NUS-3696

CONTROL ROOM HABITABILITY EVALUATION

H. B. ROBINSON STEAM ELECTRIC GENERATING PLANT

(NRC TMI ACTION PLAN ITEM III.D.3.4)

Prepared for

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1.0 PREFACE AND SUMMARY

In the past year, the U.S. Nuclear Regulatory Commission (NRC) developed a comprehensive list of new requirements based on the recommendations of the many studies of the accident at Three Mile Island (TMI) Unit 2. This list was formally released in May 1980 as NRC's TMI Action Plan (NUREG-0660). By letter dated May 7, 1980, Darrell G. Eisenhut of the NRC directed all operating reactor licensees to address five items identified by the NRC as being applicable to operating reactors. One of these was Item III.D.3.4, "Control Room Habitability."

In requiring licensees to address Item III.D.3.4, the NRC sought "to assure that workers (plant operators) are adequately protected from radioactivity, radiation, and other hazards, and that the control room can be used in the event of an emergency." The NRC required that all facilities that have not been reviewed for conformance to current NRC requirements be evaluated against these requirements by January 1, 1981.

Most of these requirements have been promulgated since 1975 and any plants licensed after the promulgation of these requirements have generally had to conform to them or to justify nonconformance to them. Plants licensed before the promulgation of these requirements, such as H. B. Robinson Unit 2, have generally not had to address conformance or to justify nonconformance.

"Current requirements" identified by the NRC in Action Plan Item III.D.3.4 include:

- Standard Review Plan Sections 2.2.1 and 2.2.2, "Identification of Potential Hazards in Site Vicinity"
- Standard Review Plan Section 2.2.3, "Evaluation of Potential Accidents"

- Standard Review Plan Section 6.4, "Habitability Systems"

The NRC also stated that the following guides could be used in performing this evaluation:

- Regulatory Guide 1.78, "Assumptions for Evaluating the Habitability of a Nuclear Power Plant Control Room During a Postulated Hazardous Chemical Release"

- Regulatory Guide 1.95, "Protection of Nuclear Power Plant Control Room Operators Against an Accidental Chlorine Release"

- K. G. Murphy and K. M. Campe, "Nuclear Power Plant Control Room Ventilation System Design for Meeting General Design Criterion 19," 13th Atomic Energy Commission Air Cleaning Conference, August 1974

The NRC's position on this study has been clarified by NUREG-0737, issued October 31, 1980. These clarifications emphasize the NRC's interest in assuring control room habitability under accident conditions and in identifying and correcting potential weaknesses in the design of older control room habitability systems.

From the description of Action Plan Item III.D.3.4 and Eisenhut's letter, it was determined that this study should focus on two objectives:

1. Assessment of the present condition of the habitability equipment installed in the plant

2. Evaluation of the control room operator exposures under the present condition of the habitability systems

To accomplish the first objective, the installed equipment was inspected and the plant design features and layout were examined. The mechanical equipment and plant design were compared with the criteria specified by the NRC. The extent of the mechanical design review is described in Section 4.0. The point-by-point comparison of the current plant design with the NRC criteria is given in Appendix A of this report.

The second objective was accomplished by conducting radiological and toxic chemical habitability analyses. In preparation for these analyses, a considerable amount of plant design, systems operation, and maintenance information was reviewed. Sources of information useful to this study included the following:

- Plant personnel
- Personal observations
- Plant drawings
- Final Safety Analysis Report
- Plant modification descriptions
- Plant system descriptions
- Operating procedures
- Periodic test procedures
- Preoperational test procedures
- Technical specifications
- Environmental Report
- Environmental Impact Statement

In addition, an extensive survey of the plant environs was conducted to identify potential sources of toxic chemical hazards within the prescribed 5-mile radius of the plant. The scope and results of the survey are described in Section 2.0 of this report.

From these sources, the assumptions shown in Section 5.0 for the radiological analysis and in Section 6.0 for the toxic chemical analysis were developed. The site meteorological analysis for

estimation of dispersion factors is presented in Section 3.0. The results obtained in the radiological analysis are presented in Section 5.0 of this report (the methods used in the radiological analysis are described in Appendix E of this report) and show that the operator doses are not within NRC General Design Criterion 19 when evaluated using conservative NRC assumptions. The methods used in the toxic chemical analysis are described in Section 6.0 of this report and conform to Regulatory Guides 1.78 and 1.95.

Appendix B presents specific information requested by the NRC in the clarification letter.

2.0 SURVEY OF POTENTIALLY HAZARDOUS MATERIALS

In accordance with the directions in Eisenhut's letter of May 7, 1980, a survey of the Robinson site vicinity was conducted to identify locations of chemicals stored or transported within 5 miles of the plant, which, if accidentally released, might present a hazard to control room operators. The focus of the survey was the determination of locations, quantities, transportation, storage, and use of the toxic chemicals listed in the Appendix of NUREG-0570 (Ref. 1). The survey was conducted for an area within approximately an 8-mile radius of the plant, to ensure identification of potential hazards adjacent to the 5-mile radius of the required study area.

General characteristics and significant features of the Robinson site are described in the Robinson Final Safety Analysis Report (FSAR). The study area is a relatively uniform plain about 85 miles northeast of Columbia, South Carolina, and 75 miles southeast of Charlotte, North Carolina. As shown in Figure 2-1, the study area includes the city of Hartsville, South Carolina, and its adjoining built-up areas as well as rural portions of Darlington and Chesterfield counties. U.S. Route 15 (US 15) and South Carolina Route 151 (SC 151) are the principal highways serving the area; the Seaboard Coast Line Railroad is the principal rail line.

The site study began by initial telephone and reconnaissance contacts with local business, industry, and governmental representatives to identify potential chemical users and key contacts. These discussions were followed by a field survey and by personal interviews with the key contacts. Field observations and initial contacts led to secondary contacts and clarifications of information found in maps and other published references. Federal and State governmental agencies were contacted to determine whether

they had jurisdiction over or information on hazardous chemicals; these agencies were expected to be the primary sources of information on the transportation of hazardous chemicals. The Family Lines Railroad (Seaboard Coast Line) was contacted directly.

Table 2-1 shows the principal contacts that corroborated other sources or provided information on nonstationary hazards in the vicinity of the Robinson plant.

2.1 Key Sources Identified

The key sources surveyed and pertinent data on hazardous chemicals identified in this study are listed in Table 2-2, and these data are presented graphically in Figure 2-1. Important points about these sources are amplified below. It can be noted from the figure that all of these fixed facilities are located beyond the 5-mile radius of the required study area.

a. Sonoco Products. All chemical storage tanks at Sonoco Products are located within confinement areas that would hold the full capacity of the respective tanks. These tanks are seldom, if ever, completely filled. The formaldehyde and sulfuric acid are both used in processing circulation systems, which accounts for their variable storage distributions. Two tank cars of formaldehyde, three to four tank cars of sulfuric acid, and one tank car of phenol are shipped to the company each month. Acetic acid is manufactured and shipped in drums by truck and rail from the plant.

b. International Minerals & Chemical Corporation (IMC). The chemicals at IMC are used directly from the rail tank cars. No spill confinement provisions exist for the anhydrous ammonia or nitrogen. A one-quarter-acre holding pond is provided for the sulfuric acid. The

IMC receives approximately one railcar load of each chemical per working day.

c. Hartsville Mill. According to information on file with the South Carolina Department of Health and Environmental Control, the Hartsville Mill stores trichloroethylene.

d. Hartsville Oil Mill. Several sources in Hartsville suggested that the Hartsville Oil Mill may use or store nitric acid and other hazardous chemicals. To date, no confirmation or additional information has been obtained from the Hartsville Oil Mill.

e. Hartsville Public Works. Water wells of the Hartsville Public Works Department are scattered throughout Darlington County. Small chlorine cylinders, typically two 150-pound tanks, are located at each well; these wells are at least 1 mile from the plant.

2.2 Additional Information Being Sought

Additional information has been requested from several sources to quantify the potential for truck accidents on US 15, US Alternate 15, and SC 151. Most truck through-shipments of chemicals move via US 15 and Alternate 15, which are 4.9 miles from the Robinson plant at their closest approach. SC 151 is used for some shipments; it passes within 0.4 mile of the plant. Discussions with the local police and fire officials indicated that there had been no hazardous chemical incidents on local highways and rail lines in the last 5 years. Additional information on rail shipments has been requested from the Seaboard Coast Line Railroad. According to information already obtained from Seaboard, no rail shipments of chemicals pass the Hartsville plant; they are moved along the line to Florence, South Carolina, approximately 25 miles southeast of Hartsville (the Robinson plant is northwest of Hartsville).

The toxic chemical analysis in Section 6.0 of this report provides a bounding analysis of toxic chemical release on SC 151 at its point of closest approach to the plant.

2.3 Reference

1. U.S. Nuclear Regulatory Commission. 1979. NUREG-0570, "Toxic Vapor Concentrations in the Control Room Following a Postulated Accidental Release."

TABLE 2-1

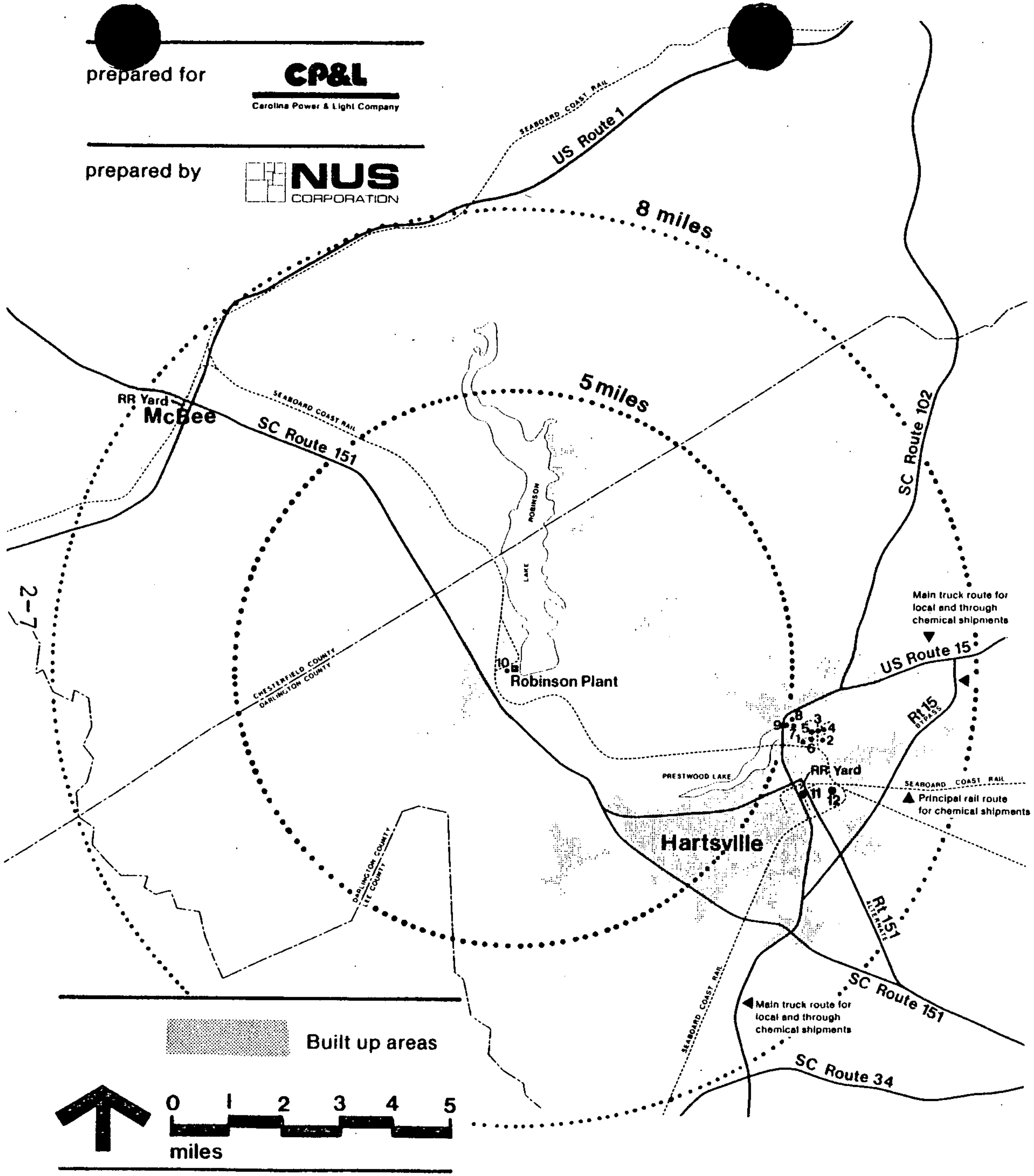
HAZARDOUS CHEMICAL INFORMATIONAL CONTACTS

Contact	Location	Information Type
National Highway Traffic Safety Administration	Washington, DC	Hazardous shipments
Federal Highway Administration	Washington, DC	Hazardous shipments, accident incidents
Federal Railroad Administration	Washington, DC	Rail shipments
U.S. Environmental Protection Agency	Washington, DC	Toxic substance monitoring
South Carolina Department of Health & Environmental Control	Columbia, SC	Hazardous chemical monitoring
South Carolina Department of Transportation	Columbia, SC	Hazardous shipments
South Carolina Public Service Commission	Columbia, SC	Licensing and permit-issuing
Hartsville Police Department	Hartsville, SC	Incidents, emergency plans, general background
Hartsville Fire Department	Hartsville, SC	Incidents, emergency plans, general background
Darlington County Sheriff	Darlington, SC	Incidents, emergency plans, general background
Coker Seed Company	Hartsville, SC	Use of hazardous chemicals
Seaboard Coast Line Railroad	Florence, SC Jacksonville, FL	Rail shipments

TABLE 2-2

HAZARDOUS CHEMICAL FACILITIES SURVEY

		Storage Characteristics				
Company/Facility	Chemical	Type	Number of Units	Quantity/ Unit	Inside/ Outside	Distance from Plant (mi)
Sonoco Products	Propane	Tank	2	1K gal.	Outside	5.1
	Sulfuric acid	Tank	2	12.5K gal.	90% inside	5.3
	Phenol	Tank	2	5K gal.	Outside	5.4
	Acetic acid	Tank	1	10K gal.	Outside	5.4
	Formaldehyde	Tank	1	40K gal.	75% outside	5.3
	Chlorine	Cylinder	1	1K gal.	Outside	5.3
International Minerals & Chemical Corporation	Anhydrous ammonia	Tank car	1	80 tons	Outside	5.0
	Nitrogen	Tank car	1	46-92 tons	Outside	5.0
	Sulfuric acid	Tank car	1	600-1000 tons	Outside	5.0
Hartsville Mill	Trichloroethylene	Drum		55 gal.-2440 lb total		5.3
Hartsville Oil Mill	See text					5.7
Hartsville Public Works	Chlorine	Cylinder	8	150 lb	2 cylinders/ well	None within 1 mile of plant
Robinson Steam Electric Plant	Miscellaneous laboratory chemicals--see text					Onsite



Hazardous Chemical Storage Locations Near Robinson Steam Electric Generating Plant

SONOCO PRODUCTS

Symbol	Units	Quantity/Unit	Storage	Chemical
●1	2	10K gallons	tank	propane
●2	2	25K gallons	tank	sulfuric acid
●3	1	10K gallons	tank	phenol
●4	1	10K gallons	tank	acetic acid
●5	1	40K gallons	tank	formaldehyde
●6	multiple/ scattered	<1 K gallons	tank	chlorine

INTERNATIONAL MINERALS & CHEMICAL CORP.

Symbol	Units	Quantity/Unit	Storage	Chemical
●7	1	80 tons	tank	anhydrous ammonia
●8	1-2	46-92 tons	tank	nitrogen
●9	1	60-100 tons	tank	sulfuric acid

ROBINSON STEAM ELECTRIC PLANT

Symbol	Units	Quantity/Unit	Storage	Chemical
●10	multiple	varies	case	miscellaneous laboratory chemicals (see text)

HARTSVILLE MILL

Symbol	Units	Quantity/Unit	Storage	Chemical
●11	see notes below		drums	trichloroethylene

Note: Number of units unknown; total quantity 2440 pounds in 55-gallon drums.

