4.62E+08	6.27E+06	0.00E+00	1.96E+06
I-131	1.57E+09	1.57E+09	8.95E+08	5.21E+11	2.58E+09	0.00E+00	1.40E+08
I-132	8.30E-01	1.53E+00	7.02E-01	7.08E+01	2.34E+00	0.00E+00	1.80E+00

TABLE 3.3
CHILD PATHWAY DOSE FACTORS (R_I) FOR RADIONUCLIDES OTHER THAN NOBLE GASES

Grass-Goat-Milk Pathway
(m^2mrem/yr) per (µCi/sec)

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

TABLE 3.3
CHILD PATHWAY DOSE FACTORS (R_I) FOR RADIONUCLIDES OTHER THAN NOBLE GASES
Vegetation Pathway
(m^2mrem/yr) per (μCi/sec)

Nuclide	Bone	Liver	Total Body	Thyroid	Kidney	Lung	GI-LLI
H-3	ND	4.01E+03	4.01E+03	4.01E+03	4.01E+03	4.01E+03	4.01E+03
Be-7	3.38E+05	5.76E+05	3.70E+05	0.00E+00	5.65E+05	0.00E+00	3.21E+07
Cr-51	0.00E+00	0.00E+00	1.17E+05	6.50E+04	1.78E+04	1.19E+05	6.21E+06
Mn-54	0.00E+00	6.65E+08	1.77E+08	0.00E+00	1.86E+08	0.00E+00	5.58E+08
Fe-55	8.01E+08	4.25E+08	1.32E+08	0.00E+00	0.00E+00	2.40E+08	7.87E+07
Fe-59	3.98E+08	6.43E+08	3.20E+08	0.00E+00	0.00E+00	1.87E+08	6.70E+08
Co-57	0.00E+00	2.99E+07	6.04E+07	0.00E+00	0.00E+00	0.00E+00	2.45E+08
Co-58	0.00E+00	6.44E+07	1.97E+08	0.00E+00	0.00E+00	0.00E+00	3.76E+08
Co-60	0.00E+00	3.78E+08	1.12E+09	0.00E+00	0.00E+00	0.00E+00	2.10E+09
Zn-65	8.13E+08	2.17E+09	1.35E+09	0.00E+00	1.36E+09	0.00E+00	3.80E+08
Rb-86	0.00E+00	4.52E+08	2.78E+08	0.00E+00	0.00E+00	0.00E+00	2.91E+07
Sr-89	3.60E+10	0.00E+00	1.03E+09	0.00E+00	0.00E+00	0.00E+00	1.39E+09
Sr-90	1.24E+12	0.00E+00	3.15E+11	0.00E+00	0.00E+00	0.00E+00	1.67E+10
Y-90	3.01E+06	0.00E+00	8.04E+04	0.00E+00	0.00E+00	0.00E+00	8.56E+09
Y-91	1.86E+07	0.00E+00	4.99E+05	0.00E+00	0.00E+00	0.00E+00	2.48E+09
Zr-95	3.86E+06	8.48E+05	7.55E+05	0.00E+00	1.21E+06	0.00E+00	8.85E+08
Nb-95	7.48E+05	2.91E+05	2.08E+05	0.00E+00	2.74E+05	0.00E+00	5.39E+08
Ru-103	1.53E+07	0.00E+00	5.90E+06	0.00E+00	3.86E+07	0.00E+00	3.97E+08
Ru-106	7.45E+08	0.00E+00	9.30E+07	0.00E+00	1.01E+09	0.00E+00	1.16E+10
Ag-110m	3.21E+07	2.17E+07	1.73E+07	0.00E+00	4.04E+07	0.00E+00	2.58E+09
Cd-109	0.00E+00	2.45E+08	1.14E+07	0.00E+00	2.18E+08	0.00E+00	7.94E+08
Sn-113	1.58E+09	3.25E+07	9.00E+07	2.40E+09	0.00E+00	0.00E+00	1.12E+09
Sb-124	3.52E+08	4.57E+06	1.23E+08	7.77E+05	0.00E+00	1.95E+08	2.20E+09
Sb-125	4.99E+08	3.85E+06	1.05E+08	4.63E+05	0.00E+00	2.78E+08	1.19E+09
Te-127m	1.32E+09	3.56E+08	1.57E+08	3.16E+08	3.77E+09	0.00E+00	1.07E+09
Te-129m	8.41E+08	2.35E+08	1.31E+08	2.71E+08	2.47E+09	0.00E+00	1.03E+09
I-130	6.16E+05	1.24E+06	6.41E+05	1.37E+08	1.86E+06	0.00E+00	5.82E+05
I-131	1.43E+08	1.44E+08	8.17E+07	4.76E+10	2.36E+08	0.00E+00	1.28E+07

TABLE 3.3
CHILD PATHWAY DOSE FACTORS (R_I) FOR RADIONUCLIDES OTHER THAN NOBLE GASES

Vegetation Pathway
(m^2mrem/yr) per (μCi/sec)

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

TABLE 3.4
ADULT PATHWAY DOSE FACTORS (R_I) FOR RADIONUCLIDES OTHER THAN NOBLE GASES
Inhalation Pathway
(mrem/yr) per ($\mu Ci/m^3$)

Nuclide	Bone	Liver	Total Body	Thyroid	Kidney	Lung	GI-LLI
H-3	ND	1.26E+03	1.26E+03	1.26E+03	1.26E+03	1.26E+03	1.26E+03
Be-7	4.27E+02	9.68E+02	4.70E+02	ND	ND	4.21E+04	5.35E+03
Cr-51	ND	ND	1.00E+02	5.95E+01	2.28E+01	1.44E+04	3.32E+03
Mn-54	ND	3.96E+04	6.30E+03	ND	9.84E+03	1.40E+06	7.74E+04
Fe-55	2.46E+04	1.70E+04	3.94E+03	ND	ND	7.21E+04	6.03E+03
Fe-59	1.18E+04	2.78E+04	1.06E+04	ND	ND	1.02E+06	1.88E+05
Co-57	ND	6.92E+02	6.71E+02	ND	ND	3.70E+05	3.14E+04
Co-58	ND	1.58E+03	2.07E+03	ND	ND	9.28E+05	1.06E+05
Co-60	ND	1.15E+04	1.48E+04	ND	ND	5.97E+06	2.85E+05
Zn-65	3.24E+04	1.03E+05	4.66E+04	ND	6.90E+04	8.64E+05	5.34E+04
Rb-86	ND	1.35E+05	5.90E+04	ND	ND	ND	1.66E+04
Sr-89	3.04E+05	ND	8.72E+03	ND	ND	1.40E+06	3.50E+05
Sr-90	9.92E+07	ND	6.10E+06	ND	ND	9.60E+06	7.22E+05
Y-90	2.09E+03	ND	5.61E+01	ND	ND	1.70E+05	5.06E+05
Y-91	4.62E+05	ND	1.24E+04	ND	ND	1.70E+06	3.85E+05
Zr-95	1.07E+05	3.44E+04	2.33E+04	ND	5.42E+04	1.77E+06	1.50E+05
Nb-95	1.41E+04	7.82E+03	4.21E+03	ND	7.74E+03	5.05E+05	1.04E+05
Ru-103	1.53E+03	ND	6.58E+02	ND	5.83E+03	5.05E+05	1.10E+05
Ru-106	6.91E+04	ND	8.72E+03	ND	1.34E+05	9.36E+06	9.12E+05
Ag-110m	1.08E+04	1.00E+04	5.94E+03	ND	1.97E+04	4.63E+06	3.02E+05
Cd-109	ND	3.67E+05	1.31E+04	ND	3.57E+05	6.83E+05	5.82E+04
Sn-113	5.72E+04	2.18E+03	4.39E+03	1.24E+03	ND	9.44E+05	1.18E+05
Sb-124	3.12E+04	5.89E+02	1.24E+04	7.55E+01	ND	2.48E+06	4.06E+05
Sb-125	5.34E+04	5.95E+02	1.26E+04	5.40E+01	ND	1.74E+06	1.01E+05
Te-127m	1.26E+04	5.77E+03	1.57E+03	3.29E+03	4.58E+04	9.60E+05	1.50E+05
Te-129m	9.76E+03	4.67E+03	1.58E+03	3.44E+03	3.66E+04	1.16E+06	3.83E+05
I-130	4.58E+03	1.34E+04	5.28E+03	1.14E+06	2.09E+04	ND	7.69E+03
I-131	2.52E+04	3.58E+04	2.05E+04	1.19E+07	6.13E+04	ND	6.28E+03

