

MONTICELLO NUCLEAR GENERATING PLANT

MAIN CONTROL ROOM

TOXIC CHEMICAL STUDY

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1.0 INTRODUCTION

Due to the toxicity of commonly used chemicals, which may be transported near the Monticello Nuclear Generating Station by railroad and/or highway, a survey was performed to predict which chemicals may become hazardous to plant operators in the event of a spill. This analysis is specifically required and modeled to conform to the guidances set forth by the Nuclear Regulatory Commission Regulatory Guide 1.78⁽¹⁾ and NUREG-0570⁽²⁾. The purpose of this analysis is to determine which chemicals are shipped near the site, stored on site, and which chemicals must be monitored in order to prevent concentrations in the control room from reaching toxic levels in the event of an accident.

2.0 REGULATORY GUIDE 1.78

Regulatory Guide 1.78 discusses the requirements and guidelines to be used for determining the toxicity of chemicals in the control room following a postulated accident. The guidelines for determining the toxicity of a given chemical include shipment frequencies, distance from source to site, and general properties of the chemical such as vapor pressure and its toxicity limit.

In defining hazardous concentrations, two types of standard limits are considered. One is the threshold limit value (TLV), defined as the concentration below which a worker may be exposed for 8 hours a day, 5 days a week without adverse health effects. Another limit is the short term exposure limit (STEL), which is defined as the maximum concentration to which workers can be exposed for 15 minutes without suffering from irritation, tissue damage, or narcosis leading to accident proneness or reduction of work

efficiency. The effects of concentrations between the TLV and STEL are not generally predictable. Both these limits are considered in the following analyses.

The guidelines for shipment frequencies given the maximum number of shipments which can pass by the site before the chemical is to be examined for toxicity limits in the control room. For trucks (highway shipments), the maximum number of shipments is 10 per year. Railroads have a maximum number of 30 shipments per year and barges have a maximum number of 50 shipments per year. For the Monticello site, the barge traffic will not be considered since the Mississippi River which runs near the site is not navigable by barge in this area. The shipment frequencies specified by R.G. 178 are based upon the relative accident frequency and potential consequences for the transportation mode. This explains why the railroad and barge shipment frequencies are much higher than the truck frequency.

The distance from the transportation mode, railroad, or highway also controls whether the mode is to be examined for shipments of toxic chemicals. For Monticello, highways I-94 and U.S. 10 both fall within the guidelines set forth by R.G. 1.78 being 5 miles of the Plant Site. Also, the Burlington Northern Railroad line falls within this 5 mile range in 2 locations, approximately 2 miles to the north of the site and 1/2 mile to the south (see Figure 1, Ref. 3). The Burlington line, located 1/2 mile to the south of the site is abandoned and does not transport any materials. As a result, only the above 2 mentioned highways and the Burlington line to the north of the site will be considered in this study.

3.0 SOURCES AND DATA FOR CHEMICALS

The list of chemicals to be initially considered as potentially hazardous was drawn from several sources in a wide range of industries. The majority of the chemicals which are to be examined are given as a partial list from Regulatory Guide 1.78⁽¹⁾ and NUREG-0570⁽²⁾. Also, two other sources were found to list hazardous chemicals - the Association of American Railroads under Specifications for Tank Cars⁽⁴⁾ and the Committee on Safety of Nuclear Installations Organization⁽⁵⁾. A complete list of the hazardous chemicals listed from the sources above are given in Table 1.

Along with the above list of chemicals, additional information concerning the physical properties was obtained. This includes the molecular weight, boiling point, density, heat capacity, heat of vaporization, vapor pressure, diffusion coefficient and the threshold limit value. These chemical properties along with the critical pressure and temperature of some of the chemicals are given in Table 2 using references 2 and 5 to 13.

4.0 CONTROL ROOM TOXIC CHEMICAL CONCENTRATIONS:

The models developed to calculate the concentration of toxic chemicals in the control room in the event of an accident are consistent with the models described in NUREG-0570. A description of the model used to determine the control room toxic concentrations is given in Appendix A; these include a consideration of the following factors:

- a. There is a failure of one container of toxic chemicals (tank car, tank truck, cylinder or drum) releasing all

its contents. Instantaneously, a puff of that fraction of the chemical which would flash to a gas at atmospheric pressure is released. The remaining chemical is assumed to spread uniformly on the ground and evaporate as a function of time due to the heat acquired from the sun, ground and surroundings. Further, no losses of chemicals are assumed to occur as a result of absorption into the ground, flow into the river, cleanup operations, or chemical reactions.

- b. From the geography of the area near Monticello a spill from a railroad tank car is assumed to spread over a roughly circular shape over the railroad bed. A spill occurring on the highways is also assumed to take a roughly circular shape over the road surface.
- c. The initial puff due to flashing as well as the continuous plume due to evaporation is transported and diluted by the wind to impact on the control room inlet. The atmospheric dilution factors are calculated using the methodology of R.G. 1.78 and NUREG-0570, with partial building wake effects conservatively considered.
- d. To determine which chemicals need monitoring, the control room ventilation systems were assumed to continue normal operation for the analysis. The chemical concentrations as a function of time were calculated and the maximum levels determined. These were compared to the Threshold Limit Values (TLV) published by the American Conference of Governmental Industrial Hygienists (ACGIH). Where TLVs were not available, toxicity limits were obtained from available literature.

- e. For all cases, concentrations were calculated as a function of time for eight hours following the accident to compare with the published 8 hour TLV levels. For conservativeness, the maximum concentrations reached in the 8 hour period were compared to the TLV levels to determine which chemicals need monitoring.

The control room ventilation system is designed to draw 5730 cfm of outside air into the control room. At present, there are no toxic chemical monitors installed to isolate the control room. Therefore, it was assumed that the ventilation system operates continuously at the design flow rates throughout the duration of the accident.

5.0 METHODOLOGY

As stated in Section 2, there are two highways and one railroad line to be examined for the shipment of hazardous chemicals. The specific location of the highways and railroads which are under consideration are shown in the Monticello off-site map in Figure 1. The railroad analysis was performed by generating an initial list of chemicals to be examined. This was done by assuming the maximum load on a railroad car for each chemical in Table 1 as a 13,750 gallon tank car⁽¹⁴⁾. Then, a computer run was done, using the models in Appendix A, which resulted in 87 chemicals which could pose a problem to the operators. These chemicals are shown on Table 3. At this point, Burlington Northern Company of St. Paul, Minnesota, was contacted and asked to examine their shipments through the area of the Monticello site for quantities and shipment frequencies of the hazardous chemicals⁽¹⁵⁾. The results of their survey are shown in Table 4; this includes 3 chemicals which may be hazardous.

For the highway analysis the procedure is different because no agency maintains records of highway shipments of toxic chemicals. All that is required is that the shipper mark the truck with the appropriate hazardous chemical emblem. Since this is the case, a phone survey was performed by contacting the manufacturers and users of chemicals in the immediate area through the use of the Minnesota Industrial Directory⁽¹⁶⁾. First, it is assumed that all of the shipments passing through the Monticello area are initiated within an area encompassed by a boundary to the west and to the north beginning at the cities of St. Paul and Minneapolis as indicated in Figure 2. Secondly, the shipments passing the Monticello area are generated only within the State of Minnesota for cities to the north-west of the site. The assumption was backed by obtaining manufacturers directories for the states of North Dakota⁽¹⁷⁾ and Montana⁽¹⁸⁾ which indicated that the consumption and production of chemicals within these states is small. Thirdly, since the manufacturers directory for the State of Minnesota shows low production and consumption of chemical products to the north-west of the site, the majority of chemicals shipped are from the Minneapolis-St. Paul area. Consequently, the majority of producers in the Minneapolis-St. Paul area were contacted to obtain the maximum number of chemical shipments. Table 5 shows the chemical producers and users contacted in the state. It should be noted that the chemicals initiated from the east, namely the city of Chicago, would most likely be shipped to the Minneapolis-St. Paul area only due to the low consumption activities north-west of this area. The results of the survey are shown in Table 6.