HARTSVILLE OIL MILL (see text)

Symbol	Units	Quantity/Unit	Storage	Chemical
●12	–	–	–	–

HARTSVILLE PUBLIC WORKS DEPARTMENT

Symbol	Units	Quantity/Unit	Storage	Chemical
See below	4 water wells	2-150 pound cylinders/well	cylinders	chlorine

Note: these locations are scattered within a 5-mile radius of plant

Figure 2-1. Lake Robinson-McBee-Hartsville Area, South Carolina

3.0 ATMOSPHERIC DISPERSION ANALYSES

Atmospheric dispersion estimates were calculated for both the radiological release and toxic chemical release analyses for the control room habitability assessment. Calculations were made of relative concentrations (X/Q values) at the control room air intake based on appropriate conservative models and methodology selected for the particular release-point characteristics and dose assessment methodology. Values of X/Q were computed considering the following NRC guidelines:

- Regulatory Guide 1.145, "Atmospheric Dispersion Models for Potential Accident Consequence Assessments at Nuclear Power Plants"
- Regulatory Guide 1.78, "Assumptions for Evaluating the Habitability of a Nuclear Power Plant Control Room During a Postulated Hazardous Chemical Release"
- Standard Review Plan 6.4, "Habitability Systems"
- NUREG/CR-1152, "Recommended Methods for Estimating Atmospheric Concentrations of Hazardous Vapors After Accidental Release near Nuclear Reactor Sites"
- NUREG-0570, "Toxic Vapor Concentrations in the Control Room Following a Postulated Accidental Release"
- NUREG/CR-1394, "Diffusion near Buildings as Determined from Atmospheric Tracer Experiments"
- "Nuclear Power Plant Control Room Ventilation System Design for Meeting General Criterion 19," Murphy and Campe, 13th Atomic Energy Commission Air Cleaning Conference

Radiological releases from the containment were analyzed based on considerations of building geometries and onsite wind flows. Figure 4-2 shows the relative locations of the potential release points and the intake.

The dispersion analyses for the toxic chemical assessment are based on offsite releases transported toward the plant. The X/Q values were calculated at various distances and equivalent wind speeds were calculated for a determination of effluent travel times.

The methodology and meteorological data used to calculate the X/Q values are discussed in the following sections.

3.1 Calculations - Radiological Releases

The X/Q values for radiological releases from the containment were calculated based on procedures outlined in References 1, 2, and 3. These releases were assumed to be from a diffuse source (i.e., activity leaking from many points on the surface of the containment) with a point receptor (a single intake). The X/Q values were calculated for time periods of 0 to 8 hours, 8 to 24 hours, 1 to 4 days, and 4 to 30 days (Ref. 3).

For the 0- to 8-hour calculation, results of recent analysis of diffusion tests near buildings were used (Ref. 2). The results of these tests have shown that for most meteorological combinations of atmospheric stability and wind speed, the model and methodology provided in Reference 1 overestimate the concentration, usually by one to two orders of magnitude. Because of this large overestimation of the NRC model, the 0- to 8-hour X/Q value was calculated based on the recommendations of Reference 2. The studies provided in the reference were conducted at two dissimilar sites with containment areas differing by nearly a factor of two.

Consistency between the two sets of measured concentrations was obtained by scaling the plume path length by the square root of the minimum cross-sectional area of the containment, as long as this scaled distance was less than 1.0. Using this approach and Figure 9 of Reference 2, a 1-hour X/Q value (conservatively assumed to apply for 0 to 8 hours) for Robinson can also be calculated. The assumptions for this determination are outlined below.

<u>Robinson Containment</u>

Containment cross-sectional area	= 2274 m^2
Minimum distance to intake	= 35 m
Scaled distance	= 0.73
X/Q from Figure 9	= 2.0×10^{-3} sec/m^3

X/Q values for the remaining time periods (8 to 24 hours, 1 to 4 days, and 4 to 30 days) were calculated using the methodology in Reference 1. Analysis of the plant building configuration indicates that five wind sectors could affect the intake for releases from the containment. Winds from the west through north were used in the analysis. Data from these wind sectors were then used to obtain the necessary wind speed and direction factors.

These factors are

s/d ratio	= 0.84
Wind sectors	= W, WNW, NW, NNW, N
Wind speeds (10 m)	
5 percent	= 0.40 m/s
10 percent	= 0.57 m/s
20 percent	= 0.88 m/s
40 percent	= 1.50 m/s
Wind direction frequency	= 27.77 percent

Factors used to adjust the X/Q values are provided in Table 3-1; the X/Q values are provided in Table 3-2. The meteorological data used in the calculations are discussed in Section 3.3.

3.2 Calculations - Toxic Chemical Releases

The X/Q values were calculated to support the toxic chemical analysis discussed in Section 6.0. These X/Q calculatons produced continuous release (1 hour), direction-independent X/Q values (shown in Table 3-3) at a series of distances out to 5 miles from the plant. The calculations used Equation 1 of Regulatory Guide 1.145 (Ref. 4), without the building wake credit or plume meander. From these calculated values of X/Q, the corresponding wind speed was calculated (based on a representative atmospheric stability class of extremely stable, G) for use in the atmospheric dispersion analysis discussed in Section 6.0.

3.3 Meteorological Data

Meteorological data for the atmospheric dispersion analyses were collected at the site during the 4-year period January 1, 1976, through December 31, 1979. The data used for each analysis are listed below.

Analysis	Atmospheric Stability	Wind Speed/ Wind Direction	Combined Data Recovery (%)
Radiological releases, containment	N/A	11-m level (wind speeds converted to 10 m)	99
Toxic chemical releases	$\Delta T_{62-11\ m}$	11-m level (wind speeds converted to 10 m)	99

The joint frequency distributions of wind speed and wind direction, by atmospheric stability class, are provided in Appendix C. A brief description of the onsite meteorological system is provided in Appendix D.

3.4 References

1. K. G. Murphy and K. M. Campe. 1974. "Nuclear Power Plant Control Room Ventilation System Design for Meeting General Criterion 19." 13th Atomic Energy Commission Air Cleaning Conference.

2. J. F. Sagendorf, N. R. Ricks, G. E. Start, and C. R. Dickson. 1980. Diffusion near Buildings as Determined from Atmospheric Tracer Experiments. Technical Memorandum ERL ARL-84, National Oceanic and Atmospheric Administration.

3. U.S. Nuclear Regulatory Commission. Standard Review Plan, NUREG-75/087, Section 6.4, "Habitability Systems."

4. U.S. Nuclear Regulatory Commission. Regulatory Guide 1.145, "Atmospheric Dispersion Models for Potential Accident Consequence Assessments at Nuclear Power Plants."

TABLE 3-1

ADJUSTMENT FACTORS USED TO CALCULATE EFFECTIVE RELATIVE CONCENTRATIONS FOR SELECTED TIME INTERVALS, ROBINSON

Adjustment Factor	Time Interval			
	0-8 Hr	8-24 Hr	1-4 Days	4-30 Days
Wind speed	1.0	0.69	0.45	0.26
Wind direction	1.0	0.82	0.64	0.28
Occupancy	1.0	1.0	0.60	0.40
Overall reduction[a]	1.0	0.57	0.17	0.029

[a]The overall reduction factor is defined as the products of the wind speed factor times the wind direction factor times the occupancy factor.

TABLE 3-2

CALCULATED X/Q VALUES AT THE CONTROL ROOM INTAKE FOR RADIOLOGICAL RELEASES FROM THE ROBINSON CONTAINMENT[a] (includes occupancy factor)

Time Period	X/Q (sec/m^3)
0-8 hours	2.0×10^{-3}
8-24 hours	1.1×10^{-3}
1-4 days	3.4×10^{-4}
4-30 days	5.8×10^{-5}

[a]These X/Q values were calculated for use in the control room habitability analysis and are not intended for other applications.

TABLE 3-3

ONE HOUR X/Q VALUES FOR THE TOXIC CHEMICAL ANALYSIS AT ROBINSON[a] (1976-1979 onsite data, Robinson, 11-m winds, $\Delta T_{62-11\ m}$, no meander, no building wake, no initial plume volume, 5% direction-independent)

Distance (m)	X/Q (sec/m^3) Robinson
100	7.5×10^{-2}
500	4.9×10^{-3}
1000	1.6×10^{-3}
1500	8.2×10^{-4}
2000	5.3×10^{-4}
2500	3.9×10^{-4}
3000	3.0×10^{-4}
4000	2.0×10^{-4}
5000	1.5×10^{-4}
6000	[b]1.2×10^{-4}
7000	[b]9.9×10^{-5}
8045 (5 miles)	[b]8.3×10^{-5}

[a]These X/Q values were calculated for use in the control room habitability analysis and are not intended for other applications.

[b]Maximum sector-dependent X/Q value greater (Regulatory Guide 1.145 0.5%) than indicated.

4.0 SUMMARY OF HEATING, VENTILATING, AND AIR-CONDITIONING (HVAC) DESIGN AND DESIGN REVIEW

4.1 System Description

The H. B. Robinson control room ventilation system is a once-through, push-pull design. Figure 4-1 shows the system arrangement and flows; Figure 4-2 shows the plant arrangement and control room location. A 100 percent capacity 5000 cubic feet per minute (cfm) air-conditioning unit (HVA-1) (location E-9, Figure 4-1) with direct expansion cooling coil and steam heating coil provides cooling and heating and a 100 percent capacity filter train and fan (HVE-19) (C-7, Figure 4-1) serve to reduce the concentration of airborne radionuclides. A low-pressure sheet-metal ductwork air distribution supply system and return air system are routed through the cable room no. 1 and up through a duct chase to the control room. The fresh air inlet (C-5, Figure 4-1) provides 600 cfm of fresh air and is dampered to provide isolation from the outside. The 600-cfm fresh air supply balances the 600 cfm that is normally exhausted outdoors by fan HVE-16 (G-2, Figure 4-1) from the toilet, kitchen, and storage closet located in the control room.

The refrigerant for cooling in the direct expansion cooling coil of the air-conditioning unit is condensed in two 100 percent capacity air-cooled condensers (ACC-1A and ACC-1B) (C-11, Figure 4-1) located on plant grade, beneath the turbine operating deck.

4.2 System Operation

The system relies on pneumatic controls and automatically enters the emergency mode of operation upon detection of high radiation in the control room. Under normal operation, air-conditioning unit HVA-1 is started manually and a solenoid valve is energized to provide instrument air to the automatic pneumatic controls.

A pneumatic room thermostat set at 75°F energizes ACC-1A and ACC-1B through two P-E switches set at 0-4 and 0-6 pounds per square inch gauge (psig), respectively, to provide the necessary cooling. When the room temperature drops below 75°F, the thermostat increases the control pressure, shutting down the condensers. The steam valve (F-7, Figure 4-1), closed at 8 psig, is fully opened at 13 psig to provide heating.

Exhaust fans HVE-16 (G-3, Figure 4-1) and HVE-19 are interlocked with fan HVA-1. Exhaust fan HVE-16 is started with the air-conditioning unit HVA-1. Recirculation fan HVE-19 is started on an isolation signal from the radiation monitor R-1 (B-6, Figure 4-1) in the control room, or by the selector switch on the control room panel.

The selector switch on the reactor turbine generator board allows control room personnel to select flow through the various components as follows:

Mode	Outside Air Intake Damper	Exhaust Fan HVE-16	Bypass Damper	Filter Dampers	Fan HVE-19
Normal ventilation	Open	On	Open	Closed	Off
Emergency ventilation	Open	On	Closed	Open	On
Normal recirculation	Closed	Off	Open	Closed	Off
Emergency recirculation	Closed	Off	Closed	Open	On

An air flow switch in the discharge of fan HVE-19 annunciates on low flow and sounds an alarm in the control room.

A Pitot tube, sensing velocity pressure and located in the inlet duct to the filters, modulates the pneumatic operation of the filter damper to maintain constant flow through a differential pressure controller.

When fan HVE-16 is energized, the fan discharge damper is opened by means of a pneumatic operator.

4.3 Design Review

The control room ventilation system and auxiliary building areas adjacent to the control room were reviewed to assess the level of protection provided control room occupants during a postulated design basis radiological release or toxic chemical release. This assessment was performed by comparing the plant design with the guidance provided in Standard Review Plan 6.4 and field inspections. The results are summarized below:

a. The zone serviced by the control room ventilation system contains all critical areas requiring access, such as the control room, kitchen, sanitary facility, and storage area. Those areas not requiring access are excluded from the zone by means of closed doors.

b. The capacity of the control room in terms of the number of people it can accommodate for any extended period of time was reviewed. The control room does not have on hand a supply of emergency food, cots, blankets, or breathing air supplies for all expected occupants. The number of occupants during emergency conditions is related to the requirements of the site emergency plans. Carbon dioxide buildup should not limit occupancy during isolation because the infiltration rate of the control room is high. The control room could be isolated indefinitely by closing doors and dampers, without the buildup of excessive carbon dioxide. Leakage through dampers, ductwork,

electrical penetrations, and outside doors should provide adequate fresh air.

c. The control room ventilation system layout and functional design were reviewed to determine flow rates and filter efficiencies. The control room system design air flow is 5000 cfm. During isolation the calculated infiltration rate is 950 cfm, based on ASHRAE 79 Equipment, Chapter 1, and ASHRAE 77 Fundamentals, Chapter 21. This leakage rate provides 2.83 air volume changes per hour. Additional information is provided in Appendix A.

d. The design flow rate of the filter system was reviewed. The design flow rate of the recirculating system is 5000 cfm and periodic testing has shown that the particulate and iodine removal efficiencies of the filters are above allowable minimums.

e. The layout of the control room and adjacent auxiliary building spaces was reviewed and there are several routes for outside air to enter the control room, including the following:

   1. Direct infiltration through electrical penetrations from the cable rooms below the control room
   2. Leakage through the fresh air inlet damper
   3. Leakage through the outside doors
   4. Leakage through the door from relay room no. 1
   5. Leakage into the control room return air ducts in cable room no. 1 and the HVAC equipment room

f. An analysis of plant shielding was submitted to the NRC in December 1979 in response to NUREG-0578 Item 2.1.6.b. The charcoal filter could become a radiation source following a design basis accident, but it is not located

under the control room and should not be a significant source of radiation to the control room operators.

4.4 Results

Differences between the design of the Robinson control room ventilation system and current NRC criteria set forth in Standard Review Plan 6.4 are detailed in Appendix A. In addition, the following areas were identified as concerns:

a. Data from tests of the Halon system in the cable room suggest there may be substantial leakage from that room into the control room. During inspections of the control room perimeter, an unsealed cutout between the component cooling water surge tank room and the Hagen room was found.

b. The air-cooled condensers, ACC-1A and ACC-1B, are located on-grade, between the Radiation Control & Testing office and the security checkpoint. This location is a high-traffic walkway for workers entering and leaving Unit 2. The condensers are separated by approximately 3 feet, but are not sheltered from passers-by or from potential wind-blown or falling debris.

c. The control room radiation detection is provided by an area monitor located on the wall behind the main control panel. This location is relatively distant from the principal air circulation paths in the control room. A detector on the control room air intake would respond more quickly.

d. Holes were found in the flexible joint downstream of the charcoal adsorbers.

e. There may not be sufficient self-contained breathing apparatuses in the control room and compressed air storage for the control room emergency manning requirements.

