NUS-3697
REVISION 2

CONTROL ROOM HABITABILITY EVALUATION

BRUNSWICK STEAM ELECTRIC 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 Brunswick Units 1 and 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 the following:

- 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 sults 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 from the radiological analysis are presented in Section 5.0 of this report (the methods used in the radiological analysis are described in Appendix E) and show that the operator doses are within NRC General Design Criterion 19 without consideration of main steam isolation valve leakage. 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 Brunswick 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 a 10-mile radius of the plant, to ensure identification of potential hazards adjacent to the 5-mile radius of the required study area.

A large, potential source of a hazardous chemical is found onsite at Brunswick. Liquefied compressed chlorine gas is used in the service water system and kept at the site near the service water intake structure approximately 450 feet from the control room air intake. As described in the Brunswick Final Safety Analysis Report (FSAR), the chlorine is obtained, stored, and used directly from a 55-ton rail tank car. The potential effects of the rupture of this tank car are discussed in FSAR Chapter 6 and are shown to be acceptable. R1

General characteristics and significant features of the Brunswick site are described in the FSAR. The study area is a uniform coastal plain situated along the Atlantic Ocean and the Cape Fear River, about 25 miles south of Wilmington, North Carolina. As shown in Figure 2-1, the study area includes the city of Southport, North Carolina; several beach communities and adjoining built-up areas; and rural portions of Brunswick County. The principal highways serving the area are North Carolina Routes (NC) 211, 133, and

87. The area is also served by connections to the Seaboard Coast Line Railroad system via the federally owned and operated rail line to the Sunny Point Terminal.

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 clarification 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 in the area; 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 Brunswick area.

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:

- Standard Products. All of the chemical storage containers at Standard Products are confined within 3- to 4-foot cinderblock berms. Eight 47,000-pound loads of sulfuric acid are delivered to the plant

each year. Two 20,000-gallon shipments of caustic soda and two 500-gallon shipments of chlorine are also delivered to the plant each year. All shipments are delivered by truck, primarily from Wilmington, North Carolina. Some shipments may use NC 87/133, which at its closest point, is 1.4 miles from the plant.

- Pfizer Chemical Company. A 12,000-ton sulfuric acid storage tank is located on the Pfizer property. The sulfuric acid is transported to the Pfizer site by ship (approximately four shipments per year, 6000-ton capacity). Due to its negligible vapor pressure, sulfuric acid spills in transit or at the Pfizer site do not represent a toxic hazard to the Brunswick control room.

  A rail spur from the federally owned rail line to the Sunny Point Terminal serves the Brunswick plant. A branch line from this spur serves the Pfizer Chemical Company and traverses the Brunswick site to within approximately one-half mile of the control room. The line is used primarily for outgoing shipments of citric acid, which is manufactured at the Pfizer plant site. As discussed above, sulfuric acid shipments do not represent a toxic hazard to the Brunswick control room. RI

  No other chemicals of concern are used in large quantities by Pfizer Chemical Company. Small amounts of aqueous ammonia (housekeeping and citric acid production), sodium hypochlorite (waste treatment), and chlorine (150-pound cylinder for cooling tower bacteria control) are used.

- Sunny Point Military Ocean Terminal. The Sunny Point Military Ocean Terminal is a major U. S. Department of Defense installation for the movement of conventional ammunition and weapons overseas. The Military Traffic Management Command indicated in a briefing October 2, 1980, that no chemical or biological weapons were handled at Sunny Point. The only potentially hazardous chemicals likely to be at the site are those used domestically at Sunny Point and the fuel of Lance missiles shipped through Sunny Point. Each Lance missile contains 375 pounds of liquid hydrazine and 1107 pounds of red fuming nitric acid. This fuel is contained within the missile during its shipment and temporary storage. Each missile is individually protected against rough handling; they have been drop-tested successfully from 40 feet. Furthermore, the terminal is ringed by a 4600-acre buffer zone on the west side of the Cape Fear River. Inspection, storage, and holding areas are designed with blast-restricting earthen berms, and the nearest area to the Brunswick plant is a rail holding yard 2.0 miles from the plant. The bermed area is about 270,000 square feet with berms ranging from 10 to 15 feet in height.

  The chemicals used domestically include sulfuric acid, trichloroethylene, and chlorine, as listed in Table 2-2. The chlorine is used in 150-pound cylinders attached to seven wells scattered around the post. The other chemicals are used in maintenance operations.

- Brunswick County Department of Public Works. The Brunswick County Department of Public Works

uses ten 1-ton chlorine cylinders at its waterworks. The waterworks, however, is over 6 miles from the Brunswick plant.

- Intracoastal Waterway (ICW). Research to date suggests that significant quantities of chemicals are shipped on the Cape Fear River segment of the ICW below Wilmington. Information received to date from governmental and industrial sources indicates, however, that little of this traffic consists of hazardous chemicals. One waterway user, W. R. Grace Company of Wilmington, ships approximately 9400 tons of anhydrous ammonia in a four-tank barge every 3 weeks; occasionally this shipment may reach 10,000 tons in a five-tank barge. Approximately 20,000 tons of ammonia nitrate are shipped once in every 10-month period.

  The Chlorine Institute indicated that, to its knowledge, no chlorine was shipped over the Cape Fear segment of the ICW and no evidence contradicting this has been found to date.

  Because these shipments are infrequent (less than about 20 per year), they have not been considered in the analysis of control room habitability. Furthermore, the possibility of a major spill via collision or grounding is remote. Hull rupture alone would not lead to a release because the chemical tanks are physically separate from the ship structure. Therefore, the U. S. Coast Guard considers the probability of a toxic chemical release associated with water transport on the Cape Fear River near the Brunswick site to be negligible. R1

- Highway network. The highway network in the vicinity of Southport, North Carolina, is comprised of feeder routes servicing the military and industrial activity discussed above. In general, that portion of the highway network closest to the Brunswick plant would be used for hazardous material transportation only if the material was being shipped to or from the plant. Therefore, based on limited survey data and on the experience of local CP&L employees, it is reasonable to assume that hazardous material shipments within 5 miles of the Brunswick plant are not large enough nor frequent enough to warrant further analysis, or that shipments to and from the plant itself are amenable to administrative control by the plant staff. R1

2.2 Conclusions

The current information on hazardous material transportation in the vicinity of the Brunswick site indicates that local highway, railroad, and waterway routes do not present a toxic hazard to control room personnel. Shipments not under the control of the plant itself are either too small or too infrequent to require a specific toxic hazard analysis.

2.3 Reference

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

TABLE 2-1

HAZARDOUS CHEMICAL INFORMATION 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
U.S. Army, Military Traffic Management Command	Arlington, VA	Sunny Point Terminal Operations
U.S. Army, Redstone Arsenal	Huntsville, AL	Lance Missile Program
U.S. Maritime Administration	Washington, DC	Intracoastal Waterway (ICW) shipments
U.S. Coast Guard, 5th District	Wilmington, NC	ICW shipments
North Carolina Department of Human Resources	Raleigh, NC	Hazardous materials monitoring
North Carolina Department of Commerce	Raleigh, NC	Hazardous materials information
North Carolina Department of Transportation	Raleigh, NC	Hazardous shipments
Southport Fire Department	Southport, NC	Incidents, emergency plans, general background
Southport Police Department	Southport, NC	Incidents, emergency plans, general background

TABLE 2-1

HAZARDOUS CHEMICAL INFORMATION CONTACTS (continued)

Contact	Location	Information Type
Brunswick County	Bolivia, NC	Highway and rail information
Seaboard Coast Line Railroad	Jacksonville, FL	Rail shipments
Dupont Chemical	Wilmington, NC	Hazardous chemical shipments on ICW
Hercofina Chemical	Wilmington, NC	Hazardous chemical shipments on ICW
Brunswick Energy Company	Southport, NC	Hazardous chemical shipments on ICW
Paktank Chemical	Wilmington, NC	Hazardous chemical shipments on ICW
W. R. Grace Company	Wilmington, NC	Hazardous chemical shipments on ICW
The Chlorine Institute	New York, NY	Hazardous chemical shipments on ICW

TABLE 2-2

HAZARDOUS CHEMICAL SOURCES IDENTIFIED

		Storage Characteristics				
Company/Facility	Chemical	Type	Number of Units	Quantity/ Unit	Inside/ Outside	Distance from Plant (mi)
Standard Products	Sulfuric acid	Tank	2	20 tons	Outside	2.2
	Caustic soda	Tank	1	20 tons	Outside	2.2
	Chlorine	Cylinder	3	1 ton	Outside	2.2
Pfizer Chemical Company	Chlorine	Cylinder	1	220 ft^3	--	1.4
	Sulfuric acid	See text			--	1.4
Sunny Point Military Ocean Terminal	Trichloroethylene	Drum	1	55 gal.	Indoors	2.0 (min)
	Sulfuric acid	Carboy	Numerous	5 gal. (200 gal. total)	Indoors	2.0 (min)
	Chlorine	Cylinder	7	150 lb	Outdoors	2.0 (min)
	Nitric acid	Lance missiles	--	1,107 lb per missile	Outdoors	
Brunswick County Department of Public Works	Chlorine	Cylinder	10	1 ton	Outside	6.1
Intracoastal Waterway	Several (see text)	Barges/ships	--	--	N/A	2.3

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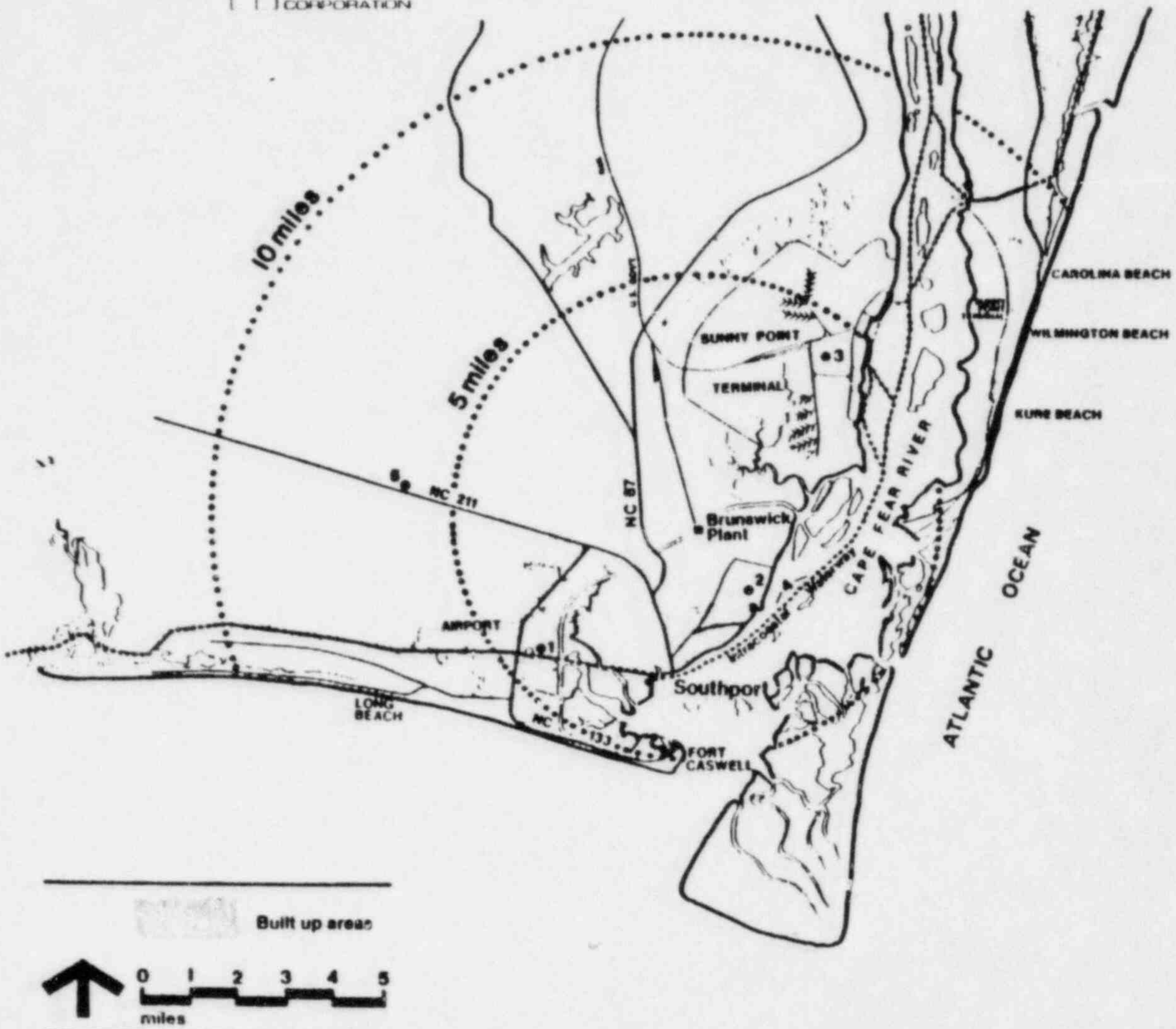
Hazardous Chemical Storage Locations Near Brunswick Steam Electric Plant



STANDARD PRODUCTS

Symbol	Units	Quantity/Unit	Storage	Chemical
●1	2	20 tons	tank	sulfuric acid
	1	20 tons	tank	caustic soda
	3	1 ton	cylinder	chlorine

PFIZER CHEMICAL COMPANY

Symbol	Units	Quantity/Unit	Storage	Chemical
●2	1	220 ft^3	cylinder	chlorine
	see text	—	—	sulfuric acid

SUNNY POINT MILITARY OCEAN TERMINAL

Symbol	Units	Quantity/Unit	Storage	Chemical
●3	1	55 gal	drum	trichloroethylene
	numerous	5 gal (200 gal total)	carboy	sulfuric acid
	7	150 lb	cylinder	chlorine
	see text	Lance Missiles	—	nitric acid

INTRACOASTAL WATERWAY

Symbol	Units	Quantity/Unit	Storage	Chemical
4 (●-●-●)	see text	—	—	—

BRUNSWICK COUNTY DEPARTMENT OF PUBLIC WORKS

Symbol	Units	Quantity/Unit	Storage	Chemical
●5	10	1 ton	cylinder	chlorine

Figure 2-1. Southport–Cape Fear River Area, North 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

Two types of releases were analyzed for Brunswick for the radiological assessment. The X/Q values were calculated at the intake for (1) releases from both the Unit 1 and Unit 2 containments and (2) releases from the 100-meter stack. Because of the location of the release points and intake relative to surrounding buildings and because of the different release modes, the two releases were analyzed with different methods. Figure 4-3 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

3.1.1 Radiological Releases - Units 1 and 2 Containments

The X/Q values for radiological releases from the two containments 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). Each containment was analyzed separately. 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 data 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 Brunswick can also be calculated. The assumptions for this determination are outlined below.

Units 1 and 2

Containment cross-sectional area	= 2095 m^2
Minimum distance to intake	= 38 m
Scaled distance	= 0.83
X/Q from Figure 9	= 1.7×10^{-3} sec/m^3

The 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 both Units 1 and 2. For releases from Unit 1, winds from the northeast through southeast were used in the analysis. For Unit 2 releases, winds from the southeast through southwest were used. Data from these wind sectors were then used to obtain the necessary wind speed and direction factors.

These factors are

Unit 1

s/d ratio	= 0.89
Wind sectors	= NE, ENE, E, ESE, SE
Wind speeds (10 m)	
5 percent	= 0.88 m/s
10 percent	= 1.33 m/s
20 percent	= 1.99 m/s
40 percent	= 3.10 m/s
Wind direction frequency	= 21.84 percent

Unit 2

s/d ratio	= 0.89
Wind sectors	= SE, SSE, S, SSW, SW
Wind speeds (10 m)	
5 percent	= 1.20 m/s
10 percent	= 1.77 m/s
20 percent	= 2.61 m/s
40 percent	= 3.98 m/s
Wind direction frequency	= 34.73 percent

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

3.1.2 Radiological Releases - 100 Meter-Stack

Releases from the 100-meter stack necessitate a different type of analysis from those of the two containment structures. Because the stack is freestanding, a 100 percent elevated release was assumed. The methodology of Regulatory Guide 1.145, then, was used to analyze these releases using only those meteorological conditions associated with wind directions that could affect the intake

if effluents were released from the stack (Ref. 4). These wind directions were determined to be southeast, south-southeast, and south. The 0.5 percent X/Q (assumed to be the 0- to 2-hour value) and the fumigation X/Q were calculated in each of the three affected downwind sectors and the maximum values were chosen for the evaluation.

Because the Brunswick plant is located greater than 3200 m inland, the fumigation X/Q is applied to the first one-half hour of the accident. For time periods greater than 2 hours, the values were determined by logarithmic interpolation between the 2-hour and the annual average values. The assumptions used in this analysis are outlined below.

<u>Stack</u>

Affected downwind sectors	= NW, NNW, N
Downwind distance	= 190 m
Release height	= 100 m
Receptor height	= 25 m
Building wake	= None

The X/Q values for the stack releases are provided in Table 3-4. Meteorological data used in the analysis are discussed in Section 3.3.

3.2 Calculations - Toxic Chemical Releases

X/Q values were calculated to support the toxic chemical analysis discussed in Section 6.0. These X/Q calculations produced continuous release (1 hour), direction-independent X/Q values (shown in Table 3-5) 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 be'ow.

