8.0 OFF-SITE DOSE CALCULATION MANUAL

10 CFR Part 50.36a requires reactor licensees to develop technical specifications on effluents released from power plants. These must ensure that radionuclides in the effluent will be less than the maximum permissible concentrations specified in 10 CFR Part 20.1302. In addition, 10 CFR Part 50.34a requires the construction and operation of equipment to keep releases of radioactive materials in effluents "as low as reasonably achievable" (ALARA). Guidelines for what is meant by the term ALARA are contained in Appendix I to 10 CFR Part 50. Appendix I contains guidance regarding levels of doses to the public that are acceptable to the NRC.

An Off-site Dose Calculation Manual, (ODCM) is required for each nuclear power plant. Each facility ODCM contains:

- Methodology and parameters for calculating off-site doses
- Dose limit(s) for safe operation
- Monitoring techniques and sampling frequency
- Related monitoring instrument setpoints
- Limits or controls on radiological effluents

The setpoint is the monitoring instrument reading, typically in counts per minute, that corresponds to a pre-established limit of operation. If the instrument reads above the setpoint, action must be taken to reduce radioactive releases. The operating limits are contained in the Radiological Environmental Technical Specifications (RETS) section of the ODCM.

This chapter:

- Discusses the methodology for calculating radiation dose limits to members of the general public as established in the Radiological Environmental Technical Specifications (RETS)
- Reviews the potentially significant pathways of radionuclide transport and modes of exposure of the off-site population
- Discusses the requirements for an ODCM

Nuclear power plants release liquid and gaseous effluents that contain small quantities of radionuclides. Strict limits for releases of radioactive material into the environment are enforced to ensure that doses to the general public are ALARA.

Radwaste systems collect and stabilize as much of the generated radionuclides for safe disposal as possible, rather than release them into the environment.

Facility effluents are measured to verify they are within prescribed limits. Since releases cannot normally be completely avoided, a dose to the public is calculated and compared against acceptable standards. Off-site environmental monitoring is used for verifying that a release pathway has not been overlooked or that radionuclide release quantities have not been underestimated.

The dose to the public is estimated in two general ways. The first method is to measure the amount of radionuclides released from the various plant liquid and gaseous release points such as drains or vents. Data from these release points are then used to calculate the dose to members of the public at various off-site locations. The calculations are based on environmental transport processes and conditions applicable to the area of concern. The second method is to measure the amount of radionuclides that exist in off-site water, air, and biota samples as well as the direct radiation from the plant. These measurements are then compared to values that are considered acceptable. Both methods are used at nuclear power plants.

8.1 RADIOLOGICAL EFFLUENT TECHNICAL SPECIFICATIONS

A nuclear power plant is operated within the conditions and limitations specified in its license to ensure its safe operation. Conditions that are related to releases of radionuclides from the plants are called Radiological Effluent Technical Specifications (RETS). An example of a RETS is a limit on the dose to a member of the public at an off-site location from releases from a plant vent.

NRC Generic Letter 89-01, permits a change in the format of the RETS and ODCM. Formerly, RETS were part of the Technical Specifications (Tech Specs). Tech Specs are proposed by the licensee as part of the license application and, after review and acceptance by the NRC, are included as an appendix to the license. The RETS were composed of limits called Limiting Conditions of Operation (LCO), such as maximum off-site dose from releases from a vent. The RETS also gave the Surveillance Requirement, which briefly discussed in general terms what surveillance would be done and how often.

The old ODCM gave methods for calculating the LCOs, such as off-site doses. In conjunction with this, the ODCM also provided setpoint calculations to determine instrument readings that corresponded to an LCO. In 1989, the NRC revised the required format for the Tech Specs ODCM (see NUREG-1301 and -1302). The programmatic or general features of the RETS were retained in the Tech Specs. The procedural details, however, are now a part of the ODCM. In addition, the LCOs are now called controls. The rest of the ODCM (i.e., dose and setpoint calculation methods) remains as before.