TABLE 3.4
ADULT PATHWAY DOSE FACTORS (R_I) FOR RADIONUCLIDES OTHER THAN NOBLE GASES
Inhalation Pathway
(mrem/yr) per (µCi/m^3)

Nuclide	Bone	Liver	Total Body	Thyroid	Kidney	Lung	GI-LLI
I-132	1.16E+03	3.26E+03	1.16E+03	1.14E+05	5.18E+03	ND	4.06E+02
I-133	8.64E+03	1.48E+04	4.52E+03	2.15E+06	2.58E+04	ND	8.88E+03
I-134	6.44E+02	1.73E+03	6.15E+02	2.98E+04	2.75E+03	ND	1.01E+00
I-135	2.68E+03	6.98E+03	2.57E+03	4.48E+05	1.11E+04	ND	5.25E+03
Cs-134	3.73E+05	8.48E+05	7.28E+05	ND	2.87E+05	9.76E+04	1.04E+04
Cs-136	3.90E+04	1.46E+05	1.10E+05	ND	8.56E+04	1.20E+04	1.17E+04
Cs-137	4.78E+05	6.21E+05	4.28E+05	ND	2.22E+05	7.52E+04	8.40E+03
Ba-140	3.90E+04	4.90E+01	2.57E+03	ND	1.67E+01	1.27E+06	2.18E+05
La-140	3.44E+02	1.74E+02	4.58E+01	ND	ND	1.36E+05	4.58E+05
Ce-141	1.99E+04	1.35E+04	1.53E+03	ND	6.26E+03	3.62E+05	1.20E+05
Ce-144	3.43E+06	1.43E+06	1.84E+05	ND	8.48E+05	7.78E+06	8.16E+05
Pr-143	9.36E+03	3.75E+03	4.64E+02	ND	2.16E+03	2.81E+05	2.00E+05
Pr-144	3.01E-02	1.25E-02	1.53E-03	ND	7.05E-03	1.02E+03	2.15E-08
Nd-147	5.27E+03	6.10E+03	3.65E+02	ND	3.56E+03	2.21E+05	1.73E+05
Eu-154	5.92E+06	7.28E+05	5.18E+05	ND	3.49E+06	4.67E+06	2.72E+05
Hf-181	1.41E+04	6.82E+04	6.32E+03	ND	1.48E+04	6.85E+05	1.39E+05

TABLE 3.4
ADULT PATHWAY DOSE FACTORS (R_I) FOR RADIONUCLIDES OTHER THAN NOBLE GASES
Meat Pathway
(m^2mrem/yr) per (μCi/sec)

Nuclide	Bone	Liver	Total Body	Thyroid	Kidney	Lung	GI-LLI
H-3	ND	3.25E+02	3.25E+02	3.25E+02	3.25E+02	3.25E+02	3.25E+02
Be-7	4.57E+03	1.04E+04	5.07E+03	ND	1.10E+04	ND	1.81E+06
Cr-51	ND	ND	7.04E+03	4.21E+03	1.55E+03	9.34E+03	1.77E+06
Mn-54	ND	9.17E+06	1.75E+06	ND	2.73E+06	ND	2.81E+07
Fe-55	2.93E+08	2.02E+08	4.72E+07	ND	ND	1.13E+08	1.16E+08
Fe-59	2.65E+08	6.24E+08	2.39E+08	ND	ND	1.74E+08	2.08E+09
Co-57	ND	5.63E+06	9.36E+06	ND	ND	ND	1.43E+08
Co-58	ND	1.82E+07	4.08E+07	ND	ND	ND	3.69E+08
Co-60	ND	7.51E+07	1.66E+08	ND	ND	ND	1.41E+09
Zn-65	3.56E+08	1.13E+09	5.11E+08	ND	7.57E+08	ND	7.13E+08
Rb-86	ND	4.87E+08	2.27E+08	ND	ND	ND	9.60E+07
Sr-89	3.01E+08	ND	8.65E+06	ND	ND	ND	4.83E+07
Sr-90	1.24E+10	ND	3.05E+09	ND	ND	ND	3.59E+08
Y-90	1.21E+05	ND	3.24E+03	ND	ND	ND	1.28E+09
Y-91	1.13E+06	ND	3.02E+04	ND	ND	ND	6.23E+08
Zr-95	1.87E+06	6.00E+05	4.06E+05	ND	9.42E+05	ND	1.90E+09
Nb-95	3.15E+06	1.75E+06	9.43E+05	ND	1.73E+06	ND	1.06E+10
Ru-103	1.05E+08	ND	4.53E+07	ND	4.01E+08	ND	1.23E+10
Ru-106	2.80E+09	ND	3.54E+08	ND	5.40E+09	ND	1.81E+11
Ag-110m	6.68E+06	6.18E+06	3.67E+06	ND	1.21E+07	ND	2.52E+09
Cd-109	ND	1.59E+06	5.55E+04	ND	1.52E+06	ND	1.60E+07
Sn-113	1.37E+09	3.88E+07	7.86E+07	2.22E+07	ND	ND	4.09E+09
Sb-124	1.98E+07	3.74E+05	7.84E+06	4.79E+04	ND	1.54E+07	5.61E+08
Sb-125	1.91E+07	2.13E+05	4.54E+06	1.94E+04	ND	1.47E+07	2.10E+08
Te-127m	1.11E+09	3.98E+08	1.36E+08	2.85E+08	4.53E+09	ND	3.74E+09
Te-129m	1.13E+09	4.23E+08	1.79E+08	3.89E+08	4.73E+09	ND	5.71E+09
I-130	2.12E-06	6.27E-06	2.47E-06	5.31E-04	9.78E-06	ND	5.40E-06
I-131	1.08E+07	1.54E+07	8.82E+06	5.04E+09	2.64E+07	ND	4.06E+06

TABLE 3.4
ADULT PATHWAY DOSE FACTORS (R_I) FOR RADIONUCLIDES OTHER THAN NOBLE GASES

Meat Pathway
(m^2mrem/yr) per (μCi/sec)

Nuclide	Bone	Liver	Total Body	Thyroid	Kidney	Lung	GI-LLI
I-132	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	ND	0.00E+00
I-133	3.67E-01	6.39E-01	1.95E-01	9.38E+01	1.11E+00	ND	5.74E-01
I-134	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	ND	0.00E+00
I-135	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	ND	0.00E+00
Cs-134	6.57E+08	1.56E+09	1.28E+09	ND	5.06E+08	1.68E+08	2.74E+07
Cs-136	1.20E+07	4.76E+07	3.42E+07	ND	2.65E+07	3.63E+06	5.40E+06
Cs-137	8.71E+08	1.19E+09	7.81E+08	ND	4.04E+08	1.34E+08	2.31E+07
Ba-140	2.87E+07	3.61E+04	1.88E+06	ND	1.23E+04	2.07E+04	5.91E+07
La-140	2.21E+02	1.11E+02	2.94E+01	ND	ND	ND	8.18E+06
Ce-141	1.40E+04	9.49E+03	1.08E+03	ND	4.41E+03	ND	3.63E+07
Ce-144	1.46E+06	6.09E+05	7.82E+04	ND	3.61E+05	ND	4.92E+08
Pr-143	2.10E+04	8.40E+03	1.04E+03	ND	4.85E+03	ND	9.18E+07
Pr-144	3.52E+02	1.46E+02	1.79E+01	ND	8.24E+01	ND	5.06E-05
Nd-147	7.07E+03	8.17E+03	4.89E+02	ND	4.77E+03	ND	3.92E+07
Eu-154	8.02E+06	9.86E+05	7.01E+05	ND	4.72E+06	ND	7.14E+08
Hf-181	3.01E+06	1.46E+07	1.35E+06	ND	3.14E+06	ND	1.66E+10

TABLE 3.4
ADULT PATHWAY DOSE FACTORS (R_I) FOR RADIONUCLIDES OTHER THAN NOBLE GASES

Grass-Cow-Milk Pathway
(m^2mrem/yr) per (μCi/sec)