The effects on the control room habitability from an accident involving chlorine stored on-site is also evaluated.

Chlorine is stored on-site in 1 ton cylinders in the Intake Structure, which is 61 meters from the control room. Conservatively, the chlorine tank is assumed to rupture outside of the Intake Structure.

6.0 RESULTS

Of the chemicals found by the survey to be shipped near Monticello (Tables 4 and 6), three were found to be shipped in quantities and shipment frequencies which may affect the control room habitability. These chemicals are shipped on the Burlington Northern Railroad. The chemicals are ammonia, hydrochloric acid, and hydrogen sulfide.

An analysis of these chemicals was performed using the assumptions and models of Section 4 and Appendix A. Also, an assumption that the chemicals are shipped on 30 ton tank cars was used to determine the net weight of the chemicals. The results of the analysis, shown on Table 7, show that these chemicals if spilled near Monticello would produce concentrations in the control room well above the TLV levels if no provisions for isolation are available. Therefore, to insure that the control room habitability requirements of R.G. 1.78 are met, these chemicals need to be monitored and the control room needs to be isolated on receipt of high concentration alarm.

The effect of chlorine stored on site on the control room habitability were also evaluated. As seen on Table 7, the chlorine concentrations exceed the TLV, thus requiring monitoring and isolation of the control room.

7.0 RECOMMENDATIONS

Table 7 shows that 4 chemicals would exceed TLV levels in the control room if an accidental release occurred, thus necessitating monitors to detect toxic concentration of these chemicals.

A monitor would need to be set to isolate the control room at sufficiently low level to insure that adequate time (2 minutes is specified by footnote 6 of Regulatory Guide 1.78) is available for the control room operators to put on a breathing mask. The TLV levels for the chemicals can be used as the monitor set point. If the control room is isolated when the TLV is reached at the monitor location, the operators will have adequate time to don breathing apparatus before the concentrations in the control room reach the STEL levels. Potential monitor set points, TLV and STEL levels are shown on Table 8.

To ensure that the operators have adequate time, the location of the monitors and the monitor response times are important. Monitors should be placed as close as possible to the fresh air intakes, upstream of the isolation dampers, so that hazardous chemicals are detected at the earliest possible time. The monitor response time is the time required for the concentrations in the control room to reach the TLV levels after they have been reached at the monitor location.

For chlorine, which is stored on site, a monitor could be placed near the storage tank, thus assuring ample time for the operators to take protective actions. For the other chemicals, monitors would have to be located at the fresh air intake.

Monitor response times (the time needed for the monitor to act and isolation dampers to close) need to be evaluated to ensure that operators have adequate time to take protective actions. Monitor response times along with the detector levels should be used to determine which monitor systems will be used.

Figure 3 illustrates the effects of a typical hazardous chemical spill on the control room atmosphere. If the control room is not isolated, the control room air concentration quickly approaches the air concentration at the control room fresh air inlet. For the isolation mode, the monitor is set to isolate when the air concentration at the inlet reaches the TLV level (time T_0). The monitor system requires a certain time to detect the chemicals and isolate the control room. Isolation is achieved at time T_{ISO} . The control room concentration continues to increase due to inleakage from the outside air. At time T_{STEL} , the control room concentration reaches the STEL level. As described above, the monitor and isolation valve response time ($T_{ISO} - T_0$) should allow at least 2 minutes for the time period $T_{STEL} - T_{ISO}$.

REFERENCES

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6. Field Manual of Military Chemistry and Chemical Compounds, Headquarters, Dept. of the Army, October 1975.
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14. Schulz, Jorge, Personal Communication, July 1980.
15. Telecon, T. K. Leiferman of Bechtel with Charlie Bryan of Burlington Northern, July 31, 1980.
16. "Minnesota Industrial Directory", dated 1979.
17. "North Dakota Industrial Directory", dated 1980.
18. "Montana Industrial Directory", dated 1977.

TABLE 1

HAZARDOUS CHEMICAL SOURCES

	(1) AAR <u>TANK CAR</u>	(2) R. G.	(3) <u>NUREG-0570</u>	(4) <u>CSNI</u>
Acetaldehyde		X	X	
Acetic Anhydride			X	X
Acetone		X	X	
Acetone Cyanohydrin			X	
Acrolein	X		X	
Acrylonitrile		X	X	
Aliphatic Mercaptan Mixtures	X	(See individual Mercaptans)		
Allyl Chloride	X		X	
Ammonia	X	X	X	
Amyl Mercaptan	X			
Aniline		X	X	
Antiknock Compound	X	(See Tetramethyl lead and Tetraethyl lead)		
Arsine			X	
Benzene		X	X	
Benzyl Chloride	X			
Butane				X
Bromine	X		X	
Bromobenzyl Cyanide ⁽⁶⁾			X	
Butadiene	X	X	X	
Butanol			X	
Butenes		X		
Butyl Mercaptan	X			
Carbon Dioxide	X	X	X	
Carbon Disulfide			X	
Carbon Monoxide	X	X	X	
Carbon Tetrachloride			X	
Chlorine	X	X	X	
Chlorine Trifluoride	X			
Chloroacetyl Chloride	X			
Chloropicrin	X			
Chloroprene	X			
CNB ⁽⁶⁾			X	
CNC ⁽⁶⁾			X	
CNS ⁽⁶⁾			X	
Cresol			X	
Cumene Hydroperoxide	X			
Cyanogen Chloride ⁽⁶⁾			X	
Cyclohexane				X

TABLE 1 (Continued)

	(1) AAR <u>TANK CAR</u>	(2) R. G.	(3) NUREG-0570	(4) CSNI
Diethylamine			X	
Di-isopropyl Benzene Hydroperoxide	X	(See Cumene Hydroperoxide)		
Difluoroethane	X			
Dimethylamine	X			
Dimethyl Dichlorosilane	X			
Dimethyl Ether	X			
Dimethylformamide			X	
Dimethyl Hydrazine (6)	X			
Diphenylchloroarsine (6)			X	
Diphenylcyanoarsine (6)			X	
Diphosgene (6)			X	
Epichlorohydrin			X	
Ethane	X			
Ethyl Acetate			X	
Ethyl Benzene			X	
Ethyl Chloride		X	X	
Ethyldichloroarsine (6)			X	
Ethyldichlorosilane	X			
Ethylene Dichloride		X	X	
Ethylene Oxide	X	X	X	
Ethyl Ether		X	X	
Ethyl Mercaptan	X			
Ethyl Trichlorosilane	X			
Ethylene	X			
Ethylene Glycol				X
Fluorine		X	X	
Formaldehyde		X	X	
Formic Acid	X			
Gasoline				
Helium		X	X	
Hexylene Glycol			X	
Hydrazine	X		X	
Hydrochloric Acid	X		X	
Hydrogen	X			
Hydrogen Cyanide	X	X	X	
Hydrogen Fluoride	X		X	
Hydrogen Peroxide	X			
Hydrogen Sulfide	X	X	X	

TABLE 1 (Continued)