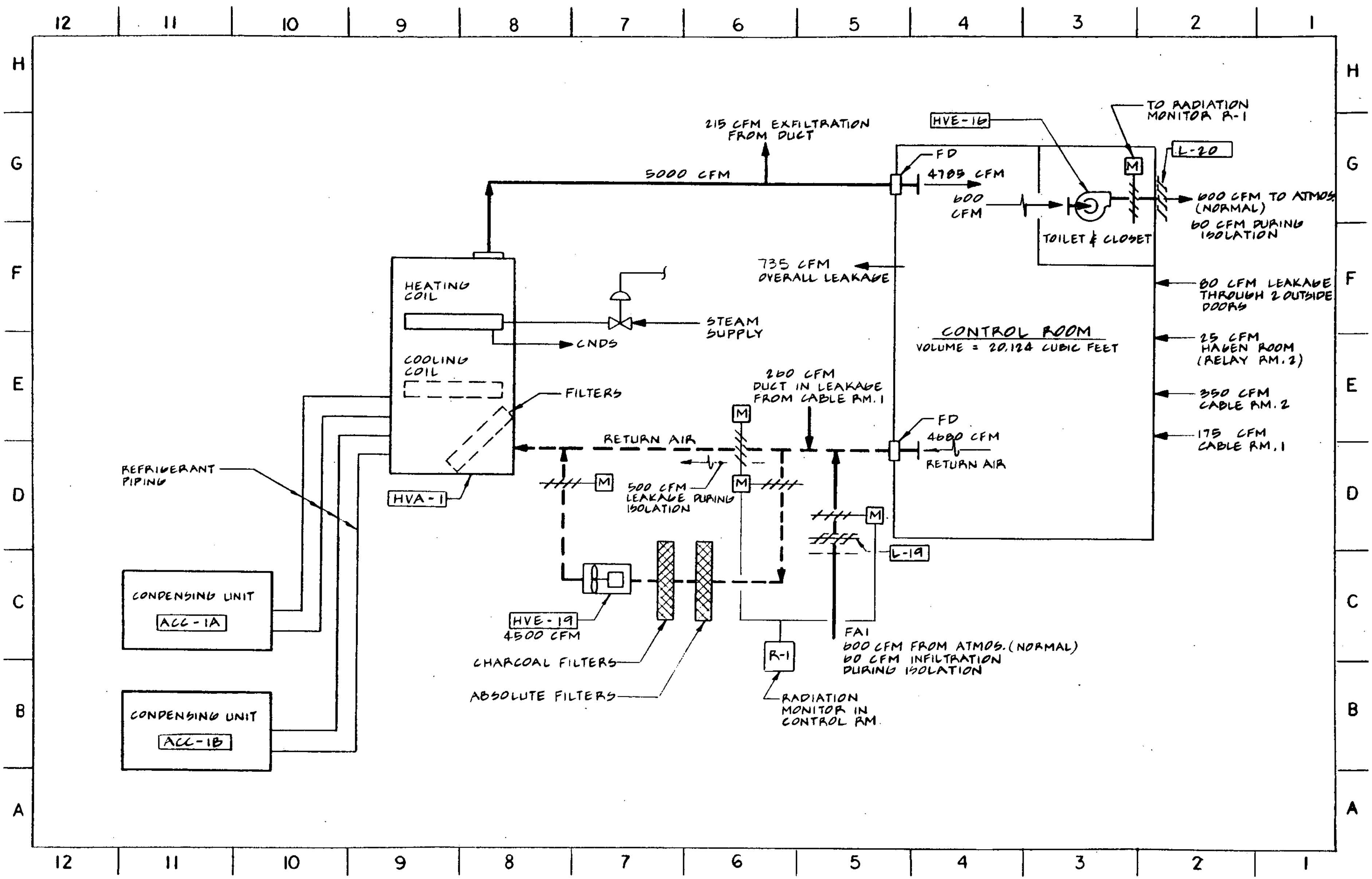


Figure 4-1. Schematic Diagram of the Control Room Ventilation System, H. B. Robinson Unit 2

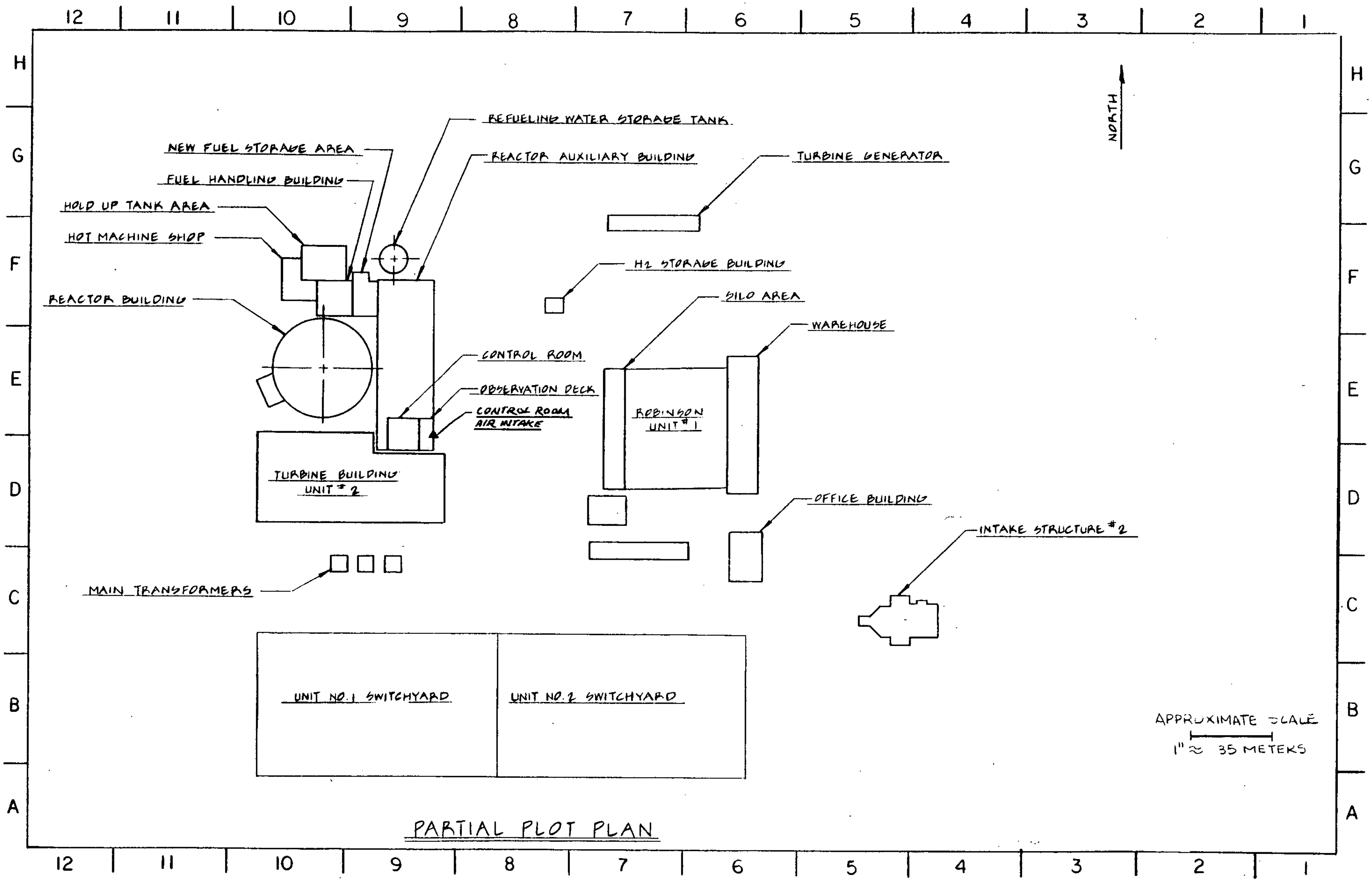


Figure 4-2. Partial Plot Plan, H. B. Robinson Units 1 and 2

5.0 RADIOLOGICAL ANALYSIS

This section summarizes the methods and results of the analysis of control room habitability during postulated radiological accidents at the Robinson plant.

5.1 Methods

The methods used to calculate the beta and gamma whole body dose and the thyroid dose to the control room operators are standard calculational techniques for modeling the generation, release, transport, buildup, and removal of radionuclides. The equations used to model these phenomena are well known, and the specific equations incorporated into the computer program used in this study to calculate the control room operator doses are presented in Appendix E of this report. The analysis of direct radiation from sources outside the control room was submitted to the NRC in December 1979 in response to NUREG-0578 Item 2.1.6.b.

5.2 Assumptions

Assumptions used in the control room dose analysis are described below and in Table 5-1:

- Radionuclides released from the reactor core are uniformly distributed throughout the containment volume.
- The entire free volume of the containment is sprayed.
- The accident duration is 30 days.
- Radionuclides in the control room atmosphere are assumed to be uniformly distributed throughout the control room volume.

- The breathing rate of the control room operators is 3.47×10^{-4} m^3/sec.

- Leakage from emergency core cooling system components outside containment is 165.7 cc/min. The volume of water used in calculating the source strength is 8.14×10^8 cc, approximately the volume of water contained in the refueling water storage tank.

In addition, two assumptions were varied from very conservative NRC values to more reasonable values. For the first case, the containment leak rate was assumed to be 0.1 percent per day for the first 24 hours of the accident and 0.045 percent per day thereafter, as conservatively assumed in the Robinson Unit 2 FSAR. This initial leak rate is greater than the value of containment leak rate given in the Robinson Unit 2 technical specifications, but the minimum allowable in NRC dose calculations. The efficiency of the control room charcoal and HEPA filter was conservatively assumed to be 95 percent removal of elemental and particulate iodine and 90 percent removal of organic iodine. For the second case, the containment leak rate was assumed to be equal to the Robinson technical specification limit of 0.08 percent per day for the first 24 hours of the accident and half of that value (0.04 percent per day) thereafter. In addition, the control room filter efficiency was assumed to be equal to the Robinson Unit 2 technical specification limit of 99 percent removal of elemental and particulate iodine and 90 percent removal of organic iodine. For the third case, the containment leak rate was assumed to be 0.035 percent per day for the duration of the accident. This leak rate is the upper bound 95 percent confidence value measured in the last Robinson Unit 2 containment integrated leak rate test. The control room filter efficiency was assumed to be the same as that of the second case above.

5.3 Results

The radiation dose to individuals within the control room during a postulated design basis accident at the Robinson station is computed using the assumptions above and those presented in Table 5-1 and Appendix E. The meteorological data and HVAC design parameters are based on the information presented in Sections 3.0 and 4.0, respectively.

As indicated in the Robinson FSAR, the maximum calculated dose to an individual within the control room occurs during a postulated design basis loss of coolant accident (LOCA). This is because the magnitude and duration of the radionuclide release during a LOCA is much greater than that for any other accident. (For further discussion, refer to the FSAR.)

The dose to control room personnel from radioactivity buildup within the control room is calculated using the HVAC system model and the data shown in Figure 5-1. This figure shows the possible inleakage paths into the ductwork and into the control room itself.

The 30-day integrated doses to control room operators based on the assumptions given above are shown in Table 5-2. The whole body doses (ranging from 0.6 rem in Case 1 to 0.3 rem in Case 3) and the beta skin doses (ranging from 20 rem in Case 1 to 8 rem in Case 3) are less than the current NRC criteria of 5 rem and 30 rem, respectively. The whole body dose contribution due to sources outside the control room is 0.05 rem (Ref. 1). The thyroid doses (ranging from approximately 320 rem in Case 1 to 140 rem in Case 3) are higher than the current NRC criterion of 30 rem.

During a radiological accident, the control room ventilation system is isolated from the outside air by the closure of the supply

air damper and the exhaust damper. The principal source of exposure during isolation is the calculated inleakage of contaminated outside air, described in Section 4.0 of this report. Calculations of the control room doses as a function of inleakage showed that the inleakage would have to be reduced to approximately 24 cfm to reduce the thyroid dose in a design basis accident (the Case 1 assumptions) to the current NRC criterion of 30 rem. This outside air exchange rate is below that recommended by ASHRAE to assure nonradiological air quality in the relatively small control room at Robinson.

5.4 Reference

1. Ebasco Services Incorporated. 1979. Radiation Shielding Design Review Carolina Power and Light Company, H. B. Robinson Steam Electric Plant, Unit No.2

TABLE 5-1

ASSUMPTIONS IN CONSERVATIVE RADIOLOGICAL ANALYSIS OF THE ROBINSON CONTROL ROOM

Power level = 2350 MWt

Operating time = 1000 days

Containment volume = 2.1×10^6 ft^3

Spray removal rate for elemental iodine = 10 hr^{-1}

Spray removal rate for particulate iodine = 0

Spray removal rate for organic iodine = 0

Containment leak rate = 0.1 percent/day (0-24 hr); 0.045 percent/day (>24 hr)

Control room ventilation system iodine filter efficiencies

Elemental = 95 percent
Organic = 90 percent
Particulate = 95 percent

X/Q values of control room intake

Time	X/Q (sec/m^3)
0-8 hr	2.0×10^{-3}
8-24 hr	1.1×10^{-3}
1-4 days	3.4×10^{-4}
4-30 days	5.8×10^{-5}

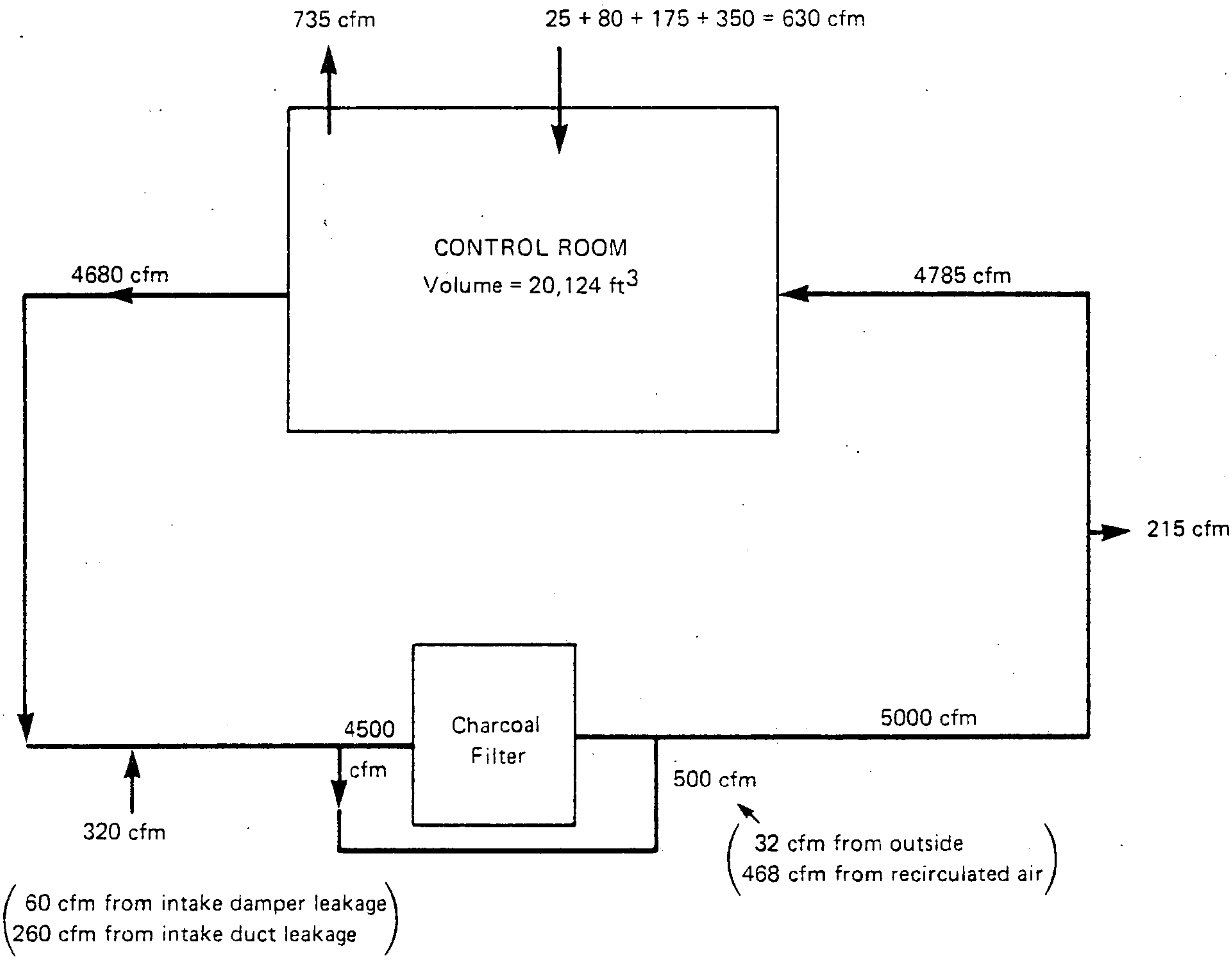
Control room volume = 20,124 ft^3

TABLE 5-2

RESULTS OF RADIOLOGICAL ANALYSIS
OF THE ROBINSON CONTROL ROOM

Organ	Calculated Doses (rem) Case 1 (0.1%/day, 95%/90% efficiency)	Case 2 (0.08%/day, 99%/90% efficiency)	Case 3 (0.035%/day, 99%/90% efficiency)
Whole body	0.6	0.5	0.3
Thyroid			
Due to containment leakage	301	240	129
Due to ECCS[a] leakage outside containment	21	15	15
Total	322	255	144
Beta skin	20	16	8

[a]Emergency core cooling system.



NOTES:

Total leakage from outside that will be unfiltered = 630 + 32
= 662 cfm.

Total leakage from outside that will be filtered = 320 - 32
= 288 cfm.

Total flow that is recirculated through filter = 4680 - 468
= 4212 cfm.

Figure 5-1. Robinson Control Room HVAC Flow Diagram Showing Calculated Flow Rates and Inleakage

6.0 TOXIC CHEMICAL ANALYSIS

6.1 Introduction

This section presents an evaluation of toxic chemicals both on the site and off the site and determines the effect on control room habitability of postulated toxic chemical releases. The buildup of toxic chemical concentrations at the control room air intake and within the control room volume are evaluated. The results are compared to Regulatory Guide 1.78 requirements (Ref. 1) to identify the acceptability or unacceptability of control room habitability with respect to postulated toxic chemical releases.

Table 6-1 summarizes the general input data used in the analysis. Table 6-2 presents the identified offsite chemicals which were the subject of this analysis. No onsite toxic chemicals have been identified, excluding laboratory quantities of a few hazardous chemicals.

In addition, scoping calculations were performed for postulated spills involving shipments of 10,000 gallons of anhydrous ammonia, chlorine, and formaldehyde solution on SC Route 151 near the plant.

6.2 Methods of Analysis

The procedures used first apply the toxic chemical screening methods described in Regulatory Guide 1.78. Table C-2 of this guide determines maximum quantities of toxic chemicals at distances from control room air intake with adjustments for control room ventilation system design. Toxic chemicals that satisfied the criteria of Regulatory Guide 1.78 Table C-2 were not further analyzed.