Nuclide	Bone	Liver	Total Body	Thyroid	Kidney	Lung	GI-LLI
H-3	ND	7.63E+02	7.63E+02	7.63E+02	7.63E+02	7.63E+02	7.63E+02
Be-7	1.63E+03	3.72E+03	1.81E+03	ND	3.93E+03	ND	6.45E+05
Cr-51	ND	ND	2.86E+04	1.71E+04	6.30E+03	3.79E+04	7.19E+06
Mn-54	ND	8.42E+06	1.61E+06	ND	2.50E+06	ND	2.58E+07
Fe-55	2.51E+07	1.74E+07	4.05E+06	ND	ND	9.68E+06	9.96E+06
Fe-59	2.97E+07	6.98E+07	2.68E+07	ND	ND	1.95E+07	2.33E+08
Co-57	ND	1.28E+06	2.13E+06	ND	ND	ND	3.25E+07
Co-58	ND	4.72E+06	1.06E+07	ND	ND	ND	9.56E+07
Co-60	ND	1.64E+07	3.62E+07	ND	ND	ND	3.08E+08
Zn-65	1.37E+09	4.37E+09	1.97E+09	ND	2.92E+09	ND	2.75E+09
Rb-86	ND	2.60E+09	1.21E+09	ND	ND	ND	5.12E+08
Sr-89	1.45E+09	ND	4.17E+07	ND	ND	ND	2.33E+08
Sr-90	4.68E+10	ND	1.15E+10	ND	ND	ND	1.35E+09
Y-90	7.43E+02	ND	1.99E+01	ND	ND	ND	7.87E+06
Y-91	8.59E+03	ND	2.30E+02	ND	ND	ND	4.73E+06
Zr-95	9.44E+02	3.03E+02	2.05E+02	ND	4.75E+02	ND	9.59E+05
Nb-95	9.65E+04	5.37E+04	2.89E+04	ND	5.31E+04	ND	3.26E+08
Ru-103	1.02E+03	ND	4.39E+02	ND	3.89E+03	ND	1.19E+05
Ru-106	2.04E+04	ND	2.58E+03	ND	3.94E+04	ND	1.32E+06
Ag-110m	5.82E+07	5.39E+07	3.20E+07	ND	1.06E+08	ND	2.20E+10
Cd-109	ND	1.13E+06	3.95E+04	ND	1.08E+06	ND	1.14E+07
Sn-113	1.34E+08	3.81E+06	7.73E+06	2.18E+06	ND	ND	4.02E+08
Sb-124	2.57E+07	4.86E+05	1.02E+07	6.24E+04	ND	2.00E+07	7.31E+08
Sb-125	2.04E+07	2.28E+05	4.87E+06	2.08E+04	ND	1.58E+07	2.25E+08
Te-127m	4.58E+07	1.64E+07	5.58E+06	1.17E+07	1.86E+08	ND	1.54E+08
Te-129m	6.02E+07	2.25E+07	9.53E+06	2.07E+07	2.51E+08	ND	3.03E+08
I-130	4.21E+05	1.24E+06	4.91E+05	1.05E+08	1.94E+06	ND	1.07E+06
I-131	2.97E+08	4.25E+08	2.43E+08	1.39E+11	7.28E+08	ND	1.12E+08

TABLE 3.4
ADULT PATHWAY DOSE FACTORS (R_I) FOR RADIONUCLIDES OTHER THAN NOBLE GASES

Grass-Cow-Milk Pathway
(m^2mrem/yr) per (μCi/sec)

Nuclide	Bone	Liver	Total Body	Thyroid	Kidney	Lung	GI-LLI
I-132	1.65E-01	4.42E-01	1.55E-01	1.55E+01	7.04E-01	ND	8.30E-02
I-133	3.88E+06	6.75E+06	2.06E+06	9.92E+08	1.18E+07	ND	6.07E+06
I-134	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	ND	0.00E+00
I-135	1.29E+04	3.37E+04	1.25E+04	2.23E+06	5.41E+04	ND	3.81E+04
Cs-134	5.65E+09	1.35E+10	1.10E+10	ND	4.35E+09	1.45E+09	2.35E+08
Cs-136	2.63E+08	1.04E+09	7.48E+08	ND	5.79E+08	7.93E+07	1.18E+08
Cs-137	7.38E+09	1.01E+10	6.61E+09	ND	3.43E+09	1.14E+09	1.95E+08
Ba-140	2.69E+07	3.38E+04	1.76E+06	ND	1.15E+04	1.93E+04	5.54E+07
La-140	4.14E+01	2.09E+01	5.51E+00	ND	ND	ND	1.53E+06
Ce-141	4.85E+03	3.28E+03	3.72E+02	ND	1.52E+03	ND	1.25E+07
Ce-144	3.58E+05	1.50E+05	1.92E+04	ND	8.87E+04	ND	1.21E+08
Pr-143	1.58E+02	6.34E+01	7.83E+00	ND	3.66E+01	ND	6.92E+05
Pr-144	1.10E+00	4.58E-01	5.61E-02	ND	2.58E-01	ND	1.59E-07
Nd-147	9.42E+01	1.09E+02	6.51E+00	ND	6.36E+01	ND	5.23E+05
Eu-154	2.37E+04	2.91E+03	2.07E+03	ND	1.39E+04	ND	2.11E+06
Hf-181	1.42E+02	6.92E+02	6.41E+01	ND	1.49E+02	ND	7.87E+05

TABLE 3.4
ADULT PATHWAY DOSE FACTORS (R_I) FOR RADIONUCLIDES OTHER THAN NOBLE GASES
Grass-Goat-Milk Pathway
(m^2mrem/yr) per (µCi/sec)

Nuclide	Bone	Liver	Total Body	Thyroid	Kidney	Lung	GI-LLI
H-3	ND	1.56E+03	1.56E+03	1.56E+03	1.56E+03	1.56E+03	1.56E+03
Be-7	1.96E+02	4.47E+02	2.17E+02	ND	4.72E+02	ND	7.74E+04
Cr-51	ND	ND	3.43E+03	2.05E+03	7.56E+02	4.56E+03	8.63E+05
Mn-54	ND	1.01E+06	1.93E+05	ND	3.01E+05	ND	3.10E+06
Fe-55	3.27E+05	2.26E+05	5.26E+04	ND	ND	1.26E+05	1.30E+05
Fe-59	3.87E+05	9.08E+05	3.48E+05	ND	ND	2.54E+05	3.03E+06
Co-57	ND	1.54E+05	2.56E+05	ND	ND	ND	3.90E+06
Co-58	ND	5.66E+05	1.27E+06	ND	ND	ND	1.15E+07
Co-60	ND	1.97E+06	4.35E+06	ND	ND	ND	3.70E+07
Zn-65	1.65E+08	5.24E+08	2.37E+08	ND	3.51E+08	ND	3.30E+08
Rb-86	ND	3.12E+08	1.45E+08	ND	ND	ND	6.15E+07
Sr-89	3.05E+09	ND	8.75E+07	ND	ND	ND	4.89E+08
Sr-90	9.84E+10	ND	2.41E+10	ND	ND	ND	2.84E+09
Y-90	8.92E+01	ND	2.39E+00	ND	ND	ND	9.46E+05
Y-91	1.03E+03	ND	2.76E+01	ND	ND	ND	5.68E+05
Zr-95	1.13E+02	3.63E+01	2.46E+01	ND	5.70E+01	ND	1.15E+05
Nb-95	1.16E+04	6.45E+03	3.47E+03	ND	6.37E+03	ND	3.91E+07
Ru-103	1.22E+02	ND	5.27E+01	ND	4.67E+02	ND	1.43E+04
Ru-106	2.45E+03	ND	3.10E+02	ND	4.73E+03	ND	1.59E+05
Ag-110m	6.99E+06	6.47E+06	3.84E+06	ND	1.27E+07	ND	2.64E+09
Cd-109	ND	1.36E+05	4.74E+03	ND	1.30E+05	ND	1.37E+06
Sn-113	1.61E+07	4.58E+05	9.28E+05	2.62E+05	ND	ND	4.83E+07
Sb-124	3.09E+06	5.84E+04	1.23E+06	7.50E+03	ND	2.41E+06	8.78E+07
Sb-125	2.46E+06	2.74E+04	5.84E+05	2.50E+03	ND	1.89E+06	2.70E+07
Te-127m	5.50E+06	1.97E+06	6.70E+05	1.41E+06	2.23E+07	ND	1.84E+07
Te-129m	7.23E+06	2.70E+06	1.14E+06	2.48E+06	3.02E+07	ND	3.64E+07
I-130	5.05E+05	1.49E+06	5.88E+05	1.26E+08	2.32E+06	ND	1.28E+06
I-131	3.56E+08	5.09E+08	2.92E+08	1.67E+11	8.72E+08	ND	1.34E+08
I-132	1.98E-01	5.29E-01	1.85E-01	1.85E+01	8.43E-01	ND	9.95E-02