	(1) AAR <u>TANK CAR</u>	(2) <u>R. G.</u>	(3) <u>NUREG 0570</u>	(4) <u>CSNI</u>
Isopropyl Alcohol			X	
Isopropylamine			X	
Isopropyl Mercaptan	X			
Lewisite ⁽⁶⁾			X	
Liquified Natural Gas	X			
Liquified Petroleum Gas	X			
Mercaptans	X	(See individual Mercaptans)		
Methane	X			
Methanol		X	X	
Methyl Chloride	X			
Methyl Dichloroarsine ⁽⁶⁾			X	
Methyl Dichlorosilane	X			
Methyl Trichlorosilane	X			
Methyl Mercaptan	X			
Monochloroacetic Acid	X			
Monochlorodifluoromethane	X			
Monomethyl Amine	X			
Mustard Gas ⁽⁶⁾			X	
Mustard - Lewisite Mixture ⁽⁶⁾			X	
Muriatic Acid (Hydrochloric acid)	X			
Methyl Formate				X
Nitric Acid	X		X	
Nitrogen		X	X	
Nitrogen Dioxide	X			
Nitrogen Mustard (HN-1) ⁽⁶⁾			X	
Nitrogen Mustard (HN-2) ⁽⁶⁾			X	
Nitrogen Mustard (HN-3) ⁽⁶⁾			X	
Nitrogen Peroxide	X			
Nitrogen Tetroxide	X			
Nitrosyl Chloride	X			
Oleum (Sulfuric Acid, Fuming)	X			
Parathion				X
Paramethane Hydroperoxide	X			
Pentaborane-9 ⁽⁶⁾			X	
Perchloryl Fluoride			X	
Phenol			X	
Phenyldichloroarsine ⁽⁶⁾			X	
Phosgene	X		X	
Phosgene Oxime ⁽⁶⁾			X	
Pentaborane ⁽⁶⁾				

TABLE 1 (Continued)

	(1) AAR <u>TANK CAR</u>	(2) <u>R. G.</u>	(3) <u>NUREG 0570</u>	(4) <u>CSNI</u>
Phosphorus	X			
Phosphorus Oxybromide	X			
Phosphorus Oxychloride	X			
Phosphorus Trichloride	X			
Potassium Nitrate/ Sodium Nitrate	X			
Propionaldehyde			X	
Propylene Oxide			X	
Propyl Mercaptan	X			
Pyroforic Liquids	X			
Propane				
Sarin ⁽⁶⁾			X	
Sodium	X			
Sodium Chlorite (Sol.)	X			
Soman ⁽⁶⁾			X	
Styrene			X	
Sulfur Dioxide	X	X	X	
Sulfuric Acid	X	X	X	
Sulfur Trioxide	X			
Sodium Oxide		X		
Tabun ⁽⁶⁾			X	
Tetraethyl Lead			X	
Tetramethyl Lead			X	
Thiophosphoryl Chloride	X			
Titanium Tetrachloride	X			
Toluene			X	
Trichloroethylene			X	
Trichlorosilane	X			
Trifluorochloroethylene	X			
Trimethylamine	X			
Trimethylchlorosilane	X			
Vinyl Acetate			X	
Vinyl Chloride	X	X	X	
Vinyl Fluoride	X			
Vinyl Methylether	X			
Vinyl Pyridine				
Vinyl Trichlorosilane	X			
Xylene		X	X	

Table 2

PHYSICAL PROPERTIES OF TOXIC CHEMICALS

CHEMICAL	TLV	MW	BP	DENS	CP	HV	VP	DIFF	TCRIT	PCRIT	TYPE
ACETALDEHYDE	1.00+02	44.1	20.2	.783	.510	136.2	7.600+02	.1030			2
ACETIC ANHYDRIDE	5.00+00	102.1	140.0	1.057	.398	92.2	1.000+01	.0750	569.00	46.20	2
ACETONE	1.00+03	58.1	56.2	.791	.528	128.1	4.000+02	.1340			2
ACETONE CYANOHYDRIN	1.00+01	85.1	82.0	.932			8.000-01	.0802	496.10	42.00	2
ACROLEIN	1.00-01	56.1	52.5	.841	.511	126.1	4.750+02	.0911	506.00	51.00	2
ACRYLONITRILE	2.00+01	53.1	77.3	.806	.500		2.250+02	.0845	536.00	45.00	2
ALLYL CHLORIDE	1.00+00	76.5	45.0	.938	.313	90.5	6.500+02	.0830	513.50	46.50	2
AMMONIA	2.50+01	17.0	-33.4	.674	1.100	327.4					1
AMYL MERCAPTAN	1.00+01	104.2	126.6	.842			1.380+01	.0936	321.00	34.50	2
ANILINE	5.00+00	93.1	184.4	1.022	.521	103.7	1.500+00	.0790			2
ARSINE	5.00-02	77.9	-62.5	1.604	.283	51.2					1
BENZENE	1.00+01	78.1	80.1	.880	.419	103.6	1.900+02	.0770			2
BENZYL CHLORIDE	1.00+00	126.6	179.0	1.103	.323	76.0	1.300+00	.0810			2
BROMINE	1.00-01	159.8	58.7	3.120	.107	44.9	3.800+02	.1090			2
BROMOBENZYL CYANIDE	6.10-01	196.0	242.0	1.470		55.7	7.000-02	.0539	737.40	35.50	2
BUTADIENE	1.00+03	54.1	-4.4	.621	.545	99.8					1
BUTANE	5.00+03	58.1	-6	.601	.564	92.0					1
BUTANOL	1.00+02	74.1	117.5	.810	.563	141.3	1.800+01	.0920			2
BUTENE	1.43+05	56.1	-6.3	.595	.355	93.4					1
BUTYL MERCAPTAN	5.00-01	90.2	98.0	.836		45.9	4.600+01	.0714	563.20	38.90	2
CARBON DIOXIDE	5.00+03	44.0	-78.5	.468	.184	83.2					1
CARBON DISULFIDE	2.00+01	76.1	46.5	1.293	.241	84.1	6.250+02	.1090			2
CARBON MONOXIDE	5.00+01	28.0	-191.5		.515	51.6					3
CARBON TETRACHLORIDE	1.00+01	153.8	76.8	1.597	.201	47.3	2.110+02	.0810			2
CHLORINE	1.00+00	70.9	-34.1	1.570	.226	68.8					1
CHLORINE TRIFLUORIDE	1.00-01	92.5	11.8	1.770	.303	71.2					1
CHLOROACETYL CHLORIDE	5.00-02	112.9	105.0	1.495			2.320+01	.0760	579.90	50.40	2
CHLOROPICRIN	1.00-01	164.4	112.0	1.692			4.000+01	.0695	582.00	44.10	2
CHLOROPRENE	2.50+01	88.5	59.4	.958			6.770+02	.0771	525.50	42.00	2
CNB	5.00-02	119.7	75.0	1.140			1.200+02	.2000			2
CNC	5.00-02	129.6	60.0	1.400			1.270+02	.2000			2
CNS	5.00-02	144.5	60.0	1.470			1.270+02	.2000			2
CRESOL	5.00+00	108.1	198.0	1.010	.550	102.9	1.000+00	.0678	704.60	50.80	2
CUMENE HYDROPEROXIDE	1.00+00	152.2	153.0	1.050			2.500+01	.0629	576.10	33.70	2
CYANOGEN CHLORIDE	3.00-01	61.5	13.1	1.218	.358	103.0					1
CYCLOHEXANE	3.00+02	84.2	80.7	.779	.432	93.8	1.000+02	.0738			2
DIETHYL AMINE	2.50+01	73.1	55.5	.685	.564	96.4	4.250+02	.1090			2
DIFLUOROETHANE	1.43+05	66.1	-26.5	1.004	.333	78.0					1
DIMETHYL AMINE	1.00+01	45.1	6.9	.680	.724	130.5					1
DIMETHYL DICHLOROSILANE	5.00+00	129.1	70.0	1.100			1.080+02	.0676	519.80	33.10	2
DIMETHYL ETHER	4.00+02	46.1	-23.7	.661	.535	111.6					1
DIMETHYL FORMAMIDE	1.00+01	73.1	153.0	.953		155.4	3.700+00	.0706	647.10	43.70	2
DIMETHYL HYDRAZINE	5.00-01	60.1	63.3	.782			1.570+02	.0902	521.90	53.60	2
DIPHENYL CHLOROARSINE	5.00-02	264.5	307.0	1.387		56.6	1.600-03	.2000			2
DIPHENYL CYANOARSINE	5.00-02	255.0	290.0	1.320		79.3	5.000-05	.2000			2
DIPHOSGENE	1.00-01	197.9	127.0	1.660			1.030+01	.2000			2
EPICHLOROHYDRIN	5.00+00	92.5	116.1	1.181			4.000+01	.0709	596.00	42.00	2
ETHANE	1.43+05	30.7	-88.6	.446	.321	117.0					1
ETHYL ACETATE	4.00+02	88.1	77.2	.895	.459	102.0	1.860+02	.0935			2
ETHYL BENZENE	1.00+02	106.2	136.2	.867	.409	95.1	2.000+01	.0810			2