That portion of the RETS that was transferred to the ODCM is now called the Standard Radiological Effluent Controls (SREC). An example of a page from the new ODCM dealing with controls on the release of iodine, tritium, and particulate radionuclides is shown in Table 8.1-1. It consists of the control (which in this case is dose limits of 7.5 mrem per quarter and 15 mrem per year to any organ), the action to be taken if the dose limit is exceeded, and the surveillance requirements (which specify how often the measurement must be made).

8.2 REGULATORY GUIDANCE

Guidance for the preparation of the RETS and ODCM is contained in:

- NUREG-0133
- NUREG-0472
- NUREG-0473
- NUREG-1301
- NUREG-1302

A summary of the controls contained in NUREG-0472 and -0473 is contained in Table 8.2-1. Those parameters that require immediate action if a dose or concentration is exceeded are regulatory requirements. In item number 3 of Table 8.2-1, Liquid Effluent Concentration, the concentration limits are specified in 10 CFR 20, Appendix B. In number 6, Gaseous Effluent Dose Rate, the whole body dose rate is based on the old Part 20 values. The other doses are recommended values, some of which are given in Appendix I of 10 CFR 50.

NOTE: Because the liquid effluent release rate and gaseous effluent release rate controls are not Part 20 limits, but are used to help ensure compliance with the design objectives in Appendix I of 10 CFR Part 50, licensees are not required to change their TS or ODCM to incorporate the revised values in 10 CFR Part 20. Thus, licensees can continue to use, for release rate controls only, the old Part 20 values. Licensees may switch to the new Part 20 values; however, this will result in a significant reduction in the release rate of the radioactive effluents. Historical data has shown that radioactive effluents from nuclear power plants are already ALARA, thus there is no requirement to further reduce the rate at which the effluent is released. If a licensee chooses to use the new Part 20 values and retain the existing, acceptable level of release rate control, the licensee may apply for a TS amendment to allow a factor of 10 to be applied to the Appendix B liquid effluent concentrations in the revised Part 20. For gaseous effluents, the acceptable effluent release rate control remains at 500 mrem/yr to the whole body, 3000 mrem/yr to the skin, and 1500 mrem/yr to any organ.

The methods of dose calculation that are used by the NRC in reviewing licensee's submittals are given in Regulatory Guides:

- 1.109 Calculation of Annual Doses to Man from Routine Releases for the Purpose of Evaluating Compliance with 10 CFR part 50, Appendix I
- 1.111 Methods for Estimating Atmospheric Transport and Dispersion of Gaseous Effluents from Light-Water-Cooled Power Reactors
- 1.112 Calculation of Releases of Radioactive Materials in Gaseous and Liquid Effluents from Light-Water-Cooled Power Reactors
- 1.113 Estimating Aquatic Dispersion of Effluents from Accidental and Routine Reactor Releases for the Purpose of Implementing App. I
- 1.23 Meteorological Programs in Support of Nuclear Power Plants.

The NRC has prepared a guide to dose calculation methods and input parameters that it considers acceptable in Regulatory Guide 1.109. The Regulatory Guide presents equations for the pathways as listed in Table 8.2-2.

The NRC conducts regular inspections at reactor facilities, using Inspection Procedure 71124.06, “Radioactive Gaseous and Liquid Effluent Treatment” (Attachment 8-1). this module is typically conducted in two parts, one to evaluate the licensee’s compliance with the effluents portion of their TS/ODCM, including: an evaluation of instrument calibration and reliability; testing of air cleaning systems; and, evaluation of effluent alarm set point calculations. The second review evaluates the licensee’s environmental monitoring program, including the collection and evaluation of environmental and biotic samples.

8.3 ENVIRONMENTAL PATHWAYS

There are a number of environmental transport pathways and exposure modes by which an individual could be exposed to releases from a plant. These are shown in Figure 8.3-1 and listed in Table 8.3-1.

These pathways are complicated, and the equations for calculating environmental transport and radiation doses are therefore complicated, requiring the use of numerous assumptions. The first step is environmental transport of the effluent from the release point. Any release to the atmosphere or to a body of water, such as a lake or river, will become dispersed. For example, the concentration of a radionuclide at any distance from the release point for gaseous release will depend on wind direction, speed, and turbulence. For inhalation of radionuclides, one must know the location of the individual and the inhalation rate to be able to estimate the radiation dose to the individual. For the food pathway, one must determine how radionuclides in liquid and air are concentrated in the foods that the public eats.