TABLE 3.4
ADULT PATHWAY DOSE FACTORS (R_I) FOR RADIONUCLIDES OTHER THAN NOBLE GASES

Grass-Goat-Milk Pathway
(m^2mrem/yr) per (μCi/sec)

Nuclide	Bone	Liver	Total Body	Thyroid	Kidney	Lung	GI-LLI
I-133	4.65E+06	8.09E+06	2.47E+06	1.19E+09	1.41E+07	ND	7.27E+06
I-134	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	ND	0.00E+00
I-135	1.54E+04	4.04E+04	1.49E+04	2.67E+06	6.48E+04	ND	4.57E+04
Cs-134	1.70E+10	4.04E+10	3.30E+10	ND	1.31E+10	4.34E+09	7.07E+08
Cs-136	7.91E+08	3.12E+09	2.25E+09	ND	1.74E+09	2.38E+08	3.55E+08
Cs-137	2.22E+10	3.03E+10	1.99E+10	ND	1.03E+10	3.42E+09	5.87E+08
Ba-140	3.23E+06	4.06E+03	2.12E+05	ND	1.38E+03	2.32E+03	6.65E+06
La-140	4.97E+00	2.51E+00	6.62E-01	ND	ND	ND	1.84E+05
Ce-141	5.82E+02	3.94E+02	4.46E+01	ND	1.83E+02	ND	1.50E+06
Ce-144	4.30E+04	1.80E+04	2.31E+03	ND	1.07E+04	ND	1.45E+07
Pr-143	1.90E+01	7.61E+00	9.40E-01	ND	4.39E+00	ND	8.31E+04
Pr-144	1.33E-01	5.50E-02	6.74E-03	ND	3.10E-02	ND	1.91E-08
Nd-147	1.13E+01	1.31E+01	7.82E-01	ND	7.64E+00	ND	6.28E+04
Eu-154	2.84E+03	3.49E+02	2.49E+02	ND	1.67E+03	ND	2.53E+05
Hf-181	1.71E+01	8.31E+01	7.70E+00	ND	1.79E+01	ND	9.46E+04

TABLE 3.4
ADULT PATHWAY DOSE FACTORS (R_I) FOR RADIONUCLIDES OTHER THAN NOBLE GASES
Vegetation Pathway
(m^2mrem/yr) per (μCi/sec)

Nuclide	Bone	Liver	Total Body	Thyroid	Kidney	Lung	GI-LLI
H-3	ND	2.26E+03	2.26E+03	2.26E+03	2.26E+03	2.26E+03	2.26E+03
Be-7	9.24E+04	2.11E+05	1.03E+05	ND	2.23E+05	ND	3.66E+07
Cr-51	ND	ND	4.64E+04	2.78E+04	1.02E+04	6.16E+04	1.17E+07
Mn-54	ND	3.13E+08	5.97E+07	ND	9.31E+07	ND	9.59E+08
Fe-55	2.10E+08	1.45E+08	3.38E+07	ND	ND	8.08E+07	8.31E+07
Fe-59	1.26E+08	2.96E+08	1.14E+08	ND	ND	8.28E+07	9.88E+08
Co-57	ND	1.17E+07	1.95E+07	ND	ND	ND	2.97E+08
Co-58	ND	3.07E+07	6.89E+07	ND	ND	ND	6.23E+08
Co-60	ND	1.67E+08	3.69E+08	ND	ND	ND	3.14E+09
Zn-65	3.17E+08	1.01E+09	4.56E+08	ND	6.75E+08	ND	6.36E+08
Rb-86	ND	2.19E+08	1.02E+08	ND	ND	ND	4.33E+07
Sr-89	9.97E+09	ND	2.86E+08	ND	ND	ND	1.60E+09
Sr-90	6.05E+11	ND	1.48E+11	ND	ND	ND	1.75E+10
Y-90	7.67E+05	ND	2.06E+04	ND	ND	ND	8.14E+09
Y-91	5.11E+06	ND	1.37E+05	ND	ND	ND	2.81E+09
Zr-95	1.17E+06	3.77E+05	2.55E+05	ND	5.91E+05	ND	1.19E+09
Nb-95	2.40E+05	1.34E+05	7.19E+04	ND	1.32E+05	ND	8.11E+08
Ru-103	4.77E+06	ND	2.06E+06	ND	1.82E+07	ND	5.57E+08
Ru-106	1.93E+08	ND	2.44E+07	ND	3.72E+08	ND	1.25E+10
Ag-110m	1.05E+07	9.75E+06	5.79E+06	ND	1.92E+07	ND	3.98E+09
Cd-109	0.00E+00	8.36E+07	2.92E+06	ND	8.00E+07	ND	8.43E+08
Sn-113	4.16E+08	1.18E+07	2.40E+07	6.75E+06	ND	ND	1.25E+09
Sb-124	1.04E+08	1.96E+06	4.11E+07	2.51E+05	ND	8.07E+07	2.94E+09
Sb-125	1.37E+08	1.53E+06	3.25E+07	1.39E+05	ND	1.05E+08	1.50E+09
Te-127m	3.49E+08	1.25E+08	4.26E+07	8.92E+07	1.42E+09	ND	1.17E+09
Te-129m	2.51E+08	9.38E+07	3.98E+07	8.64E+07	1.05E+09	ND	1.27E+09
I-130	3.93E+05	1.16E+06	4.57E+05	9.81E+07	1.81E+06	ND	9.97E+05
I-131	8.08E+07	1.16E+08	6.62E+07	3.79E+10	1.98E+08	ND	3.05E+07

TABLE 3.4
ADULT PATHWAY DOSE FACTORS (R_I) FOR RADIONUCLIDES OTHER THAN NOBLE GASES
Vegetation Pathway
(m^2mrem/yr) per (μCi/sec)

Nuclide	Bone	Liver	Total Body	Thyroid	Kidney	Lung	GI-LLI
I-132	5.77E+01	1.54E+02	5.40E+01	5.40E+03	2.46E+02	ND	2.90E+01
I-133	2.09E+06	3.63E+06	1.11E+06	5.33E+08	6.33E+06	ND	3.26E+06
I-134	9.69E-05	2.63E-04	9.42E-05	4.56E-03	4.19E-04	ND	2.30E-07
I-135	3.90E+04	1.02E+05	3.77E+04	6.74E+06	1.64E+05	ND	1.15E+05
Cs-134	4.67E+09	1.11E+10	9.08E+09	ND	3.59E+09	1.19E+09	1.94E+08
Cs-136	4.27E+07	1.69E+08	1.21E+08	ND	9.38E+07	1.29E+07	1.91E+07
Cs-137	6.36E+09	8.70E+09	5.70E+09	ND	2.95E+09	9.81E+08	1.68E+08
Ba-140	1.29E+08	1.61E+05	8.42E+06	ND	5.49E+04	9.24E+04	2.65E+08
La-140	1.58E+04	7.98E+03	2.11E+03	ND	ND	ND	5.86E+08
Ce-141	1.97E+05	1.33E+05	1.51E+04	ND	6.19E+04	ND	5.10E+08
Ce-144	3.29E+07	1.38E+07	1.77E+06	ND	8.16E+06	ND	1.11E+10
Pr-143	6.26E+04	2.51E+04	3.10E+03	ND	1.45E+04	ND	2.74E+08
Pr-144	2.03E+03	8.43E+02	1.03E+02	ND	4.75E+02	ND	2.92E-04
Nd-147	3.33E+04	3.85E+04	2.31E+03	ND	2.25E+04	ND	1.85E+08
Eu-154	4.85E+07	5.97E+06	4.25E+06	ND	2.86E+07	ND	4.32E+09
Hf-181	1.40E+05	6.82E+05	6.32E+04	ND	1.47E+05	ND	7.76E+08

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:

a) 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;

b) Dose to skin due to beta radiation from submersion in a cloud of radioactive noble gases, and ground plane exposure;

c) Thyroid dose due to inhalation and ingestion of radioiodines; and

d) 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. (Ref. 11.12.5)

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 (Ref. 11.12.3).