Tabl. 2

PHYSICAL PROPERTIES OF TOXIC CHEMICALS

CHEMICAL	TLV	MW	BP	DENS	CP	HV	VP	DIFF	TCRIT	PCRIT	TYPE
ETHYL CHLORIDE	1.00+03	64.1	12.3	.924	.368	90.6					1
ETHYL DICHLOROARSINE	7.00-02	174.9	156.0	1.690		52.5	9.500+00	.2000			2
ETHYL DICHLOROSILANE	5.00+00	129.1	70.3	2.000			1.080+02	.0675	520.30	33.10	2
ETHYLENE	1.43+05	28.0	-103.9	.610	.371	115.4					1
ETHYLENE DICHLORIDE	1.00+01	99.0	83.5	1.253	.301	77.3	1.650+02	.0803	561.00	53.00	2
ETHYLENE GLYCOL	1.00+02	62.1	197.5	1.113	.561	258.0	5.000-02	.0904	645.00	76.00	2
ETHYLENE OXIDE	5.00+01	44.1	10.7	.897	.476	138.5					1
ETHYL ETHER	4.00+02	74.1	34.6	.708	.547	83.9	4.420+02	.0955			2
ETHYL MERCAPTAN	5.00-01	62.1	36.2	.839	.276	105.0	5.270+02	.0925	499.00	54.20	2
ETHYL TRICHLOROSILANE	5.00+00	163.5	99.5	1.240			2.550+01	.0756	573.60	53.10	2
FLUORINE	1.00+00	38.0	-188.3		.367	39.8					3
FORMALDEHYDE	2.00+00	30.0	97.0	1.100			1.980+02	.1289	408.00	65.00	2
FORMIC ACID	5.00+00	46.0	100.8	1.227			4.000+01	.1066	580.00	86.40	2
GASOLINE	5.00+02	110.0	99.0	.700			4.000+01	.2000			2
HELIUM	1.43+05	4.0	-268.9		.860	4.8					3
HEXYLENE GLYCOL	2.50+01	118.2	197.1	.923	.537	151.0	3.000-01	.0708	620.90	47.50	2
HYDRAZINE	1.00-01	32.0	113.5	1.008	.740	305.0	3.000+01	.1298	653.00	145.00	2
HYDROCHLORIC ACID	5.00+00	36.5	-85.0	1.194	.900	103.1					1
HYDROGEN	1.43+05	2.0	-252.8		.231	108.0					3
HYDROGEN CYANIDE	1.00+01	27.0	25.7	.687	.627	247.0	4.000+02	.2120			2
HYDROGEN FLUORIDE	3.00+00	20.0	19.5	1.003	.610	80.5	7.600+02	.1334	461.00	64.00	2
HYDROGEN PEROXIDE	1.00+00	34.0	107.0	1.710			1.000+00	.2000			2
HYDROGEN SULPHIDE	1.00+01	34.1	-60.8	.993	.478	131.0					1
ISOPROPYL ALCOHOL	4.00+02	60.1	80.3	.785	.780	159.4	1.060+02	.1060			2
ISOPROPYL AMINE	5.00+00	59.1	32.4	.694	.385	110.0	4.550+02	.0929	476.00	50.00	2
ISOPROPYL MERCAPTAN	1.00+01	76.0	51.0	.814			1.220+02	.0792	532.20	43.60	2
LEWISITE	6.00-02	207.4	190.0	1.890		58.0	1.000+00	.2000			2
METHANE	1.43+05	16.0	-161.5		.495	121.9					3
METHANOL	2.00+02	32.0	64.7	.792	.600	262.8	2.600+02	.1620			2
METHYL CHLORIDE	1.00+02	50.5	-23.7	.918	.381	101.3					1
METHYL DICHLOROARSINE	7.00-02	160.9	133.0	1.830		49.0	1.000+01	.2000			2
METHYL DICHLOROSILANE	5.00+00	115.0	41.0	1.100			3.600+02	.0750	487.90	37.70	2
METHYL FORMATE	1.00+02	60.1	31.5	.980	.516	112.4	5.000+02	.0976	487.20	59.20	2
METHYL MERCAPTAN	5.00-01	48.1	7.6	.868	.439	122.1					1
METHYL TRICHLOROSILANE	5.00+00	149.5	66.5	1.280			1.400+02	.0686	516.40	35.00	2
MONOCHLOROACETIC ACID		94.5	101.1	1.070			1.689+01	.0836	555.20	57.10	2
MONOCHLORODIFLUOROMETHANE		80.5	-40.8	1.194	.300	55.8					1
MONOMETHYL AMINE	1.00+01	31.1	-6.8	.662	.784	198.6					1
MUSTARD GAS	7.00-02	159.1	227.8	1.270		94.0	4.000-01	.2000			2
MUSTARD-LEWISITE MIXTURE	7.00-02	178.5	190.0	1.660		58.0	1.000+00	.2000			2
NITRIC ACID	2.00+00	63.0	120.5	1.410	.615	114.9	1.000+01	.1046	574.50	93.70	2
NITROGEN	1.43+05	28.0	-195.8	.806	.474	47.5					1
NITROGEN DIOXIDE	5.00+00	46.0	21.0	1.491			5.650+02	.1329	431.40	100.00	2
NITROGEN MUSTARD (HN-1)	7.00-02	170.1	85.0	1.090		77.0	5.000-01	.2000			2
NITROGEN MUSTARD (HN-2)	7.00-02	156.1	75.0	1.150		78.8	1.160+00	.2000			2
NITROGEN MUSTARD (HN-3)	7.00-02	204.5	137.0	1.240		72.0	3.800-02	.2000			2
NITROGEN PEROXIDE	2.50+01	30.0	-151.8		.238	109.7					3
NITROGEN TETROXIDE	5.00+00	46.0	21.0	1.491	.360	99.0	5.650+02	.1329	431.40	100.00	2
NITROSYL CHLORIDE	1.00+01	65.5	-5.8	1.250	.230	91.6					1
PARAMETHANE HYDROPEROXIDE		48.0	40.0	1.997			3.700+02	.1156	464.00	77.50	2

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Table 2 (Explanation)

TLV=TRESHOLD LIMIT VALUE (PPM)
MW=MOLECULAR WEIGHT (GM/MOLE)
BP=BOILING POINT (DEGREE CENTIGRADE)
DENS=DENSITY OF LIQUID (GM/CM**3)
CP=HEAT CAPACITY OF LIQUID (CAL/GM-DEGREE CENT)
HV=HEAT OF VAPORIZATION (CAL/GM)
VP=VAPOR PRESSURE OF LIQUID (MM-HG)
DIFF= DIFFUSION COEFFICIENT (CM**2/SEC)
TCRIT=CRITICAL TEMPERATURE (DEGREE KELVIN)
PCRIT=CRITICAL PRESSURE (ATM)
TYPE=TYPE OF CHEMICAL
1=LOW-BOILING POINT
2=NORMAL-BOILING POINT
3=COMPRESSED GAS