Analysis	Atmospheric Stability	Wind Speed/ Wind Direction	Combined Data Recovery (%)
Radiological releases, containment	N/A	11-m level (wind speeds converted to 10 m)	98
Radiological releases, stack	$T_{105-11\ m}$	105-m level (wind speeds converted to 100m)	98
Toxic chemical releases	$T_{105-11\ m}$	11-m level (wind speeds converted to 10 m)	98

The joint frequency distributions of wind speed and wind direction, by atmospheric stability class for both the 11- and 105-meter levels, 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, BRUNSWICK UNIT 1

Adjustment Factor	Time Interval			
	0-8 Hr	8-24 Hr	1-4 Days	4-30 Days
Wind speed	1.0	0.67	0.45	0.29
Wind direction	1.0	0.80	0.61	0.22
Occupancy	1.0	1.0	0.60	0.40
Overall reduction[a]	1.0	0.54	0.16	0.026

[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

ADJUSTMENT FACTORS USED TO CALCULATE EFFECTIVE RELATIVE CONCENTRATIONS FOR SELECTED TIME INTERVALS, BRUNSWICK UNIT 2

Adjustment Factor	Time Interval			
	0-8 Hr	8-24 Hr	1-4 Days	4-30 Days
Wind speed	1.0	0.68	0.45	0.30
Wind direction	1.0	0.84	0.67	0.35
Occupancy	1.0	1.0	0.60	0.40
Overall reduction[a]	1.0	0.57	0.18	0.042

[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 3-3

CALCULATED X/Q VALUES AT THE CONTROL ROOM INTAKE FOR RADIOLOGICAL RELEASES FROM BRUNSWICK UNITS 1 AND 2 CONTAINMENTS (includes occupancy factor)

Time Period	Unit 1 X/Q (sec/m^3)	Unit 2 X/Q (sec/m^3)
0-8 hours	1.7×10^{-3}	1.7×10^{-3}
8-24 hours	9.2×10^{-4}	9.7×10^{-4}
1-4 days	2.7×10^{-4}	3.1×10^{-4}
4-30 days	4.4×10^{-5}	7.1×10^{-5}

TABLE 3-4

CALCULATED X/Q VALUES AT THE BRUNSWICK CONTROL ROOM INTAKE FOR RADIOLOGICAL RELEASES FROM THE 100-METER STACK[a]
(includes occupancy factor)

Time Period	X/Q (sec/m^3)
0-1/2 hour (fumigation)	3.3×10^{-4}
1/2-8 hours	1.8×10^{-6}
8-24 hours	1.1×10^{-6}
1-4 days	2.0×10^{-7}
4-30 days	2.7×10^{-8}

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

TABLE 3-5

ONE HOUR X/Q VALUES FOR THE
TOXIC CHEMICAL ANALYSIS AT BRUNSWICK[a]
(1976-1979 onsite data, 11 m winds,
$\Delta T_{104-11\ m}$, no meander, no building
wake, no initial plume volume,
5% direction-independent)

Distance (m)	X/Q (sec/m^3) Brunswick
100	5.2×10^{-2}
500	3.4×10^{-3}
1000	1.0×10^{-3}
1500	5.4×10^{-4}
2000	3.5×10^{-4}
2500	2.6×10^{-4}
3000	2.0×10^{-4}
4000	1.4×10^{-4}
5000	1.0×10^{-4}
6000	8.1×10^{-5}
7000	6.7×10^{-5}
8045 (5 miles)	[b]5.6×10^{-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 REVIEW

4.1 System Description

The control building heating, ventilating, and air conditioning system consists of individual once-through ventilation systems, a recirculating ventilation system, and an emergency air filtering system. All system equipment, controls, and ductwork supports are designed to Seismic Category I re~uirements and are protected by tornado-proof constructions Redundant ventilating, air conditioning, and emergency fi ering equipment is provided to ensure proper environmental conditions within the control room, computer rooms, electronic equipment rooms, and electronics workrooms. The control room HVAC equipment is located in a penthouse on the roof of the control building at an elevation of 70 feet, 0 inches.

Outside air is taken into the control building through two tornado pressure check valves which are designed to prevent flow reverse due to a sudden drop in outside air pressure. The air is then filtered by the intake plenum roll filter and distributed to the various ventilation systems. R1

Each cable spreading room, each battery room, and the mechanical equipment room is provided with a once-through ventilation system equipped with an individual supply fan and exhaust fan. The supply fan for each system takes suction from the intake plenum air filter through a supply damper, and discharges to its associated room. The exhaust fan takes suction from the ventilated room and discharges through a damper and a tornado pressure check valve to the atmosphere outside the control building. Temperature regulation

for each of the rooms is accomplished by temperature-controlled vortex dampers located in the supply ducting of each supply fan.

The battery room must be maintained at a negative static pressure with respect to the rest of the building to prevent the exfiltration of battery-generated gases. This negative static pressure is maintained by pressure-controlled vortex dampers located in the supply ducting to the battery exhaust fans.

The recirculating ventilation system provides conditioned air (75°F at 50 percent relative humidity) to the main control room and its associated areas (i.e., computer room, electronic equipment room). This multi-room area is maintained at a positive static pressure to prevent the inadvertent inflow of toxic gases, radioactive airborne contamination, and smoke. Each computer room has an individual air handling unit and condensing unit located within the electronic equipment room.

R1

The recirculating ventilation system make-up air and recirculated air are constantly filtered by the recirculation roll filter to remove dust, smoke, and other particles that may be present in the air. The roll filter is located in the return air plenum. This roll filter and the outside air filter have an Air Institute weight method efficiency of 80 to 85 percent. The volume of normal make-up air (2000 cfm) sufficiently compensates for the normal exhaust (1000 cfm) of the system's single exhaust fan and the building exfiltration (1000 cfm).

From the recirculation air filter, the air is routed to the air conditioning cooling coils. The recirculating ventilation system is equipped with three air conditioning units

(two normally operating with one serving as a spare) capable of handling the large concentrated heat gains from the computers and electronic equipment, as well as the variable heat gains from personnel and lighting. These units also provide the necessary humidity controls to maintain proper environmental conditions. Individual heating coils (15 Kw heating elements) are located in the discharge ducting of each air conditioning unit cooling coil to aid in temperature control.

After conditioning, the air is directed to the suctions of the three recirculating ventilation supply fans (one serves as a spare). The air discharged by the fans is routed to the main control room area where it is dispersed to the various rooms. The air is then recirculated and conditioned for reuse.

The emergency air filtering system provides the additional filtering necessary to maintain habitable conditions within the control room area during emergency situations. The emergency air filtering system consists of two filtering trains, each consisting of an emergency air filter and recirculation fan. One filtering train is required for system operation with the other serving as the standby train. System operation is initiated upon either of the following conditions: R1

a. Abnormally high radiation levels detected by the control building area radiation monitors.

b. Smoke detected by the control room area fire detection systems.

Two redundant radiation monitors located in the control building air inlet plenum are provided to protect against

the intake of contaminated outside air. Figure 4-1 illustrates the state of the control room HVAC system following isolation on a high radiation signal.

Should either monitor detect high radiation, the control room annunciator will be actuated and the following control actions will occur automatically:

a. The normal fresh air intake and exhaust dampers of the ventilation systems in the control and electronic equipment rooms are closed.

b. The emergency bypass ventilation system is placed in service to filter 1000 cfm of recirculated air and 1000 cfm of outside air to cleanup and pressurize the control room air and provide fresh breathing air.

c. Carbon filters are automatically placed in service with the filters in the recirculation duct.

d. The cable spreading room ventilation systems are shut down to protect these areas from the intake of potentially contaminated outside air.

e. The mechanical equipment room ventilator fan is shut down to reduce the intake of potentially contaminated outside air into the mechanical equipment room.

f. The control building exhaust fan is shut down and the 1000 cfm return air from the washroom is shunted through the emergency filters to aid in recirculating air cleanup. R1

Should smoke-filled air be drawn into the control room, smoke detectors within the control room and mechanical equipment room will alarm. Controls are available to reduce the volume of normal makeup air, and/or to place the bypass ventilation system filter trains in service. R1

Chlorine protection is provided by six chlorine detectors: two detectors are mounted at the control room air intakes; two detectors are attached to the wall of the service water intake structure immediately adjacent to the rail siding where the chlorine tank car is located; two detectors are located inside the chlorination building. The first two locations are inside or on the outer wall of Category I structures and are seismically protected. The detectors have a sensitivity of 1 part per million or better and a response time of less than 3 seconds.

Detection of high chlorine concentration in the chlorination building alarms in the control room and at the sensor location. Detection of high chlorine concentration at the tank car siding or in the control room air intake will alarm in and automatically isolate the control room. Figure 4-2 illustrates the state of the control room HVAC system following isolation on a high chlorine signal. Isolation consists of closing the outside air makeup damper, termination of ventilation air to both the mechanical equipment room and cable spreading rooms, and stopping the control building exhaust fan. To prevent degradation of the charcoal filters by chlorine contamination, the emergency recirculation system fans do not operate during chlorine isolation.

Each cable spreading room and battery room and the mechanical equipment room have an individual supply and exhaust fan. The battery rooms are held at a negative pressure with respect to the control building to ensure that hydrogen fumes do

not enter other areas of the building. The ventilation systems for the mechanical equipment room and the cable spreading rooms are automatically shut down on either the high radiation or the chlorine signal. The ventilation systems for the battery rooms continue to operate during an emergency.

The control building HVAC control air system is provided with two redundant emergency instrument air compressors for improved reliability. These air compressors provide control air for the HVAC pneumatic controllers during a control air system low pressure condition. R1

Figure 4-3 shows the location of the control room air intake, the plant stack, the reactor buildings, and the service water intake structure.

4.2 Functional and Operational Control

4.2.1 Control Room Area Air Conditioning

The air conditioning equipment for each unit is controlled from its respective unit's RTGB XU-2 using control switches 1-VA-CS-1026 and 2-VA-CS-1028 (Units 1 and 2 respectively). The spare air conditioning equipment may be controlled from either unit's RTGB XU-2 using control switches VA-CS-1027-1 and VA-CS-1027-2 (Units 1 and 2 respectively). Operation of each air conditioning unit is identical. The following is an operational description for the Unit 2 air conditioning unit. R1

The air conditioning unit and its associated supply fan are started simultaneously by the same control switch. Selecting the START position of control switch 2-VA-CS-1028 energizes solenoid valve 2-VA-SV-1028 which supplies air to the operating mechanism of the supply fan discharge damper.

The damper fully opens actuating a limit switch to initiate the start of the supply fan and air conditioning unit. The "FAN ON" indication is actuated by an air flow switch located in the fan discharge ducting.

The spare air conditioning unit may be placed in service as a replacement for either unit's air conditioning unit, provided one of the air conditioning units is operating. Start of the spare unit can only be initiated from the RTGB associated with the shutdown air conditioning unit. The spare air conditioning unit is then started in the manner previously described.

The air conditioning units operate in conjunction with the electric heating coils to regulate ventilation air temperature. If ventilation air temperature is below the ventilation thermostatic controller setpoint, the controller will cycle the heating coils as necessary to increase temperature, provided the associated ventilation fan is operating. R1

4.2.2 Emergency Air Filtering Trains

The emergency air filtering trains may be operated in the automatic or manual mode. Each filter train is provided with a three position, ON-PREF-STBY, control switch (2-VA-CS-915A and 2-VA-CS-915B). Both control switches are located on the Unit 2 RTGB XU-3. Status indicating lights are also located on each Unit's RTGB XU-3.

An automatic start signal is initiated by the control building area radiation monitors or the control room area fire detection system. During normal operation, one filtering train control switch is selected to the PREF (preferred) position and the second train is selected to the STBY (standby) position. The initiation of an automatic start signal places the preferred filtering train in operation.

When a start signal is received, the inlet and outlet dampers of the preferred filtering train open. In the fully open position, each damper actuates a limit switch to initiate the start of the filtering train recirculation fan. If for any reason the fan fails to start or trips, a start signal for the standby filtering train is initiated within 10 seconds. The starting sequence is identical to that of the preferred train. With an automatic start signal present, the filtering train will continue to operate.

Selecting a filtering train control switch to the ON position initiates a starting sequence identical to that initiated by an automatic start signal. The filtering train can then be shut down by selecting the PREF or STBY positions, provided an automatic start signal is not present.

If, during filtering train operation, a high chlorine level is detected in the control building air intake plenum, the operating emergency recirculation fan trips and its associated dampers close. Shutdown of the filtering train prevents the introduction of chlorine gas into the control room area. A heat detection system (fire detection system) is also incorporated into the carbon filter of each emergency air filter. If a high temperature is detected, the filtering train automatically shuts down. R1

4.2.3 Makeup Air Dampers

During normal operation, the normal makeup air damper (2L-D-CB) is open and diverting 2000 cfm of air from the air intake plenum to the recirculation air plenum, and the emergency makeup air damper (2J-D-CB) is closed. During the operation of the emergency air filtering system, the normal makeup air damper closes and the emergency makeup air damper opens to divert 1000 cfm of recirculating air to the emergency air filtering trains. The operation of these dampers is automatic and cannot be directly controlled by the operator.

The makeup air dampers move to their emergency positions under any of the following conditions:

a. Abnormally high radiation levels detected by the control building area radiation monitors.

b. Smoke detected by the control room area fire detection system.

c. Either emergency air filtering train control switch selected to the ON position.

The makeup air dampers reset to their normal positions when all of the following conditions are satisfied:

a. Control building area radiation monitors reset.

b. Control room area fire detection system reset. R1

c. Emergency and filtering train control switches selected to either the PREF or STBY positions.

During all modes of operation, both dampers close if a high chlorine level is detected in the control building intake plenum.

4.2.4 Cable Spreading Room Ventilation

The cable spreading room supply and exhaust fans are controlled from their respective RTGB XU-2 using two-position, OFF-AUTO, control switches (1-VA-CS-928-1 and 2-VA-CS-929-1). In addition, individual two-position, OFF-ON, key-locked control switches (1-VA-CS-1586-1 and 2-VA-CS-1586-2) are provided to allow the bypassing of protective interlocks during periods of extreme emergency.

The OFF-AUTO control switch initiates the start of both the supply and exhaust fans for the associated cable spreading room. Selecting the AUTO position initiates the opening of the supply and exhaust dampers. When the dampers are in the fully open position both fans start. If a fan should fail to start or trip for any reason, its associated damper will close. The fan running indications are provided by a signal generated from an air flow switch located in the discharge ducting of each fan.

The supply and exhaust fans are automatically tripped by the following emergency conditions:

a. Abnormally high radiation levels detected by the control building area radiation monitors.

b. Smoke detected by the control building fire detection system.

c. High chlorine level detected in the control building intake plenum.

R1

If any of these conditions occur, the fans may be operated by selecting the key-locked bypass switch to the ON position and selecting the associated fan control switch to the AUTO position.

4.2.5 Control Building Emergency Instrument Air Compressors

The control building emergency instrument air compressors are controlled by individual three-position, AUTO-OFF-MAN control switches located on RTGB XU-3. Selection of the MAN position initiates a manual start of the associated air compressor. In the AUTO position, the air compressor

starts when the associated air receiver pressure decreases to 78 psig. The air compressor continues to operate to raise receiver pressure to 92 psig, at which time the air compressor will shut down.

4.2.6 Intake Plenum and Recirculation Air Filters

Control of the intake plenum and recirculation air filters is completely automatic. An adjustable timer is provided to enable a fixed amount of clean filter media to be advanced. The timer motor operates until the set time interval is completed, at which time clean filter media is introduced. The range of adjustment is between 1 to 24 inches of media movement per 24 hours. R1

A pressure differential switch is provided to override the timer and advance the filter media if a filter differential pressure of 0.5 inches of water is reached. The filters are also provided with a local advance pushbutton to manually override the automatic controls.

4.3 Design Review

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

a. The zone serviced by the control room ventilation system includes all critical areas, such as the control room, kitchen, sanitary facility, the

computer rooms, and the electronics rooms. Areas not requiring access are excluded from the zone by administratively controlled closed doors. R1

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. Makeup air (1000 cfm) is provided to ensure that carbon dioxide levels do not become excessive. The emergency food stockpile is currently stored in a locked cabinet in the northwest corner of the control room. Breathing apparatus are also stored in the control room. R1

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 20,000 cfm recirculation by each of two supply fans and 2000 cfm makeup and pressurization flow. Preoperational testing confirmed that this flow was sufficient to maintain a positive pressure in the control room during normal operation.

d. The design of the emergency filter system was reviewed. The system design differs from some of the criteria of Standard Review Plan 6.5.1, as indicated in Appendix A of this report. R1

e. The layout of the control room and adjacent areas was reviewed. There are several routes by which potentially contaminated outside air could enter the control room, including the following: R1

- Leakage through the normal outside air makeup damper (closed on radiation and chlorine isolation signals).

- Leakage into the control room air ducts in the mechanical equipment room.

- Leakage into the control building elevator shaft, into the control building stairwells, and through the control room doors.

- Leakage into the Unit 2 cable access way via openings in the cable penetration cutout to the rattlespace between the control and reactor buildings.

A summary of key leakage calculations (based on ASHRAE Equipment Specifications and Fundamentals) is given below.

The normal control room system airflow rate is 40,000 cfm with 2000 cfm of fresh air. During high radiation isolation, the calculated infiltration rate to the control room is 1780 cfm. In addition, 106 cfm of air from the mechanical equipment room is calculated to leak into the suction side of the control room ventilation system. This duct inleakage comes from the mechanical equipment room, which is calculated to exchange air with the outside at the rate of 2640 cfm.

During chlorine detection, the infiltration rate to the control room is calculated to be 1250 cfm. The duct inleakage during chlorine detection remains the same as during high radiation detection.

The relatively low infiltration rate during high radiation is attributable to the filtered makeup air system that provides 1000 cfm for pressurization.

As indicated above, the mechanical equipment room has an inleakage rate of 2640 cfm. A large portion of the infiltration will come through the elevator machine room which has an opening of approximately 1 square foot between both the mechanical equipment room and the outside air. Infiltration through these openings will be assisted by the "pumping action" resulting from elevator travel.

f. Radiation shielding of the control room has been analyzed in the FSAR and in Carolina Power & Light (CP&L) Company's December 1979 submittal in response to NUREG-0578 Item 2.1.6.b. Additional analyses described in Section 5.0 of this report confirmed the adequacy of previous calculations.