The remaining chemicals were next analyzed by evaluating the concentration of each toxic chemical at the control room air intake. The concentration was calculated using the Gaussian dispersion model, selecting either the continuous release or a puff release as appropriate for the storage method and chemical being analyzed. Overall assumptions are as follows:

- The wind direction is always from the postulated spill toward the plant air intake.
- Atmospheric stability and wind speed selected are representative of the worst 5 percentile dispersion conditions based on onsite data.
- For chemicals that are liquids at normal conditions, the spill spreads out over an area such that the average depth is 1 centimeter, unless there is a berm around the tank. In this case the spill fills the entire berm.
- The temperature of the spilled chemical is assumed to be 100°F.
- Toxic chemical vapors and toxic gases are assumed to have the same density as air.
- No credit for diffusion is taken for topographical features along the drift path.
- If multiple-sized containers are employed, the largest is assumed to fail.
- The tank is assumed filled to nominal capacity at the time of the spill and the total contents are released.
- Puff release includes the isenthalpic flash fraction of stored material.

Evaporation rates of spilled chemicals with vapor pressures less than atmospheric were evaluated using the general methodology for mass transfer between liquid and vapor phases given by Bird, Stewart, and Lightfoot (Ref. 2). This evaporation model is dependent on the spill area, the wind speed, the mass transfer coefficient, and the effect of Sherwood, Reynolds, and Schmidt numbers using the analogy between heat and mass transfer.

Concentrations of liquefied compressed gases at the control room air intake were analyzed using procedures in Appendix B of Regulatory Guide 1.78. The quantity of the puff release (flash fraction) is evaluated assuming an isenthalpic expansion. Based on this analysis, chemicals with concentrations at the control room air intake less than the toxic limit were eliminated from further study.

Chemicals for which the calculated concentrations at the control room air intake exceed the toxic limit were analyzed further to determine the buildup of chemical concentration in the control room, using conservation of mass equations for the control room HVAC system operation. A Gaussian dispersion model is used to calculate the concentration dilution as the vapors drift from the spill site to the air intake. For purposes of this analysis, the Robinson plant ventilation system, normal mode, is represented by the simplified schematic shown in Figure 6-1.

The control room concentration as a function of time is represented by the following differential equation:

$$V_{cr} \frac{d X_{cr}}{dt} = Q_1 X_{oa} - Q_2 X_{cr}$$

where

V_{cr} = volume of control room
Q_1 = inflow of outside air

X_{oa} = toxic chemical concentration at air intake (based on Gaussian model)

Q_2 = outflow of control room air

X_{cr} = toxic chemical concentration of control room air

Emergency mode operation is assumed to be identical to normal operation because no toxic chemical detectors are installed. Therefore, automatic isolation of the control room does not occur during toxic chemical intrusion.

6.3 Analysis of Hypothetical Highway Truck Accident

South Carolina Route 151 passes the Robinson plant at a closest approach distance of 0.4 mile. In order to determine the importance of defining toxic chemical traffic on this route, hypothetical shipments of chemicals known to be used in the region (chlorine, ammonia, and formaldehyde) were considered. The worst-case analysis is based on the following extremely conservative assumptions: the accident occurs at the point of closest approach, the wind is blowing towards the plant, the truck is the largest capacity allowed on the highway, the truck is loaded to capacity, and the accident results in complete loss of lading in a relatively short period of time. The calculated concentrations resulting from these very conservative analyses of hypothetical accidents are greater than the toxic limits. Because actual shipments of the magnitudes assumed in these calculations have not been verified, further investigation is necessary before Carolina Power & Light determines if these postulated accidents are real concerns.

6.4 Summary of Results

Table 6-2 summarizes the numerical results of this Robinson plant toxic chemical habitability analysis and shows compliance with the appropriate limits. The Regulatory Guide 1.78 screening procedure eliminated four chemicals stored in the vicinity as possible threats to control room habitability: propane,

chlorine, nitrogen, and trichloroethylene. Of the remaining chemicals, only postulated releases of formaldehyde and ammonia result in calculated concentrations at the control room air intake that are greater than the toxic limit. The buildup in the control room was evaluated for these two chemicals, and the results are plotted in Figures 6-2 and 6-3. While the peak toxic chemical concentration exceeds the recommended limit (Ref. 1) for habitability, both ammonia and formaldehyde are readily detectable by odor and eye irritation (Ref. 3). The odor thresholds (Ref. 4) are shown in Figures 6-2 and 6-3. The elapsed time between reaching the odor threshold and the toxic limit concentrations in the control room for both chemicals is seen in these figures to be greater than the 2-minute time allowed in Regulatory Guide 1.78 for operators to locate and put on self-contained breathing apparatus.

6.5 References

1. U.S. Nuclear Regulatory Commission. Regulatory Guide 1.78, "Assumptions for Evaluating the Habitability of a Nuclear Power Plant Control Room During a Postulated Hazardous Chemical Release."

2. R. B. Bird, W. E. Stewart, and E. N. Lightfoot. 1942. Transport Phenomena. New York: John Wiley and Sons.

3. American Conference of Governmental Industrial Hygienists. 1971. Documentation of Threshold Limit Values. Third Edition.

4. NIOSH/OSHA Draft Technical Standard and Supporting Documentation for Formaldehyde and Ammonia.

TABLE 6-1

SUMMARY OF INPUT DATA

Parameter	Data	Units
Meteorological:		
Pasquill stability	G	Classification
Average wind speed	1.0	m/sec
Atmospheric dispersion, X/Q	See Table 3-3	sec/m^3
<u>HVAC System</u>		
Normal operation:		
Fresh air makeup	600	ft^3/min
Inleakage	890	ft^3/min
Outleakage and exhaust	1490	ft^3/min
Filter removal, toxic chemical	None	None
Loop flow	4785	ft^3/min
Air exchange rate, outside air	4.4	Per hour
Emergency operation:		
Fresh air flow (damper leakage)	60	ft^3/min
Inleakage (duct and adjacent areas)	890	ft^3/min
Outleakage and exhaust	950	ft^3/min
Filter removal, toxic chemical	None	None
Loop flow	4785	ft^3/min
Air exchange rate, outside air	2.8	Per hour
Volume of control room	20,124	ft^3

TABLE 6-2

RESULTS OF TOXIC CHEMICAL ANALYSIS

Location	Distance (mi)	Chemical	Storage Condition	Quantity Stored (1000 gal)	Quantity Stored (lb)	Quantity Allowed per Regulatory Guide 1.78 (lb)	Toxic Limit (mg/m^3)	Concentration at Intake (mg/m^3)	Concentration in Control Room at 2 Minutes After Human Detection (mg/m^3)
SONOCO	5.1	Propane	Liquefied gas under pressure, 2 tanks	10	48.8K	235K	1800	N/C[a]	N/C
SONOCO	5.3	Sulfuric acid	Ambient temperature and pressure	25	382.5K	262	2	0.08	N/C
SONOCO	5.4	Phenol	Ambient temperature and pressure	10	89.4K	2487	19	3.7	N/C
SONOCO	5.4	Acetic acid	Ambient temperature and pressure	10	87.5K	3270	25	18	N/C
SONOCO	5.4	Formaldehyde (aqueous)	Ambient temperature	40	334K (123.5K)[b]	1570	12	996	<12[c]
SONOCO	5.3	Chlorine	Liquefied gas under pressure	<1.0	12.3K (2840)[d]	5890	45	N/C	N/C
IMC	5.0	Ammonia (anhydrous)	Liquefied gas under pressure	--	160K (36.5K)[d]	9160	70	3120	<70[e]
IMC	5.0	Nitrogen	--	--	184K	7.85M	Asphyxiant, 84%	N/C	N/C
IMC	4.8	Sulfuric acid	Ambient temperature and pressure	--	200K	262	2	0.077	N/C
Hartsville Mill	5.3	Trichloro-ethylene	55 gal. drum, ambient temperature and pressure	--	668	1570	535	N/C	N/C

TABLE 6-2 (continued)

RESULTS OF TOXIC CHEMICAL ANALYSIS

Location	Distance (mi)	Chemical	Storage Condition	Quantity Stored (1000 gal)	Quantity Stored (lb)	Quantity Allowed per Regulatory Guide 1.78 (lb)	Toxic Limit (mg/m³)	Concentration at Intake (mg/m³)	Concentration in Control Room at 2 Minutes After Human Detection (mg/m³)
Darlington County water well heads	Various, all more than 100 meters from control room	Chlorine	Liquefied gas under pressure	--	150	(f)	45	N/C	N/C

[a]N/C = Not required to be calculated.
[b]Amount of formaldehyde gas in standard industrial formaldehyde solution.
[c]See Figure 6-2 for a plot of control room formaldehyde concentration as a function of time.
[d]Isenthalpic flash fraction.
[e]See Figure 6-3 for a plot of control room ammonia concentration as a function of time.
[f]According to Regulatory Guide 1.95, all chlorine must be at least 100 meters from the control room. The four Hartsville Public Works Wells in question are scattered over Darlington County at various distances (miles) from the plant, much more than 100 meters away.

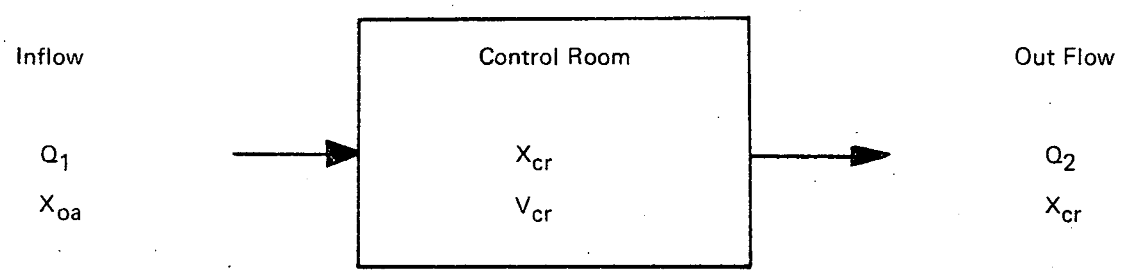


Figure 6-1. Control Room Model for Toxic Chemical Analysis of the Normal (Unisolated) Operating Mode

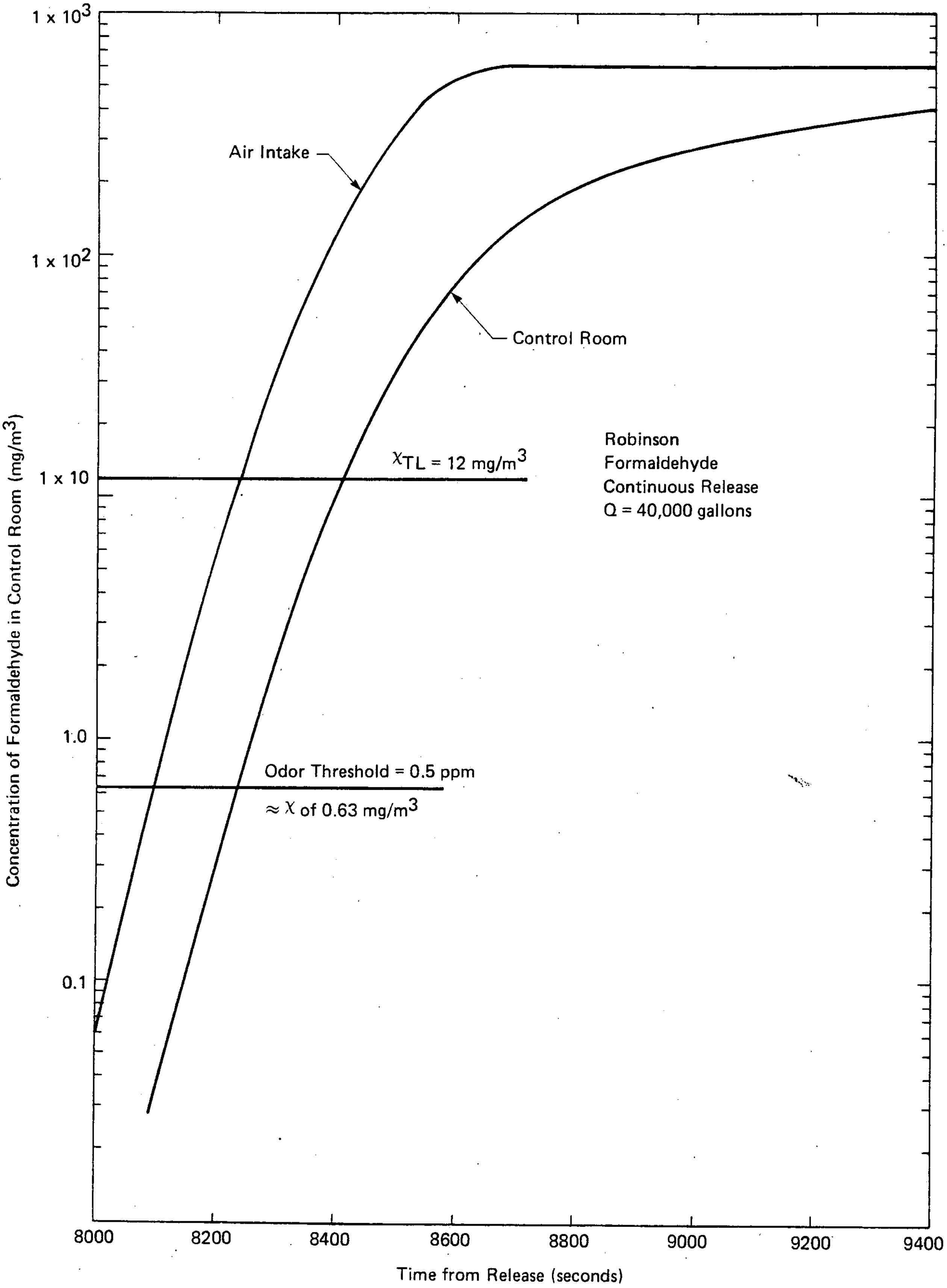


Figure 6-2. Control Room Concentration After Postulated Release of Formaldehyde

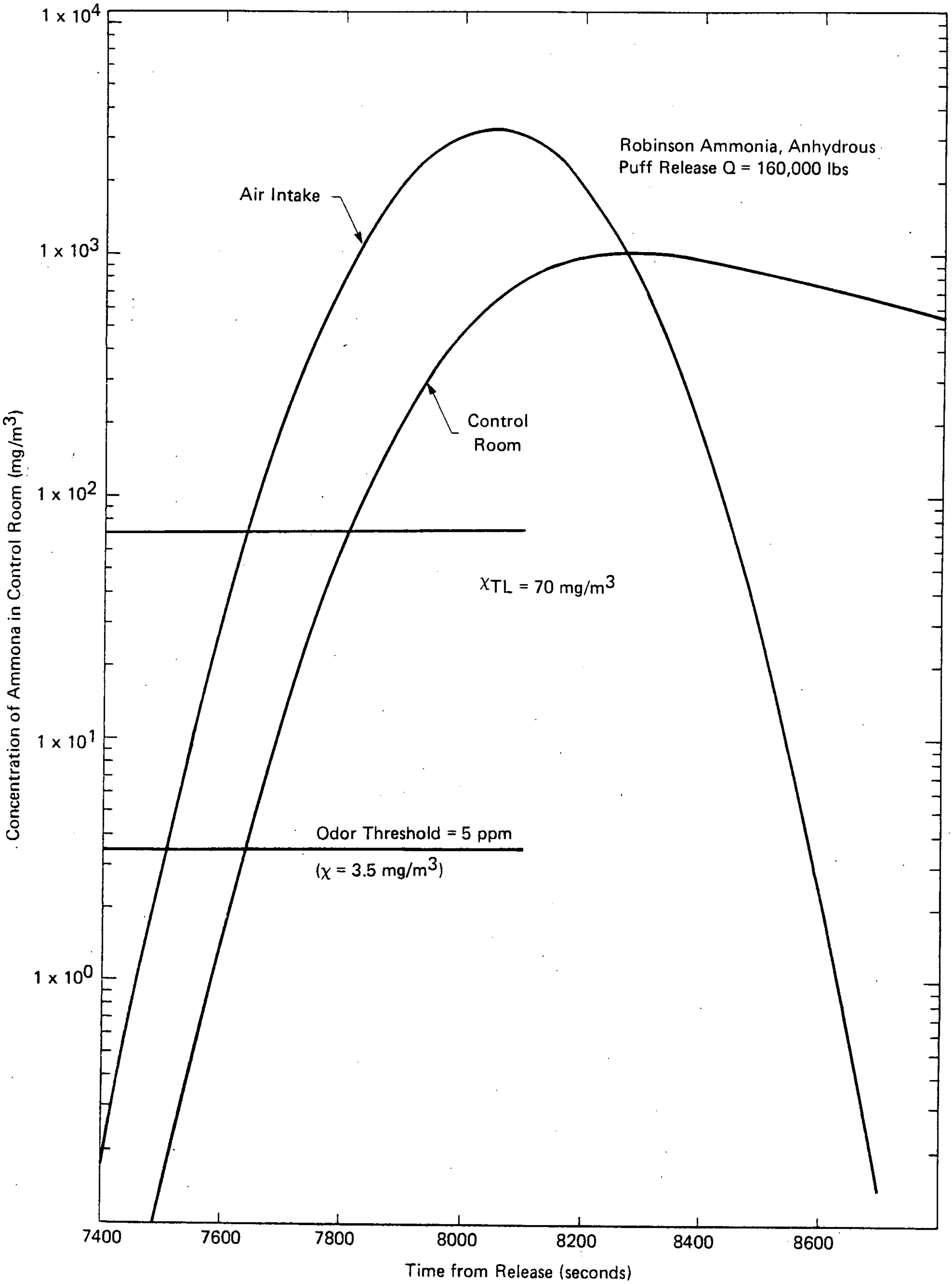


Figure 6-3. Control Room Concentration After Postulated Release of Ammonia

APPENDIX A

COMPARISON OF THE ROBINSON CONTROL ROOM TO THE CRITERIA OF NRC STANDARD REVIEW PLANS 6.4, 9.4.1, AND 6.5.1

A.1 COMPARISON WITH STANDARD REVIEW PLAN 6.4

A.1.1 Control Room Emergency Zone

The control room emergency zone includes the control panels and consoles for the fossil-fueled Unit 1 as well as the control station for Unit 2.

a. The control room safe shutdown controls are within the control room emergency zone.

b. Robinson does not have a computer room and therefore it is not part of the emergency ventilation system. The Robinson plant computer is not relied upon for safe operation of the plant.

c. Robinson does not have a shift supervisor's office; the shift supervisor operates directly from the control room.

d. The washroom, the kitchen, and a small storage closet are included within the emergency zone and are accessible at all times.

e. It is necessary for the operator to leave the emergency ventilation zone to enter the cable rooms and the relay rooms.