Table 2

PHYSICAL PROPERTIES OF TOXIC CHEMICALS

CHEMICAL	TLV	MW	BP	DENS	CP	HV	VP	DIFF	TCRIT	PCRIT	TYPE
PARATHION	8.00-03	291.0	375.0	1.265			3.000-05	.2000			2
PENTABORANE	5.00-03	63.2	0.0	.610	.571	121.9					1
PENTABORANE-9	5.00-03	63.2	58.4	.610	.571	121.9	4.000+02	.2000			2
PERCHLORYL FLUORIDE	3.00+00	102.5	-46.7	2.003	.265	45.1					1
PHENOL	5.00+00	94.1	181.9	1.058	.561	174.4	1.000+00	.0737	656.60	53.70	2
PHENYLDICHLOROARSINE	1.00-01	222.9	252.0	1.650		67.0	1.130-01	.2000			2
PHOSGENE	1.00-01	98.9	8.2	1.419	.243	59.0					1
PHOSPHORUS OXICHLORIDE	5.00+00	153.4	105.1	1.685			4.000+01	.2000			2
PHOSPHORUS TRICHLORIDE	5.00-01	137.4	74.2	1.574			1.000+02	.2000			2
PROPANE	1.43+05	44.1	-42.1	.585	.398	101.8					1
PROPIONALDEHYDE	1.00+02	58.1	48.8	.806	.522	122.8	5.600+02	.0887	496.00	47.00	2
PROPYLENE OXIDE	1.00+02	58.1	34.3	.831			4.000+02	.0915	482.20	48.60	2
PROPYL MERCAPTAN	1.00+01	76.0	67.0	.841			1.220+02	.0779	533.00	42.00	2
SARIN	2.00-02	140.1	147.0	1.089		84.9	5.500+00	.2000			2
SODIUM CHLORITE (SOL.)		90.4	101.1	1.100			1.686+01	.2000			2
SOMAN	1.00-02	182.2	167.0	1.022		78.5	7.500-01	.2000			2
STYRENE	1.00+02	104.1	145.2	.906	.416	101.7	2.000+01	.0647	647.00	39.40	2
SULFUR DIOXIDE	5.00+00	64.1	-10.0	1.460	.361	92.8					1
SULFURIC ACID	2.50-01	98.1	330.0	1.830	.339	122.1	1.000+00	.0832	815.40	104.20	2
SULFUR TRIOXIDE	5.00+00	80.1	44.8	1.925			1.510+02	.1048	491.00	81.00	2
TABUN	1.00-02	162.3	246.0	1.073		79.6	1.000-01	.2000			2
TETRAETHYL LEAD	7.00-03	323.5	200.0	1.659			1.000+00	.2000			2
TETRAMETHYL LEAD	1.12-02	267.3	110.0	1.995			3.000+01	.2000			2
THIOPHOSPHORYL CHLORIDE		169.5	125.0	1.630			2.200+01	.2000			2
TITANIUM TETRACHLORIDE	5.00+00	183.7	136.4	1.722			1.000+01	.2000			2
TOLUENE	1.00+02	92.1	110.0	.866	.421	98.6	5.500+01	.0924			2
TRICHLOROETHYLENE (TCE)	1.00+02	131.4	87.4	1.466	.223	62.3	1.400+02	.0727	571.20	45.70	2
TRICHLOROSILANE	5.00+00	135.4	31.8	1.350			4.000+02	.0768	475.40	40.00	2
TRIFLUOROCHLOROETHYLENE	1.43+05	116.5	-27.9	1.500	.297	45.6					1
TRIMETHYLAMINE	1.00+01	59.1	2.9	.662	.533	92.8					1
TRIMETHYLCHLOROSILANE	5.00+00	108.8	57.0	.854			1.840+02	.0684	498.30	30.80	2
VINYL ACETATE	1.00+01	86.1	72.0	.932	.433	95.2	2.300+02	.0781	525.00	43.00	2
VINYL CHLORIDE	5.00+00	62.5	-13.9	.920	.380	79.8					1
VINYL FLUORIDE	1.43+05	46.0	-72.0	.681	.587	91.3					1
VINYL METHYLETHYER	1.00+04	58.1	5.5	.777	.744	125.8					1
VINYL PYRIDINE	5.00+00	105.1	159.0	.975			1.440+01	.0638	659.40	39.30	2
VINYL TRICHLOROSILANE	5.00+00	162.5	90.6	1.265			7.100+01	.0640	542.70	32.50	2
XYLENE	1.00+02	106.2	140.0	.870	.400	96.0	2.000+01	.0637	630.20	36.80	2

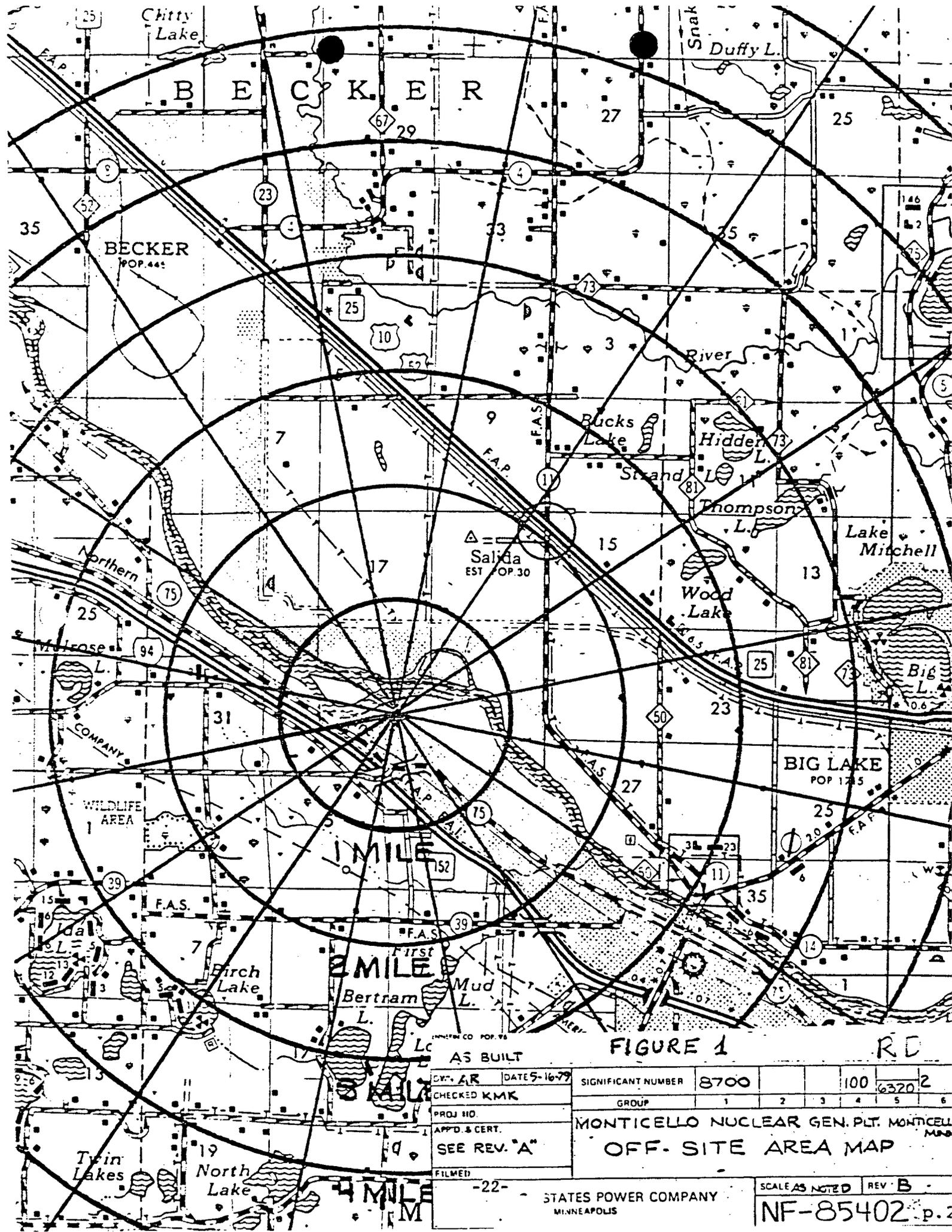


FIGURE 1

DATE: AR	DATE: 5-16-79	SIGNIFICANT NUMBER	8700	100	6320	2
CHECKED	KMK	GROUP	1	2	3	4
PROJ. NO.		MONTICELLO NUCLEAR GEN. PLT. MONTICELLO, MINN.				
APP'D. & CERT.	SEE REV. "A"	OFF-SITE AREA MAP				
FILMED		SCALE AS NOTED				

Figure 2: STATE OF MINNESOTA MAP SHOWING AREA OF SURVEY FOR MANUFACTURERS AND USERS OF CHEMICALS.