There are no other Uranium Fuel Cycle Sources within 8km 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 for recreational or other purposes not associated with the plant (Ref. 11.4 and 11.8.10). 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 (Ref. 11.12.3 and 11.12.4).

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 outside storage tanks, 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 (Ref. 11.7.2, 11.7.3, 11.13, and 11.13.1).

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 current tenant has estimated that he spends approximately 1100 hours per year working in this area (Ref. 11.5.5). Occupancy of areas within the SITE BOUNDARY is assumed to be averaged over a period of one year.

Any reevaluation of assumptions should consider only real receptors and real pathways using realistic assumption, 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 concurrent meteorological data at the farmer's residence and historical meteorological data from Table 6.1 for activities within the SITE BOUNDARY. These dispersion parameters were calculated by assuming that the farmer's time is equally distributed over the areas farmed within the SITE BOUNDARY, and already have the total occupancy of 1100 hours/year factored into their value (Ref. 11.5.6).

The residence of the current tenant is located at a distance of 3830 meters in the SE sector. The gaseous effluents dose at the farmer's residence is due to plume exposure from Noble Gases and the ground plane, inhalation, and ingestion pathways. For conservatism, it is acceptable to assume that all of the ingestion pathways exist at this location.

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 from Outside Storage Tanks

The Refueling Water Storage Tank (RWST) has the highest potential for receiving significant amounts of radioactive materials, and constitutes the only potentially significant source of direct radiation dose from outside storage tanks to a MEMBER OF THE PUBLIC (Ref. 11.6.14, 11.6.15, 11.6.16 and 11.6.17).

Direct radiation dose from the RWST to a MEMBER OF THE PUBLIC is determined at the nearest point of the Owner Controlled Area fence which is not obscured by significant plant structures, which is 450 meters from the RWST.

The RWST is a right circular cylinder approximately 12 meters in diameter, 14 meters in height with a capacity of approximately 1,514,000 liters (Ref. 11.6.17). The walls are of type 304 stainless steel and have an average thickness of .87 cm. (Ref. 11.14.1).

The direct radiation dose from the RWST is calculated based on the tank's average isotopic content and the parameters discussed above, considering buildup and attenuation within the volume source. Appropriate methodology for calculating the dose rate from a volume source is given in TID-7004, "Reactor Shielding Design Manual" (Ref. 11.17). The computer program ISOSHLD (Ref. 11.18, 11.19 and 11.20) will normally be utilized to perform this calculation.

4.1.3.1.2 Direct Radiation Dose from the Reactor

The maximum direct radiation dose from the Unit to a MEMBER OF THE PUBLIC has been determined to be 7E-2 mrads/calendar year, based on a point source of primary coolant N-16 in the steam generators. This source term was then projected onto the inside surface of the containment dome, taking credit for shielding provided by the containment dome and for distance attenuation. No credit was allowed for shielding by other structures or components within the Containment Building. The number of gammas per second was generated and then converted to a dose rate at the given distance by use of ANSI/ANS-6.6.1, "Calculation and Measurement of Direct and Scattered Gamma Radiation from LWR Nuclear Power Plant 1979", which considers attenuation and buildup in air. The final value is based on one unit operating at 100% Power. The distance was determined to be 367 meters, which is approximately the closest point of the boundary of the Owner Controlled Area fence which is not obscured by significant plant structures (Ref. 11.14.3).

The maximum direct radiation dose from the Unit to the farmer is thus approximately 9E-3 mrads per year, assuming a maximum occupancy of 1100 hours per year.

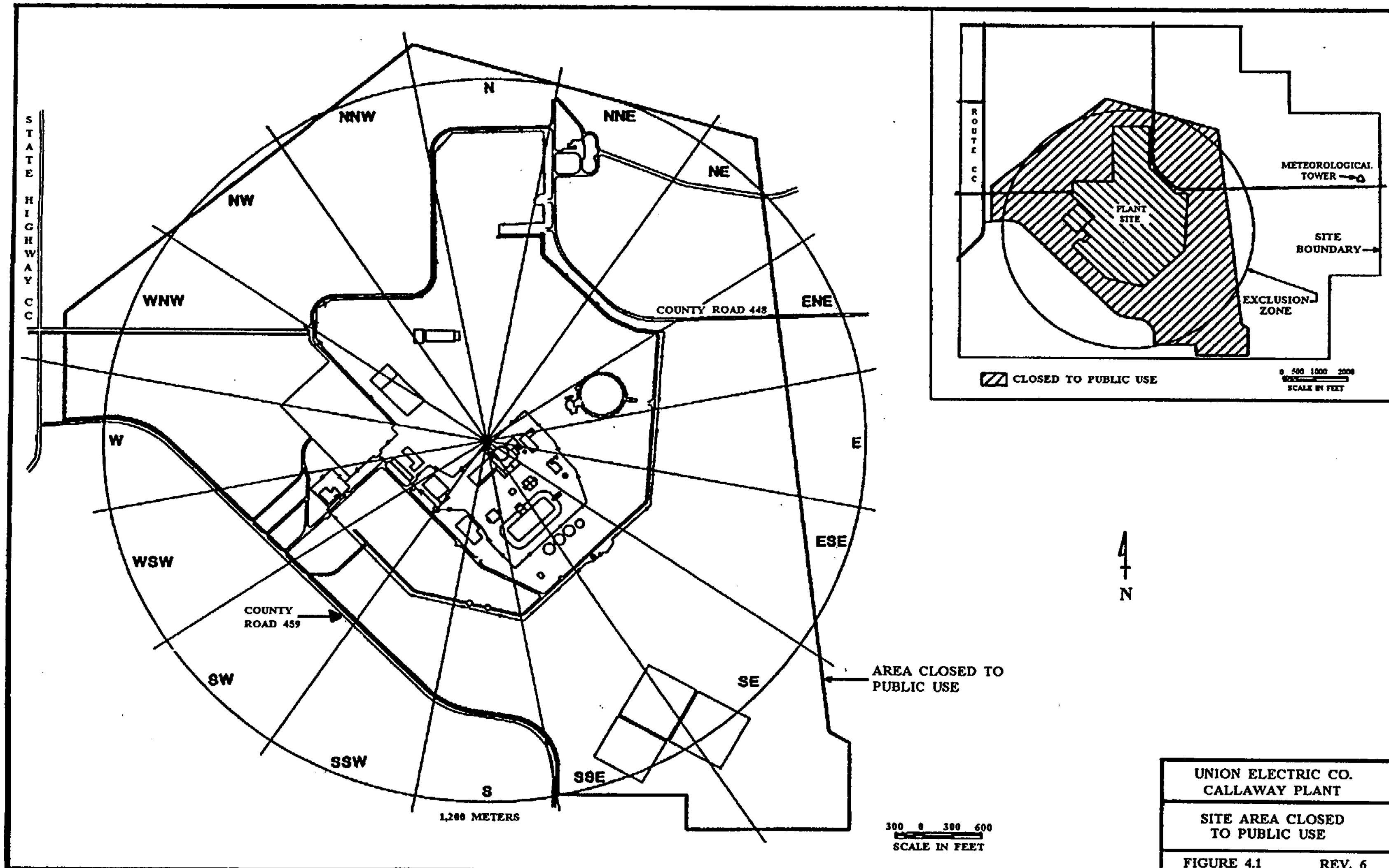
4.1.3.1.3 Direct Radiation Dose From On-Site Storage Of Low Level Radioactive Waste

The on-site storage area for radioactive wastes is located Plant Southwest of the radwaste building and consists of a concrete pad enclosed by a fence. The storage area is bounded on two sides by the radwaste building. The area is also partially bounded on a third side by the Discharge monitoring tanks dike system. The radioactive wastes are stored in this area using high integrity containers (HIC) inside Onsite Storage Containers (OSC) and LSA type storage containers. The HIC has the highest potential for containing significant amounts of radioactive material, and constitutes the only potentially significant source of direct radiation from on-site radioactive waste storage.

Direct radiation dose from the HICs to a MEMBER OF THE PUBLIC is determined at the nearest point of the Owner Controlled Area fence which is not obscured by significant plant structures.