A.1.2 Control Room Personnel Capacity

The control room at the Robinson plant houses the personnel for the fossil-fueled Unit 1 as well as for Unit 2. Control room

manning requirements are as given in the technical specifications. There are no specific storage facilities for food, blankets, and cots for the normal occupancy for 5 days.

A.1.3 Ventilation System Layout and Functional Design

The system description is provided in Section 4.1 of this report. Isolation is effected automatically on high radiation. During isolation, the fresh air intake closes, the exhaust fan stops, and the exhaust damper closes. The system is not designed to pressurize the emergency zone to prevent infiltration.

a. The isolation dampers are of standard commercial quality without resilient seals.

b. The isolation dampers, emergency filter and filter fan HVE-19, and the air-conditioning unit are not redundant components.

c. The system is not designed to pressurize the control room. The leakage rates calculated for dampers, doors, and penetrations will provide an air-change rate of 2.8 air changes per hour.

A.1.4 Toxic Gas Protection

Two self-contained breathing apparatuses are available in the control room. No special protection against toxic gas intrusion and no toxic gas detectors are provided in the design of the Robinson control room.

A.1.5 Emergency Standby Filters

See Section A.3 below.

A.1.6 Relative Location of Source and Control Room

a. Air Inlets. The control room ventilation air inlet, as well as other auxiliary building air inlets, are on the east wall approximately 35 meters from the containment.

b. Toxic Gases. As discussed in Section 4.0, there are no significant quantities of toxic gases stored at the site. The offsite sources of hazardous chemicals are discussed in Sections 2.0 and 6.0 of this report.

c. Confined Area Releases. The potential for contamination of the control room air from releases inside adjacent areas of the auxiliary building is discussed in Sections 4.0 and 5.0 of this report.

A.1.7 Radiation Shielding

Shielding is discussed in Section 5.0 and in CP&L's submittal to the NRC in December 1979 in response to NUREG-0578 Item 2.1.6.b.

A.1.8 Radioactive and Toxic Gas Hazards

These are discussed in Sections 5.0 and 6.0, respectively, of this report.

A.2 COMPARISON WITH STANDARD REVIEW PLAN 9.4.1

A.2.1 Single Failure Analysis

The control room ventilation equipment is not redundant or backed up by standby equipment, although there are two refrigerant condensing units for the control room cooling system. Therefore, any single active failure could result in a loss of, or reduction of, the system functional performance capability.

The consequences of key failures are given below:

a. Failure of single dampers will affect the system functional performance as shown in Table A-1.

b. Failure of the air-conditioner fan HVA-1 will cause a loss of cooling in the control room.

c. Failure of the refrigerant condensers ACC-1A and ACC-1B will cause a loss of cooling in the control room.

d. Failure of the recirculation fan HVE-19 will cause a reduction of the filtered volume and could result in an increase in the radioactivity or gas concentration during a postulated accident. An alarm will sound on low flow, but there is no alternative standby equipment.

e. The loss of the instrument air supply will start the condensing units ACC-1A and ACC-1B when cooling may not be required and heating may be required.

f. The loss of instrument air supply will automatically put the system into the recirculation mode with no control on the air flow. The increase in air flow will cause a proportionate increase in differential pressure, but no damage or loss of function by the filters.

g. Failure of exhaust fan HVE-16 to operate would have little effect on the performance of the ventilation system in an accident, because HVE-16 is shut down when the control room is isolated. Failure of HVE-16 to stop when it should could increase the infiltration of outside air into the control room during isolation.

h. Loss of ventilation to the HVAC equipment room will have little effect on the control room system performance.

A.2.2 Separation Analysis

None of the control room ventilation equipment is redundant and the equipment in the HVAC equipment room is arranged so that missiles generated by one piece of equipment will not strike another.

The refrigerant condensers located outdoors are both exposed to the same hazards (e.g., both condensers are exposed to potential tornado missiles and potential seismic debris from the nonseismic turbine deck).

A.2.3 Analysis of Failure of Nonseismic Equipment

Nonseismic equipment hanging beneath the turbine deck postulated in a seismic event to fall on the condenser or refrigerant piping could impair their operation. Loss of control room cooling would cause the control room temperature to rise at approximately 6°F per minute and to stabilize at a high temperature.

A.2.4 Adequacy To Maintain Suitable Environment

Ten years of operating experience indicate that the system design is adequate to maintain a suitable environment for personnel and for machines.

A.2.5 Ability To Detect, Filter, and Discharge Airborne Contaminants in the Control Room

There are no radiation monitors or gas detectors on the air intake to the control room. There is a radiation monitor, R-1, located in a corner of the control room behind the control panel.

It automatically will place the system on the emergency recirculation mode if the radioactivity exceeds the setpoint of 2.5 millirem per hour.

The normal design ventilation rate of 600 cfm is adequate to clear the control room of smoke and fumes within approximately 30 minutes, if the control room was sealed and tight. At the calculated infiltration rate, less than 30 minutes would be needed.

A.2.6 Provisions To Detect and Isolate Portions of System in Fires, Failures, and Malfunctions

Fire dampers on the control room supply and return ducts are provided and each has a position switch to alarm the closed position. Because the system serves no other area, it is not necessary to isolate a portion of the system.

A.3 COMPARISON WITH STANDARD REVIEW PLAN 6.5.1

A.3.1 The System Was Designed To Operate After a Design Basis Accident by Manual Control from the Control Room

A.3.2 Comparison with Paragraph II.2 of Standard Review Plan 6.5.1

a. A high-efficiency filter (HEPA) is not provided after the charcoal filter; a prefilter and HEPA are provided. A moisture separator is not required in this application.

b. No redundancy of the filter system is provided and no separation of redundant components is needed.

c. The filter system design flow is less than the 30,000 cfm maximum defined in Standard Review Plan 6.5.1.

d. An investigation of the original seismic design of the control room ventilation system is being conducted.

e. The single-filter system is instrumented to signal and alarm on low flow; it does not record pressure drop or flow rate.

f. The emergency filter system is activated automatically by a high-radiation signal from the control room radiation monitor or by a containment isolation signal. The control room radiation monitor is located behind the control panel in the southwest corner of the control room.

A.3.3 Comparison with Paragraph II.4 of Standard Review Plan 6.5.1.

a. The filter design predated ANSI N509-1976 and is not constructed for and does not have provisions for the testing described in Section 5.4 of ANSI N509-1976.

b. Moisture removal equipment is not required to ensure a relative humidity less than 70 percent.

c. Although not required by the original plant design, prefilters were recently added to the HEPA filters. There are no provisions for testing them separately.

d. The HEPA filters are DOP-tested once per operating cycle, per technical specifications.

e. Filter and adsorber mounting frames have proven satisfactory, but were not in accordance with current practice and ANSI N509-1976. For example, they do not include quick-release clamps.

f. Filter housings including floors and doors are not in accordance with ANSI N509-1976. Lights and viewing ports are not provided. Fire protection for the charcoal filter is not provided based on the results of the fire protection review.

g. Water drains were not provided because no sprinkler system was provided.

h. The adsorbent is acceptable for adsorbing gaseous iodides.

i. The adsorption unit maximum loading of total iodine is as given in Regulatory Guide 1.52.

j. No provisions were included to inhibit off-design temperatures in the adsorber section.

k. The ductwork was designed to SMACNA low-pressure duct construction standards and is not in accordance with ANSI N509-1976.

l. The dampers are not low-leakage dampers.

A.3.4 Comparison with Paragraphs II.5 and II.6 of Standard Review Plan 6.5.1

The space between mounting frames and the provisions for testing each filter stage do not meet the criteria of these paragraphs. The HEPA and charcoal filter efficiencies can be verified by separate tests. Complete visual inspections necessitate removal of the filters.

A.3.5 Equipment Environment

The control room HVAC equipment is located in the heating and ventilation equipment room and is designed to meet the conditioned environment of that room. The filters are not shielded and could become a radiation source after a postulated design basis accident.

A.3.6 Component Design and Qualification Testing

a. The design standards of the filter system are not in accordance with current practice and do not incorporate the recommendations of ANSI N509-1976.

b. No protection is provided against charcoal fires and none is needed, based on the results of the fire protection review program.

A.3.7 In-Place Testing

Both the HEPA and charcoal filter systems have been tested. From the test results, the filter performance is acceptably above the minimum efficiencies.

TABLE A-1

CONTROL ROOM VENTILATION SYSTEM
DAMPER FAILURES AND THEIR CONSEQUENCES

Damper	Failure	Symptom	Results
Fresh air inlet L-19	Stays open	Increase inlet air	Increase radioactivity or gas concentration during DBA
Exhaust air outlet L-20	Stays open	Increase exfiltration	Increase radioactivity or gas concentration during DBA
Bypass damper	Stays open	Airflow bypasses filter	Increase radioactivity or gas concentration during DBA
Filter damper at inlet	Stays closed	Minimal airflow through filter	Increase radioactivity or gas concentration during DBA and increase temperature in the control room
Filter damper at outlet	Stays closed	Minimal airflow through filter	Increase radioactivity or gas concentration during DBA and increase temperature in the control room
Fire damper (supply)	Closes	Reduced airflow (fire alarm)	High temperature in control room
Fire damper (return)	Closes	Reduced airflow (fire alarm)	High temperature in control room

APPENDIX B

ADDITIONAL INFORMATION REQUIRED BY THE NRC

1. Control Room Mode of Operation:

   Response: Filtered recirculation for a radiological accident or toxic chemical release.

2. Control Room Characteristics:

   a. control room air volume:

      Response: 20,124 cubic feet

   b. control room emergency zone:

      Response: The emergency zone includes the Unit 1 and Unit 2 control room, kitchen, washroom, and storage area.

   c. control room ventilation system schematic with normal and emergency air flow rates:

      Response: See Figure 4-1 in this report.

   d. infiltration leakage rate:

      Response: The calculated infiltration leakage rate is 630 cfm.

   e. HEPA filter and charcoal adsorber efficiencies:

      Response: Technical specifications require 99 percent HEPA efficiency, 99 percent elemental iodine

removal efficiency, and 90 percent methyl iodide removal efficiency.

f. closest distance between containment and air intake:

Response: approximately 35 meters.

g. layout of control room, air intakes, containment building, and chlorine or other chemical storage facility with dimensions:

Response: See Figure 4-2 in this report and Figure 7.7-1 in the FSAR.

h. control room shielding including radiation streaming from penetrations, doors, ducts, stairways, etc:

Response: See CP&L's response to NUREG-0578 Item 2.1.6.b, submitted to the NRC December 31, 1979, and Section 7.7.1 of the Robinson FSAR.

i. automatic isolation capability--damper closing time, damper leakage, and area:

Response: Damper closing time is less than 5 seconds.

Damper leakage is estimated to be 10 percent of normal design flow, per ASHRAE 79, Equipment. For the outside air intake isolation damper, L-19, the leakage is estimated to be 60 cfm.

The area of damper L-19 and L-20, the exhaust damper, is approximately 1.5 square feet.

j. chlorine detectors or toxic gas (local or remote):

Response: None provided.

k. self-contained breathing apparatus (SCBA) availability (number):

Response: Two SCBAs are kept in the control room.

l. bottled air supply (hours):

Response: The compressed air station has four 423-scf tanks.

m. emergency food and potable water supply (how many days and how many people):

Response: None stored in control room.

n. control room personnel capacity (normal and emergency):

Response: The minimum shift complement in the control room is as defined by technical specifications. In an emergency, CP&L would limit the number of people in the control room to the minimum required.

o. potassium iodide drug supply:

Response: CP&L intends to purchase a stockpile of pharmaceutical grade potassium iodide to be administered by a physician during a radiological accident.

3. Onsite Storage of Chlorine and Other Hazardous Chemicals:

   a. total number and size of containers:

      Response: As indicated in the FSAR, Robinson uses chlorine only in the liquid (hypochlorite) form for water treatment. No other hazardous chemicals are stored at the site in significant quantities.

   b. closest distance from control room air intake:

      Response: Not applicable, as indicated above.

4. Offsite Manufacturing, Storage, or Transportation Facilities of Hazardous Chemicals:

   a. identify facilities within a five-mile radius,

   b. distance from control room,

   c. quantity of hazardous chemicals in one container, and

   d. frequency of hazardous chemical transportation traffic (truck, rail, and barge):

      Response: See Section 2.0 of this report.

5. Technical Specifications:

   a. chlorine detection system:

      Response: Robinson has no chlorine detection system in the control room.

b. control room emergency filtration system including the capability to maintain the control room pressurization at 1/8 inch water gauge, verification of isolation by test signals, and damper closure time and filter testing requirements:

Response: Table 4-3 and Section 4.15 of the Robinson Unit 2 technical specifications provide the surveillance requirements of the fans and associated charcoal and absolute filters for the control room.