As an example of the equations in Regulatory Guide 1.109, the equation for the dose from consumption of aquatic food is presented in somewhat simplified form below.

$$Ri = 1{,}100\ UM/F \sum Q_i B_i D_i \exp(-\lambda_i t)$$

where:

Ri	=	The annual dose to an organ of an individual in mrem/yr
U	=	A usage factor that specifies the exposure time or intake rate in, hr/yr, L/yr, or kg/yr
M	=	The mixing ratio at the point of exposure (or point of harvest of aquatic food). It is dimensionless
F	=	The flow rate of the liquid effluent in ft^3/sec
Q_i	=	The release rate of nuclide I, in Ci/yr
B_i	=	The equilibrium bio-accumulation factor expressed as the ratio of the concentration in biota (pCi/kg) to the concentration in water (pCi/L) in L/kg
D_i	=	The factor that converts intake of a radionuclide to a dose expressed as a ratio of the dose rate (mrem/hr) and the areal radionuclide concentration (pCi/m^2)
λ_i	=	The radioactive decay constant in hr^{-1}
t	=	The average transit time required for the nuclide to reach the point of exposure, in hrs
1,100	=	A factor to convert from (Ci/yr)/(ft^3/sec) to pCi/L
I	=	A radionuclide.

Additional detail and values for many of the above terms can be obtained from tables in Regulatory Guide 1.109. The factor M, which is related to aquatic dispersion, can be calculated using Regulatory Guide 1.113. The factors vary depending on the age of the recipient and the organ being considered.

Table 8.1-1: Example of Control in ODCM

RADIOACTIVE EFFLUENTS

DOSE - IODINE-131, IODINE-133, TRITIUM, AND RADIOACTIVE MATERIALS IN PARTICULATE FORM

CONTROLS

3.11.2.3 In accordance with [plant name] TS 6.8.4.g.5) and 9), the dose to a MEMBER OF THE PUBLIC from Iodine-131, Iodine-133, tritium, and all radionuclides in particulate form with half-lives greater than 8 days in gaseous effluents released from each unit to areas at and beyond the SITE BOUNDARY shall be limited to the following:

a. During any calendar quarter: Less than or equal to 7.5 mrem to any organ.

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

APPLICABILITY: At all times.

ACTION:

a. With the calculated dose from the release of Iodine-131, Iodine-133, tritium, and radionuclides in particulate form with half-lives greater than 8 days, in gaseous effluents exceeding any of the above limits, prepare and submit to the Commission within 30 days, pursuant to Control 6.9.2, a Special Report that identifies the cause(s) for exceeding the limit(s) and defines the corrective actions that have been taken to reduce the releases and the proposed corrective actions to be taken to assure that subsequent releases will be in compliance with the above limits.

b. The provisions of Controls 3.0.3 and 3.0.4 are not applicable.