The HICs typically are right circular cylinders approximately 1.7 meters in diameter and 1.8 meters in height. The HICs are stored inside OSCs which typically are constructed of concrete with additional shielding as necessary to minimize external doses. The individual parameters (e.g., dimensions, shielding material, etc.) for each OSC will be accounted for in the calculations.

The direct radiation dose from the On-Site Storage area is the summation of the individual calculated HIC doses based on the HIC isotopic contents and the OSC design parameters, considering buildup, attenuation, and shielding. Appropriate methodology for calculating the dose rate is given in Safety Analysis Calculations ZZ-293 and ZZ-310. The computer program MICROSHIELD (Ref. 11.24) will normally be utilized to perform this calculation.



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 act as a background data base for preoperation 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 can be adequately 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.

REMP sampling locations that use meteorological sectors and or distance from the plant site were verified as described in reference 11.28.

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

Airborne, waterborne, and ingestion samples collected under the monitoring program are analyzed by an independent, third-party laboratory. This laboratory is required to participate in the Environmental Measurements Laboratory Quality Assessment Program (EML) or an equivalent program. Participation includes all of the determinations (sample medium - radionuclide combination) that are offered by EML and that are also included in the monitoring program.

5.2 PERFORMANCE TESTING OF ENVIRONMENTAL THERMOLUMINESCENCE DOSIMETERS

Thermoluminescence Detectors (TLD's) used in the Environmental Monitoring Program are tested for accuracy and precision to demonstrate compliance with Regulatory Guide 4.13 (Ref. 11.16).

Energy dependence is tested at several energies between 30keV and 3MeV corresponding to the approximate energies of the predominant Noble Gases (80, 160, 200 keV), Cs-137 (662 keV), Co-60 (1225 keV), and at least one energy less than 80 keV. Other testing is performed relative to either Cs-137 or Co-60. (Ref. 11.14.10)

6 DETERMINATION OF ANNUAL AVERAGE AND SHORT TERM ATMOSPHERIC DISPERSION PARAMETERS

6.1 ATMOSPHERIC DISPERSION PARAMETERS

The values presented in Table 6.1 and Table 6.2 were determined through the analysis of on-site meteorological data collected during the three year period of May 4, 1973 to May 5, 1975 and March 16, 1978 to March 16, 1979.

6.1.1 Long-Term Dispersion Estimates

The variable trajectory plume segment atmospheric transport model MESODIF-II (NUREG/-CR-0523) and the straight-line Gaussian dispersion model XOQDOQ (NUREG/CR2919) were used for determination of the long-term atmospheric dispersion parameters. A more detailed discussion of the methodology and data utilized to calculate these parameters can be found elsewhere (Ref. 11.6.12).

The Unit Vent and Radwaste Building Vent releases are at elevations of 66.5 meters and 20 meters above grade, respectively. Both release points are within the building wake of the structures on which they are located, and the unit Vent is equipped with a rain cover which effectively eliminates the possibility of the exit velocity exceeding five times the horizontal wind speed. All gaseous releases are thus considered to be ground-level releases, and therefore no mixed mode or elevated release dispersion parameters were determined (Ref. 11.5.2).

6.1.2 Determination of Long-Term Dispersion Estimates for Special Receptor Locations

Calculations utilizing the PUFF model were performed for 22 standard distances to obtain the desired dispersion parameters. Dispersion parameters at the SITE BOUNDARY and at special receptor locations were estimated by logarithmic interpolation according to (Ref. 11.6.13):

$$X = X_1 \left(d/d_1\right)^B \qquad (6.1)$$

Where:

$$B = \ln\left(X_2/X_1\right)/\ln\left(d_2/d_1\right).$$

X_1, X_2 = Atmospheric dispersion parameters at distance d_1 and d_2, respectively, from the source.

The distances d_1 and d_2 were selected such that they satisfy the relationship.

$$d_1 < d < d_2$$

6.1.3 Short Term Dispersion Estimates

Airborne releases are classified as short term if they are less than or equal to 500 hours during a calendar year and not more than 150 hours in any quarter. Short term dispersion estimates are determined by multiplying the appropriate long term dispersion estimate by a correction factor (Ref. 11.9.1 and 11.15.1):

$$F = \left(T_s / T_a\right)^S \qquad (6.2)$$

Where:

T_s = The total number of hours of the short term release.

T_a = The total number of hours in the data collection period from which the long term diffusion estimate was determined (Refer to Section 6.1).

Values of the slope factor (S), are presented in Table 6.3.

Short term dispersion estimates are not applicable to short term releases which are sufficiently random in both time of day and duration (e.g., the short term release periods are not dependent solely on atmospheric conditions or time of day) to be represented by the annual average dispersion conditions (Ref. 11.8.1).

6.1.3.1 The Determination of the Slope Factor (S)

The general approach employed by subroutine PURGE of XOQDOQ (Ref. 11.15.1) was utilized to produce values of the slope of the (X/Q) curves for both the Radwaste Building Vent and the Unit Vent. However, instead of using approximation procedures to produce the 15 percentile (X/Q) values, the 15 percentile (X/Q) value for each release and at each location was determined by ranking all the 1-hour($(X/Q)_1$) values for that release and at that location in descending order. The $(X/Q)_1$ value which corresponded to the 15 percentile of all the calculated (X/Q) values within a sector was extracted for use in the intermittent release (X/Q) calculation.

The intermittent release (X/Q) curve was constructed using the calculated 15 percentile $(X/Q)_1$ and its corresponding annual average $(X/Q)_a$. A graphic representation of how the computational procedure works is illustrated by Figure 4.8 of reference 11.15.1. The straight line connecting these points represents $(X/Q)_1$ values for intermittent releases, ranging in duration from one hour to 8760 hours. The slope (S) of the curve is expressed as:

$$S = \frac{-\log\left((X/Q)_1/(X/Q)_a\right)}{\log\left(T_a/T_1\right)} \qquad (6.3)$$

or

$$S = \frac{-\left(\log(X/Q)_1 - \log(X/Q)_a\right)}{\log T_a - \log T_1} \qquad (6.4)$$

6.1.4 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 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 within the SITE BOUNDARY, and that his time is divided evenly over all of the croplands. Fractional acreage/time - weighted dispersion parameters were calculated for each plot as described in reference 11.5.6. The weighted dispersion parameters for each plot were then summed (according to type) in order to produce a composite value of the dispersion parameters which are presented in Tables 6.1 and 6.2. 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 computer codes and models consistent with XOQDOQ (Ref. 11.15). These codes have been validated and verified by a qualified meteorologist prior to implementation. 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 6.5.

The vertical height of the highest adjacent building (V) used to perform concurrent year annual average atmospheric dispersion (X/Q) calculations is 169.16 meters (Ref. 11.29).

Meteorological Data is periodically verified to ensure valid data is being collected. Health Physics is responsible to ensure this review is performed.

TABLE 6.1
HIGHEST ANNUAL AVERAGE ATMOSPHERIC DISPERSION PARAMETERS
UNIT VENT

LOCATION (b)	SECTOR	DISTANCE (METERS)	X/Q	X/Q DECAYED/ UNDEPLETED	X/Q DECAYED/ DEPLETED	D/Q
			(sec/m^3)	(sec/m^3)	(sec/m^3)	(m^{-2})
SITE BOUNDARY(a)	NNW	2200	1.0E-6	9.9E-7	8.5E-7	4.3E-9
Nearest Residence (c) (d)	NNW	2897	6.7E-7	6.6E-7	5.6E-7	2.6E-9
Farmer's Residence(c)	SE	3830	2.5E-7	2.5E-7	2.1E-7	1.1E-9
Farming Areas within the Site Boundary (c) (e)	N/A	N/A	2.6E-7	2.6E-7	2.4E-7	1.3E-9

(a) Values given are from FSAR Table 2.3-82

(b) Data from 1998 Land Use Census

(c) Values derived from FSAR Table 2.3-83, using the methodology presented in Equation (6.1) (Ref. 11.5.6)

(d) All pathways are assumed to exist at the location of the nearest resident.

(e) These values were derived for a narrow scope application. Extreme caution should be exercised when determining their suitability for use in other applications.