APPENDIX C

JOINT FREQUENCY DISTRIBUTIONS OF WIND SPEED AND WIND DIRECTION BY ATMOSPHERIC STABILITY CLASS

January 1, 1976 - December 31, 1979

JOINT PERCENTAGE FREQUENCIES OF WIND DIRECTION AND SPEED
FOR THE PERIOD 12:00 AM 1/ 1/76 TO 11:00 PM 12/31/79

STABILITY CLASS A
STABILITY CALCULATED FROM DIFF. TEMPERATURE #1+2

ROBINSON ON-SITE METEOROLOGICAL FACILITY

LOWER WIND DIRECTION	CALM	SPEED CLASS(MPH) 0.75- 3.5	3.5- 7.5	7.5-12.5	12.5-18.5	18.5-25.0	GREATER THAN 25.0	TOTAL	AVG. WIND SPEED
N	0.0	0.02	0.69	0.43	0.03	0.0	0.0	1.18	7.25
NNE	0.0	0.02	0.92	0.42	0.01	0.0	0.0	1.36	6.76
NE	0.0	0.05	0.72	0.40	0.01	0.0	0.0	1.19	6.72
ENE	0.0	0.05	0.90	0.33	0.00	0.0	0.0	1.28	6.37
E	0.0	0.06	0.61	0.08	0.0	0.0	0.0	0.75	5.63
ESE	0.0	0.08	0.54	0.06	0.01	0.0	0.0	0.67	5.22
SE	0.0	0.07	0.80	0.09	0.01	0.0	0.0	0.97	5.60
SSE	0.0	0.02	0.44	0.21	0.01	0.0	0.0	0.68	6.68
S	0.0	0.01	0.36	0.40	0.02	0.0	0.0	0.79	7.79
SSW	0.0	0.01	0.51	0.67	0.09	0.0	0.0	1.29	8.38
SW	0.0	0.02	0.80	0.64	0.08	0.0	0.0	1.55	7.76
WSW	0.0	0.02	0.67	0.36	0.03	0.0	0.0	1.08	7.13
W	0.0	0.02	0.49	0.28	0.01	0.0	0.0	0.79	6.93
WNW	0.0	0.01	0.29	0.28	0.01	0.0	0.0	0.59	7.55
NW	0.0	0.01	0.28	0.23	0.01	0.0	0.0	0.53	7.32
NNW	0.0	0.00	0.18	0.14	0.01	0.0	0.0	0.33	7.30
TOTAL	0.0	0.47	9.20	5.02	0.35	0.0	0.0	15.04	6.90

NUMBER OF CALMS - 0
NUMBER OF BAD HOURS - 300

JOINT PERCENTAGE FREQUENCIES OF WIND DIRECTION AND SPEED
FOR THE PERIOD 12:00 AM 1/ 1/76 TO 11:00 PM 12/31/79

STABILITY CLASS B
STABILITY CALCULATED FROM DIFF. TEMPERATURE #1+2

ROBINSON ON-SITE METEOROLOGICAL FACILITY

LOWER WIND DIRECTION	SPEED CLASS(MPH) CALM	0.75- 3.5	3.5- 7.5	7.5-12.5	12.5-18.5	18.5-25.0	GREATER THAN 25.0	TOTAL	AVG. WIND SPEED
N	0.0	0.01	0.21	0.06	0.02	0.0	0.0	0.31	6.62
NNE	0.0	0.02	0.23	0.08	0.00	0.0	0.0	0.34	6.12
NE	0.0	0.02	0.19	0.08	0.00	0.0	0.0	0.30	6.24
ENE	0.0	0.05	0.15	0.05	0.0	0.0	0.0	0.25	5.37
E	0.0	0.03	0.18	0.03	0.0	0.0	0.0	0.23	5.39
ESE	0.0	0.06	0.15	0.03	0.0	0.0	0.0	0.23	5.04
SE	0.0	0.02	0.19	0.03	0.00	0.0	0.0	0.23	5.24
SSE	0.0	0.03	0.16	0.05	0.00	0.0	0.0	0.24	5.70
S	0.0	0.01	0.12	0.08	0.01	0.0	0.0	0.21	7.73
SSW	0.0	0.02	0.18	0.15	0.02	0.0	0.0	0.38	7.62
SW	0.0	0.01	0.24	0.16	0.02	0.0	0.0	0.44	7.24
WSW	0.0	0.04	0.20	0.09	0.03	0.00	0.0	0.35	7.13
W	0.0	0.01	0.19	0.06	0.01	0.0	0.0	0.26	6.35
WNW	0.0	0.03	0.14	0.05	0.00	0.0	0.0	0.22	6.36
NW	0.0	0.01	0.08	0.03	0.0	0.0	0.0	0.13	6.40
NNW	0.0	0.01	0.06	0.02	0.01	0.0	0.0	0.09	6.33
TOTAL	0.0	0.39	2.66	1.03	0.13	0.00	0.0	4.22	6.30

NUMBER OF CALMS - 0
NUMBER OF BAD HOURS - 8

JOINT PERCENTAGE FREQUENCIES OF WIND DIRECTION AND SPEED
FOR THE PERIOD 12:00 AM 1/ 1/76 TO 11:00 PM 12/31/79

STABILITY CLASS C
STABILITY CALCULATED FROM DIFF. TEMPERATURE #1+2

ROBINSON ON-SITE METEOROLOGICAL FACILITY

LOWER WIND DIRECTION	CALM	0.75- 3.5	3.5- 7.5	7.5-12.5	12.5-18.5	18.5-25.0	GREATER THAN 25.0	TOTAL	AVG. WIND SPEED
	SPEED CLASS(MPH)								
N	0.0	0.03	0.21	0.05	0.02	0.0	0.0	0.31	6.28
NNE	0.0	0.05	0.21	0.14	0.00	0.0	0.0	0.40	6.45
NE	0.0	0.05	0.16	0.09	0.01	0.0	0.0	0.32	6.31
ENE	0.0	0.05	0.15	0.04	0.0	0.0	0.0	0.24	5.63
E	0.0	0.04	0.13	0.01	0.0	0.0	0.0	0.18	4.91
ESE	0.0	0.06	0.12	0.01	0.01	0.0	0.0	0.20	4.86
SE	0.0	0.05	0.16	0.03	0.00	0.0	0.0	0.24	5.12
SSE	0.0	0.03	0.12	0.03	0.01	0.0	0.0	0.18	5.94
S	0.0	0.01	0.11	0.07	0.02	0.0	0.0	0.21	7.35
SSW	0.0	0.01	0.19	0.11	0.01	0.0	0.0	0.32	7.23
SW	0.0	0.02	0.26	0.15	0.02	0.0	0.0	0.45	7.08
WSW	0.0	0.03	0.25	0.08	0.01	0.0	0.0	0.38	6.34
W	0.0	0.02	0.21	0.05	0.02	0.0	0.0	0.31	6.45
WNW	0.0	0.02	0.12	0.04	0.01	0.0	0.0	0.19	6.26
NW	0.0	0.01	0.13	0.03	0.00	0.0	0.0	0.17	5.99
NNW	0.0	0.01	0.10	0.02	0.0	0.0	0.0	0.12	5.68
TOTAL	0.0	0.50	2.62	0.97	0.14	0.0	0.0	4.22	6.12

NUMBER OF CALMS - 0
NUMBER OF BAD HOURS - 11

JOINT PERCENTAGE FREQUENCIES OF WIND DIRECTION AND SPEED
FOR THE PERIOD 12:00 AM 1/ 1/76 TO 11:00 PM 12/31/79

STABILITY CLASS D
STABILITY CALCULATED FROM DIFF. TEMPERATURE #1+2

ROBINSON ON-SITE METEOROLOGICAL FACILITY

LOWER WIND DIRECTION	CALM	0.75- 3.5	3.5- 7.5	7.5-12.5	12.5-18.5	18.5-25.0	GREATER THAN 25.0	TOTAL	AVG. WIND SPEED
	SPEED CLASS(MPH)								
N	0.0	0.23	0.96	0.40	0.04	0.0	0.0	1.63	6.10
NNE	0.01	0.36	2.52	1.42	0.06	0.0	0.0	4.36	6.65
NE	0.01	0.40	1.62	0.67	0.06	0.01	0.0	2.75	6.15
ENE	0.01	0.32	1.13	0.25	0.00	0.00	0.0	1.71	5.40
E	0.00	0.31	1.00	0.13	0.01	0.00	0.0	1.44	5.07
ESE	0.01	0.36	0.83	0.13	0.01	0.00	0.0	1.34	4.98
SE	0.0	0.28	0.85	0.20	0.02	0.01	0.0	1.36	5.51
SSE	0.0	0.22	0.92	0.39	0.05	0.01	0.0	1.58	6.27
S	0.0	0.14	0.88	0.49	0.12	0.03	0.0	1.66	7.23
SSW	0.0	0.29	1.01	0.48	0.12	0.01	0.0	1.91	6.65
SW	0.01	0.34	0.92	0.45	0.08	0.00	0.00	1.79	6.21
WSW	0.01	0.34	0.83	0.38	0.06	0.00	0.0	1.62	6.19
W	0.00	0.29	0.56	0.20	0.02	0.0	0.0	1.07	5.44
WNW	0.0	0.19	0.40	0.13	0.02	0.0	0.0	0.74	5.37
NW	0.0	0.14	0.33	0.15	0.00	0.0	0.0	0.62	5.60
NNW	0.0	0.17	0.58	0.28	0.01	0.0	0.0	1.04	6.11
TOTAL	0.04	4.37	15.33	6.14	0.67	0.08	0.00	26.64	5.93

NUMBER OF CALMS - 14
NUMBER OF BAD HOURS - 35

JOINT PERCENTAGE FREQUENCIES OF WIND DIRECTION AND SPEED
FOR THE PERIOD 12:00 AM 1/ 1/76 TO 11:00 PM 12/31/79

STABILITY CLASS E
STABILITY CALCULATED FROM DIFF. TEMPERATURE #1+2

ROBINSON ON-SITE METEOROLOGICAL FACILITY

LOWER WIND DIRECTION	CALM	SPEED CLASS(MPH) 0.75- 3.5	3.5- 7.5	7.5-12.5	12.5-18.5	18.5-25.0	GREATER THAN 25.0	TOTAL	AVG. WIND SPEED
N	0.01	0.56	0.85	0.09	0.0	0.0	0.0	1.52	4.28
NNE	0.02	0.62	1.18	0.11	0.01	0.0	0.0	1.94	4.61
NE	0.01	0.47	0.78	0.04	0.0	0.0	0.0	1.31	4.31
ENE	0.01	0.35	0.42	0.04	0.00	0.0	0.0	0.82	4.01
E	0.0	0.25	0.33	0.08	0.00	0.0	0.0	0.65	4.47
ESE	0.0	0.20	0.29	0.06	0.01	0.0	0.0	0.56	4.50
SE	0.00	0.32	0.35	0.08	0.00	0.0	0.0	0.76	4.40
SSE	0.01	0.54	1.55	0.28	0.06	0.0	0.0	2.44	5.21
S	0.03	1.14	1.78	0.53	0.08	0.01	0.0	3.56	5.14
SSW	0.05	1.85	2.06	0.45	0.06	0.00	0.0	4.47	4.53
SW	0.03	1.14	1.17	0.26	0.02	0.01	0.00	2.63	4.36
WSW	0.02	0.82	0.93	0.14	0.01	0.0	0.0	1.92	4.25
W	0.02	0.61	0.66	0.06	0.00	0.0	0.0	1.34	3.90
WNW	0.01	0.52	0.45	0.08	0.00	0.0	0.0	1.07	4.05
NW	0.01	0.59	0.59	0.10	0.01	0.0	0.0	1.29	4.02
NNW	0.02	0.68	1.60	0.26	0.0	0.0	0.0	2.56	4.75
TOTAL	0.26	10.66	14.99	2.66	0.27	0.01	0.00	28.85	4.42

NUMBER OF CALMS - 90
NUMBER OF BAD HOURS - 59

JOINT PERCENTAGE FREQUENCIES OF WIND DIRECTION AND SPEED
FOR THE PERIOD 12:00 AM 1/ 1/76 TO 11:00 PM 12/31/79

STABILITY CLASS F
STABILITY CALCULATED FROM DIFF. TEMPERATURE #1+2

ROBINSON ON-SITE METEOROLOGICAL FACILITY

LOWER WIND DIRECTION	CALM	0.75- 3.5	3.5- 7.5	7.5-12.5	12.5-18.5	18.5-25.0	GREATER THAN 25.0	TOTAL	AVG. WIND SPEED
				SPEED CLASS(MPH)					
N	0.04	0.53	0.13	0.0	0.0	0.0	0.0	0.69	2.57
NNE	0.02	0.30	0.02	0.0	0.0	0.0	0.0	0.34	2.26
NE	0.01	0.17	0.08	0.0	0.0	0.0	0.0	0.26	2.92
ENE	0.0	0.05	0.03	0.0	0.0	0.0	0.0	0.08	3.20
E	0.0	0.04	0.02	0.0	0.0	0.0	0.0	0.06	2.39
ESE	0.0	0.06	0.01	0.0	0.0	0.0	0.0	0.07	2.44
SE	0.0	0.09	0.03	0.0	0.0	0.0	0.0	0.12	2.49
SSE	0.02	0.33	0.14	0.01	0.0	0.0	0.0	0.50	2.89
S	0.08	1.16	0.33	0.00	0.0	0.0	0.0	1.58	2.82
SSW	0.11	1.54	0.41	0.01	0.0	0.0	0.0	2.06	2.76
SW	0.07	0.95	0.32	0.01	0.0	0.0	0.0	1.34	2.75
WSW	0.04	0.60	0.23	0.00	0.0	0.0	0.0	0.87	2.85
W	0.04	0.53	0.10	0.0	0.0	0.0	0.0	0.67	2.59
WNW	0.04	0.57	0.11	0.00	0.0	0.0	0.0	0.73	2.56
NW	0.05	0.66	0.24	0.0	0.0	0.0	0.0	0.95	2.79
NNW	0.07	0.99	0.65	0.01	0.0	0.0	0.0	1.72	3.16
TOTAL	0.59	8.56	2.87	0.03	0.0	0.0	0.0	12.05	2.72

NUMBER OF CALMS - 203
NUMBER OF BAD HOURS - 36

C-7

JOINT PERCENTAGE FREQUENCIES OF WIND DIRECTION AND SPEED
FOR THE PERIOD 12:00 AM 1/ 1/76 TO 11:00 PM 12/31/79

STABILITY CLASS G
STABILITY CALCULATED FROM DIFF. TEMPERATURE #1+2

ROBINSON ON-SITE METEOROLOGICAL FACILITY

LOWER WIND DIRECTION	CALM	SPEED CLASS(MPH) 0.75- 3.5	3.5- 7.5	7.5-12.5	12.5-18.5	18.5-25.0	GREATER THAN 25.0	TOTAL	AVG. WIND SPEED
N	0.16	0.77	0.10	0.0	0.0	0.0	0.0	1.02	1.97
NNE	0.08	0.38	0.03	0.0	0.0	0.0	0.0	0.49	1.63
NE	0.03	0.14	0.02	0.0	0.0	0.0	0.0	0.19	1.74
ENE	0.01	0.07	0.01	0.00	0.0	0.0	0.0	0.08	1.72
E	0.0	0.04	0.01	0.00	0.0	0.0	0.0	0.05	2.00
ESE	0.0	0.04	0.00	0.0	0.0	0.0	0.0	0.04	1.29
SE	0.02	0.08	0.01	0.0	0.0	0.0	0.0	0.10	1.35
SSE	0.06	0.26	0.03	0.0	0.0	0.0	0.0	0.34	1.77
S	0.16	0.78	0.09	0.0	0.0	0.0	0.0	1.03	2.25
SSW	0.15	0.76	0.06	0.0	0.0	0.0	0.0	0.98	2.17
SW	0.09	0.42	0.07	0.00	0.0	0.0	0.0	0.58	2.37
WSW	0.07	0.35	0.07	0.0	0.0	0.0	0.0	0.50	2.25
W	0.06	0.26	0.02	0.0	0.0	0.0	0.0	0.34	2.05
WNW	0.06	0.27	0.04	0.0	0.0	0.0	0.0	0.36	2.02
NW	0.11	0.55	0.03	0.0	0.0	0.0	0.0	0.70	2.03
NNW	0.30	1.48	0.38	0.0	0.0	0.0	0.0	2.16	2.58
TOTAL	1.35	6.06	0.97	0.01	0.0	0.0	0.0	8.97	1.95

NUMBER OF CALMS - 461
NUMBER OF BAD HOURS - 57

JOINT PERCENTAGE FREQUENCIES OF WIND DIRECTION AND SPEED
FOR THE PERIOD 12:00 AM 1/ 1/76 TO 11:00 PM 12/31/79

SUMMARY
STABILITY CALCULATED FROM DIFF. TEMPERATURE #1+2

ROBINSON ON-SITE METEOROLOGICAL FACILITY

LOWER WIND DIRECTION		SPEED CLASS(MPH)							AVG.
	CALM	0.75- 3.5	3.5- 7.5	7.5-12.5	12.5-18.5	18.5-25.0	GREATER THAN 25.0	TOTAL	WIND SPEED
N	0.21	2.16	3.15	1.04	0.11	0.0	0.0	6.67	5.01
NNE	0.12	1.74	5.12	2.17	0.08	0.0	0.0	9.24	5.83
NE	0.06	1.30	3.58	1.28	0.08	0.01	0.0	6.32	5.65
ENE	0.02	0.93	2.78	0.72	0.01	0.00	0.0	4.47	5.33
E	0.00	0.76	2.27	0.33	0.01	0.00	0.0	3.38	5.00
ESE	0.01	0.86	1.94	0.29	0.03	0.00	0.0	3.13	4.83
SE	0.02	0.90	2.38	0.43	0.04	0.01	0.0	3.78	5.08
SSE	0.09	1.43	3.36	0.96	0.12	0.01	0.0	5.97	5.36
S	0.27	3.26	3.67	1.56	0.25	0.03	0.0	9.04	5.21
SSW	0.31	4.49	4.43	1.87	0.31	0.01	0.0	11.41	5.04
SW	0.19	2.69	3.78	1.67	0.23	0.01	0.01	8.77	5.29
WSW	0.14	2.20	3.19	1.04	0.15	0.01	0.0	6.73	5.17
W	0.11	1.74	2.23	0.64	0.06	0.0	0.0	4.79	4.78
WNW	0.11	1.62	1.55	0.59	0.04	0.0	0.0	3.90	4.67
NW	0.17	1.98	1.69	0.54	0.02	0.0	0.0	4.39	4.28
NNW	0.39	3.35	3.54	0.72	0.02	0.0	0.0	8.02	4.21
TOTAL	2.22	31.61	48.65	15.86	1.56	0.09	0.01	100.00	5.10

NUMBER OF CALMS - 768
NUMBER OF BAD HOURS - 506

APPENDIX D

H. B. ROBINSON ONSITE METEOROLOGICAL MEASUREMENTS PROGRAM

D.1 ONSITE OPERATIONAL PROGRAM

A 360-foot, guyed, open-latticed tower supports the lower and upper levels of the meteorological instrumentation. Wind direction, wind speed, and wind variance (sigma theta) are recorded at both levels. Ambient temperature and dew point temperature are measured at the lower level. The differential temperature between the upper and lower levels is measured by twin, redundant delta temperature systems operating simultaneously. Solar radiation and precipitation are collected near ground level. The wind sensors are mounted on 12-foot booms oriented perpendicular to the general northeast-southwest prevailing wind flow to minimize tower shadow effects. The temperature probes and lithium chloride dew point sensor are housed in Climet aspirated shields mounted on 8-foot booms. A complete specification of major system component operating conditions is presented in Table D-1; component manufacturer and manufacturer model numbers may be found in Table D-2. Operational sensor elevations are displayed in Table D-3 and component accuracies are shown in Table D-4.