4.4 Results

Differences between the design of Brunswick's control room ventilation system and current NRC criteria set forth in Standard Review Plan 6.4 Rev 1 are detailed in Appendix A of this report. R1

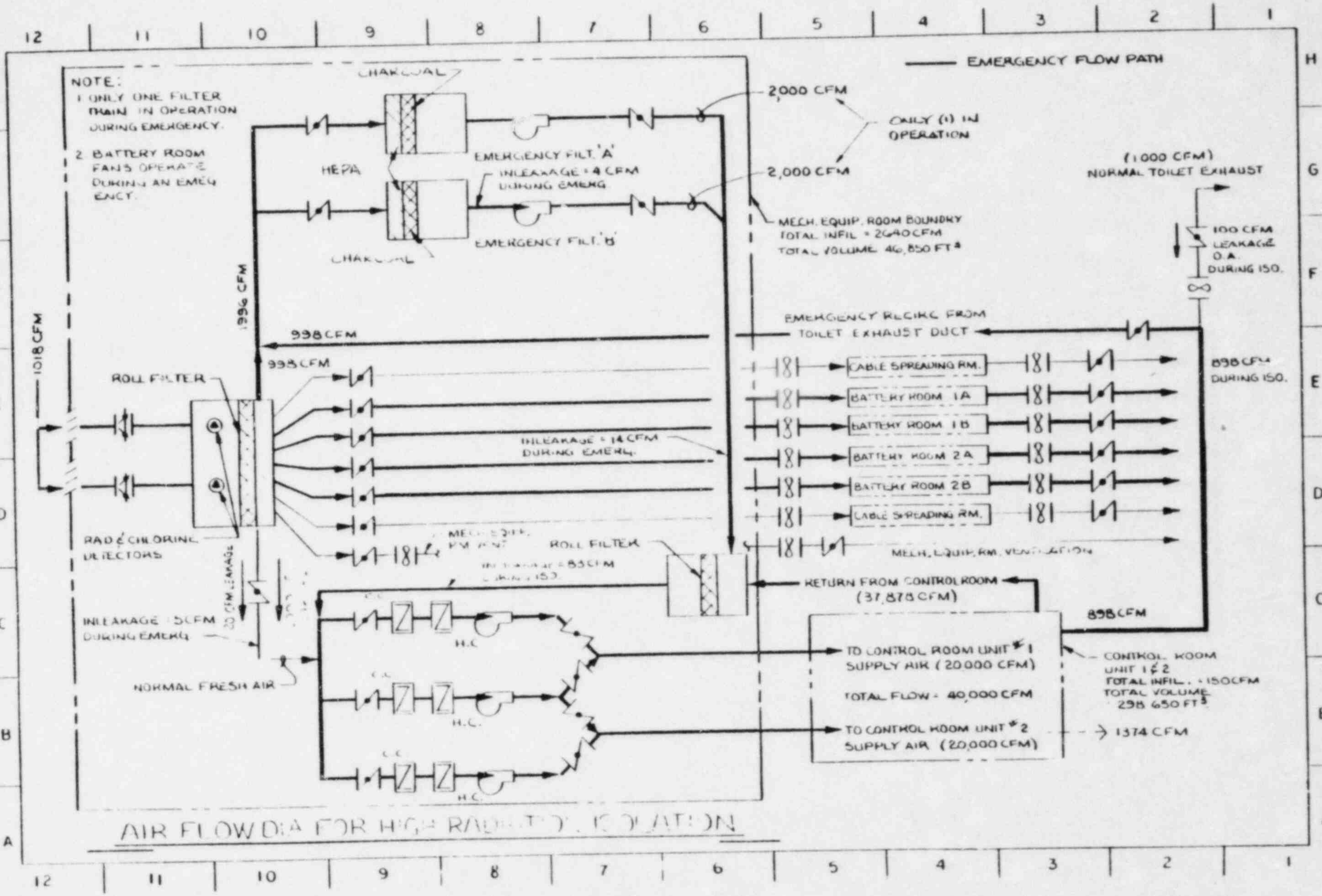


Figure 4-1. Schematic Diagram of the Control Room Ventilation System, Brunswick – Air Flow Diagram for High Radiation Isolation

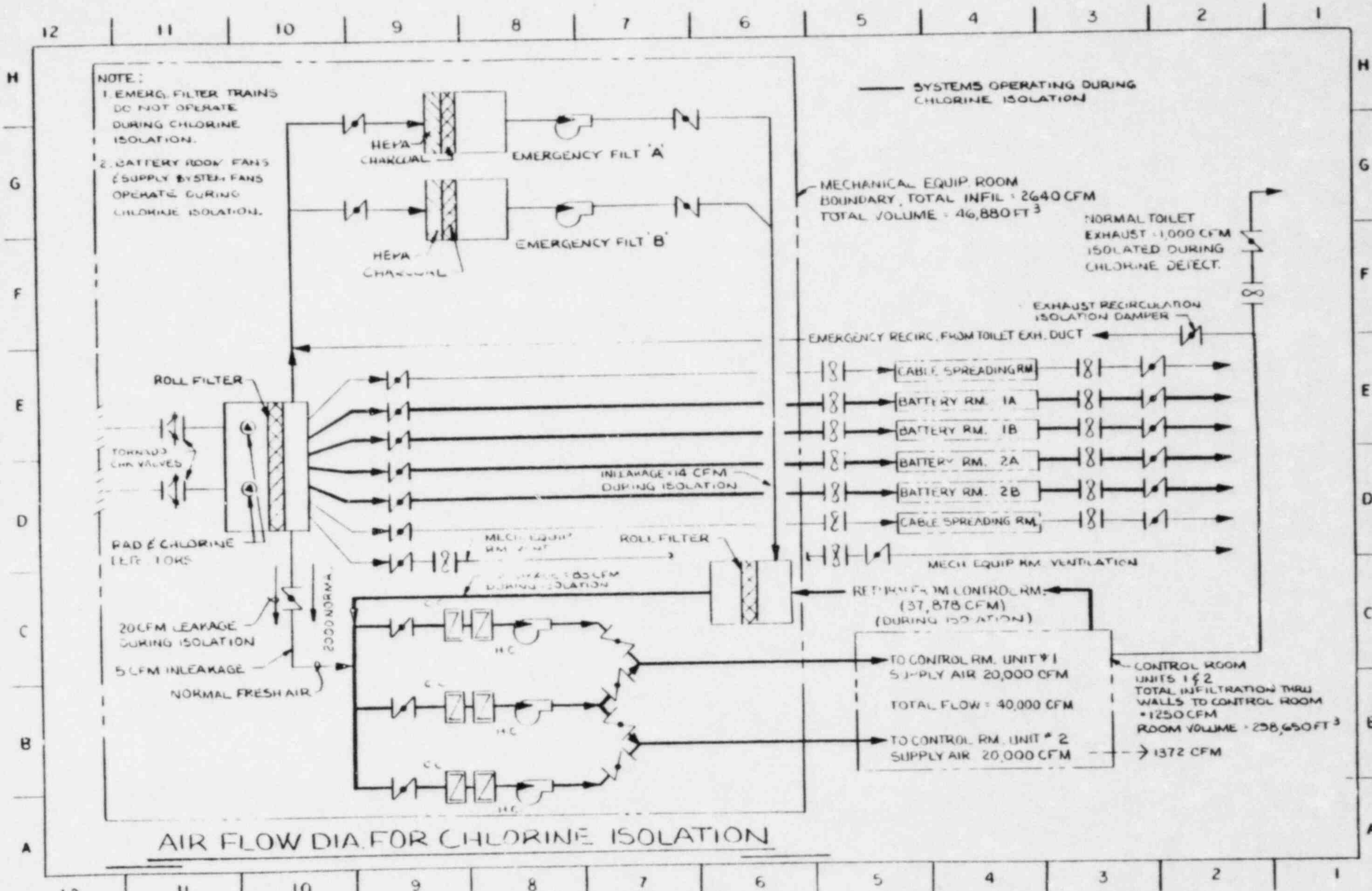


Figure 4-2. Schematic Diagram of the Control Room Ventilation System, Brunswick – Air Flow Diagram for Chlorine Isolation

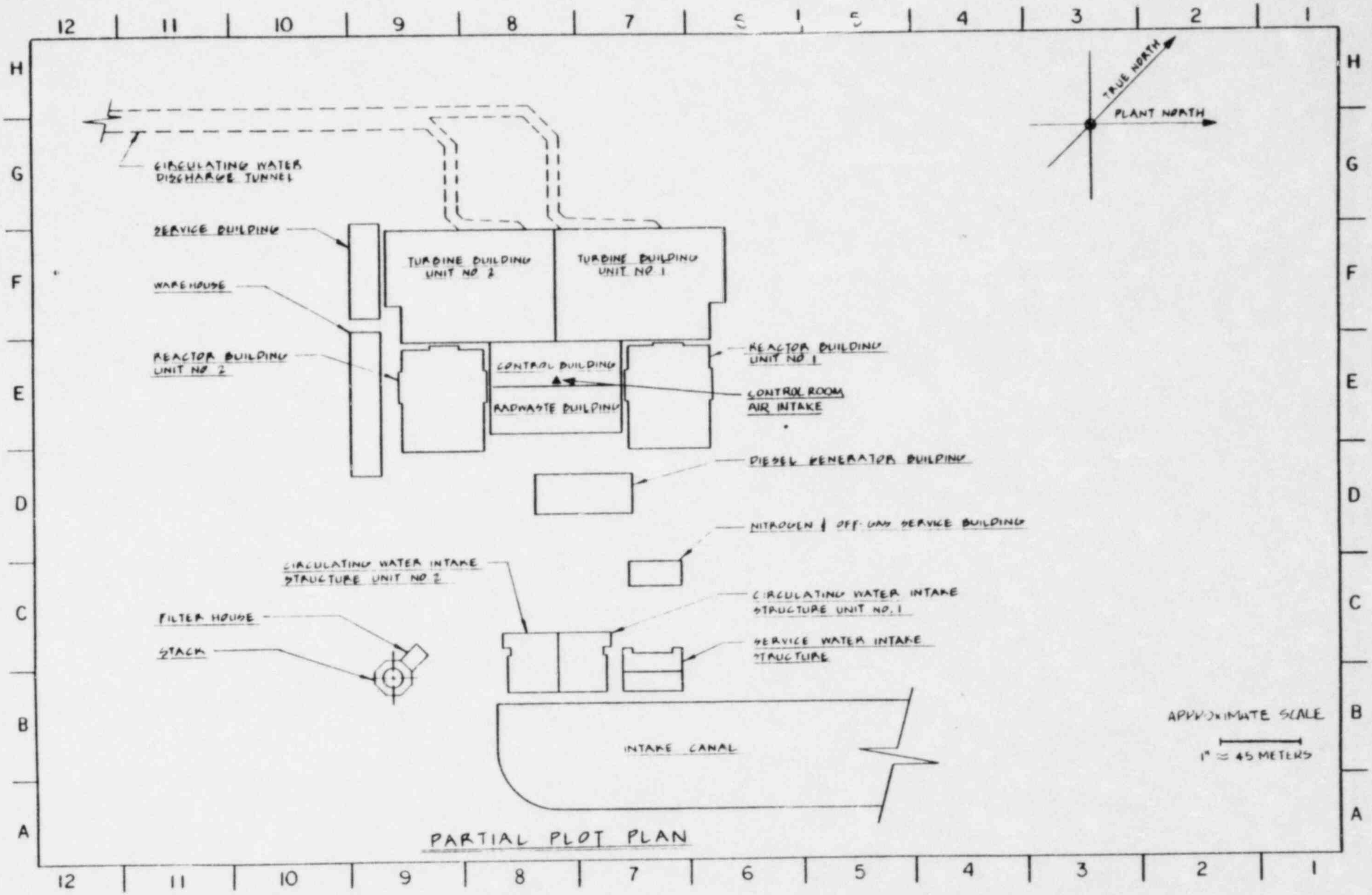


Figure 4-3. Partial Plot Plan, Brunswick Units 1 and 2

5.0 RADIOLOGICAL ANALYSIS

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

5.1 Methods

The methods used to calculate the beta and gamma whole body doses 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 methods used to compute the whole body dose contributed by sources of direct radiation outside the control room are based on the work of Jaeger, Chapter 6 (Ref. 1). The shine dose from liquid source terms was presented in CP&L's response to NUREG-0578 Item 2.1.6.b.

5.2 Assumptions

The assumptions used in this analysis of control room radiation exposures are described below and in Table 5-1:

- Radionuclides released from the reactor core are uniformly distributed throughout the primary containment. Radionuclides released to the secondary containment are assumed to be uniformly distributed throughout the secondary containment.

- The primary containment leaks at a constant rate of 0.5 percent per day for the duration of the accident.

- The primary containment is assumed to consist of a single volume with no washout of radionuclides by containment spray.

- The secondary containment exhaust rate is assumed to be one secondary containment volume per day.

- There is no direct leakage from the primary containment to the environment. All exhaust from the secondary containment is filtered by the standby gas treatment system. The dose calculation does not include consideration of MSIV leakage.

- The accident duration is assumed to be 30 days.

- Radionuclides in the control room are assumed to be uniformly distributed throughout that volume.

- The breathing rate of the control room operators is assumed to be 3.47×10^{-4} cubic meters per second for the duration of the accident.

- The control room X/Q values are adjusted for the occupancy factors given in NRC Standard Review Plan 6.4.

5.3 Results

The radiation dose to individuals within the control room during a postulated design basis accident at the Brunswick 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 described in the Brunswick FSAR, the maximum calculated dose to individuals within the control room occurs during a postulated

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. This is discussed further in References 2 and 3.

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 dose due to airborne radioactivity within the control room is summarized in Table 5-2. The dose due to various sources of radioactivity outside the control room is also listed in Table 5-2. These results are based on data given in the Brunswick FSAR (Ref. 2, Ref. 3) and the Brunswick shield design review (Ref. 4) and on the work of Egap (Ref. 5).

The dose due to reactor building shine was calculated using the QAD computer code (described in Appendix E). The features of the reactor and control building essential to the control room shielding analysis were input in the QAD code. The sources used in the QAD code were based on the method described in Appendix E. These results are based on a reactor building concrete wall thickness of 2.0 feet and control building wall and roof concrete thicknesses of 2.0 feet each.

As shown in Table 5-2, the calculated control room doses are well within the current NRC criteria of 5 rem whole body and 30 rem thyroid given in Standard Review Plan 6.4 (Ref. 6).

5.4 References

1. R. G. Jaeger et al. 1968. Engineering Compendium on Radiation Shielding. Volume 1, Springer-Verlag New York, Inc., 1968.

2. Carolina Power & Light Company. 1972. BSEP-1 & 2 FSAR. Amendment 13, p. M14.1-1.

3. Carolina Power & Light Company. 1972. BSEP-1 & 2 FSAR. Amendment 15, p. M14.4-1.

4. Brunswick Shield Design Review. Submitted December 31, 1979 to U.S. Nuclear Regulatory Commission in response to NUREG-0578 Item 2.1.6.b.

5. M. A. Egap. 1980. Dose Rates and Integrated Dose at the Main Control Room from Various Sources Resulting from a TID-14844 Source Term Accident.

6. U.S. Nuclear Regulatory Commission. NUREG-75/001, Section 6.4.

TABLE 5-1

ASSUMPTIONS IN RADIOLOGICAL ANALYSIS OF THE BRUNSWICK CONTROL ROOM

Power level = 2,550 MWt

Operating time = 1,000 days

Fraction of core radionuclide inventory released to drywell

Noble gases = 100 percent
Halogens = 25 percent

Drywell free volume = 164,000 ft^3

Maximum/minimum wetwell free volume = 134,600/124,000 cfm

Reactor building free volume = 2,000,000 ft^3

Standby gas treatment system flow rate = 3,000 cfm

Standby gas treatment system filter efficiencies for iodine

Elemental = 95 percent
Organic = 95 percent
Particulate = 99 percent

Primary containment leak rate = 0.5 percent/day

Secondary containment air exchange rate = 100 percent/day

Control room volume = 298,650 ft^3

Control room ventilation system filter efficiencies for iodine

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

Stack height = 100 meters

Atmospheric diffusion factors for stack release

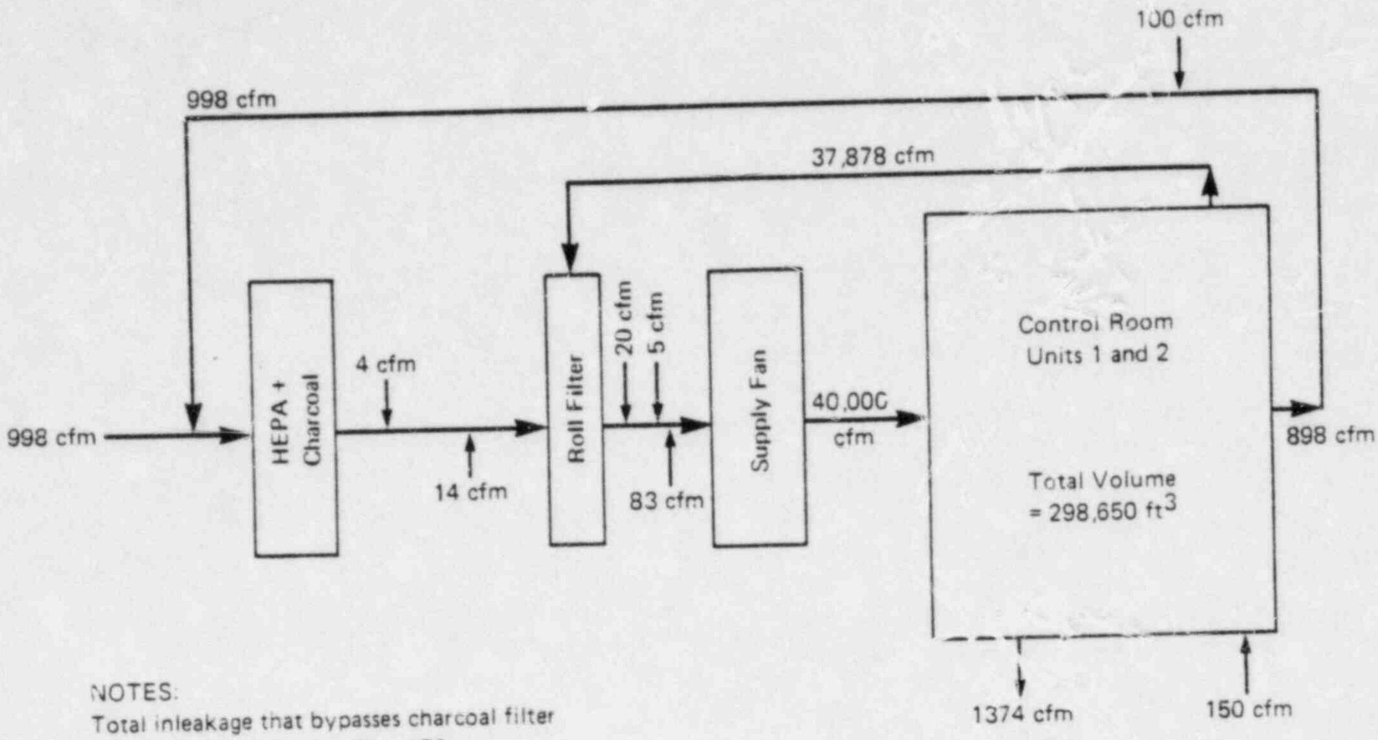
Time	X/Q value (sec/m^3)
0-1/2 hr	3.3×10^{-4}
1/2-8 hr	1.8×10^{-6}
8-24 hr	1.1×10^{-6}
1-4 days	2.0×10^{-7}
4-30 days	2.7×10^{-8}

TABLE 5-2

RESULTS OF RADIOLOGICAL ANALYSIS OF THE BRUNSWICK CONTROL ROOM

Source of Radiation	Dose (rem)		
	Whole Body	Thyroid	Beta Skin
Airborne radioactivity released from the SGTS[a] through the plant stack	0.002	0.41	0.039
Reactor building--shielded portion	0.004	--	--
Reactor building--refueling area	<0.109	--	--
SGTS charcoal filters	<0.001	--	--
Control room charcoal filter	0.054	--	--
Cloud outside the control room	<0.160	--	--
Core spray line within the reactor building	0.085	--	--
Stack structure shine	Negligible	--	--
Total	0.415	0.41	0.039

[a]Standby Gas Treatment System.