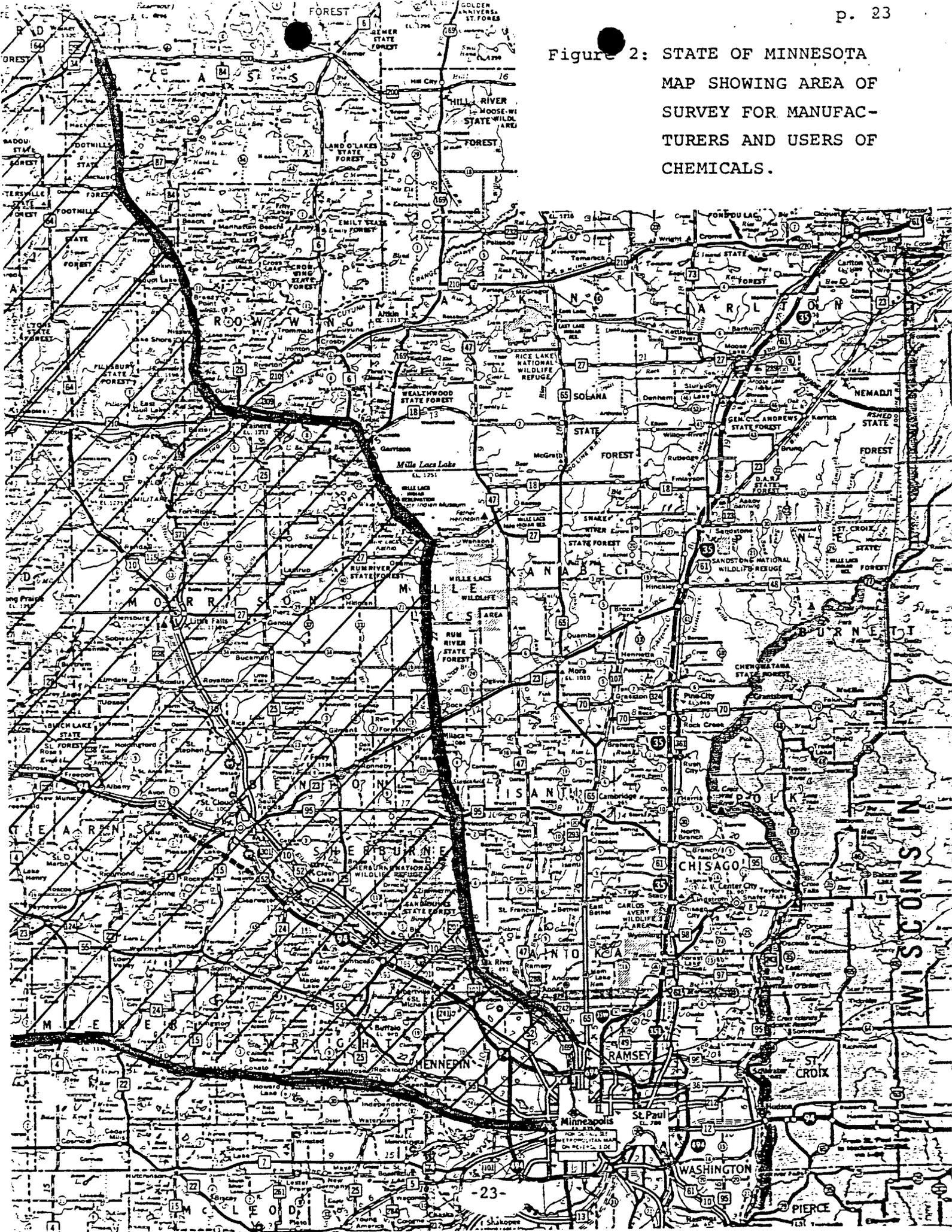


FIG 3- CONTROL ROOM CONCENTRATION FOR A TYPICAL CHEMICAL

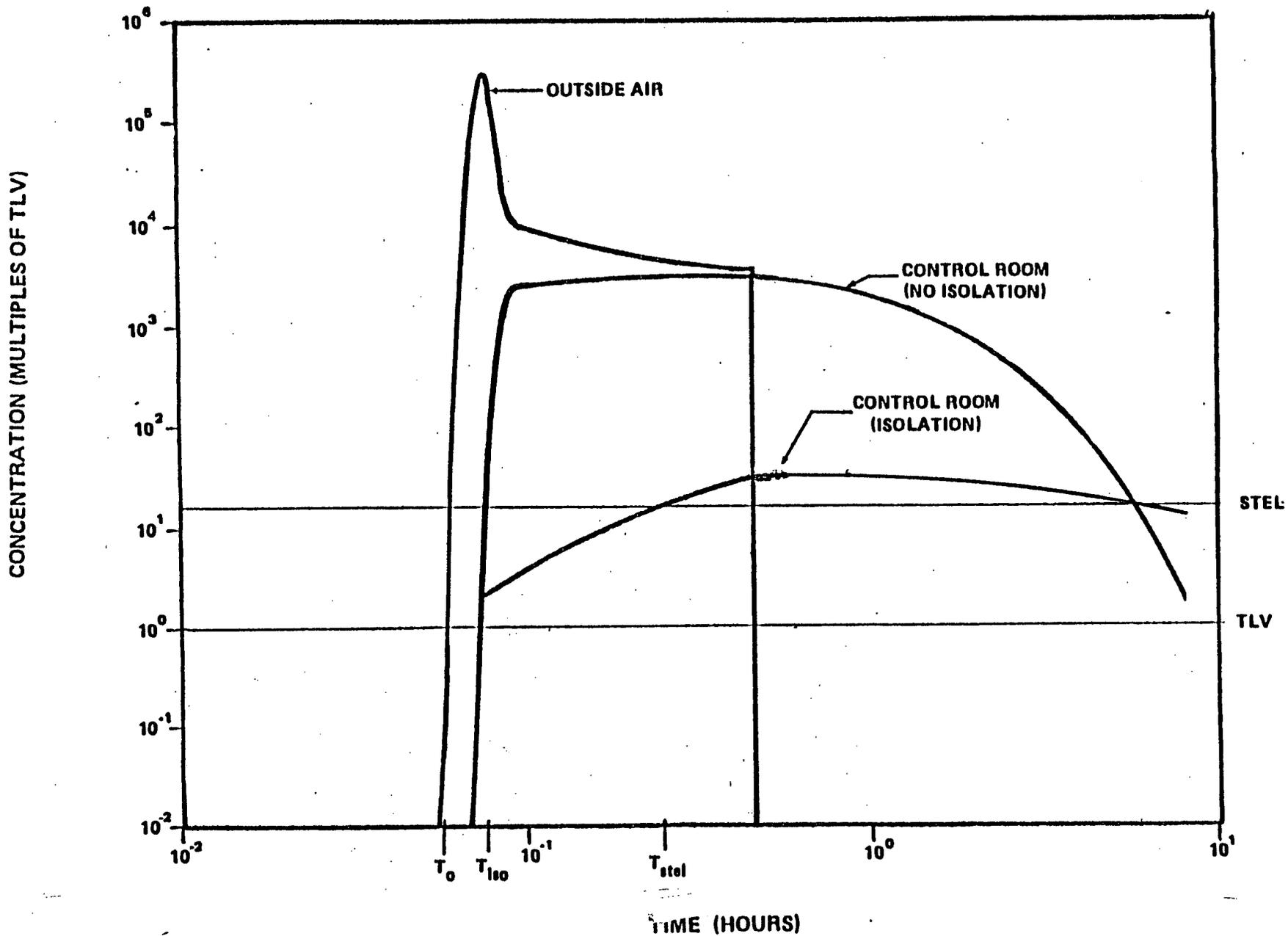


TABLE 3

LIST OF CHEMICALS TO BE REVIEWED FOR NUMBER
OF YEARLY SHIPMENTS AND CONTAINER SHIPPING SIZE

ACETALDEHYDE	EPICHLOROHYDRIN	NITROGEN DIOXIDE
ACROLEIN	ETHYL DICHLOROARSINE	NITROGEN MUSTARD (HN-1)
ACRYLONITRILE	ETHYL DICHLOROSILANE	NITROGEN MUSTARD (HN-2)
ALLYL CHLORIDE	ETHYLENE DICHLORIDE	NITROGEN PEROXIDE (NO)
AMMONIA	ETHYLENE OXIDE	NITROGEN TETROXIDE
ARSINE	ETHYL MERCAPTAN	NITROSYL CHLORIDE
BENZENE	FLUORINE	PARAMETHANE HYDROPEROXIDE
BROMINE	FORMALDEHYDE	PENTABORANE
BUTADIENE	FORMIC ACID	PENTABORANE-9
BUTYL MERCAPTAN	HYDRAZINE	PERCHLORYL FLUORIDE
CARBON DILSULFIDE	HYDROCHLORIC ACID	PHOSGENE
CARBON MONOXIDE	HYDROGEN CYANIDE	PHOSPHORUS OXICHLORIDE
CARBON TETRACHLORIDE	HYDROGEN FLUORIDE	PHOSPHORUS TRICHLORIDE
CHLORINE	HYDROGEN SULPHIDE	PROPYL MERCAPTAN
CHLORINE TRIFLUORIDE	ISOPROPYL AMINE	SARIN
CHLOROACETYL CHLORIDE	ISOPROPYL MERCAPTAN	SODIUM CHLORITE (SOL.)
CHLOROPICRIN	LEWISITE	SOMAN
CHLOROPRENE	METHYL CHLORIDE	SULFUR DIOXIDE
CNB	METHYL DICHLOROARSINE	SULFUR TRIOXIDE
CNC	METHYL DICHLOROSILANE	TABUN
CNS	METHYL FORMATE	TETRAETHYL LEAD
CUMENE HYDROPEROXIDE	METHYL MERCAPTAN	TETRAMETHYL LEAD
CYANOGEN CHLORIDE	METHYL TRICHLOROSILANE	THIOPHOSPHORYL CHLORIDE
DIETHYL AMINE	MONOCHLOROACETIC ACID	TRICHLOROSILANE
DIMETHYL AMINE	MONOCHLORODIFLUOROMETHANE	TRIMETHYLAMINE
DIMETHYL DICHLOROSILANE	MONOMETHYL AMINE	TRIMETHYLCHLOROSILANE
DIMETHYL ETHER	MUSTARD GAS	VINYL ACETATE
DIMETHYL HYDRAZINE	MUSTARD-LEWISITE MIXTURE	VINYL CHLORIDE
DIPHOSGENE	NITRIC ACID	VINYL TRICHLOROSILANE

TABLE 4

Chemicals Shipped by Burlington Northern Past Monticello

(1 July 1979 - 5 July 1980)

Chemical	Number of Shipments	Gross Weight of Shipment (tons)	
		Average	Maximum
Acetaldehyde			
Ammonia, Anhydrous ⁽¹⁾			
Carbon Bisulfide (or)			
Carbon Disulfide			
Chlorine			PROPRIETARY
Dimethylamine, Anhydrous			
Hydrocyanic	ALID		
Hydrofluoric	ALID, Anhydrous		
Hydrochloric	ALID ⁽¹⁾		
Hydrogen Sulfide ⁽¹⁾			
Irritating Agent, n.o.s			
Monochlorodifluoro Methane			
Sulfur Dioxide			
Poisonous Liquids			

(1) These chemicals shipped over 30 times/year need to be evaluated to determine the effects of an accidental spill on the control room operators.

TABLE 5

Chemical Producers and Users Contacted

Bingham Samuel Co.	Minneapolis, Minnesota
Bushnell Company, Inc.	St. Paul, Minnesota
Glidden-Durkee, Div. of SLM Corp.	Minneapolis, Minnesota
Koppers Co., Inc., Organic Materials Division	St. Paul, Minnesota
Lan O. Sheen, Inc.	St. Paul, Minnesota
Linde Div. of Union Carbide	Inver Grove Hts., Minn.
M & M Industries, Inc.	St. Paul, Minnesota
Rubber Research Elastomerics, Inc.	Minneapolis, Minnesota
Tanner Systems, Inc.	Sauk Rapids, Minnesota

TABLE 6