SURVEILLANCE REQUIREMENTS

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

Table 8.2-1: Radiological Effluent Controls

Parameter	Control	Action
Radioactive Liquid Effluent Monitoring Instrumentation	Be operable and reading within setpoint value.	Stop release of effluent or perform sampling.
Radioactive Gaseous Effluent Monitoring Instrumentation	Be operable and reading within setpoint value.	Stop release of effluent or perform sampling.
Liquid Effluent Concentration	Release to unrestricted areas be less than 10 CFR 20, Appendix B, except for noble gases, which shall be <2 x 10^{-4} μ Ci/mL. If approved: Release to unrestricted areas to be less than 10 times the concentration values in Appendix B, Table 2, Column 2 to 10 CFR 20.1001-2402, except for noble gases which shall be < 2 x 10^{-4} μ Ci/mL.	Immediately restore concentration to within limits.
Limit Effluent Dose	Dose to public <1.5 mrem to whole body and 5 mrem to any organ per quarter, and <3 mrem to whole body and 10 mrem to any organ per year.	Take corrective action and report to NRC within 30 days.
Liquid Radwaste Treatment System	Be operable and dose to unrestricted area <0.06 mrem to whole body and 0.2 mrem to any organ per month.	Take corrective action and report to NRC within 30 days.
Gaseous Effluent Dose Rate	Dose at site boundary for noble gases <500 mrem/yr to the whole body and 3,000 mrem/yr to skin and for Iodine-131, Iodine-133, tritium, and particulate radionuclides with half-life greater than 8 days, dose <1,500 mrem/yr to any organ.	Immediately restore release rate within limits.
Gaseous Effluent Noble Gas Dose	Dose at site boundary <5 mrad gamma and 10 mrad beta per quarter and 10 mrad gamma and 20 mrad beta per year.	Take corrective action and report to NRC within 30 days.
Gaseous Effluent I-131, I-133, Tritium, Particulate Radionuclides	Dose at site boundary <7.5 mrem to any organ per quarter and 15 mrem to any organ per year.	Take corrective action and report to NRC within 30 days.
Gaseous Radwaste Treatment System (BWR)	Be operable when main condenser air ejector system is in operation.	Take corrective action and report to NRC within 30 days.
Ventilation Exhaust Treatment System (BWR Only)	Be operable and dose at site boundary <0.2 mrad gamma, or 0.4 mrad beta, or 0.3 mrem to any organ of public per month.	Take corrective action and report to NRC within 30 days.
Mark I or II Containment (BWR Only)	Venting of drywell shall be through Standby Gas Treatment System.	Suspend all venting.
Total Dose	Annual dose to public from uranium fuel cycle sources <25 mrem to whole body or any organ except thyroid which shall be <75 mrem.	Total dose calculations are done only if other control doses are exceeded by factor of 2. In that case, prepare report to NRC within 30 days.

Table 8.2-2: Regulatory Guide 1.109 Calculation Methods

Doses from Liquid Effluent Pathways

- Potable Water
- Aquatic Foods
- Shoreline Deposits
- Irrigated Foods

Gamma and Beta Doses from Noble Gases Discharged to the Atmosphere

- Annual Gamma Air Dose from Noble Gas Releases from Free-Standing Stacks More than 80 Meters High
- Annual Gamma Air Dose from All Other Gas Releases; Annual Beta Air Dose from All Noble Gas Releases
- Annual Total Body Dose from Noble Gas Releases from Free-Standing Stacks More than 80 Meters High
- Annual Skin Dose from Noble Gas Releases from Free-Standing Stacks More than 80 Meters High
- Annual Total Body Dose from All Other Noble Gas Releases
- Annual Skin Dose from All Other Noble Gas Releases

Doses from Radioiodine and Other Radionuclides Released to the Atmosphere

- Annual Organ Dose from External Irradiation from Radionuclides Deposited onto the Ground Surface
- Annual Organ Dose from Inhalation of Radionuclides in Air
- Annual Organ Dose from Ingestion of Atmospherically Released Radionuclides in Food

Integrated Doses to the Population

Table 8.3-1: Exposure Pathways

Radionuclide	Discharge Mode	Principal Exposure Pathways	Critical Organ
Radioiodine	Airborne	Ground deposition - external irradiation	Whole body
		Air inhalation	Thyroid gland
		Grass-cow-milk	Thyroid gland
		Leafy vegetables	Thyroid gland
	Water	Drinking water	Thyroid gland
		Fish consumption	Thyroid gland
		Shellfish	Thyroid gland
Tritium	Airborne	Air inhalation and transpiration	Whole body
		Submersion	Skin
		Drinking water	Whole body
	Water	Food consumption	Whole body
Noble gases	Airborne	External irradiation	Whole body and skin
Cesium	Airborne	Ground deposition - external irradiation	Whole body
		Grass-cow-milk	Whole body
		Grass-meat	Whole body
		Inhalation	Whole body
	Water		
		Sediments - external irradiation	Whole body
		Drink water	Whole body
		Fish consumption	Whole body
Transition metals: (Fe, Co, Ni, Zn, Mn)	Water	Drinking water	G.I. tract
		Shellfish consumption	G.I. tract
		Fish consumption	G.I. tract
Direct radiation		External irradiation	Whole body