NOTES:
Total inleakage that bypasses charcoal filter
= 4 + 14 + 20 + 5 + 83 + 150
= 276 cfm
Total inleakage that goes through charcoal filters = 100 cfm

Figure 5-1. Brunswick Control Room HVAC System Flow Diagram

6.0 TOXIC CHEMICAL ANALYSIS

6.1 Introduction

This section presents an evaluation of offsite toxic chemicals 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.

The only significant onsite toxic chemical is a 55-ton tank car of liquefied chlorine gas, located approximately 450 feet from the control room air intake. Other onsite toxic chemicals are limited to quantities that are sufficiently small to be excluded from this analysis. The rupture of the chlorine tank car was shown in the FSAR not to impair control room habitability.

In addition, scoping calculations were performed for postulated spills involving shipments of 1200 tons of anhydrous ammonia and chlorine on the Intracoastal Waterway 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 X/Q values shown in Table 3-5 of this report. Consideration was given to 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 $100^{\circ}F$.

- 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.

Hypothetical large releases were evaluated using a flash fraction release, a drifting cloud dispersion model, and a simple differential equation for control room concentration as a function of time. 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, normal and isolated operational modes of the Brunswick plant ventilation system are 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:

$$V\frac{d_{X_{CR}}}{dt} = [Q_8 + Q_j] X_{QA} - Q_5 X_{CR};\ j = 1 \text{ or } 6$$

where

V = volume of space served by control room ventilation system

X_{CR} = toxic chemical concentration of control room air, mg/m^3

X_{QA} = toxic chemical concentration of control room air intake, mg/m^3 (based on Gaussian dispersion model)

Q_8 = total system infiltration

Q_j = fresh air input during normal or isolated mode

Q_5 = total system outleakage

6.3 Analysis of Hypothetical Barge and Truck Accidents

The Intracoastal Waterway (ICW) passes the Brunswick plant at a distance of closest approach of 2.3 miles. In order to determine the importance of toxic chemicals that may be aboard barges on the ICW, two hypothetical accidents have been postulated for this study of control room habitability. The accidents assume worst-case conditions based on the following extremely conservative assumptions for accidents releasing chlorine and ammonia:

- Complete release of the largest tank normally carried aboard barges.

- Wind direction is towards the plant.

- Wind stability is Pasquill Class G.

- Release occurs at the closest point of waterway approach.

- Average wind speed is 1.5 meters per second.

State Highways 87/133 pass 1.4 miles from the plant. Accidents involving hypothetical shipments of ammonia and chlorine were also evaluated for this transportation route.

The concentration in the control room was evaluated using the control room model and the toxic chemical concentration differential equation described in Section 6.2. For both chlorine and ammonia, the calculated concentrations resulting from these very conservative analyses of hypothetical accidents are greater than the toxic limits.

Based on further evaluation of the local highway network and on further conversations with representatives of organizations familiar with the use of the Intracoastal Waterway, it has been concluded that actual shipments of the magnitudes assumed in the calculations either not occur or do not occur frequently enough to be of concern. Section 2.1 provides information in support of this conclusion. R1

6.4 Summary of Results

Table 6-2 summarizes the numerical results of this toxic chemical habitability analysis for the Brunswick plant and shows compliance with the appropriate limits. The Regulatory Guide 1.78 screening procedures eliminated all toxic chemicals stored in the vicinity except sulfuric acid. Sulfuric

acid was eliminated because of its low vapor pressure resulting in a concentration at the air intake much less than the toxic limit.

6.5 References

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

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

TABLE 6-1

SUMMARY OF INPUT DATA

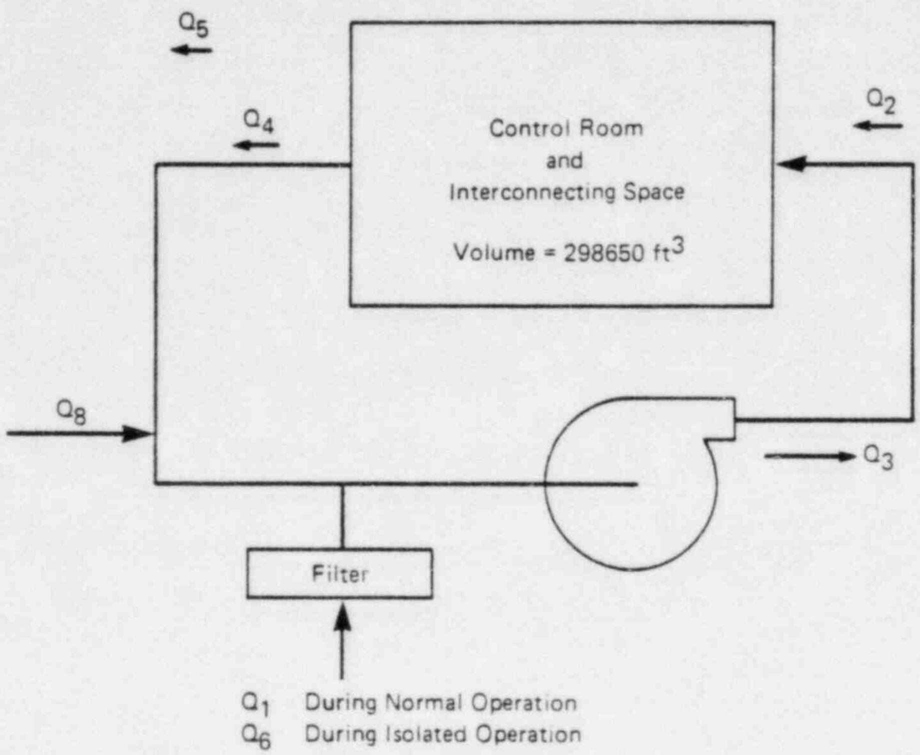
Parameter	Data	Units
Meteorological:		
Pasquill stability	G	None
Average wind speed	1.0	m/sec
Atmospheric dispersion, X/Q	See Table 3-3	sec/m^3
HVAC System		
Normal operation:		
Fresh air makeup	2,000	ft^3/min
Inleakage	272	ft^3/min
Outleakage and exhaust	2,272	ft^3/min
Filter removal, toxic chemical	None	None
Loop flow	40,000	ft^3/min
Air exchange rate, outside air	0.46	Per hour
Emergency operation (chlorine isolation):		
Fresh air flow (damper leakage)	1,100	ft^3/min
Inleakage (duct and adjacent areas)	272	ft^3/min
Outleakage and exhaust	1,372	ft^3/min
Filter removal, toxic chemical	None	None
Loop flow	40,000	ft^3/min
Air exchange rate, outside air	0.28	Per hour
Volume of control room	298,650	ft^3

TABLE 6-2

RESULTS OF TOXIC CHEMICAL ANALYSIS

Location	Distance (mi)	Chemical	Storage Condition	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)
Standard Products	4.0	Sulfuric acid	Tank ambient temperature and pressure	40,000	2,500	2.0	0.01	N/C[a]
Standard Products	4.0	Chlorine	Liquefied gas under pressure	2,000 (464)[b]	30,000	45	N/C	N/C
Pfizer Chemical	1.7	Chlorine	Liquefied gas under pressure	45	2,300	45	N/C	N/C
Pfizer Chemical	1.7	Sulfuric acid	(c)	(c)	(d)	2.0	--	--
Sunny Point	4.2	Trichloroethylene	55 gal. drum	668	670,000	535	N/C	N/C
Sunny Point	4.2	Red fuming nitric acid	Lance missile fuel tank	1,107	6,260	5	N/C	N/C
Sunny Point	4.2	Hydrazine	Lance missile fuel tank	375	8,100	6.5	N/C	N/C
Sunny Point	4.2	Chlorine	Wellhead tanks	150	30,000	45	N/C	N/C

[a]Not required to be calculated.
[b]Isenthalpic flash fraction.
[c]Information on Pfizer not available due to Pfizer proprietary restrictions.
[d]Conservatively assuming a storage temperature of 145°F, a release greater than 2,000,000 lb would be necessary to cause a concentration equal to the toxic limit at the air intake, if analyzed according to Regulatory Guide 1.78.



Ventilation Flow, Q_i	Operating Mode: Normal	Isolated (chlorine)
	Flow ft^3/min	Flow ft^3/min
Q_1	2,000	2,000
Q_2	40,000	40,000
Q_3	40,000	40,000
Q_4	37,728	37,728
Q_5	2,272	1,372
Q_6	0	1,100
Q_8	272	272

Figure 6-1. Simplified Brunswick Control Room Ventilation System

APPENDIX A

Comparison of the Brunswick Control Room to the Criteria of the 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

Criterion:

The emergency zone should include the following:

1. instrumentation and controls necessary for a safe shutdown. R1
2. the computer room.
3. the shift supervisor's office.
4. the operator's wash room and the kitchen.

The emergency zone should be limited to those spaces requiring occupancy. The spaces should be located on one floor and contiguous.

Response:

The zone serviced by the control room ventilation system contains all critical areas requiring access. The areas are located on one floor and are contiguous. The areas include the control room, kitchen, sanitary facility, computer rooms and electronics rooms. The cable and battery rooms are not directly accessible from the control room and have their own ventilation systems. Areas not requiring access are excluded from the zone by administratively controlled closed or locked doors.

The electronic equipment rooms for Units 1 and 2 are open to the control room and therefore increase the surface area of the control room ventilation zone and the potential for interchange from adjacent potentially contaminated areas. This area and the control room were designed to permit continuous occupancy by operating personnel under all normal operating conditions and postulated design-basis accidents; however, the electronics rooms are only periodically occupied.

Although the shift supervisor maintains an administrative office outside the emergency zone, all procedures and other operational material are located inside the zone. The emergency zone has protected office space and an adequate number of tables, chairs, and desks for use during emergencies by personnel inside the zone. R1

A.1.2 Control Room Personnel Capacity

Criterion:

Food, water and medical supplies should be sufficient to maintain the emergency team (at least five people) for five days.

Response:

The Brunswick control room is common to both Units 1 and 2; therefore, two operating crews will normally occupy the control room. The control room manning requirements are as given in the Technical Specifications. In an emergency, the number of people allowed in the control room would be limited.

Because of the makeup air (1000 cfm) and the large volume of the emergency zone, CO_2 buildup is not a problem under the postulated design-basis accident conditions at the Brunswick facilities.

There is an ample supply of food and water to last emergency personnel located in the control room (at least five people) for at least 5 days. The food stockpile is currently stored in the northwest corner of the control room. The food is edible for a period of 10 years and at present will require cycling in 1987. The water is supplied from a large storage tank. The tank is normally supplied from city water but can be isolated from this source in emergencies. The water supply is sufficient to last at least 5 days. A periodic test PT-47.0, "Inventory of Emergency Foodstuffs," is performed once per calendar year to ensure the adequacy of the emergency food supplies. R1

A.1.3 Ventilation System Criteria

Criterion:

a. Isolation dampers must be leaktight

Response:

The emergency filter isolation valves are heavy-duty, low-leakage, single-blade dampers. They are designed for open/closed operation and fail as-is upon the unlikely event of air or electric failure (such failures are not expected, as further discussed in Section A.2.1 of this appendix). They have provisions for hand operation. The valve seals are designed for no leakage and are compatible with the gas stream

properties. The frames, blades, Form "C" switches and axles are designed to perform at a maximum differential of 10 inches H_2O at 2000 fpm maximum face velocity and at a maximum temperature of $150^{\circ}F$. The valve frame is 7-gauge steel with mounting flanges on both sides. The blades are 1/4-inch steel with reinforcing channel bolted to the axle.

The intake and exhaust isolation dampers are of standard HVAC system and quality designed for a maximum leak rate of 1% of 2000 scfm, which is full valve flow in the open position, per ASHRAE standards for dampers. This amounts to 20 scfm and is the value used for the infiltration calculations. The potential for radiological inleakage, however, is enveloped by the conservative radiological analysis discussed in Section A.2.1 of this appendix. The potential for chlorine inleakage is mitigated by the presence of adequate emergency air capability, as discussed in Section A.1.4 of this appendix. Also, Section 6 of this report indicates that there is no significant toxic threat to the control room. R1

Criterion:

b. A single failure of an active component should not result in loss of the system's functional performance.

Response:

See Section A.2.1 of this appendix for a discussion of this topic.

Criterion:

c. Pressurization systems: Those systems having pressurization rates of less than 0.25 volume change are required to verify that a positive 1/8-inch water gauge differential pressure is maintained with the design makeup air flow rate. This test will be conducted every 18 months. In addition, they will be required to verify that air makeup is ±10% of design value every 18 months. R1

Response:

The Brunswick facility has a volume change rate less than 0.25. Periodic Test PT-46.4 is conducted every 18 months. This includes a verification of positive pressure, but a provision for quantifying the 1/8-inch water gauge differential pressure is not included. The test will be revised to include this quantification. The other area of question relative to verification of ± 10% design makeup air flow is included in PT 21.1. R2

A.1.4 Toxic Gas Protection

Criterion:

At least five self-contained breathing apparatus for control room emergency personnel should be available with a six-hour onsite bottled air supply with the R1

capability for unlimited offsite replenishment capability from nearby locations.

Response:

The Brunswick control room maintains 12 Scott Air Pak self-contained breathing apparatus for use by control room personnel during emergencies. An additional 19 Air Paks are located in the document control room. Additional Air Paks are available from the fire brigade, if necessary. The onsite fire house air compressor is used as the normal source for filling the Air Pak bottles.

A bank of six 2000 ft^3 capacity air bottles are located on the ground floor of the service building. An additional 18 bottles are held in reserve and are used as necessary. The 2000 ft^3 air bottles are normally refilled by an outside supplier. R1

A.1.5 Emergency Standby Filters

Criterion:

See Standard Review Plan 6.5.1.

Response:

See Section A.3.2 of this appendix for a discussion of the control room emergency filter system.

A.1.6 Relative Location of Source and Control Room

Criterion a:

Radiation sources - the control room ventilation inlet should be separated from the major potential release

points by at least 100 feet laterally and by 50 feet vertically.

Response a:

The control room air intake is approximately 25 meters above grade, located on the roof of the control building. The plant stack, the major potential release point, is located approximately 180 meters away from the control room air inlet and is 100 meters above grade. The Unit 1 and the Unit 2 reactor buildings are located approximately 40 meters away. See Section 5.0 of this report for further information.

Criterion b:

Toxic Gases - the minimum separation distance between the control air inlet and the gas in question is dependent upon the gas in question, the container size and the available control room protection provisions. The following provisions or their equivalent are required in the emergency zone ventilation system: R1

1. quick-acting toxic gas detectors.
2. automatic emergency zone isolation.
3. emergency zone leaktightness.
4. limited fresh air makeup rates.
5. breathing apparatus and associated bottled air supply.

Response b:

The chlorine tank car is the only toxic substance stored in the vicinity of the control room air inlet that could pose a threat to the reactor operators. The tank car is a 55-ton railroad tank car and normally

contains approximately 33,000 gal of chlorine. The tank car is located approximately 140 meters away from the control room air inlet inside a fenced area. The tank car can be relocated, if necessary, by a "truck" capable of operating on rails. FSAR Section 6.4.4.2 shows that the rupture of the chlorine tank car does not impair control room habitability.

The five subsections listed above under Criterion A.1.6.b are discussed as follows:

Subsection A.1.6.b.1:

Quick-acting toxic gas detectors.

Response:

See Section 4.1 and Appendix B.2.j.

R1

Subsection A.1.6.b.2:

Automatic emergency zone isolation.

Response:

See Sections 4.1 and 4.2.

Subsection A.1.6.b.3:

Emergency zone leaktightness.

Response:

See Section 4.3.

Subsection A.1.6.b.4:

Limited fresh air makeup rates.

Response:

The control room ventilation system is isolated upon chlorine detection so that no fresh air makeup is maintained. Air infiltration rates are given in Section 4.1.

Subsection A.1.6.b.5:

Breathing apparatus and associated bottled air supply.

Response:

See Section A.1.4 of this Appendix. The potential for contamination of the control room air from release of toxic gases from adjacent areas is discussed in Sections 2, 4, and 6.

A.1.7 Radiation Shielding

Criterion:

General Design Criterion 19 is invoked with respect to evaluations of radiation shielding effectiveness associated with

R1

1. control room structure boundary.
2. radiation streaming.
3. radiation shielding from internal sources.

Response:

Control room shielding is discussed in the Brunswick FSAR 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

Criterion:

a. GDC-19 of Appendix A to 10 CFR Part 50 for Radiation Hazard.

Response:

See Section 5.0 of this report and Section A.2.1 of this appendix.