Chemicals Shipped on Highways Near Monticello

Chemical	Container Size	Shipment Frequency ⁽¹⁾
Chlorine	150 lb.	3/year
Methanol	54 gal.	N.A.
Aromatic Aliphatic Roller Wash	55 gal.	N.A.
Petroleum Hydrocarbon Emulsive Roller Wash	55 gal.	N.A.

(1) If shipment frequencies not available, the material was assumed to be shipped over 10 times/year.

TABLE 7

FINAL ANALYSIS RESULTS

Chemical	Net Weight (tons)	TLV (ppm)	Maximum Control Room Concentration (ppm)
Ammonia	100	25	5159
Hydrochloric Acid	98	5	9886
Hydrogen Sulfide	95	10	6088
Chlorine (on site)	1	1	7803

TABLE 8

MONITOR SET POINTS AND TOXICITY LEVELS

Chemical	Monitor Set Point (PPM)	TLV (PPM)	STEL (PPM)
Ammonia	25	25	35
Hydrochloric Acid	5	5	10
Hydrogen Sulfide	10	10	15
Chlorine ⁽¹⁾	1	1	15

(1) The STEL for chlorine was obtained from R.G. 1.95 (2-minute level).

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A.1 INTRODUCTION

The models used to calculate the concentrations of toxic chemicals in the control room atmosphere are consistent with the models described in NUREG-0570.

Several conservative assumptions consistent with NUREG-0570 were made to calculate the concentrations of toxic vapor. Some of these are:

1. The entire inventory or cargo in one container is released.
2. The area of the spill, as predicted by eq. (2.3-1) spreads until a depth of 1 cm for the spill is achieved.
3. The vapor, in the form of a puff or plume, moves directly towards the air intake of the control room.

It should be pointed out that the probabilistic nature of the catastrophic spill of toxic chemicals, during transportation and in storage, is not considered here. That is, the frequency of shipment and cargo size of each toxic chemical past the Monticello site, the accident rates of on-site release and of each shipment type, the distribution of wind speeds and directions, and the uncertainty of the weather conditions will not be included in the assessment of vapor concentrations.

A.2 MASS TRANSFER FROM SPILL TO ATMOSPHERE

The volatility of a substance is a direct function of its vapor pressure. Compressed gases, liquified gases, and many liquids have sufficiently high vapor pressures so that when released to the atmosphere, they will either vaporize or evaporate. For compressed gases and liquified gases and those liquids where normal boiling points are far below the ambient temperature, instantaneous flashing will first take place. The remaining liquid will vaporize by drawing heat from the surroundings. On the other hand, if the normal boiling point is above the ambient temperature, the liquid will evaporate into the atmosphere.

A.2.1 Low Boiling-Point-Liquids and Compressed Gases

For simplicity, a low boiling point liquid is considered to be a compressed gas, liquified gas, or a liquid whose boiling point is below the ambient temperature.