The meteorological tower is located 0.9 mile north of the reactor complex, with the base of the tower at 617 feet above mean sea level. An environmentally controlled shelter, which houses recording instruments, signal conditioning devices, and remote data access equipment, is located adjacent to the tower.

The Westinghouse Environmental Monitoring System is the primary data collection system. This system converts sensor outputs to a proportional number of discrete pulses that are electronically integrated and recorded on magnetic tape in 15-minute averaging periods. Also, direct readout of any parameter is possible with this system. A test jack for each parameter is provided so that

a pulse test counter may be plugged into it. The counter sums the pulses produced in a specific time interval, and the subsequent pulse total can then be converted to engineering units by use of a formula of the form $y = mx + b$.

Esterline Angus Twin Strip Chart Recorders are used for providing an analog record of both the upper and lower level wind directions and speeds to back up the Westinghouse system. In addition, 15-minute averaged upper and lower level wind speeds and directions, both differential temperatures, and ambient temperature parameters are telemetered to the CP&L general offices on an hourly basis via voice grade telephone lines to the site, giving CP&L the capability of detecting malfunctions of these parameters within 24 hours.

D.2 DATA REDUCTION

The Westinghouse system magnetic tape cassettes are changed and brought back to the general office approximately once per month for translating. Computer programs convert all parameter pulse totals into engineering units. The data is then reviewed and checked for consistency with the onsite strip charts and Columbia, South Carolina, Weather Service data. The edited 15-minute averaged data is then compiled into hourly averages and stored on magnetic history tapes. Routine computer outputs from the Westinghouse pulse data collection system include the following:

a. Monthly Data Summaries listing maximum temperature, minimum temperature, average temperature, barometric pressure, precipitation, solar radiation, and upper level and lower level dew point temperatures as a daily average and monthly average

b. Hourly averages of precipitation, barometric pressure, ambient temperature, differential temperature, lower level dew point, upper and lower level wind directions and wind speeds, upper and lower level wind direction

variance (sigma theta), Pasquill stability classes (as outlined in Regulatory Guide 1.23) computed from the average of the two delta temperature systems, and accumulated solar radiation (langlies/minute)

c. The 15-minute averages of both upper and lower level wind directions, speeds, and sigma theta; barometric pressure; and accumulated solar radiation

d. Joint wind frequency distributions by direction (as outlined in Regulatory Guide 1.23) for both upper and lower levels, showing average wind speeds and number of unrecovered data hours.

The analog strip charts are changed twice per month. They are used as backup data to provide checks on the other systems and to provide consistency of data.

D.3 MAINTENANCE AND CALIBRATION

An onsite maintenance and calibration program was initiated in 1976. Regulatory Guide 1.23 data recovery requirements are met by performing scheduled calibrations carried out on a semiannual basis such that

a. All wind systems are changed and replaced with National Bureau of Standards (NBS) traceable calibrated wind sensors, per Regulatory Guide 1.23.

b. All ambient and differential temperature systems are changed and replaced with NBS traceable calibrated systems, per Regulatory Guide 1.23

c. The lithium chloride dew point sensor bobbin is changed

d. Calibrations of the barometric pressure, solar radiation, and precipitation systems are verified (sensors are changed on an annual basis)

e. All other onsite equipment is calibrated or its calibration is verified

In addition to the scheduled calibrations, interim calibrations are performed at 6-week intervals. A further enhancement of data recovery is achieved by operating twin, redundant, delta, temperature systems simultaneously. Comparison of the two systems on a real-time basis through the hourly data (received at CP&L general offices) gives CP&L the capability to detect discrepancies in either system, usually within 24 hours (except on weekends).

TABLE D-1

OPERATING CONDITIONS

Component	Conditions
Wind sensor	-40 F to +120 F, up to 100 percent relative humidity, up to 125 mph wind speed
Temperature sensors	-50 F to +130 F
Aspirated temperature shields	-60 F to +150 F
Honeywell dew point sensor	-40 F to +160 F, 11 percent relative humidity and above
Total precipitation sensor	No limitations
Solar radiation sensor	No limitations
Barometric pressure sensor	-30 F to +170 F, 0 percent to 90 percent relative humidity
Magnetic tape recording packages	-20 F to +140 F
Strip chart recorder	+20 F to +120 F
Signal converter (transmuter)	-40 F to +120 F, 5 percent to 95 percent relative humidity
Telecoder[R] (encoder)	0 F to +120 F, 0 percent to 100 percent relative humidity at +77 F to +104 F without condensation

TABLE D-2

MAJOR COMPONENTS

Component	Manufacturer	Model Number
Sensors		
Wind sensor	Meteorology Research, Inc.	1074-22
Single-element temperature sensor	Rosemount	103ABG-1
Dual-element temperature sensor	Rosemount	104ABG-2
Dew point sensor	Honeywell	SSP029D021
Total precipitation sensor	Weathermeasure Corp.	P-511E
Solar radiation sensor	Eppley Laboratory, Inc.	8-48
Barometric pressure sensor	Rosemount	115A9A1
Sensor support equipment		
Strip chart recorders for wind speed and direction	Esterline Angus	E1102R
Aspirated temperature shield for single-element temperature sensor	Climet	016-1
Aspirated temperature shield for dual-element temperature sensor and Honeywell dew point sensor	Climet	016-2

TABLE D-3

OPERATIONAL SENSOR ELEVATIONS

Sensor	Operational Elevations Above Tower Base (m)
Wind	11.0 and 62.4
Honeywell dew point	9.3
Solar radiation	1.5
Differential temperature	9.3 to 60.8
Precipitation	1.5
Barometric pressure	1.5

TABLE D-4

COMPONENT ACCURACY

Component	Accuracy Range
Wind sensor	
Wind speed	±0.4 mph or 1 percent, whichever is greater = 1.0 mph
Wind direction, 0 to 540	±5.4 degrees
Honeywell dew point sensor	±2 F at or above 11 percent relative humidity
Solar radiation sensor (pyranometer)	±0.04 calories/square centimeter/minute (langleys)
Differential temperature system	±0.186 F over ambient temperature range from -50 F to +130 F
Ambient temperature system	±0.498 F
Magnetic tape recorder	±1 pulse per interval
Strip chart recorder	±1 percent of full scale, direction = ±5.4 degrees, speed = ±1.0 mph
Total precipitation sensor	±0.5 percent (calibrated at 0.5 inch per hour)
Barometric pressure sensor	±0.006 inch of mercury (temperature effect: ±0.1 inch of mercury per 100 degrees of Fahrenheit operating temperature span)

APPENDIX E

METHODS USED IN RADIOLOGICAL ANALYSIS

The control room dose calculation computer program (AXIDENT) consists of a release pathway model and a dose evaluation model. The release model computes activity inventories and releases in the containment and control room based on TID-14844 (Ref. 1) releases and prespecified flow rates, filter efficiencies, halogen non-removal factors, and meteorological data. The program computes individual doses within the control room.

E.1 RELEASE MODEL

The activity release pathway model is shown in Figure E-1. Four activity nodes are represented: two primary containment volumes (sprayed and unsprayed), the secondary containment volume, and the control room. The equations for nodal activities, containment release and integrated control room activity are derived from first order activity balances in the following paragraphs. The definitions of all variables used are presented in Section E.3.

E.1.1 Primary Activity

The primary containment activity is the sum of the activity in the sprayed and unsprayed regions.

$$A_p = A_1 + A_2 \tag{1}$$

$$\frac{dA_1}{dt} = -\lambda_{sp} A_1 - \lambda_1 A_1 - \lambda_r A_1 - \lambda_p A_1 - \frac{Q}{V_1} A_1 + \frac{Q}{V_2} A_2 \tag{2}$$

$$\frac{dA_2}{dt} = -\lambda_1 A_2 - \lambda_r A_2 - \lambda_p A_2 - \frac{Q}{V_2} A_2 + \frac{Q}{V_1} A_1 \tag{3}$$

The simultaneous solution of Equations 2 and 3 when combined with Equation 1 gives the primary containment activity as

$$A_p = C_2 e^{-m_2 t} - C_1 e^{-m_1 t} \tag{4}$$

$$C_2 = \frac{A_{10}(\lambda_1' - m_1) + A_{20}(\lambda_2' - m_1)}{m_2 - m_1} \tag{5}$$

$$C_1 = \frac{A_{10}(\lambda_1' - m_2) + A_{20}(\lambda_2' - m_2)}{m_2 - m_1} \tag{6}$$

$$m_1, m_2 = \tfrac{1}{2}\left(\lambda_1' + \lambda_2' + \frac{Q}{V_1} + \frac{Q}{V_2}\right) \pm \tfrac{1}{2}\left[\left(\lambda_1' + \lambda_2' + \frac{Q}{V_1} + \frac{Q}{V_2}\right)^2 - 4\left(\frac{Q}{V_2}\lambda_1' + \frac{Q}{V_1}\lambda_2' + \lambda_1'\lambda_2'\right)\right]^{\frac{1}{2}} \tag{7}$$

$$\lambda_1' = \lambda_1 + \lambda_r + \lambda_p + \lambda_{sp} \tag{8}$$

$$\lambda_2' = \lambda_1 + \lambda_r + \lambda_p \tag{9}$$

$$A_1 = C_4 e^{-m_2 t} - C_3 e^{-m_1 t} \tag{10}$$

$$C_4 = \frac{A_{10}\,(\lambda_1' - m_1 + \frac{Q}{V_1}) - \frac{Q}{V_2} A_{20}}{m_2 - m_1} \qquad (11)$$

$$C_3 = \frac{A_{10}\,(\lambda_1' - m_2 + \frac{Q}{V_1}) - \frac{Q}{V_2} A_{20}}{m_2 - m_1} \qquad (12)$$

$$A_2 = (C_2 - C_4)\, e^{-m_2 t} - (C_1 - C_3)\, e^{-m_1 t} \qquad (13)$$

Note that the above solution for Ap degenerates to a one-volume problem if $\lambda_{sp} = 0$.

E.1.2 Secondary Activity

The rate of change of secondary containment activity is the fraction of the primary activity that goes to the secondary containment less the removal by decay, cleanup, and leakage (or exhaust) to the environment.

$$\frac{d A_s}{dt} = f_s \lambda_1 A_p - \lambda_3 A_s - \lambda_r A_s - \lambda_s A_s \qquad (14)$$

$$= f_s \lambda_1 A_p - \lambda_4 A_s \qquad (15)$$

$$\lambda_4 = \lambda_3 + \lambda_r + \lambda_s \qquad (16)$$

$$A_s = \frac{f_s \lambda_1 C_2}{\lambda_4 - m_2} e^{-m_2 t} - \frac{f_s \lambda_1 C_1}{\lambda_4 - m_1} e^{-m_1 t} + C_5 e^{-\lambda_4 t} \qquad (17)$$

$$C_5 = A_{so} - \frac{f_s \lambda_1 C_2}{\lambda_4 - m_2} + \frac{f_s \lambda_1 C_1}{\lambda_4 - m_1} \qquad (18)$$

E.1.3 Containment Activity Release Rate

The containment activity release rate has two components: the secondary containment release after filtration, and the fraction of the primary containment leakage that bypasses the secondary containment.

$$R_r = F \lambda_3 A_s + (1 - f_s) \lambda_1 A_p \quad (19)$$

$$R_r = F \lambda_3 f_s \lambda_1 \left[\frac{C_2}{\lambda_4 - m_2} e^{-m_2 t} - \frac{C_1}{\lambda_4 - m_1} e^{-m_1 t} \right] \quad (20)$$

$$+ F\lambda_3 C_5 \; e^{-\lambda_4 t} +$$

$$(1 - f_s)\lambda_1 \left[C_2 e^{-m_2 t} - C_1 e^{-m_1 t} \right]$$

$$R_r = C_6 e^{-m_2 t} - C_7 e^{-m_1 t} + C_8 e^{-\lambda_4 t} \quad (21)$$

$$C_6 = \left[\frac{F\lambda_3 f_s}{\lambda_4 - m_2} + 1 - f_s \right] \lambda_1 C_2 \quad (22)$$

$$C_7 = \left[\frac{F\lambda_3 f_s}{\lambda_4 - m_1} + 1 - f_s \right] \lambda_1 C_1 \quad (23)$$

$$C_8 = F \lambda_3 C_5 \quad (24)$$

E.1.4 Integrated Release from Containment

The integrated release from the containment is obtained by integrating the release rate, Equation 21, over the time period of interest.

$$R = \int R_r dt \tag{25}$$

$$R = \frac{C_6}{m_2} \left(1-e^{-m_2 t}\right) - \frac{C_7}{m_1} \left(1-e^{-m_1 t}\right) + \frac{C_8}{\lambda_4} \left(1-e^{-\lambda_4 t}\right) \tag{26}$$

E.1.5 Control Room Activity

The rate of change of activity in the control room is the difference between the rate at which activity is drawn in from the outside air and the rate at which it is removed by decay, cleanup, and leakage (or exhaust).

$$\frac{dA_c}{dt} = F_2 q_{cc} (\chi/Q)_c R_r - \lambda_r A_c - \frac{q_{cc}}{V_{cc}} A_c - \lambda_c A_c \tag{27}$$

$$\frac{dA_c}{dt} = C_9 R_r - \lambda_7 A_c \tag{28}$$

$$\lambda_7 = \lambda_r + \frac{q_{cc}}{V_{cc}} + \lambda_c \tag{29}$$

$$C_9 = F_2 q_{cc} (\chi/Q)_c \tag{30}$$

$$\frac{dA_c}{dt} = C_9 C_6 e^{-m_2 t} - C_9 C_7 e^{-m_1 t} + C_9 C_8 e^{-\lambda_4 t} - \lambda_7 A_c \tag{31}$$

$$A_c = \frac{C_9 C_6}{\lambda_7 - m_2} e^{-m_2 t} - \frac{C_9 C_7}{\lambda_7 - m_1} e^{-m_1 t} + \frac{C_9 C_8}{\lambda_7 - \lambda_4} e^{-\lambda_4 t} + C_{10} e^{-\lambda_7 t} \tag{32}$$

$$C_{10} = A_{co} - \frac{C_9 C_6}{\lambda_7 - m_2} + \frac{C_9 C_7}{\lambda_7 - m_1} - \frac{C_9 C_8}{\lambda_7 - \lambda_4} \quad (33)$$

E.1.6 Integrated Activity in Control Room

The integrated activity in the control room is obtained by integrating Equation 32 over the time period of interest.

$$R_c = \int A_c dt \quad (34)$$

$$R_c = \frac{C_9 C_6}{(\lambda_7 - m_2) m_2} (1 - e^{-m_2 t}) - \frac{C_9 C_7}{m_1 (\lambda_7 - m_1)} (1 - e^{-m_1 t}) + \frac{C_9 C_8}{\lambda_4 (\lambda_7 - \lambda_4)} (1 - e^{-\lambda_4 t}) + \frac{C_{10}}{\lambda_7} (1 - e^{-\lambda_7 t}) \quad (35)$$

Implicit in the above derivations is the assumption of constant coefficients. In the actual transient simulation, solutions are broken into a sequence of discrete time intervals over which the input parameters that make up the coefficients are prespecified constants. The input parameters consist of flow rates, X/Qs, decay and iodine removal constants, provided as stepwise constant functions of time.

Initial secondary containment and control room activity inventories are assumed to be zero. Initial primary activity may be based on the analysis of TID-14844 (Ref. 1) using the fractional iodine release assumptions of Regulatory Guide 1.3 (Ref. 2) or 1.4 (Ref. 3). The source term equation is

$$A_{p_o} = 3.65 \times 10^3 \, P_o \gamma_i f_r f_i (1 - e^{-\lambda_r T_o}) \text{ (curies)} \quad (36)$$

E.2 DOSE MODEL

At the end of each time interval, control room individual thyroid and whole body doses are determined using the containment release rate, integrated control room activity, and input values of X/Q at the control room intake.