Criterion:

b. There should be no chronic effects from exposure to toxic gases, and acute effects, if any, should be reversible within a short period of time (several minutes) without benefit of medication other than the use of self-contained breathing apparatus.

Response:

As stated in Section 6.0 of this report and Section A.1.6.b of this appendix, there is no significant toxic threat R1 to the control room. Automatic control room isolation procedures and detection equipment are used to help prevent toxic concentrations in the control room. Also, self-contained breathing apparatus are provided in the event they are needed (see Appendix Sections A.1.4 and B.2.8).

A.2 Comparison with Standard Review Plan 9.4.1

The acceptability of the control room area ventilation system (CRAVS) design, as described in the safety analysis report, is based on specific general design criteria and regulatory guides. These include General Design Criteria 2, 4, 5 and 19 and Regulatory Guides 1.26, 1.29, and 1.117. In addition, Branch Technical Positions ASB 9.5-1, ASB 3-1 and MEB 30-1 are included in the Acceptance Criteria.

The specific areas of review performed by the Auxiliary Systems Branch as described in Section 1 of Standard Review Plan 9.4.1 Revision 1, are addressed below.

A.2.1 Single Failure Analysis

Review criterion:

> A single active failure cannot result in loss of the system functional performance capability. R1

Response:

> Redundancy criteria are satisfied, except that the fresh air makeup damper (2L-D-CB), emergency recirculation damper (2J-D-CB), bathroom exhaust damper (2H-D-CB), and solenoid valve SV-916 are not redundant. However, on loss of power or damper controller failure dampers 2J-D-CB and 2H-D-CB are spring loaded to fail shut. Damper 2L-D-CB, the fresh-air makeup damper, also fails closed on loss of power due to the system control logic.

Failure of the various dampers to operate due to a mechanical failure of some internal component of the valve is remote because of the design of these dampers (see Section A.1.3 of Appendix A). In addition, Periodic Test PT-23.1 requires a functional test of the system once every 31 days to ensure proper system function and to detect any system abnormalities. If by some remote occurrence a valve (damper) actuator does fail to function, the linkage to the automatic actuator can be easily disengaged and the damper position manually shifted and locked in place until the actuator can be fixed.

Failure of solenoid valve SV-916 to properly function after radiation or smoke detection would cause damper 2L-D-CB to remain open and damper 2J-D-CB(emergency recirculation damper) to remain shut. This is believed to be the worst case degradation of the CRAVS following a single failure of an active component during a casualty. The failure of SV-916 was assumed and a bounding radiation analysis was performed. The analysis used design-basis accident (DBA) conditions. This type of failure of the CRAVS system would cause the maximum amount of outside air (3000 cfm) to enter the system while allowing only partial filtration of the air via the emergency recirculation system (no filtration of the recirculated air would occur although filtration of the incoming air would take place). The results of the analysis indicate that the whole body and thyroid radiation limits of 10 CFR 100 are not exceeded; therefore, failure of SV-916 in this instance does not result in a threat to control room personnel. R1

Failure of the solenoid valve SV-916 during smoke detection would allow smoke to enter the control room, if the origin of the smoke was from outside the control building. Filtration of recirculated air would not occur. In this case the operators would have access to emergency air breathing apparatus, if needed, until personnel were able to manually close the inlet air damper and open the recirculation damper. As mentioned above, this can be easily and quickly performed.

Failure of solenoid valve SV-916 during a chlorine casualty will not affect either damper 2J-D-CB or 2L-D-CB. This is because damper 2J-D-CB is already closed and because SV-916 does not control 2L-D-CB during this casualty. Solenoid valve SV-916-1 functions during this casualty to ensure that the fresh air makeup damper 2L-D-CB goes to a shut position. Failure of solenoid valve SV-916-1 will cause damper 2L-D-CB to close. R1

Failure of the bathroom exhaust damper (2H-D-CB) is not a concern for smoke or radiation emergencies because the exhaust fan is stopped during these casualties and the control room remains pressurized. This would ensure that air flow is always out the exhaust system. In addition, even in an assumed worst case failure of the CRAV system (see above) radiation limits are not exceeded. Failure of this valve during a chlorine casualty would allow some infiltration of outside air into the control room at some point after the control room has been isolated (i.e., depressurized). However, this valve can be shut manually, as described above for the other two dampers. As noted below, failure of the damper is remote and failure of either the solenoid controlling the air damper or the loss

of instrument air would cause the damper to fail-safe in a shut position.

Loss of operating air at Brunswick is not a concern because of the redundant safety-grade air supplies to the CRAVS system, and the redundant backup instrument air compressors. Any one of these safety-grade sources is sufficient to properly operate the valves.

As mentioned in Appendix A, Section A.3.9, the dampers are low leakage dampers designed for less than 1% of full-rated flow. Analysis of air inleakage using this assumed value 1% of full-rated flow did not cause levels of toxic gases, radiation, etc., from exceeding toxic limits. In addition, the above dampers are made to fail safe to a shut position on loss of power. Because of this and the results of the analysis conducted, we believe that the present design will ensure operator safety under accident situations. R1

Although the outside air intake is not an active component of the system, it is an important part of the overall design. The intake is approximately 4 ft by 12 ft long located on the roof of the control building. Because of its shape, the chance of obstructing the intake with a single object is remote; however, if obstructed, personnel have access to the control building roof and could clear away the obstruction.

A.2.2 Separation Analysis

Review criterion:

Components and piping have sufficient physical separation or barriers to protect essential portions of

the system from external missiles, pipe whip and fires (GDC-4).

Response:

The control room area ventilation system is enclosed in a tornado proof Seismic Category I structure and would therefore not be subjected to externally generated missiles.

With respect to internally generated missiles, the three control room supply fans and the two emergency recirculation fans are the only components of the CRAVS considered to be potential sources of such missiles. Based on the arrangement of the supply fans, a single fan-generated missile could damage only one other fan, leaving at least one fan operable. The emergency recirculation fans are partially protected by a concrete support structure and have a sheet metal covering over both fans. A missile-hazard analysis of the emergency recirculation fans indicates that no missiles of sufficient force would be generated by these fans to cause damage to equipment close by. The remainder of the system is either sufficiently protected by physical barriers or is sufficiently separated to prevent damage. R1

There is no high energy piping close to any CRAVS equipment that would cause damage due to pipe whip. In addition, the entire CRAVS is seismically supported. Fire dampers are provided for all penetrations through firewalls to prevent the spread of any fire and smoke.

See Section A.2.6 of this appendix for further information on this subject.

A.2.3 Analysis of Failure of Non-seismic Equipment

Review criterion:

Failures of non-seismic Category I equipment or components will not affect the CRAVS.

Response:

As stated in Section A.2.5 of this appendix, the entire control building HVAC system, including the CRAVS, system was built to Seismic Category I criteria inside a tornado-proof Category I structure. Although portions of the system are considered nonessential for control room habitability, they are necessary for normal system operation. The fact that the entire system meets the same design criteria indicates that this issue is not a concern at the Brunswick plant. Further information on component separation, missile hazards, etc., can be found in Sections A.2.1, A.2.2, and A.2.9 of this appendix. R1

A.2.4 Adequacy to Maintain a Suitable Environment

Review criterion:

Review the ability of the control room heating and cooling subsystems to maintain a suitable ambient temperature for control room personnel and equipment.

Response:

The recirculating ventilation system is equipped with three air conditioning units (one serving as a common

spare) capable of handling the large concentrated heat gains from the computers and electronic equipment as well as the variable heat gains from personnel and lighting. These units also provide the necessary humidity controls to maintain proper environmental conditions. Individual heating coils are located in the discharge ducting of each air conditioning unit cooling coil to aid in temperature control.

The air conditioning units each consist of an air-cooled condensing unit and a direct expansion cooling coil assembly. Each air-cooled condensing unit is rated at 457,000 Btu/hr. Each cooling coil assembly is rated at 425,600 Btu/hr with 20,000 cfm of air flow. The individual heating coils are finned, tubular, resistance heating elements rated at 51,180 Btu/hr, and are operated during low temperature conditions. They are controlled by their respective temperature controllers. R1

The temperature of the control room is maintained at 75°F at 50% relative humidity with only two units in operation. If one unit should fail, the identical spare unit would be placed into service. These units are powered from emergency buses and will function on loss of offsite power when the emergency diesel generators are supplying power to the emergency buses.

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

Review criterion:

Review the ability of the ventilation system to detect, filter or expedite safe discharge of airborne contaminants inside the control room.

Response:

Contaminant monitoring and alarm equipment is discussed in Sections 5 and 6 of this report and in Appendix B.

The recirculating ventilation system makeup air and recirculated air are constantly filtered by the recirculation air filter to remove dust, smoke and other particulates that may be present in the air. The volume of normal makeup air (2000 cfm) sufficiently compensates for the normal exhaust (1000 cfm) of the systems single exhaust fan and the building exfiltration (approximately 1000 cfm).

The emergency air filtering system provides the additional filtering necessary to maintain habitable conditions within the control room area during emergency situations. This system is discussed further in Sections 4.1 and 4.2 of this report. R1

A.2.6 Provisions to Detect and Isolate Portions of System in the Event of Fires, Failures and Malfunctions

Review criterion:

Review the provisions available to detect and isolate portions of systems in the event of fires, failures or malfunctions.

Response:

The cable spreading room, mechanical equipment rooms, control room, and battery rooms are independently ventilated. This serves to minimize the potential for the spreading of smoke throughout the building. Fire dampers are provided for all penetrations through

firewalls. Smoke detectors are provided in the control room area and the mechanical equipment room, and a heat detection system is located in the carbon type filter of each emergency air filter train.

A review was conducted by CP&L to evaluate and document the adequacy of the present location of the smoke detectors. The review concluded that installation of an additional smoke detector was not warranted (Ref. 1).

The optimum location for a smoke detector would be in the 2000 cfm normal makeup air duct. This location would sense any smoke in the fresh air makeup supply. The remainder of the air for the control room is recirculated and the detection system in the control room area would sense the smoke and align the emergency recirculation mode of the HVAC system before a significant amount of makeup air has entered the system. Smoke and particulates would be removed by the emergency filter system and thus provide a habitable environment. R1

In addition, fire detection equipment is also installed in the mechanical (HVAC) equipment room and receives the same air as that of the makeup air duct. This also provides sufficient indication of smoke intrusion. This detection system also aligns the emergency recirculation mode of the control room HVAC system upon receipt of an alarm condition.

The alarms used to detect any system malfunction are discussed in Section A.3.2.3 of this appendix. System failures or malfunctions are discussed in Sections A.2.1 and A.2.7 of this appendix.

A.2.7 Ability of Equipment to Function under Degraded CRAVS Performance

Review criterion:

Determine the ability of essential equipment being serviced by the ventilation system to function under the worst anticipated degraded CRAVS performance.

Response:

The worst anticipated situation for control room personnel was discussed in Section A.2.1 of this appendix. The analysis performed for this situation indicated that control room personnel would be exposed to radiation well within the limits of 10 CFR 100. The redundancy of the system, alarms, and emergency equipment (i.e., emergency air breathing apparatus) ensure that R1 control room personnel would be adequately protected in cases of toxic gas or smoke intrusion.

The primary concern with equipment is the heat generated by the electronic equipment and cable ways. The redundancy of the recirculation air conditioning units ensures that two units are functional (see Sections 4.1 and 4.2 of this report). However, should the spare unit fail to start after failure of one of the normally running units, only a single air-conditioning unit would be available to cool the equipment and control room. In this case, the temperature of the control room would rise, but not to a level to preclude habitability or to cause equipment malfunction. This is ensured by the mixing of the recirculation air in the return header prior to flowing through the two sets of cooling coils and also by the introduction

of 2000 scfm of outside air and exhaust of 1000 scfm of control room air. The returning air flow is in two separate ducts providing conditioned air to both sides of the control room and adjacent rooms. For this event, the administratively controlled doors for the effected area could be opened to help keep those rooms cooler. No equipment failures are expected on failure of two of the three air-conditioning units.

A.2.8 Seismic Design Requirements

Review criterion:

Determine that the quality group and seismic design requirements are met for the system.

Response:

R1

The HVAC equipment, controls and ductwork supports are designed to Seismic Category I criteria and are protected by tornado-proof constructions. The design criteria for ductwork supports and the method of analysis were reviewed in response to NRC IE Bulletin 79-07 (Ref. 2) and the results of the reanalysis have been documented (Ref. 3). The reanalysis concluded that the duct supports were seismically analyzed in accordance with the prevailing criteria at that time and that the analysis conformed with the requirements of Bulletin 79-07. In addition, it was verified that the duct support design was adequate to withstand hypothetical loads generated by the computer analysis.

A.2.9 Supplemental Information

The CRAVS system is located inside a tornado-proof Seismic Category I structure. Tornado pressure check valves are installed in the inlet and outlet lines to prevent surge

evacuation of air from the system ductwork, thereby preventing its collapse in the event of a tornado. The CRAVS is protected from missiles generated from breaks in high-and moderate-energy piping (pipe whipe, jet impingement, etc.), turbine missiles, or tornado-generated missiles. Adequate protection against internally generated missiles is obtained either by missile barriers or separation, or has been shown by analysis not to be of concern (see Section A.2.2 of this appendix). R1

Design information concerning control room General Design Criteria 5 and 19 is provided in the Brunswick 1 and 2 FSAR.

A.3 Comparison with Standard Review Plan 6.5.1

A.3.1 Operation After a Design-Basis Accident

Criterion:

Atmosphere cleanup systems should be designed so that they can operate after a design-basis accident (DBA) and retain radioactive material after the DBA.

Response:

The control building HVAC systems are designed to permit continuous occupancy of the control room, computer rooms and the electronic workrooms under normal operating conditions and under the postulated design-basis accident throughout the life of the plant (see FSAR Section 9.4.1). Redundant cooling equipment, filter trains, recirculation trains and fans are provided to ensure continued operation. The FSAR states that single failure criteria as described in IEEE 279-1971 and Section 6.5 of IEEE 379-1972 have been met. R1

Iodine removal efficiencies of the activated coconut charcoal are given in Table 5-1. Additional information regarding radioactive material retention is given in response to Criterion A.3.4.i.

A.3.2 Design Features of the Emergency Filter System

Criteria:

a. Each atmosphere cleanup system should be able to prefilter the air, remove moisture ahead of

charcoal absorbers and remove particulate matter by HEPA filters before and after the charcoal absorbers.

Response:

Each emergency filter train contains a charcoal filter bank and a HEPA filter upstream of the charcoal. The filter trains do not require a moisture separator because the mixing of 50 percent outdoor air and recirculation air ensures that the relative humidity will be maintained below the critical conditions.

There is no downstream HEPA filter; however, prior to entering the control room area the recirculated air is first drawn through an 80 to 85% efficient roll filter. Analysis has shown that even without the use of the roll filter, radiological limits inside the control room area will not be exceeded due to charcoal dust from the emergency filter system. If use of the roll filter is considered, levels reached in the control room would be significantly reduced. R1

Criterion:

b. Redundancy of filter trains should be provided, with the trains physically separated so that damage to one system will not cause damage to the other.

Response:

The redundant emergency filter trains are constructed to Seismic Category I requirements and separated by a barrier so that damage to one system will not cause

damage to the other system. The emergency filter fans are separated but have only a partial protective barrier between them; however, analysis has shown that these fans pose no missile hazard to each other (see Section A.2.2 of this appendix). Also, these fans are seismically mounted and located in a tornado-proof Seismic Category I structure.

Criterion:

c. All components should be designated as Seismic Category I.

Response:

All components are Seismic Category I (see Section A.2.8 of this appendix). R1

Criterion:

d. Individual systems should be limited to a volumetric air flow rate of 30,000 cfm.

Response:

The emergency system flow rate is less than 30,000 cfm.

Criterion:

e. Each system should be instrumented to signal, alarm, and record pressure drop and flow rate at the control room.

Response:

Differential pressure gauges are furnished across the following elements:

1. HEPA filters.
2. Calibrated flow elements.
3. Charcoal adsorbers.

Stainless steel thermowells with 4-inch dial thermometers are installed before and after every filter bank. A local relative humidity indicator (direct reading type) is installed between the HEPA filter bank and the charcoal filters.

Each emergency filter unit contains a calibrated flow measuring device fitted with a pressure drop gauge. The auxiliary operator outside the control room can R1 easily observe locally if the system flow is above or below the design rating due to system malfunction. The instrument sensitivity is ±2% of the optimum air flow.

Control room alarms are associated with failed emergency recirculation fans, vent fans, supply and booster fans, and the exhaust fan. In addition, control room alarms are actuated for control room intake air high chlorine, low instrument air pressure, low mechanical room temperature and various fire alarms including the charcoal filter high temperature alarm.

Additional monitoring instrumentation includes the battery room temperatures and differential pressure, outside air temperature, air cor itioning temperatures for Unit 1 and Unit 2, instrument air compressor pressure (upstream and downstream of reducer) and the normal and emergency makeup air damper position.

Although control room annunciators are not associated with the differential pressure gauges or flow rate indicators, indication is available. The monthly functional test on this system requires the logging of this information so that significant degradation of the system would be determined during these tests. Also, when the system is placed into operation, either in the emergency mode or the normal mode, system malfunction would be indicated in the control room either by air flow switches to show that a fan is not running and limit switches to indicate the associated damper position, or, as in the case of the emergency recirculation system, by the starting of the standby filter train and associated damper positions. The normal and emergency damper positions are also indicated in the control room.

In addition to system indicators and alarms, Operating Procedure OP-37, "Control Building Ventilation System," is used to verify the proper operation of the CRAVS in the normal mode and following emergency auto-initiation of the emergency recirculation system. R1

Criterion:

f. The applicable engineered safety feature atmosphere cleanup systems should be automatically activated after a design-basis accident (DBA) unless (1) the atmosphere cleanup system is operating during the time the DBA occurs, or (2) the activation is the result of another engineered safety feature signal (e.g., temperature, pressure).

Response:

The emergency filter recirculation system is automatically activated on high radiation or smoke detection.

The control building HVAC automatic initiation system is tested at least once every 18 months, in accordance with Periodic Test PT-46.4 (see Sections 4.1 and 4.2 of this report).

A.3.3 Equipment Environment

Criterion:

a. Expected conditions for the filter system, including maximum pressure and pressure differential, radiation dose rate received by the components, relative humidity, and maximum and minimum temperature should be based on the conditions in a postulated design-basis accident.