Building Shape Parameter (C) = 0.5 (Ref. 11.5.3)

Vertical Height of Highest Adjacent Building (V) = 66.45 meters (Ref. 11.5.3)

TABLE 6.2
HIGHEST ANNUAL AVERAGE ATMOSPHERIC DISPERSION PARAMETERS
RADWASTE VENT AND LAUNDRY DECON FACILITY DRYER EXHAUST

LOCATION (b)	SECTOR	DISTANCE (METERS)	X/Q (sec/m^3)	X/Q DECAYED/ UNDEPLETED (sec/m^3)	X/Q DECAYED/ DEPLETED (sec/m^3)	D/Q (m^{-2})
SITE BOUNDARY(a)	NNW	2200	1.3E-6	1.3E-6	1.1E-6	4.3E-9
Nearest Residence (c) (d)	NNW	2897	8.5E-7	8.5E-7	7.1E-7	2.6E-9
Farmer's Residence(c)	SE	3830	3.0E-7	3.0E-7	2.4E-7	1.1E-9
Farming Areas Within Site Boundary (c) (e)	N/A	N/A	3.5E-7	3.5E-7	3.2E-7	1.3E-9

(a) Values given are from FSAR Table 2.3-84

(b) Data from 1998 Land Use Census

(c) Values derived from FSAR Table 2.3-81, using the methodology presented in Equation (6.1) (Ref. 11.5.6)

(d) All pathways are assumed to exist at the location of the nearest resident.

(e) These values were derived for a narrow scope application. Extreme caution should be exercised when determining their suitability for use in other applications.

Building Shape Parameter (C) = 0.5 (Ref. 11.5.3)

Vertical Height of Highest Adjacent Building (V) = 19.96 meters (Ref. 11.5.3)

TABLE 6.3
SHORT DISPERSION PARAMETERS (a) (c)

Location (b)	Sector	Distance	Slope Factor(s) Unit Vent	Slope Factor(s) Radwaste Building Vent
Site Boundary	S	1300	-.328	-.320
Nearest Residence (d)	NNW	2897	-.264	-.268

(a) Reference 11.5.3

(b) Data from 1998 Land Use Census

(c) Recirculation Factor = 1.0

(d) All pathways are assumed to exist at the location of the nearest resident.

TABLE 6.4
APPLICATION OF ATMOSPHERIC DISPERSION PARAMETERS

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 H-3, x/Q, decayed/depleted is used instead of D/Q (Ref. 11.11.1).

TABLE 6.5

METEOROLOGICAL DATA SELECTION HIEARCHY

Parameter	Primary	First Alternate	Second Alternate	Third Alternate
Wind Speed	10m Pri	10m Sec	60m Pri	90m Pri
Wind Direction	10m Pri	10m Sec	60m Pri	90m Pri
Air Temperature	10m Pri	10m Sec		
Wind Variability	10m Pri	10m Sec	60m Pri	90m Pri
Temp Different	60-10m Pri	90-10m Pri	90-60 Pri	
Dew Point	10m Pri			
Precipitation	1m Pri			

(a) Pri indicates primary tower

(b) Sec indicates secondary tower

Table 6.6

Application of Atmospheric Dispersion Parameters: Radioactive Effluent Release Report

Dose Pathway	Dispersion Parameter	Controlling Age Group	Dispersion Values	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
			Concurrent Historical	Farmer's Residence Inside Site Boundary
Ground Plane Deposition Dose	D/Q	N/A	Concurrent	Site Boundary Nearest Resident
			Concurrent Historical	Farmer's Residence Inside Site Boundary
Inhalation Dose	x/Q, decayed/depleted (8 day half-life)	Child	Concurrent	Site Boundary Nearest Resident
		Adult	Concurrent Historical	Farmer's Residence Inside Site Boundary
Ingestion Dose Pathways	D/Q*	Child	Concurrent	Site Boundary Nearest Resident
		Adult	Concurrent Historical	Farmer's Residence Inside Site Boundary

* For H-3, x/Q, decayed/depleted is used instead of D/Q (Ref. 11.11.1).

7 REPORTING REQUIREMENTS

7.1 ANNUAL RADIOLOGICAL ENVIRONMENTAL OPERATING REPORT **(COMN 2804)**

The reporting requirements for the Annual Radiological Environmental Operating Report have been relocated to FSAR Section 16.11.5.1.

7.2 RADIOACTIVE EFFLUENT RELEASE REPORT **(COMN 2805)**

The reporting requirements for the Radioactive Effluent Release Report have been relocated to FSAR Section 16.11.5.2.

8 IMPLEMENTATION OF ODCM METHODOLOGY **(COMN 2791)**

The ODCM provides the mathematical relationships used to implement the Radioactive Effluent Controls. For routine effluent release and dose assessment, computer codes are utilized to implement the ODCM methodologies. These codes are evaluated in accordance with the requirements of plant operating procedures to ensure that they produce results consistent with the methodologies presented in the ODCM. Plant procedures implement the ODCM methodology.

9 RADIOACTIVE EFFLUENT CONTROLS (REC)

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

10 ADMINISTRATIVE CONTROLS

10.1 MAJOR CHANGES TO LIQUID AND GASEOUS RADWASTE TREATMENT SYSTEMS

10.1.1 Licensee-initiated major changes to the Radwaste Treatment Systems (liquid and gaseous):

a. A summary of the change MUST be reported to the Commission in the Radioactive Effluent Release Report for the period in which the evaluation was reviewed by the On-Site Review Committee (ORC). On site documentation MUST contain:

1) A summary of the evaluation that led to the determination that the change could be made in accordance with 10 CFR 50.59;

2) Sufficient detailed information to totally support the reason for the change without benefit of additional or supplemental information;

3) A detailed description of the equipment, components and process involved and the interfaces with other plant systems;

4) 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;

5) 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;

6) 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;

7) An estimate of the exposure to plant operating personnel as a result of the change; and

8) Documentation of the fact that the change was reviewed and found acceptable by the ORC.

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

10.2 CHANGES TO THE OFFSITE DOSE CALCULATION MANUAL (ODCM) **(COMN 2815)**

10.2.1 All changes to the ODCM shall be completed pursuant to **T/S AC 5.5.1** and approved as per APA-ZZ-00101, "Preparation, Review, Approval and Control of Procedures".

10.2.1.1 All changes shall be approved by the ORC prior to implementation.

10.2.2 Review for each revision of the ODCM must include, as a minimum, the Health Physics, and Quality Assurance Departments.

10.2.3 A complete and legible copy of each revision of the ODCM that became effective during the last annual period shall be submitted as a part of, or concurrent with that years Radioactive Effluent Release Report pursuant to **T/S AC 5.5.1** .

11 REFERENCES

11.1 Title 10, "Energy", Chapter 1, Code of Federal Regulations, Part 20; U.S. Government Printing Office, Washington, D.C. 20402.

11.1.1 Statements of Consideration, Federal Register, Vol. 56, No. 98, Tuesday, May 21, 1991, Subpart D, page 23374.

11.2 Title 10, "Energy", Chapter 1, Code of Federal Regulations, Part 50, Appendix I; U.S. Government Printing Office, Washington, D.C. 20402.

11.2.1 10 CFR 50.36 a (b)

11.3 Title 40, "Protection of Environment", Chapter 1, Code of Federal Regulations, Part 190; U.S. Government Print Office, Washington, D.C. 20402.

11.4 U.S. Nuclear Regulatory Commission, "Technical Specifications Callaway Plant, Unit NO. 1", NUREG-1058 (Rev. 1), October 1984. Section 5.4.1

11.5 COMMUNICATIONS

11.5.1 Letter NEO-54, D. W. Capone to S. E. Miltenberger, dated January 5, 1983; Union Electric Company correspondence.

11.5.2 Letter BLUE 1285, "Callaway Annual Average X/Q and D/Q Values", J. H. Smith (Bechtel Power Corporation), to D. W. Capone (Union Electric Co.), dated February 27, 1984.

11.5.3 Letter BLUE 1232, "Callaway Annual Average X/Q Values and "S" Values", J. H. Smith (Bechtel Power Corporation) to D. W. Capone (Union Electric Co.), dated February 9, 1984.