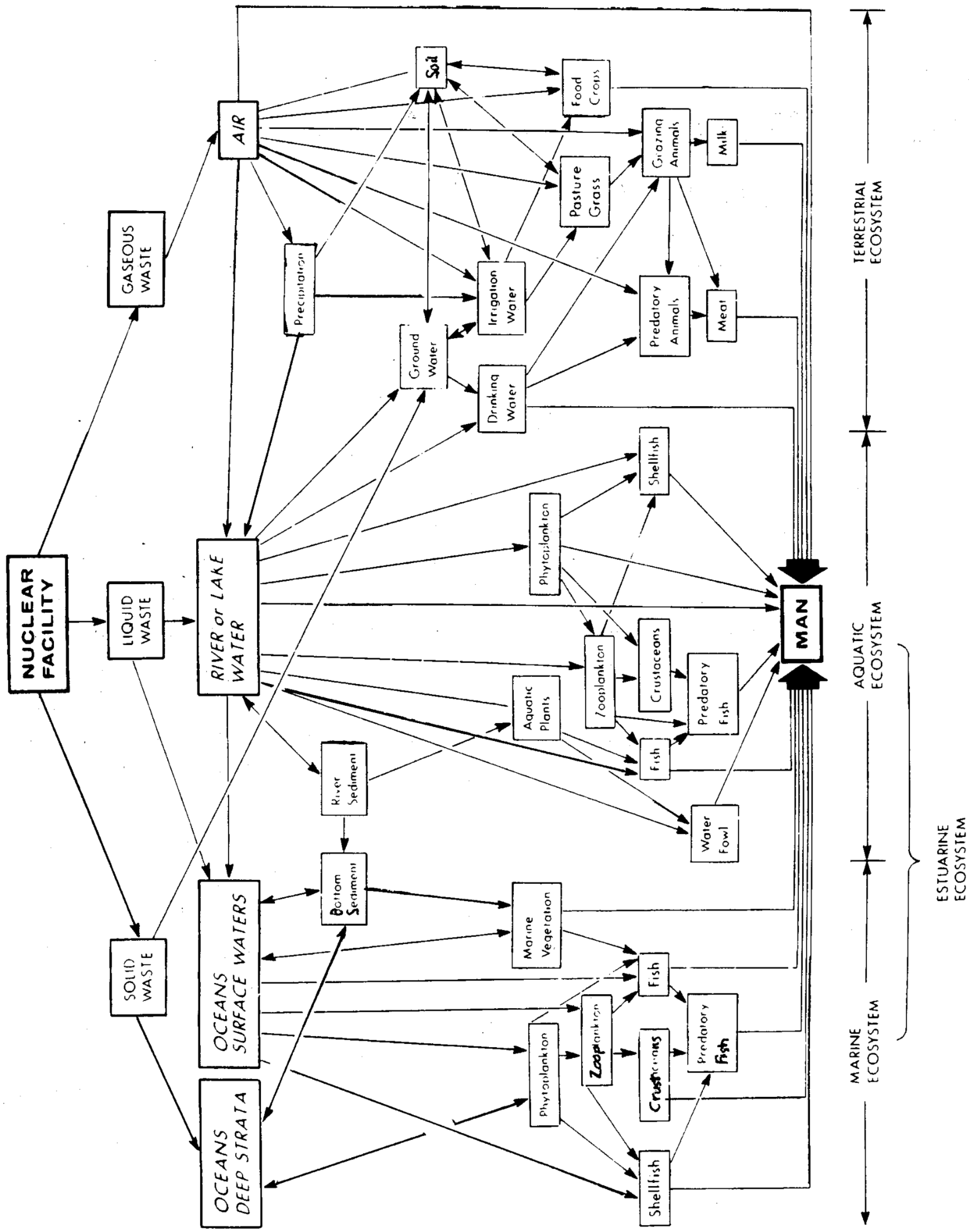

Figure 8.3-1 Exposure Pathways

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Chapter 8
Attachments

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