Response:

R1

The maximum differential pressure on the system would be expected during a tornado; however, tornado check valves are installed to ensure HVAC system integrity during this event. During normal operation, system differential pressures are ensured by periodic tests PT-23.1, "Control Building HVAC SYSYSTEMS," and PT-21.2, "Control Building Emergency Filters." The combined pressure drop across the HEPA filters and adsorber banks is less than 8.5 inches water gauge. Any sudden change in differential pressure across these filters would be indicated on the differential pressure gauges. Differential pressure across the roll filters is kept below 0.5 inches water gauge by automatic advancing of the filter media.

The largest expected dose rate to equipment would occur from a release of fission products

during a design-basis accident. The release would produce a mild radiation environment and no equipment functional degradation is expected.

The rest of the system would experience only ambient environmental conditions. Extremes of hot or cold temperatures from outside are not a problem due to the internal air conditioning system (see Section 4 of this report and Section A.2.7 of this appendix).

Criterion:

b. The radiation source terms should be consistent with the guidelines in Regulatory Guides 1.3, 1.4 and 1.25.

Response: R1

See Section 5 and Appendix E.

Criterion:

c. Shielding should be provided for essential services such as power and electrical control cables associated with the atmosphere cleanup system.

Response:

Special shielding is not required for any of the control building HVAC system because it is and would not be exposed to a radiologically high or hazardous environment. The equipment is subjected only to a mild radiological environment and therefore does not need special qualifications in accordance with IE Bulletin 79-01B.

A.3.4 Component Design and Qualification

Criterion:

a. The demisters should be designed, constructed and tested in accordance with the recommendation of Section 5.4 of ANSI N509-1976 and meet the Underwriters Laboratory (UL) Class 1 requirements.

Response:

The control room HVAC and emergency filter systems do not utilize demister filters.

Criterion:

b. Moisture removal equipment should be capable of reducing the relative humidity of the incoming atmosphere from 100% to 70%. R1

Response:

Humidity of the control room area is maintained by the air conditioning equipment and use of cooling coils. Incoming air is mixed with recirculated air to ensure the incoming atmosphere is maintained at a nominal 50% relative humidity.

Criterion:

c. Prefilters should be designed, constructed and listed in accordance with the recommendations of Section 5.3 of ANSI N509-1976.

Response:

Although the emergency filter trains do not have integral prefilters, the emergency filter system equipment present in the Brunswick design does meet the recommendations of ANSI N509-1976.

Criterion:

d. HEPA filters should be designed, constructed and tested in accordance with Section 5.1 of ANSI-N509-1976.

Response:

HEPA filters meet the recommendations of ANSI N509-1976. R1

Criterion:

e. Filter and adsorber mounting frames should be designed, arranged and constructed in accordance with the recommendations of Section 5.6.3 of ANSI N509-1976.

Response:

Filter and adsorber mounting frames meet the recommendations of ANSI N509-1976.

Criterion:

f. Filter housings, including floors and doors, should be designed and constructed in accordance with the recommendations of Section 5.6 of ANSI N509-1976.

Response:

Filter housings meet the recommendations of ANSI N509-1976.

Criterion:

g. Water drains should be designed in accordance with the recommendations of Section 4.5.8 of ERDA 76-21.

Response:

There are no water drains used in the emergency recirculation filtration system. Water traps are used by the instrument air compressor systems. R1

Criterion:

h. The adsorbent to be used for adsorbing gaseous iodine (elemental iodine and organic iodides) should be an adsorbent that has been demonstrated to remove the gaseous iodines from air at the required efficiencies referenced in ANSI N509-1976.

Response:

The filter efficiencies for iodine are given in Table 5-1 and meet ANSI N509-1976 guidelines for iodine removal efficiency.

Criterion:

i. The adsorption unit should be designed for a maximum loading of 2.5 mg of total iodine (radioactive plus stable) per gram of activated charcoal.

Response:

The bulk density of the bone dry charcoal is 25 to 30 lb per cubic foot. Potassium Iodide (KI) impregnation ranges between 4 to 6%. The specific heat of the charcoal at 15°C is 0.24 and the description temperature is greater than 150°C. The filter system is designed to withstand the anticipated fission product heat loading from a TID-14844 release without reaching the desorption temperature of the charcoal filters. The ignition temperature of the charcoal is greater than 340°F. R1

Criterion:

j. Provisions should be included to inhibit off-design temperatures in the adsorber section.

Response:

The charcoal filter units each have a heat detection system (fire detection system). If a high temperature condition is detected, the filtering train automatically shuts down to limit desorption of the charcoal. The desorption temperature of the charcoal is greater than 302°F. In addition, the filter system is constructed of heat resistant and flame-retarding materials, designed to operate efficiently at temperatures up to 250°F.

Criterion:

k. The system fan, its mounting and ductwork connections should be designed, constructed and tested in accordance with the recommendations of Section 5.7 and 5.8 of ANSI N509-1976.

Response:

The system fan, mounting, and ductwork connections meet the recommendations of ANSI N509-1976.

Criterion:

l. Ductwork should be designed, constructed and tested in accordance with the recommendations of Section 5.10 of ANSI N509-1976. R1

Response:

The ductwork meets the recommendations of ANSI N509-1976.

Criterion:

m. Dampers should be designed, constructed and tested in accordance with the recommendations of Section 5.9 of ANSI N509-1976.

Response:

The dampers meet the recommendations of ANSI N509-1976.

A.3.5 Accessibility of Engineered Safety Feature Filter System Components

Criterion:

a. Components should be provided with a minimum of 3 linear feet from mounting frame to mounting frame between banks of components.

Response:

The emergency recirculation filter system units are each constructed with two 30 x 56-inch doors for access to either the HEPA filter or the charcoal trays. There is a minimum of 30 inches to perform maintenance on the HEPA filter. Sufficient space exists above the filter for access to the filter isolation valves for either maintenance or repair. Equipment located in the mechanical equipment room is positioned to allow access to each individual component for maintenance. R1

Criterion:

b. Provisions should be made for permanent test probes with external connections in accordance with the recommendations of Section 4.11 of ANSI N509-1976.

Response:

Dioctylphthalate (DOP) injection and detection probes are provided for testing the efficiency of the charcoal filters. The recommendations of ANSI N509-1976 are satisfied.

A.3.6 In-Place Testing

Criterion:

a. Provisions should be made for visual inspection of the system and all associated components in accordance with the recommendations of Section 5 of ANSI N510-1976.

Response:

Visual inspection of the control room emergency filter system are conducted in accordance with Periodic Test PT-21.1, Section VII.1.C. In addition, the system is functionally tested for 15 minutes at least once every 31 days in accordance with Technical Specification 4.7.2.a and Periodic Test PT-23.1. The recommendations of ANSI N509-1976 are satisfied. R1

Criterion:

b. Provisions should be made for testing the air flow distribution upstream of HEPA filters and charcoal absorbers and demonstrating uniformity $\pm$20% of averaged flow per unit.

Response:

Only one flow train is operational at a time. System flow rate is tested in accordance with Sections VII.1.A and III.1.F of Periodic Test PT-21.1 and Technical Specification 4.7.2.b.3.

Criterion:

c. Provisions should be made for dioctylphthalate (DOP) testing of the HEPA filter section in accordance with the recommendations of ANSI N510-1976.

Response:

Dioctylphthalate (DOP) testing of the HEPA filter is conducted in accordance with Technical Specifications 4.7.2.e and 4.7.2.f and Periodic Test PT-21.1, Section VII.1.D. The recommendations of ANSI N509-1976 are satisfied.

Criterion:

d. Provisions should be made for leak-testing the activated carbon adsorber section with a gaseous halogenated hydrocarbon refrigerant in accordance with the recommendations of ANSI N510-1976. R1

Response:

The activated carbon adsorber is tested in accordance with Technical Specifications 4.7.2.b.2 and 4.7.2.c using Periodic Test PT-21.1, Sections VII.1.B and VII.1.E. The recommendations of ANSI N509-1976 are satisfied.

Criterion:

e. Provisions should be made for in-place testing initially and routinely thereafter. Frequency and testing requirements will be established in the Technical Specifications.

Response:

Technical Specification 4.7.2 delineates the testing requirements and frequency for the control room emergency filtration system. Periodic Test 21.1, "Control Building Emergency Filters," provides the procedure and criteria for performing the required tests on the HEPA filter banks and adsorber banks. The tests involve flow verification, visual inspection, dioctylphthalate (DOP) and halogenated hydrocarbon tests, laboratory tests of adsorber samples, and differential pressure tests.

A.3.7 Laboratory Testing of Activated Carbon Adsorbent

Criterion:

a. Qualification and batch tests on new unused adsorbent should be performed in accordance with the guidelines of ANSI N509-1976. R1

Response:

Qualification of new adsorbent is performed at the supplier's facilities prior to shipment to Brunswick. The purchasing requirements include that the testing and qualification be performed in accordance with the guidelines of ANSI N509-1976.

Criterion:

b. Provisions should be made for obtaining representative adsorbent samples in order to estimate the amount of penetration of the system.

Response:

Adsorbent samples are obtained every 720 hours of system operation in accordance with Technical Specification 4.7.2.c.

Criterion:

c. Provisions should be made for laboratory testing initially and routinely thereafter. Frequency and testing requirements will be established in the Technical Specifications. R1

Response:

Laboratory testing of the carbon adsorber is conducted prior to use and then routinely thereafter, in accordance with Technical Specifications 4.7.2.b.2 and 4.7.2.c.

A.4 References

1. Internal memorandum from J. M. Aldieri to B. L. Parks, Jr., Carolina Power & Light Company, dated February 6, 1981.

2. U. S. Nuclear Regulatory Commission, "Seismic Stress Analysis of Safety-Related Piping," IE Bulletin 79-07, April 14, 1979. R1

3. Letter from L. R. Scott, United Engineers & Constructors, to R. L. Sanders, CP&L, dated April 24, 1981.

APPENDIX B

ADDITIONAL INFORMATION REQUIRED BY THE NRC

1. Control Room Mode of Operation:

   Response: Radiological accident: pressurization and filter recirculation
   Chlorine release: isolation

2. Control Room Characteristics:

   a. control room air volume:

      Response: 298,650 cubic feet

   b. control room emergency zone:

      Response: The emergency zone includes the control room, electronics rooms, kitchen, washroom, computer rooms.

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

      Response: See Figures 4-1 and 4-2 in this report.

   d. infiltration leakage rate:

      Response: The calculated infiltration leakage rate in the radiation isolation mode is 276 cfm.

   e. HEPA filter and charcoal adsorber efficiencies:

      Response: HEPA filter efficiency: 99 percent for particulate iodine.

charcoal adsorber efficiency: 95 percent for elemental iodine, 90 percent for organic iodine.

f. closest distance between containment and air intake:

Response: The principal radiological release point is the plant stack, located approximately 180 meters from the control room air intake.

g. layout of control room, air intakes, containment building, and chlorine or other chemical storage facility with dimensions: R1

Response: See Figure 4-3 in this report.

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

Response: For analysis of the Brunswick plant shielding, refer to Section 12.4 of the Brunswick FSAR and the December 31, 1979, submittal by CP&L in response to NUREG-0578 Item 2.1.6.b. R1

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

Response: The closing time of the outside air isolation damper (2L-D-CB) is 7 seconds. R1

The damper is assumed to leak at the rate of 1 percent of flow in the open position, per ASHRAE for dampers with seals. Assumed damper leakage is 20 cfm.

The area of butterfly damper (2L-D-CB) is 1.4 square feet.

o. potassium iodide drug supply:

Response: CP&L maintains pharmaceutical grade potassium iodide which is stored at the site for administration by a physician in a radiological accident. R1

3. Onsite Storage of Chlorine and Other Hazardous Chemicals:

a. total amount and size of container:

Response: See CP&L response to comment 14.5 in the Brunswick FSAR for identification and analysis of chlorine and other hazardous chemicals stored at the site. This analysis indicates that the 55-ton chlorine tank car at the service water intake structure is the only hazardous material stored at the site in a significant quantity.

b. closest distance from control room air intake:

Response: See the response to comment 14.5 in the Brunswick FSAR. The tank car is located approximately 450 feet from the control room air intake and the control room air intake is approximately 25 meters above the grade on which the tank car is stored.

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

a. identify facilities within a 5-mile radius

b. distance from control room

c. quantity of hazardous chemicals in one container

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: See Brunswick Units 1 and 2, technical specification 3.3.5.5 for the LCO and surveillance requirements on the chlorine detection system.

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

Response: Refer to Brunswick Units 1 and 2, technical specification 3.4.7.2 for the limiting conditions for operation and the surveillance requirements on the control room emergency filtration system.

Technical specification 4.7.2.d.4 requires verification at least once per 18 months that the system maintains the control room at a positive pressure relative to the outside atmosphere during system operation.

Specifications 4.7.2.d.2 and 4.7.2.d.3 address verification of isolation by test signals.

Specifications 4.7.2.b, 4.7.2.c, 4.7.2.d.1, 4.7.2.e, and 4.7.2.f address filter testing requirements.

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

BRUNSWICK ON-SITE METEOROLOGICAL FACILITY

UPPER 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	0.00	0.00	0.01	0.01	0.02	0.01	0.05	16.76
NNE	0.0	0.0	0.0	0.02	0.0	0.0	0.0	0.02	10.73
NE	0.0	0.0	0.00	0.02	0.02	0.01	0.0	0.05	14.39
ENE	0.0	0.0	0.00	0.01	0.05	0.01	0.0	0.07	15.72
E	0.0	0.0	0.01	0.02	0.07	0.01	0.0	0.10	14.52
ESE	0.0	0.0	0.01	0.05	0.01	0.0	0.0	0.07	10.24
SE	0.0	0.0	0.00	0.10	0.01	0.00	0.0	0.12	10.46
SSE	0.0	0.0	0.01	0.03	0.00	0.0	0.0	0.04	9.09
S	0.0	0.0	0.00	0.01	0.00	0.0	0.0	0.01	10.36
SSW	0.0	0.0	0.01	0.01	0.01	0.00	0.00	0.03	14.23
SW	0.0	0.0	0.0	0.01	0.01	0.01	0.0	0.03	15.33
WSW	0.0	0.0	0.00	0.01	0.01	0.01	0.0	0.03	13.54
W	0.0	0.0	0.00	0.00	0.00	0.00	0.0	0.01	12.18
WNW	0.0	0.0	0.0	0.01	0.01	0.02	0.0	0.03	17.67
NW	0.0	0.0	0.00	0.00	0.01	0.02	0.0	0.04	17.91
NNW	0.0	0.0	0.05	0.03	0.01	0.01	0.0	0.05	11.95
TOTAL	0.0	0.00	0.06	0.33	0.24	0.12	0.01	0.75	13.44

NUMBER OF CALMS - 0
NUMBER OF BAD HOURS - 432

JOINT PERCENTAGE FREQUENCIES OF WIND DIRECTION AND SPEED
FOR THE PERIOD 12:00 AM 1/ 1/75 TO 11:00 PM 12/31/79

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

BRUNSWICK ON-SITE METEOROLOGICAL FACILITY

UPPER 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
N	0.0	0.0	0.01	0.02	0.06	0.02	0.00	0.10	14.95
NNE	0.0	0.0	0.00	0.01	0.03	0.01	0.0	0.06	13.66
NE	0.0	0.0	0.00	0.03	0.11	0.06	0.01	0.21	16.44
ENE	0.0	0.0	0.01	0.05	0.19	0.02	0.00	0.27	14.73
E	0.0	0.0	0.00	0.05	0.10	0.01	0.0	0.16	13.49
ESE	0.0	0.00	0.02	0.10	0.02	0.00	0.0	0.16	10.22
SE	0.0	0.00	0.04	0.13	0.03	0.00	0.0	0.22	9.76
SSE	0.0	0.0	0.01	0.06	0.02	0.00	0.0	0.09	11.78
S	0.0	0.0	0.0	0.03	0.05	0.02	0.0	0.10	15.31
SSW	0.0	0.0	0.01	0.04	0.08	0.02	0.0	0.15	14.56
SW	0.0	0.0	0.0	0.01	0.14	0.13	0.03	0.31	18.91
WSW	0.0	0.0	0.0	0.00	0.01	0.01	0.0	0.03	17.02
W	0.0	0.0	0.0	0.01	0.01	0.0	0.01	0.03	17.64
WNW	0.0	0.0	0.0	0.01	0.04	0.06	0.03	0.14	20.24
NW	0.0	0.0	0.00	0.01	0.09	0.05	0.01	0.16	17.52
NNW	0.0	0.0	0.01	0.03	0.07	0.03	0.00	0.15	14.91
TOTAL	0.0	0.01	0.11	0.60	1.06	0.45	0.09	2.32	15.07

NUMBER OF CALMS - 0
NUMBER OF BAD HOURS - 10

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

BRUNSWICK ON-SITE METEOROLOGICAL FACILITY

UPPER 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	0.0	0.02	0.12	0.13	0.04	0.01	0.32	13.84
NNE	0.0	0.00	0.01	0.05	0.09	0.04	0.0	0.19	13.81
NE	0.0	0.0	0.01	0.11	0.26	0.14	0.02	0.54	16.14
ENE	0.0	0.0	0.01	0.20	0.25	0.03	0.00	0.50	13.48
E	0.0	0.0	0.05	0.20	0.12	0.01	0.00	0.39	11.63
ESE	0.0	0.0	0.05	0.19	0.03	0.01	0.0	0.29	10.20
SE	0.0	0.0	0.01	0.24	0.05	0.01	0.01	0.31	11.03
SSE	0.0	0.0	0.03	0.13	0.08	0.01	0.01	0.27	11.81
S	0.0	0.0	0.01	0.09	0.17	0.03	0.00	0.31	14.20
SSW	0.0	0.0	0.0	0.11	0.32	0.04	0.02	0.49	15.18
SW	0.0	0.0	0.01	0.10	0.60	0.44	0.12	1.27	18.39
WSW	0.0	0.0	0.01	0.04	0.11	0.06	0.01	0.23	16.07
W	0.0	0.0	0.01	0.04	0.04	0.02	0.01	0.12	14.16
WNW	0.0	0.0	0.02	0.04	0.10	0.06	0.04	0.27	17.46
NW	0.0	0.0	0.01	0.15	0.15	0.08	0.03	0.43	15.51
NNW	0.0	0.0	0.01	0.17	0.17	0.07	0.01	0.42	14.05
TOTAL	0.0	0.00	0.30	1.97	2.65	1.10	0.29	6.32	14.19