11.5.4 Reference Deleted

11.5.5 Private Communication, H. C. Lindeman & B.F. Holderness, August 6, 1986

11.5.6 Calculation ZZ-67, "Annual Average Atmospheric Dispersion Parameters", April 1989.

11.6 Union Electric Company Callaway Plant, Unit 1, Final Safety Analysis Report.

11.6.1 Section 11.5.2.2.3.1

11.6.2 Section 11.5.2.2.3.4

11.6.3 Section 11.5.2.1.2

11.6.4 Section 11.5.2.2.3.2

11.6.5 Section 11.5.2.2.3.3

11.6.6 Section 11.2.3.3.4

11.6.7 Section 11.2.3.4.3

11.6.8 Section 11.5.2.3.3.1

11.6.9 Section 11.5.2.3.3.2

11.6.10 Section 11.5.2.3.2.3

11.6.11 Section 11.5.2.3.2.2

11.6.12 Section 2.3.5

11.6.13 Section 2.3.5.2.1.2

11.6.14 Section 9.2.6

11.6.15 Section 9.2.7.2.1

11.6.16 Section 6.3.2.2

11.6.17 Table 11.1-6

11.6.18 Deleted

11.6.19	Deleted
11.6.20	Deleted
11.6.21	Deleted
11.6.22	Table 2.3-68
11.7	Union Electric Company Callaway Plant Environmental Report, Operating License Stage.
11.7.1	Table 2.1-19
11.7.2	Section 2.1.2.3
11.7.3	Section 2.1.3.3.4
11.7.4	Section 5.2.4.1
11.7.5	Table 2.1-19
11.8	U.S. Nuclear Regulatory Commission, Preparation of Radiological Effluent Technical Specification for Nuclear Power Plants", USNRC NUREG-0133, Washington, D. C. 20555, October 1978.
11.8.1	Pages AA-1 through AA-3
11.8.2	Section 5.3.1.3
11.8.3	Section 4.3
11.8.4	Section 5.3.1.5
11.8.5	Section 5.1.1
11.8.6	Section 5.1.2
11.8.7	Section 5.2.1
11.8.8	Section 5.2.1.1
11.8.9	Section 5.3.1
11.8.10	Section 3.8
11.8.11	Section 3.3
11.9	U.S. Nuclear Regulatory Commission, "XOQDOQ, Program For the Meteorological Evaluation of Routine Effluent Releases at Nuclear Power Stations", USNRC NUREG-0324, Washington, D. C. 20555.
11.9.1	Pages 19-20 Subroutine PURGE
11.10	Regulatory Guide 1.111, "Methods for Estimating Atmospheric Transport and Dispersion of Gaseous Effluents in Routine Releases from Light-Water-Cooled Reactors", Revision 1, U. S. Nuclear Regulatory Commission, Washington, D. D. 20555, July, 1977.
11.10.1	Section c.1.b
11.10.2	Figures 7 through 10
11.10.3	Section c.4
11.11	Regulatory Guide 1.109, "Calculation of Annual Doses to Man from Routine Releases of Reactor Effluents for the Purposes of Evaluating Compliance with 10 CFR Part 50, Appendix I", Revision 1, U. S. Nuclear Regulatory Commission, Washington, D. C. 20555, October 1977.
11.11.1	Appendix C, Section 3.a
11.11.2	Appendix E, Table E-15
11.11.3	Appendix C, Section 1
11.11.4	Appendix E, Table E-11
11.11.5	Appendix E, Table E-9

11.12 U. S. Nuclear Regulatory Commission, "Methods for Demonstrating LWR Compliance with the EPA Uranium Fuel Cycle Standard (40 CFR Part 190)", USNRC NUREG-0543, Washington, D. C. 20555, January 1980.

11.12.1 Section I, Page 2

11.12.2 Section IV, Page 8

11.12.3 Section IV, Page 9

11.12.4 Section III, Page 6

11.12.5 Section III, Page 8

11.13 Management Agreement for the Public Use of Lands, Union Electric Company and the State of Missouri Department of Conservation, December 21, 1982.

11.13.1 Exhibit A

11.14 MISCELLANEOUS REFERENCES

11.14.1 Drawing Number M-109-0007-06, Revision 5

11.14.2 Callaway Plant Annual Environmental Operating Report (updated annually)

11.14.3 UE Safety Analysis Calculation 87-001-00

11.14.4 Calculation ZZ-48, "Calculation of Inhalation and Ingestion Dose Commitment Factors for the Adult and Child", January, 1988

11.14.5 HPCI 89-02, "Calculation of ODCM Dose Commitment Factors", March, 1989

11.14.6 HPCI 87-04, "Calculation of the Limiting Setpoint for the Containment Purge Exhaust Monitors, GT-RE-22 and GT-RE-33", March, 1987

11.14.7 HPCI 88-10, "Methodology for Calculating the Response of Gross NaI(Tl) Monitors to Liquid Effluent Streams", June, 1988

11.14.8 Calculation ZZ-57, "Dose Factors for Eu-154", January, 1989

11.14.9 Calculation ZZ-78, Rev. 2, "ODCM Gaseous Pathway Dose Factors for Adult Age Group", July, 1992.

11.14.10 HPCI 88-08, "Performance Testing of the Environment TLD System at Callaway Plant", August, 1989.

11.14.11 Calculation ZZ-250, Rev. 0, "ODCM Gaseous Pathway Dose Factors for Child Age Group and Ground Plane Dose Factors", September, 1992.

11.14.12 UOTH 83-58, "Documentation of ODCM Dose Factors and Parameters", February, 1983.

11.14.13 Calculation HPCI 95-004 (Rev. 0), "Calculation of Liquid Effluent Dose Commitment factors (A_{it}) for the Adult Age Group", June, 1996.

11.15 U. S. Nuclear Regulatory Commission, "XOQDOQ: Computer Program for the Meteorological Evaluation of Routine Effluent Releases at Nuclear Power Stations", USNRC NUREG/CR-2919, September 1982, Washington, D. C. 20555

11.15.1 Section 4, "Subroutine PURGE", pages 27 and 28

11.16 Regulatory Guide 4.13, "Performance, Testing, and procedural specifications for Thermoluminiscence Dosimetry: Environmental Applications "(Revision 1), July 1977; USNRC, Washington, D. C. 20555

11.17 TID-7004, "Reactor Shielding Design Manual", Rockwell, Theodore, Ed; March 1956.

11.18 BNWL-236, "ISOSHLD - A computer code for General Purpose Isotope Shielding Analysis", Engel, R. C., Greenberg, J., Hendrichson, M. M.; June 1966

11.19 BNWL-236, Supplement 1, "ISOSHLD- II: Code Revision to include calculation of Dose Rate from Shielded Bremstrahlung Sources", Simmons, G. L., et al; March 1967

11.20 BNWL-236, Supplement 2, "A Revised Photon Probability Library for use with ISOSHLD- III", Mansius, C. A.; April 1969.

11.21	ANSI N13.10-1974 , "Specification & Performance of On-Site Instrumentation for Continuously Monitoring Radioactivity in Effluents"; September, 1974
11.22	Nuclear Regulatory Commission Generic Letter 89-01, "Guidance for the Implementation of Programmatic Controls for RETS in the Administrative Controls Section of Technical Specifications and the Relocation of Procedural Details of Current RETS to the Offsite Dose Calculation Manual or Process Control Program", January 1989
11.23	NRC Answers to 10 CFR 20 Implementation Questions
11.23.1	Letter, F. J. Congel to J. F. Schmidt, dated December 9, 1991.
11.23.2	Internal USNRC memo, F. J. Congel to V. L. Miller, et al, dated April 17, 1992.
11.23.3	Letter, F. J. Congel to J. F. Schmidt, dated April 23, 1992.
11.23.4	Letter, F. J. Congel to J. F. Schmidt, dated September 14, 1992.
11.23.5	Letter, F. J. Congel to J. F. Schmidt, dated June 8, 1993.
11.24	USNRC Inspection Report 50-483/92002(DRSS) Section 5, page 5.
11.25	HPCI 96-005, "Calculation of Maximum Background Value for HB-RE-18".
11.26	EGG-PHY-9703, "Technical Evaluation Report for the evaluation of ODCM Revision 0 (May, 1990) Callaway Plant, Unit 1", transmitted via letter, Samual J. Collins (USNRC) to D. F. Schnell (UE), dated July 12, 1996.
11.27	HPCI 99-005, "Calculation of Setpoint for GL-RE-202".
11.28	HPCI 99-001, "Documentation of REMP Procedure Changes".
11.29	"Technical Specifications for Callaway Plant Meteorological Data Software"