Thyroid inhalation dose in the control room is given by the following equation:

$$D_T = \sum_i D_{T_i} \text{ (rem)} \tag{37}$$

$$= \frac{BR}{V_{cc}} \sum_i R_{c_i} \cdot DCF_i$$

where

BR = breathing rate

= 3.47×10^{-4} m^3/sec (Ref. 4)

Beta dose in the control room is given by:

$$D_\beta = \sum_i D_{\beta_i} \text{ (rem)} \tag{38}$$

$$= \frac{0.23}{V_{cc}} \sum R_{c_i} \cdot \bar{E}_{\beta_i} \tag{39}$$

where

$\bar{E}_\beta$ = average beta energy (MeV/dis)
(See Table E-2.)

Gamma dose in the control room is given by

$$D_\gamma = \sum_i D_{\gamma_i} \quad \text{(rem)} \tag{40}$$

$$= \frac{0.25}{V_{cc}} \sum_i R_{c_i} \sum_j E_{\gamma_{i,j}} f_{i,j} \left\{1 - e^{-\mu_j r}\left[1 + \left(\mu_j - \mu_{a_j}\right) r\right]\right\} \tag{41}$$

Gamma energies and fractions are presented in Table E-1. Absorption coefficients divided by the density of air are listed in Table E-2.

E.3 NOMENCLATURE

- A_p = Primary containment activity
- A_1 = Activity in sprayed volume
- A_2 = Activity in unsprayed volume
- λ_1 = Primary containment leak rate
- λ_r = Radiological decay constant (Sec^{-1}) (See Table E-1)
- λ_p = Cleanup rate in primary containment
- f_1 = Fraction of activity released to sprayed volume
- f_2 = Fraction of activity released to unsprayed volume
- V_1 = Sprayed volume
- V_2 = Unsprayed volume
- λ_3 = Secondary leak rate
- λ_{sp} = Spray removal rate
- f_s = Fraction of primary leakage which enters secondary
- F = Filter non-removal factor for secondary building exhaust system
- F_2 = Filter non-removal factor for control room (center) intake system
- $(X/Q)_c$ = Atmospheric dispersion to control center
- q_{cc} = Control center intake flow
- V_{cc} = Control center volume
- $\bar{E}_{\gamma i}$ = Average gamma energy (MeV/dis) (See Table E-2)
- $\bar{E}_{\beta i}$ = Average beta energy (MeV/dis) (See Table E-2)
- R_i = Integrated release from containment (Ci)
- V_{cr} = Control room free volume (m^3)
- $E_{\gamma i,j}$ = Energy of jth gamma of ith isotope (MeV/λ) (See Table E-3)
- $f_{i,j}$ = Fraction of jth gamma of ith isotope (γ/dis)
- a_j = Energy absorption coefficient for air (m^{-1}) (See Table E-4)
- μ_j = Total absorption coefficient for air (m^{-1}) (See Table E-4)
- r = Radius of hemisphere with same volume as control room (m)
- λ_s = Cleanup rate in secondary containment

λ_c = Cleanup rate in control room

V_{cc} = Control center free volume (m^3)

R_{c_i} = Integrated control room activity (Ci-sec)

DCF_i^i = Dose conversion factor (rem/curie) (See Table E-2)

P_o = Base loaded core power (Mwt)

γ_i = Fission yield (percent) (See Table E-1)

T_o = 1000 days (assumed)

f_r = Fraction of core inventory available for release
= 0.25 (for iodines) (Ref. 2)
= 1.0 (for noble gases)

f_i = 0.91 (for elemental iodine) (Ref. 2)
= 0.05 (for particulate iodine)
= 0.04 (for organic iodine)
= 1.0 (for noble gases)

Q = Mixing flow rate between sprayed and unsprayed volumes

E.4 REFERENCES

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5. M. E. Meek and B. F. Rider. 1968. Summary of Fission Product Yields for U^{235}, Pu^{239}, and Pu^{241} at Thermal, Fission Spectrum and 14 MeV Neutron Energies. APED-5398.

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8. J. H. Hubbell. 1969. "Photon Cross Sections, Attenuation Coefficients, and Energy Absorption Coefficients from 10 KeV to 100 GeV," NSRDS-NBS 29.

TABLE E-1

NUCLIDE DECAY CONSTANTS AND FISSION YIELDS (Ref. 5)

Nuclide	Decay Constant (sec^{-1})	Fission Yield (percent)
I^{131}	9.97 (-7)[a]	2.91
I^{132}	8.37 (-5)	4.33
I^{133}	9.17 (-6)	6.69
I^{134}	2.22 (-4)	7.8
I^{135}	2.87 (-5)	6.2
Kr^{83m}	1.03 (-4)	0.52
Kr^{85m}	4.38 (-5)	1.3
Kr^{85}	2.04 (-9)	0.27
Kr^{87}	1.52 (-4)	2.5
Kr^{88}	6.88 (-5)	3.56
Xe^{131m}	6.79 (-7)	0.022
Xe^{133m}	3.55 (-6)	0.17
Xe^{133}	1.52 (-6)	6.69
Xe^{135m}	7.40 (-4)	1.8
Xe^{135}	2.11 (-5)	6.3
Xe^{138}	6.60 (-4)	5.9

[a]Read as 9.97×10^{-7}

TABLE E-2

AVERAGE BETA AND GAMMA ENERGIES AND IODINE INHALATION DOSE CONVERSION FACTORS

Nuclide	γ(MeV/dis) (Ref. 6)	β(MeV/dis) (Ref. 6)	DCF (rem/curie) (Ref. 7)
I^{131}	0.371	0.197	1.48 (+6)
I^{132}	2.40	0.448	5.35 (+4)
I^{133}	0.477	0.423	4.00 (+5)
I^{134}	1.939	0.455	2.50 (+4)
I^{135}	1.779	0.308	1.24 (+5)
Kr^{83m}	0.005	0.034	
Kr^{85m}	0.156	0.233	
Kr^{85}	0.0021	0.223	
Kr^{87}	1.375	1.050	
Kr^{88}	1.743	0.341	
Xe^{131m}	0.022	0.135	
Xe^{133m}	0.033	0.155	
Xe^{133}	0.030	0.146	
Xe^{135m}	0.422	0.097	
Xe^{135}	0.246	0.322	
Xe^{138}	2.870	0.800	

TABLE E-3

ISOTOPIC GAMMA ENERGIES AND DECAY FRACTIONS (Ref. 5)

I-131		I-132		I-133		I-134		I-135		XE-131M		XE-133M		XE-133	
.0300	5.60E-02	.1472	2.00E-03	.5300	9.40E-01	.1360	5.00E-02	.2204	1.80E-02	.0050	6.00E-02	.0297	1.41E-01	.0308	3.82E-01
.0802	2.50E-02	.2630	2.00E-02	.7500	2.00E-02	.1800	7.00E-02	.2884	3.40E-02	.0300	5.90E-01	.0330	3.26E-02	.0353	8.60E-02
.1772	2.50E-03	.2850	5.00E-03	.8600	7.00E-02	.3900	7.00E-02	.4175	3.20E-02	.1640	2.30E-02	.2320	8.00E-02	.0796	6.00E-03
.2843	5.90E-02	.5040	1.00E-02	1.0300	1.00E-02	.4100	6.00E-03	.4340	8.20E-03					.0810	3.70E-01
.3258	2.50E-02	.5090	2.00E-02	1.2400	2.00E-02	.4300	3.00E-02	.5269	1.49E-01					.1607	6.60E-04
.3645	7.97E-01	.5230	1.60E-01	1.3500	2.00E-02	.5100	9.00E-03	.5465	6.20E-02					.2234	2.40E-06
.5030	3.60E-03	.6206	4.00E-02			.5400	8.00E-02	.7077	5.90E-03					.3031	5.10E-05
.6370	6.80E-02	.6300	1.90E-01			.6100	2.40E-01	.8369	5.00E-02					.3841	2.30E-04
.7229	1.50E-02	.6507	4.00E-02			.6900	7.00E-02	.9724	1.80E-02						
		.6521	4.00E-02			.7500	1.00E-02	1.0387	9.00E-02						
		.6678	9.20E-01			.7700	6.00E-02	1.1017	1.70E-02						
		.6697	6.00E-02			.8500	9.50E-01	1.1243	3.10E-02						
		.6715	6.00E-02			.8600	4.00E-02	1.1316	1.75E-01						
		.7270	3.20E-02			.8900	7.00E-01	1.1691	7.90E-03						
		.7290	3.20E-02			.9600	2.00E-02	1.2604	2.58E-01						
		.7729	8.30E-01			1.0000	5.00E-02	1.4575	7.10E-02						
		.9547	1.94E-01			1.0700	1.80E-01	1.5029	1.20E-02						
		1.1390	2.00E-02			1.1500	1.20E-01	1.5659	1.40E-02						
		1.1400	4.00E-02			1.2800	1.00E-02	1.6785	9.50E-02						
		1.2200	7.00E-03			1.3400	2.00E-02	1.7070	3.60E-02						
		1.2900	6.00E-02			1.4600	4.00E-02	1.7919	7.60E-02						
		1.3630	2.00E-02			1.4900	1.00E-02	1.8314	6.40E-03						
		1.3980	8.00E-02			1.6200	5.00E-02	2.0467	8.30E-03						
		1.4400	3.00E-02			1.7900	5.00E-02	2.2567	6.30E-03						
		1.7200	3.00E-03					2.4079	9.00E-03						
		1.7700	5.00E-03												
		1.9100	1.30E-02												
		1.9900	1.30E-02												
		2.0890	3.00E-03												
		2.1600	2.00E-03												
		2.2200	2.00E-03												
		2.3900	2.00E-03												
		2.5500	5.00E-04												
		2.6800	2.00E-04												

TABLE E-3 (continued)

ISOTOPIC GAMMA ENERGIES AND DECAY FRACTIONS (Ref. 5)

ISOTOPES, GAMMA ENERGIES AND FRACTIONS

XE-135M		XE-135		XE-138		KR-83M		KR-85M		KR-85		KR-87		KR-88	
.0045	4.00E-04	.0310	4.50E-02	.0300	3.00E-02	.0016	8.00E-02	.0016	6.50E-04	.5140	4.35E-03	.4030	5.90E-01	.1660	6.90E-02
.0304	1.35E-01	.1585	2.10E-03	.1550	7.80E-02	.0093	8.00E-02	.0128	5.20E-02			.6743	2.50E-02	.1961	3.61E-01
.5270	8.20E-01	.1999	2.00E-04	.2430	3.60E-02	.0128	1.60E-01	.1495	7.70E-01			.8360	8.00E-03	.3626	3.00E-02
		.2498	9.16E-01	.2590	3.70E-01			.3050	1.35E-01			.8459	8.10E-02	.3904	6.00E-03
		.3586	2.20E-03	.3970	7.40E-02							1.1755	1.40E-02	.4723	6.00E-03
		.3731	1.10E-04	.4020	2.80E-02							1.3380	7.50E-03	.8347	1.31E-01
		.4082	3.10E-03	.4340	2.30E-01							1.3840	5.50E-03	.8624	5.00E-03
		.5733	5.00E-05	1.7700	2.00E-01							1.7410	2.00E-02	.9867	1.63E-02
		.6066	2.40E-02	2.0000	1.60E-01							2.0120	2.60E-02	1.1417	1.60E-02
		.6546	3.20E-04									2.5560	9.50E-02	1.1833	9.00E-03
		.7319	4.60E-04									2.5590	5.10E-02	1.2500	1.10E-02
		.8126	5.00E-04									2.8112	4.00E-03	1.5135	1.50E-02
		1.0630	3.00E-05									3.3698	6.00E-03	1.5293	1.14E-01
														2.0295	4.60E-02
														2.0353	4.80E-02
														2.1959	1.51E-01
														2.2316	3.60E-02
														2.3524	2.00E-03
														2.3920	3.82E-01

TABLE E-4

ABSORPTION COEFFICIENTS FOR AIR (Ref. 8)

E MeV	μ/ρ [a] (cm²/gm)	μ_a/ρ [b] (cm²/gm)
0.01	4.99	4.61
0.015	1.55	1.27
0.02	0.752	0.511
0.03	0.349	0.148
0.04	0.248	0.0669
0.05	0.208	0.0406
0.06	0.188	0.0305
0.08	0.167	0.0243
0.1	0.154	0.0234
0.15	0.136	0.0250
0.2	0.123	0.0268
0.3	0.107	0.0288
0.4	0.0954	0.0295
0.5	0.0870	0.0297
0.6	0.0805	0.0290
0.8	0.0707	0.0289
1.0	0.0636	0.0280
1.5	0.0518	0.0257
2.0	0.0445	0.0238
3.0	0.0358	0.0212
4.0	0.0308	0.0194

[a]From Table 3.-27, NSRDS-NBS 29.
[b]From Table 1.-7, NSRDS-NBS 29.

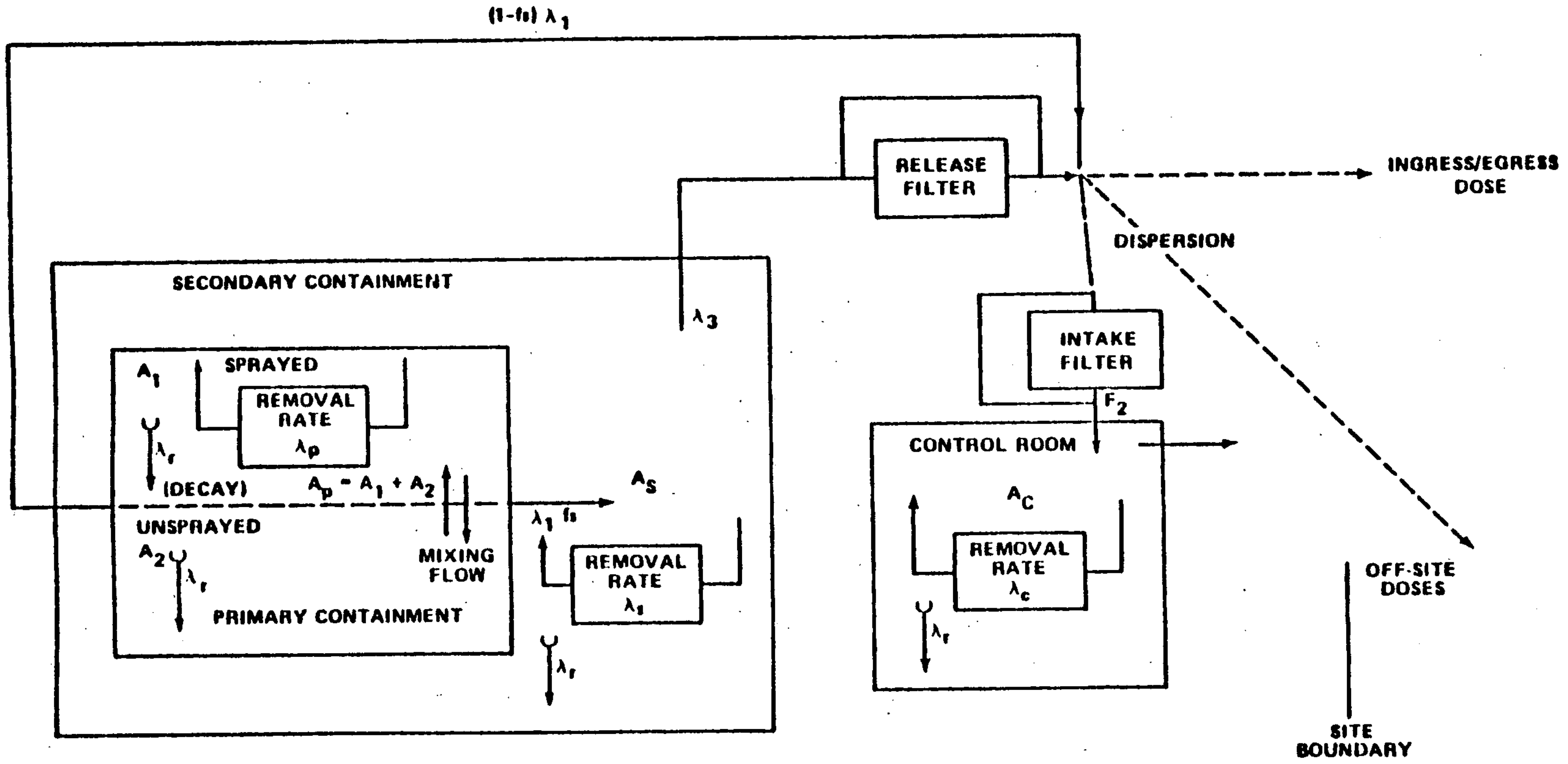

Figure E-1. Dose Model Activity Flow Schematic