NUMBER OF CALMS - 0
NUMBER OF BAD HOURS - 15

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

BRUNSWICK ON-SITE METEOROLOGICAL FACILITY

UPPER 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	0.01	0.13	0.58	1.00	0.47	0.05	2.25	14.93
NNE	0.0	0.01	0.16	0.60	1.49	0.74	0.05	3.06	15.53
NE	0.0	0.01	0.21	0.58	1.16	0.71	0.16	2.83	15.80
ENE	0.0	0.01	0.22	0.71	0.83	0.34	0.05	2.15	13.82
E	0.0	0.01	0.20	0.64	0.51	0.10	0.01	1.58	12.25
ESE	0.00	0.03	0.17	0.49	0.27	0.07	0.04	1.07	11.97
SE	0.0	0.01	0.25	0.50	0.15	0.04	0.03	0.98	10.67
SSE	0.0	0.02	0.16	0.51	0.30	0.12	0.09	1.20	13.05
S	0.0	0.01	0.20	0.73	0.54	0.24	0.15	1.86	14.03
SSW	0.0	0.01	0.25	1.03	1.56	0.89	0.35	4.10	16.00
SW	0.0	0.01	0.15	0.91	2.49	1.86	0.96	6.38	18.48
WSW	0.00	0.03	0.23	0.78	1.18	0.84	0.20	3.26	15.87
W	0.0	0.02	0.26	0.59	0.45	0.22	0.07	1.60	13.04
WNW	0.0	0.02	0.15	0.40	0.50	0.30	0.13	1.49	15.06
NW	0.0	0.01	0.15	0.37	0.50	0.35	0.12	1.50	15.42
NNW	0.0	0.01	0.17	0.50	0.83	0.52	0.10	2.13	15.39
TOTAL	0.01	0.25	3.06	9.90	13.94	7.80	2.57	37.43	14.46

NUMBER OF CALMS - 2
NUMBER OF BAD HOURS - 106

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

BRUNSWICK ON-SITE METEOROLOGICAL FACILITY

UPPER 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	0.02	0.08	0.24	0.62	0.46	0.01	1.42	15.81
NNE	0.0	0.01	0.13	0.24	1.12	0.85	0.02	2.37	16.60
NE	0.0	0.02	0.10	0.29	0.75	0.47	0.03	1.65	15.66
ENE	0.0	0.01	0.10	0.41	0.94	0.38	0.04	1.89	15.21
E	0.0	0.02	0.10	0.50	0.72	0.13	0.03	1.49	13.57
ESE	0.0	0.01	0.13	0.35	0.47	0.13	0.06	1.14	13.88
SE	0.0	0.02	0.14	0.34	0.30	0.17	0.15	1.13	15.24
SSE	0.00	0.02	0.13	0.49	0.39	0.28	0.42	1.74	17.55
S	0.0	0.01	0.15	0.50	0.47	0.29	0.57	2.00	18.55
SSW	0.00	0.02	0.18	0.44	0.90	0.70	0.72	2.95	19.00
SW	0.0	0.01	0.14	0.45	1.74	1.61	0.82	4.78	19.23
WSW	0.00	0.02	0.20	0.93	1.49	0.88	0.37	3.90	16.18
W	0.0	0.01	0.18	0.68	0.68	0.29	0.01	1.84	13.20
WNW	0.0	0.01	0.09	0.25	0.45	0.58	0.04	1.42	16.63
NW	0.0	0.01	0.08	0.22	0.39	0.32	0.04	1.07	15.73
NNW	0.0	0.01	0.09	0.27	0.56	0.44	0.02	1.39	15.79
TOTAL	0.01	0.22	2.02	6.62	11.97	7.97	3.36	32.17	16.11

NUMBER OF CALMS - 3
NUMBER OF BAD HOURS - 19

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

BRUNSWICK ON-SITE METEOROLOGICAL FACILITY

UPPER 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	0.02	0.08	0.16	0.35	0.34	0.01	0.96	15.76
NNE	0.0	0.01	0.08	0.18	0.39	0.33	0.01	1.00	15.49
NE	0.0	0.03	0.10	0.24	0.45	0.10	0.0	0.93	13.21
ENE	0.0	0.01	0.09	0.27	0.29	0.03	0.0	0.70	12.05
E	0.00	0.04	0.12	0.23	0.14	0.04	0.0	0.57	10.68
ESE	0.0	0.03	0.10	0.19	0.13	0.02	0.02	0.49	11.09
SE	0.0	0.03	0.11	0.16	0.14	0.03	0.04	0.50	11.99
SSE	0.0	0.02	0.11	0.32	0.13	0.09	0.14	0.81	14.64
S	0.0	0.01	0.12	0.31	0.15	0.15	0.04	0.78	13.22
SSW	0.0	0.01	0.14	0.23	0.18	0.12	0.03	0.71	13.18
SW	0.0	0.01	0.09	0.33	0.31	0.23	0.03	1.00	14.34
WSW	0.0	0.03	0.19	0.42	0.32	0.16	0.05	1.17	12.75
W	0.0	0.03	0.17	0.39	0.28	0.15	0.01	1.04	12.35
WNW	0.0	0.01	0.07	0.19	0.33	0.29	0.03	0.92	15.92
NW	0.0	0.02	0.05	0.13	0.27	0.21	0.03	0.72	15.75
NNW	0.0	0.01	0.07	0.11	0.23	0.22	0.01	0.66	15.58
TOTAL	0.00	0.34	1.70	3.96	4.09	2.51	0.47	12.96	13.62

NUMBER OF CALMS - 1
NUMBER OF BAD HOURS - 64

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

BRUNSWICK ON-SITE METEOROLOGICAL FACILITY

UPPER 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	0.03	0.08	0.11	0.13	0.09	0.01	0.45	12.99
NNE	0.0	0.01	0.10	0.17	0.27	0.12	0.01	0.58	13.60
NE	0.0	0.01	0.09	0.23	0.27	0.03	0.0	0.63	12.13
ENE	0.0	0.03	0.13	0.18	0.11	0.0	0.0	0.45	9.43
E	0.0	0.03	0.13	0.15	0.06	0.0	0.0	0.36	8.57
ESE	0.0	0.04	0.15	0.12	0.09	0.00	0.0	0.40	8.82
SE	0.0	0.04	0.13	0.16	0.06	0.01	0.01	0.40	9.17
SSE	0.0	0.03	0.14	0.16	0.06	0.02	0.01	0.42	9.16
S	0.00	0.04	0.16	0.15	0.07	0.01	0.00	0.43	8.94
SSW	0.0	0.03	0.16	0.15	0.12	0.02	0.00	0.49	9.98
SW	0.0	0.03	0.13	0.14	0.09	0.01	0.01	0.41	10.09
WSW	0.0	0.03	0.19	0.22	0.13	0.04	0.01	0.62	10.25
W	0.0	0.02	0.22	0.22	0.13	0.06	0.01	0.66	10.55
WNW	0.0	0.03	0.09	0.17	0.16	0.13	0.03	0.61	13.66
NW	0.0	0.02	0.09	0.15	0.17	0.12	0.01	0.56	13.42
NNW	0.0	0.03	0.07	0.14	0.14	0.08	0.01	0.47	12.60
TOTAL	0.00	0.44	2.05	2.53	2.07	0.75	0.10	8.04	10.83

NUMBER OF CALMS - 1
NUMBER OF BAD HOURS - 13

CAROLINA POWER AND LIGHT COMPANY PAGE 9

JOINT PERCENTAGE FREQUENCIES OF WIND DIRECTION AND SPEED
FOR THE PERIOD 12:01 AM 1/ 1/76 TO 11:00 PM 12/31/79

SUMMARY
STABILITY CALCULATED FROM DIFF. TEMPERATURE #1+2

BRUNSWICK ON-SITE METEOROLOGICAL FACILITY

UPPER 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	0.08	0.40	1.24	2.29	1.43	0.10	5.55	15.10
NNE	0.0	0.04	0.49	1.27	3.39	2.08	0.09	7.37	15.62
NE	0.0	0.07	0.52	1.49	3.02	1.53	0.21	6.84	15.11
ENE	0.0	0.06	0.55	1.82	2.67	0.82	0.10	6.02	13.76
E	0.00	0.09	0.60	1.79	1.81	0.31	0.04	4.64	12.23
ESE	0.00	0.11	0.62	1.49	1.02	0.23	0.13	3.61	11.86
SE	0.0	0.10	0.69	1.63	0.74	0.26	0.24	3.66	12.07
SSE	0.00	0.09	0.60	1.70	0.98	0.53	0.66	4.56	14.56
S	0.00	0.07	0.64	1.82	1.45	0.75	0.76	5.49	15.18
SSW	0.00	0.08	0.74	2.01	3.16	1.79	1.14	8.92	16.36
SW	0.0	0.06	0.53	1.96	5.38	4.29	1.98	14.19	18.19
WSW	0.01	0.11	0.83	2.40	3.25	2.00	0.64	9.24	15.23
W	0.0	0.08	0.85	1.93	1.59	0.74	0.11	5.30	12.70
WNW	0.0	0.08	0.41	1.07	1.58	1.44	0.30	4.89	15.79
NW	0.0	0.07	0.39	1.03	1.59	1.15	0.25	4.48	15.41
NNW	0.0	0.05	0.42	1.25	2.01	1.37	0.15	5.26	15.11
TOTAL	0.02	1.27	9.29	25.91	35.92	20.70	6.90	100.00	15.16

NUMBER OF CALMS - 7
NUMBER OF BAD HOURS - 719

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

BRUNSWICK 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	18.0-25.0	GREATER THAN 25.0	TOTAL	AVG. WIND SPEED
N	0.0	0.0	0.01	0.02	0.01	0.01	0.0	0.04	12.02
NNE	0.0	0.01	0.01	0.02	0.0	0.0	0.0	0.04	6.88
NE	0.0	0.00	0.01	0.03	0.07	0.00	0.0	0.11	12.08
ENE	0.0	0.0	0.00	0.05	0.04	0.0	0.0	0.09	12.32
E	0.0	0.00	0.02	0.05	0.05	0.0	0.0	0.13	10.90
ESE	0.0	0.0	0.01	0.05	0.01	0.0	0.0	0.07	9.07
SE	0.0	0.0	0.03	0.10	0.00	0.0	0.0	0.13	8.63
SSE	0.0	0.00	0.01	0.01	0.00	0.0	0.0	0.03	7.94
S	0.0	0.0	0.00	0.01	0.0	0.0	0.0	0.01	8.48
SSW	0.0	0.0	0.0	0.01	0.01	0.00	0.0	0.02	13.51
SW	0.0	0.0	0.00	0.01	0.02	0.00	0.0	0.03	13.78
WSW	0.0	0.01	0.01	0.0	0.01	0.00	0.0	0.02	8.68
W	0.0	0.00	0.0	0.00	0.01	0.0	0.0	0.01	10.87
WNW	0.0	0.00	0.0	0.01	0.02	0.0	0.0	0.03	13.18
NW	0.0	0.01	0.01	0.01	0.02	0.0	0.0	0.06	11.12
NNW	0.0	0.01	0.00	0.02	0.01	0.0	0.0	0.04	10.07
TOTAL	0.0	0.04	0.13	0.40	0.28	0.02	0.0	0.87	10.60

NUMBER OF CALMS - 0
NUMBER OF BAD HOURS - 393

JOINT PERCENTAGE FREQUENCIES OF WIND DIRECTION AND SPEED
FOR THE PERIOD 12:00 AM 1/ 1/75 TO 11:00 PM 12/31/79

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

BRUNSWICK 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	0.0	0.01	0.05	0.03	0.00	0.0	0.10	11.43
NNE	0.0	0.0	0.01	0.04	0.01	0.00	0.0	0.07	10.68
NE	0.0	0.0	0.01	0.08	0.12	0.02	0.0	0.22	13.39
ENE	0.0	0.0	0.01	0.16	0.09	0.00	0.0	0.26	11.87
E	0.0	0.0	0.01	0.11	0.05	0.0	0.0	0.17	10.89
ESE	0.0	0.0	0.06	0.12	0.01	0.0	0.0	0.19	8.51
SE	0.0	0.0	0.06	0.14	0.00	0.0	0.0	0.21	8.43
SSE	0.0	0.0	0.01	0.04	0.01	0.0	0.0	0.06	9.81
S	0.0	0.0	0.0	0.06	0.05	0.0	0.0	0.10	12.67
SSW	0.0	0.0	0.01	0.07	0.08	0.01	0.0	0.17	13.09
SW	0.0	0.0	0.0	0.04	0.19	0.08	0.0	0.31	15.85
WSW	0.0	0.0	0.0	0.00	0.01	0.0	0.0	0.01	14.67
W	0.0	0.0	0.0	0.03	0.01	0.00	0.0	0.04	11.10
WNW	0.0	0.0	0.0	0.03	0.08	0.03	0.0	0.15	15.83
NW	0.0	0.0	0.00	0.07	0.09	0.0	0.0	0.17	12.72
NNW	0.0	0.0	0.01	0.05	0.05	0.0	0.0	0.12	11.70
TOTAL	0.0	0.0	0.21	1.10	0.88	0.15	0.0	2.34	12.04

NUMBER OF CALMS - 0
NUMBER OF BAD HOURS - 2

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

BRUNSWICK 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	0.0	0.06	0.17	0.07	0.0	0.0	0.30	10.37
NNE	0.0	0.0	0.02	0.13	0.06	0.00	0.0	0.22	10.93
NE	0.0	0.0	0.04	0.22	0.25	0.02	0.0	0.54	12.52
ENE	0.0	0.0	0.03	0.30	0.13	0.01	0.0	0.49	11.36
E	0.0	0.00	0.06	0.29	0.05	0.0	0.0	0.39	9.63
ESE	0.00	0.00	0.08	0.21	0.01	0.0	0.0	0.31	8.47
SE	0.00	0.00	0.09	0.25	0.01	0.0	0.0	0.35	8.53
SSE	0.0	0.0	0.03	0.15	0.04	0.00	0.0	0.22	10.05
S	0.0	0.0	0.03	0.15	0.10	0.02	0.0	0.31	12.12
SSW	0.0	0.0	0.01	0.24	0.28	0.06	0.01	0.60	13.55
SW	0.00	0.00	0.01	0.26	0.72	0.25	0.02	1.27	15.54
WSW	0.0	0.0	0.01	0.05	0.06	0.01	0.0	0.12	12.74
W	0.00	0.00	0.03	0.05	0.06	0.01	0.0	0.15	11.62
WNW	0.0	0.0	0.03	0.12	0.11	0.03	0.0	0.29	12.79
NW	0.00	0.00	0.03	0.20	0.14	0.02	0.0	0.40	11.85
NNW	0.00	0.00	0.08	0.20	0.10	0.0	0.0	0.39	10.26
TOTAL	0.02	0.02	0.65	3.00	2.19	0.42	0.03	6.33	11.40

NUMBER OF CALMS - 6
NUMBER OF BAD HOURS - 13

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

BRUNSWICK 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	0.00	0.07	0.75	1.43	0.29	0.0	0.0	2.55	8.91
NNE	0.0	0.05	0.62	1.59	0.53	0.02	0.0	2.90	9.76
NE	0.00	0.08	0.44	1.34	0.84	0.07	0.0	2.77	10.90
ENE	0.0	0.03	0.49	1.15	0.46	0.0	0.0	2.13	9.94
E	0.0	0.03	0.41	0.91	0.16	0.01	0.0	1.53	8.92
ESE	0.00	0.06	0.44	0.53	0.08	0.02	0.0	1.12	8.17
SE	0.0	0.05	0.55	0.40	0.06	0.0	0.0	1.06	7.28
SSE	0.0	0.03	0.38	0.48	0.12	0.02	0.0	1.04	8.87
S	0.0	0.04	0.45	1.09	0.38	0.08	0.00	2.05	10.33
SSW	0.0	0.03	0.43	2.04	1.57	0.29	0.05	4.41	12.26
SW	0.0	0.03	0.39	2.27	3.06	0.74	0.15	6.65	13.83
WSW	0.00	0.07	0.39	1.10	0.82	0.14	0.03	2.55	11.62
W	0.00	0.06	0.54	0.74	0.25	0.06	0.00	1.66	9.40
WNW	0.0	0.05	0.28	0.70	0.32	0.06	0.0	1.41	10.43
NW	0.0	0.04	0.38	0.83	0.41	0.04	0.0	1.70	10.27
NNW	0.00	0.06	0.48	1.01	0.37	0.01	0.0	1.93	9.51
TOTAL	0.02	0.79	7.42	17.71	9.72	1.57	0.24	37.46	10.03

NUMBER OF CALMS - 6
NUMBER OF BAD HOURS - 109

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

BRUNSWICK ON-SITE METEOROLOGICAL FACILITY

LOWER WIND DIRECTION	CALM	0.75- 3.5	3.5- 7.5	SPEED CLASS(MPH) 7.5-12.5	12.5-18.5	18.5-25.0	GREATER THAN 25.0	TOTAL	AVG. WIND SPEED
N	0.01	0.28	1.36	0.59	0.04	0.0	0.0	2.27	6.32
NNE	0.01	0.26	0.90	0.92	0.04	0.00	0.0	2.13	7.02
NE	0.00	0.20	0.67	0.66	0.09	0.01	0.0	1.63	7.36
ENE	0.01	0.23	0.73	0.71	0.08	0.00	0.0	1.77	7.30
E	0.0	0.13	0.71	0.35	0.07	0.02	0.0	1.28	6.92
ESE	0.0	0.19	0.59	0.24	0.05	0.01	0.0	1.08	6.45
SE	0.01	0.20	0.45	0.26	0.08	0.03	0.01	1.03	7.02
SSE	0.01	0.21	0.62	0.44	0.27	0.04	0.01	1.60	8.26
S	0.01	0.23	0.74	0.50	0.38	0.09	0.02	1.96	8.99
SSW	0.0	0.18	0.68	1.07	0.63	0.13	0.01	2.71	10.12
SW	0.01	0.21	1.24	2.30	1.09	0.23	0.02	5.10	10.13
WSW	0.01	0.27	1.38	1.41	0.35	0.03	0.00	3.46	8.10
W	0.01	0.34	1.25	0.40	0.03	0.0	0.0	2.03	5.77
WNW	0.01	0.21	0.71	0.40	0.08	0.0	0.0	1.40	6.69
NW	0.01	0.24	0.64	0.31	0.03	0.0	0.0	1.23	6.06
NNW	0.01	0.23	0.99	0.27	0.01	0.0	0.0	1.51	5.71
TOTAL	0.09	3.63	13.07	10.82	3.34	0.59	0.07	32.19	7.39

NUMBER OF CALMS - 29
NUMBER OF BAD HOURS - 92

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

BRUNSWICK ON-SITE METEOROLOGICAL FACILITY

LOWER WIND DIRECTION	CALM	SPEED CLASS(MPH) 0.75- 3.5	3.5- 7.5	7.5-12.5	12.5-16.5	18.5-25.0	GREATER THAN 25.0	TOTAL	AVG. WIND SPEED
N	0.03	0.59	1.01	0.05	0.0	0.0	0.0	1.69	4.27
NNE	0.03	0.48	0.43	0.01	0.0	0.0	0.0	0.95	3.62
NE	0.01	0.20	0.33	0.02	0.0	0.0	0.0	0.56	4.11
ENE	0.01	0.23	0.14	0.02	0.0	0.0	0.0	0.39	3.52
E	0.01	0.23	0.17	0.02	0.00	0.0	0.0	0.45	3.91
ESE	0.01	0.20	0.09	0.02	0.0	0.0	0.0	0.33	3.35
SE	0.0	0.15	0.10	0.05	0.0	0.0	0.0	0.30	4.32
SSE	0.0	0.20	0.17	0.15	0.03	0.0	0.0	0.53	5.74
S	0.01	0.23	0.16	0.05	0.00	0.0	0.0	0.46	4.21
SSW	0.01	0.23	0.10	0.05	0.02	0.0	0.0	0.41	4.43
SW	0.01	0.28	0.49	0.14	0.01	0.0	0.0	0.92	5.07
WSW	0.02	0.43	0.58	0.08	0.0	0.0	0.0	1.11	4.27
W	0.03	0.58	0.67	0.01	0.0	0.0	0.0	1.30	3.73
WNW	0.03	0.47	0.52	0.02	0.0	0.0	0.0	1.04	3.86
NW	0.02	0.44	0.48	0.03	0.0	0.0	0.0	0.97	3.71
NNW	0.03	0.66	0.83	0.02	0.0	0.0	0.0	1.54	3.97
TOTAL	0.29	5.59	6.28	0.74	0.06	0.0	0.0	12.96	4.13

NUMBER OF CALMS - 98
NUMBER OF BAD HOURS - 69

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

BRUNSWICK 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	0.09	0.65	0.33	0.02	0.0	0.0	0.0	1.10	3.27
NNE	0.04	0.30	0.13	0.0	0.0	0.0	0.0	0.47	2.81
NE	0.02	0.17	0.02	0.0	0.0	0.0	0.0	0.21	2.29
ENE	0.02	0.14	0.02	0.0	0.0	0.0	0.0	0.17	2.48
E	0.01	0.10	0.02	0.0	0.0	0.0	0.0	0.13	2.21
ESE	0.01	0.10	0.03	0.0	0.0	0.0	0.0	0.14	2.66
SE	0.00	0.08	0.01	0.00	0.0	0.0	0.0	0.10	2.47
SSE	0.0	0.06	0.01	0.0	0.00	0.0	0.0	0.08	2.77
S	0.01	0.09	[illegible]	0.0	0.0	0.0	0.0	0.12	2.43
SSW	0.01	0.11	0.01	0.00	0.00	0.01	0.0	0.15	3.23
SW	0.01	0.12	0.10	0.00	0.0	0.0	0.0	0.24	3.54
WSW	0.05	0.39	0.20	0.02	0.0	0.0	0.0	0.66	3.11
W	0.07	0.57	0.22	0.0	0.0	0.0	0.0	0.86	2.87
WNW	0.06	0.51	0.27	0.01	0.0	0.0	0.0	0.86	3.12
NW	0.08	0.64	0.33	0.0	0.0	0.0	0.0	1.05	2.98
NNW	0.12	0.96	0.45	0.01	0.0	0.0	0.0	1.53	3.12
TOTAL	0.62	5.00	2.16	0.06	0.01	0.01	0.0	7.86	2.84

NUMBER OF CALMS - 214
NUMBER OF BAD HOURS - 78

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

BRUNSWICK 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	0.13	1.61	3.53	2.33	0.44	0.01	0.0	8.05	6.58
NNE	0.07	1.09	2.12	2.91	0.64	0.03	0.0	6.76	7.63
NE	0.04	0.64	1.53	2.35	1.37	0.12	0.0	6.04	9.31
ENE	0.03	0.63	1.42	2.39	0.81	0.01	0.0	5.30	8.63
E	0.03	0.50	1.40	1.73	0.38	0.03	0.0	4.08	7.77
ESE	0.03	0.55	1.31	1.18	0.15	0.03	0.0	3.25	6.97
SE	0.01	0.49	1.28	1.21	0.14	0.03	0.01	3.17	7.03
SSE	0.01	0.50	1.25	1.27	0.48	0.06	0.01	3.57	8.09
S	0.03	0.59	1.40	1.86	0.92	0.19	0.03	5.01	9.24
SSW	0.03	0.56	1.24	3.50	2.59	0.49	0.06	8.47	11.18
SW	0.04	0.64	2.24	5.01	5.09	1.31	0.19	14.51	12.01
WSW	0.08	1.17	2.57	2.65	1.25	0.18	0.04	7.93	8.41
W	0.12	1.56	2.71	1.24	0.35	0.07	0.00	6.05	6.15
WNW	0.10	1.24	1.61	1.29	0.62	0.12	0.0	5.18	7.25
NW	0.11	1.38	1.88	1.45	0.69	0.06	0.0	5.57	7.09
NNW	0.17	1.92	2.84	1.59	0.55	0.01	0.0	7.07	6.25
TOTAL	1.03	15.06	30.52	34.83	16.47	2.75	0.34	100.00	8.54

NUMBER OF CALMS - 352
NUMBER OF BAD HOURS - 746

APPENDIX D

BRUNSWICK ONSITE METEOROLOGICAL MEASUREMENTS PROGRAM

D.1 ONSITE OPERATIONAL PROGRAM

A 360-foot, guyed, open-latticed tower supports the lower and upper levels of meteorological instrumentation. Wind direction, wind speed, wind variance (sigma theta), and dew point temperatures are recorded at both levels. Ambient temperature is 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 0.3 mile north-northeast of the reactor complex, with the base of the tower at 21 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, a 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 the Wilmington, North 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, upper and lower level dew points, 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 (langleys/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. The Cambridge dew point systems are changed

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

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

In addition to the scheduled calibrations, interim calibrations are perfomed 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 the 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
Cambridge dew point system	
Transmitter unit	-80 F to +160 F
Control unit	-80 F to +120 F
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	104ABG-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	1105A9A1
Cambridge dew point sensor (transmitter unit)	EG&G International, Inc.	110
Sensor support equipment		
Cambridge dew point control unit	EG&G International, Inc.	110-C1
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	11.5 and 104.6
Honeywell dew point	10.2
Cambridge dew point	11.5 and 104.6
Solar radiation	1.5
Differential temperature	10.2 to 103.2
Precipitation	1.5
Barometric pressure	1.5

TABLE D-4

COMPONENT ACCURACY

Component	Accuracy
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
Cambridge dew point system	±0.5 F (error extreme) above a dew point of -20 F (excluding readout instrumentation). Error extreme increases in approximately linear fashion to ±2 degrees at -80 F.
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.

$$A_p = A_1 + A_2 \qquad (1)$$

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

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

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

$$A_p = C_2 e^{-m_2 t} - C_1 e^{-m_1 t} \quad (4)$$

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

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

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

$$\lambda_1' = \lambda_1 + \lambda_r + \lambda_p + \lambda_{sp} \quad (8)$$

$$\lambda_2' = \lambda_1 + \lambda_r + \lambda_p \quad (9)$$

$$A_1 = C_4 e^{-m_2 t} - C_3 e^{-m_1 t} \quad (10)$$

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

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

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

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.

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

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

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

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

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

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.

$$R = \int R_r dt \qquad (25)$$

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

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).

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

$$\frac{dA_c}{dt} = C_9 R_r - \lambda_7 A_c \qquad (28)$$

$$\lambda_7 = \lambda_r + \frac{q_{cc}}{V_{cc}} + \lambda_c \qquad (29)$$

$$C_9 = F_2 q_{cc} (X/Q)_c \qquad (30)$$

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

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

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

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.

$$R_c = \int A_c dt \tag{34}$$

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

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

$$A_{p_o} = 8.65 \times 10^3 P_o \gamma_i f_r f_i (1 - e^{-\lambda_r T_o}) \text{ (curies)} \tag{36}$$

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:

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

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

where

BR = breathing rate

= 3.47×10^{-4} m^3/sec (Ref. 4)

Beta dose in the control room is given by:

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

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

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 CALCULATION OF DOSE DUE TO DIRECT RADIATION FROM THE BRUNSWICK REACTOR BUILDING

The QAD code[5] (Ref. 5) is used to compute the integrated dose to different points within the control building from direct radiation from the reactor building after a postulated loss-of-coolant accident. QAD is the generic designation for a series of point-kernal computer programs designed for estimating the effects of gamma rays and neutrons that originate in a volume-distributed source. Gamma ray dose rates, energy depositions, uncollided fluxes, and associated quantities; as well as interpolated moments-method neutron fluxes, energy depositions, and dose rates, may be calculated. Surfaces, defined by quadratic equations, are used for a three-dimensional description of the physical situation. Speed, flexibility, and ease of use, as well as the ability to mock-up any direct-beam radiation problem, contribute to the utility of the program.

The source used is based on the following equations:

$$\frac{dA_1}{dt} = -\lambda_1^* A_1 \qquad (1)$$

$$\frac{dA_2}{dt} = \left(\frac{Q}{V}\right)_1 A_1 - \lambda_2^* A_2 \qquad (2)$$

where

$$\lambda_1^* = \lambda_r + \left(\frac{Q}{V}\right)_1$$

$$\lambda_2^* = \lambda_F + \left(\frac{Q}{V}\right)_2$$

λ_r = radionuclide decay constant (hr^{-1})

$\left(\frac{Q}{V}\right)_1$ = primary containment leakage rate (hr^{-1})

= 0.5 percent/day = 2.1×10^{-4} hr^{-1}

$\left(\frac{Q}{V}\right)_2$ = removal rate due to Standby Gas Treatment System (SGTS) operation (hr^{-1})

= 9.0×10^{-2} hr^{-1} (based on an SGTS flowrate of 3000 cfm and a secondary containment volume of 2×10^6 ft^3).

The solution to the above equations is:

$$A_1(t)_1 = A_{10}\, e^{-\lambda_1^* t} \qquad (3)$$

$$A_2(t) = \frac{\left(\frac{Q}{V}\right)_1 A_{10}}{\left(\lambda_2^* - \lambda_1^*\right)} e^{-\lambda_1^* t} - \frac{\left(\frac{Q}{V}\right)_1 A_{10}}{\left(\lambda_2^* - \lambda_1^*\right)} e^{-\lambda_2^* t} \quad (4)$$

where

A_{10} is the initial activity in the primary containment

$A_2(t)$ is the total secondary containment activity (Ci)

$A_1(t)$ is the total primary containment activity (Ci)

E.5 REFERENCES

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8. "Final Environmental Statement Concerning Proposed Rule Making Action: Numerical Guides for Design Objectives and Limiting Conditions for Operation to Meet the Criterion 'As Low as Practicable' for Radioactive Material in Light-Water-Cooled Nuclear Power Reactor Effluents," WASH-1258, Volume 2, Directorate of Regulatory Standards, U.S.A.E.C., July 1973.

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TABLE E-1

NUCLIDE DECAY CONSTANTS AND FISSION YIELDS (Ref. 6)

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. 7)	β(MeV/dis) (Ref. 7)	DCF (rem/curie) (Ref. 8)
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. 6)

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	.2530	2.00E-02	.7500	2.00E-02	.1800	7.00E-02	.2884	3.40E-02	.0300	5.90E-01	.0338	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	.2326	8.00E-02	.0796	6.00E-03
.2843	5.90E-02	.5040	1.00E-02	1.0330	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	2.49E-01	.8369	5.00E-02					.3841	2.39E-04
.7229	1.50E-02	.6502	4.00E-02			.6930	7.30E-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			.8530	9.50E-01	1.1243	3.60E-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	8.36E-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	2.60E-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						
		1.2230	7.00E-03			1.3400	2.00E-02	1.7070	3.60E-02						
		1.2430	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												
		1.9930	1.30E-02												
		2.0460	3.00E-03												
		2.1600	2.00E-03												
		2.2230	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. 6)

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	3.0[illegible]E-02
		.2498	9.16E-01	.2590	3.70E-01			.3050	1.35E-01			.8459	8.10E-02	.39[illegible]	6.[illegible]E-03
		.3586	2.20E-03	.3970	7.40E-02							1.1755	1.40E-02	.4723	6.[illegible]E-03
		.3731	1.10E-04	.4020	2.80E-02							1.3380	7.50E-03	.8337	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.[illegible]E-02
		.6066	2.40E-02	2.0000	1.60E-01							2.0120	2.60E-02	1.1417	1.63E-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	1.1[illegible]E-02
		.8126	5.06E-04									2.8112	4.00E-03	1.5135	1.50E-02
		1.0630	3.06E-05									3.3098	6.00E-03	1.5293	1.[illegible]E-01
														2.0295	[illegible]
														2.0353	4.80E-02
														2.1959	1.51E-01
														2.2316	3.63E-02
														2.3524	2.06E-03
														2.3920	3.82E-01

TABLE E-4

ABSORPTION COEFFICIENTS FOR AIR (Ref. 9)

E MeV	μ/ρ (a) cm^2/gm	μ_a/ρ (b) cm^2/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.

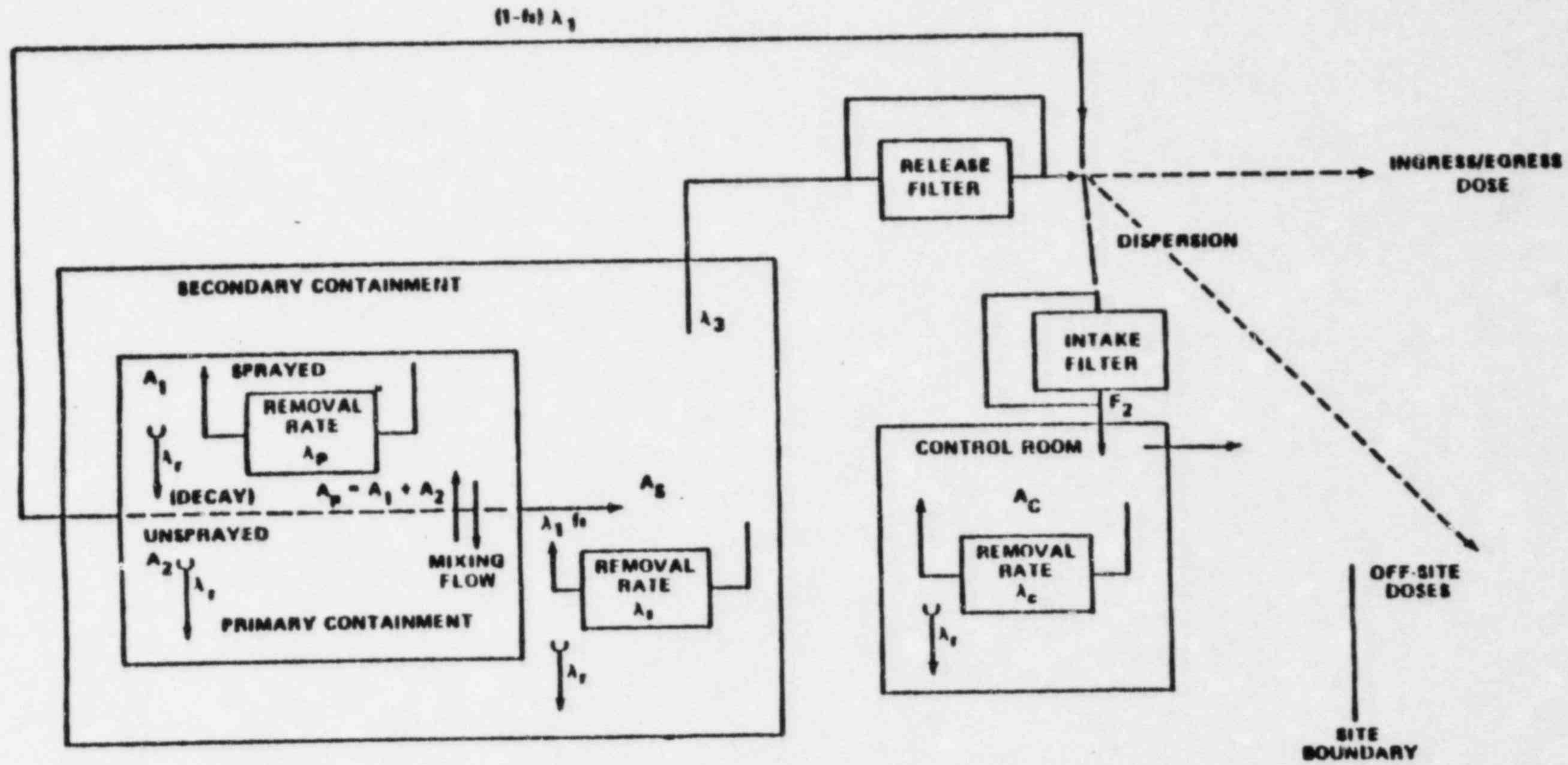

Figure E-1. Dose Model Activity Flow Schematic