A.2.1.1 Instantaneous (PUFF) Release

For liquified gases and low boiling point liquids, the heat balance in the instantaneous puff formation assuming an adiabatic change is given by:

$$m_T C_p (T_a - T_b) = m_{VO} H_v \quad (2.1-1)$$

where:

- m_T = total initial mass (g)
- C_p = heat capacity of the liquid (cal/g-°C)
- T_a = ambient temperature (°C)

T_b = normal boiling point of the liquid ($^{\circ}\text{C}$) $< T_a$
 m_{v0} = mass of the instantaneously vaporized liquid (g)
 H_v = heat of vaporization of the liquid (cal/g)

A.2.1.2 Vaporization

As a result of flashing, the temperature of the remaining fluid is reduced below ambient levels. The remaining liquid, $(m_T - m_{v0})$, will vaporize by absorption of heat from atmospheric radiation, solar radiation, convection of air, and ground conduction.

The rate of total heat transfer, in cal/sec from all of these sources can be described as follows (NUREG-0570 p. 9).

$$\frac{dQ}{dt} = A(t) (q_r + q_c + q_d) \quad (2.1-2)$$

where:

$A(t)$ = area of the spill (m^2).
 q_r = solar and atmospheric radiation fluxes
 (cal/ m^2 -sec)
 q_c = heat flux due to force convection of air over
 the spill (cal/ m^2 -sec)
 q_d = heat transfer due to earth conduction (cal/ m^2 -sec)

Various values at different locations in the southwestern region have been measured for q_r . The maximum values are (Roosevelt Reservoir AR) 115 cal/ m^2 -sec and 97 cal/ m^2 -sec for atmospheric and solar radiation, respectively for a total q_r of 212 cal/ m^2 -sec. (NUREG-0570, P. 7).

The heat flux, q_c , due to forced convection of air over the spill is (NUREG-0570, p. 8):

$$q_c = h_c(T_a - T_b) \quad (2.1-3)$$

where a value of $1.6 \text{ cal/m}^2\text{-sec } ^\circ\text{C}$ is used for h_c (NUREG-0570, p. 8).

The heat transfer by earth conduction, q_d , is given by the following relation (NUREG-0570, p. 9).

$$q_d = 197(T_E - T_b)/t^{1/2} \quad (2.1-4)$$

where

T_E = ground temperature ($^\circ\text{C}$)

t = time (sec)

For T_E , the ambient temperature T_a is used.

Placing all of the above relations into 2.1-2, we obtain

$$\frac{dQ}{dt} = A(t) \left\{ 212 + 1.6(T_a - T_b) + 197(T_a - T_b)/t^{1/2} \right\} \quad (2.1-5)$$

The vaporization rate, dm_v/dt , in g/sec, is then

$$\frac{dm_v}{dt} = \frac{1}{H_v} \left(\frac{dQ}{dt} \right) \quad (2.1-6)$$

$$= \frac{A(t)}{H_v} \left\{ 212 + \left(1.6 + \frac{197}{t^{1/2}} \right) (T_a - T_b) \right\} \quad (2.1-7)$$

where m_v = mass of the vapor

A.2.2 Normal Boiling-Point-Liquids

When exposed to the atmosphere, the liquids with normal boiling points above the ambient temperature will evaporate by diffusion into the air. The main driving force here is the vapor pressure difference, i.e., concentration gradient, between the liquid phase and the air.

A.2.2.1 Evaporation Rates

The evaporation of a liquid at ambient temperature in an open space with wind can be described as a mass transfer process by forced convection.

The evaporation rate can be calculated by the following formulae (NUREG-0570, p. 12)

$$\frac{d_{mv}}{dt} = h_d M A(t) (P_s - P_a) / R_g (T_a + 273.16) \quad (2.2-1)$$

where, for laminar flow,

$$h_d = 0.664 \frac{D}{L} (Re)^{1/2} (Sc)^{1/3} \quad (2.2-2)$$

A(t) = area of spill (cm²)

Re = Reynold number = Luρ/μ

Sc = Schmidt number = μ/Dρ

h_d = mass transfer coefficient (cm/sec)

R_g = universal gas constant

u = wind speed (cm/sec)

ρ = density of air (g/cm³)

μ = viscosity of air (g/cm-sec)

M = molecular weight of liquid (g/mole)

P_s = saturation vapor pressure of the liquid at temperature T_a (mm Hg)

P_a = actual vapor pressure of the liquid in air

L = characteristic length (cm)

D = diffusion coefficient (cm²/sec)

P_a is normally zero for all liquids. The diameter of the spill is used as the characteristic length L . Since the spill reaches its maximum dimensions quickly, the maximum diameter of the spill is used.

A.2.2.2 Diffusion Coefficient

The diffusion coefficients of the liquid into air are given for a few compounds in NUREG-0570 pp. 31-33. The diffusion coefficient, D_{AB} , of a gas A diffusing into a gas B may also be estimated by (Bird, et al., p. 511):

$$D_{AB} = 0.0018583 \frac{(T_a + 273.16)^{3/2} \left(\frac{1}{M_A} + \frac{1}{M_B} \right)^{1/2}}{P \sigma_{AB}^2 \Omega_{AB}} \quad (2.2-3)$$

where

M_A = molecular weight of gas A (g/mole)

M_B = molecular weight of gas B (g/mole)

P = atmospheric pressure (atm)

σ = Lennard-Jones parameter

Ω_{AB} = dimensionless function of temperature and intermolecular potential field E_{AB}

The Lennard-Jones parameters are empirically estimated to be:

$$\sigma_{AB} = (\sigma_A + \sigma_B)/2 \quad (2.2-4)$$

$$\epsilon_{AB} = \sqrt{\epsilon_A \epsilon_B} \quad (2.2-5)$$

Ω_{AB} is tabulated as a function of $k(T+273.16)/\epsilon_{AB}$ by Bird, et. al.

ϵ/k and σ for each gas can be estimated using the following relations (Bird, et. al. p. 22).

$$\epsilon/k = 0.77 T_C \quad (2.2-6)$$

$$\sigma = 2.44 \left(\frac{T_C}{P_C} \right)^{1/3} \quad (2.2-7)$$

for diffusion in air, the following parameters are used

$$\begin{aligned} \sigma_A &= 3.617 \text{ \AA} \\ \epsilon_{A/k} &= 97 \text{ }^\circ\text{K} \\ M_A &= 28.84 \text{ g/mole} \\ P &= 1 \text{ atmosphere} \end{aligned}$$

For chemicals where T_C and P_C were unobtainable, a diffusion coefficient of $0.2 \text{ cm}^2/\text{sec}$ was used.

A.2.3 Spill Area

The rate of mass transfer, i.e., vaporization or evaporation, of a liquid into the atmosphere is, among other things, directly proportional to the surface area of the spill. Initially, the liquid is assumed to be in the shape of a cylinder, with the height equal to the radius of the base. The liquid is assumed to spread quickly by gravity to a thin pancake. The surface area, A , is given by (NUREG-0570, p. 4):

$$A(t) = \pi \left\{ r_0^2 + 2t \left[\frac{gV_0}{\pi} \frac{(\rho_e - \rho)}{\rho_e} \right]^{1/2} \right\} \quad (2.3-1)$$

$$\text{and } V_0 = \pi r_0^3 \quad (2.3-2)$$

where

- r_0 = initial radius of the spill (cm)
- g = gravitational constant = 981 cm/sec²
- V_0 = volume of the spill (cm³)
- p_l = density of the liquid (g/cm³)
- p = density of air (g/cm³)
- t = time (sec)

The surface area, however, does not in reality expand indefinitely as eq. (2.3-1) indicates, but a maximum surface area is reached at some time. If the spill occurs on a surface that will restrict the spread of the spill, then the maximum area of the spill can be calculated. In cases where the condition of the ground cannot be accurately determined, a depth of 1 cm for the spill is assumed.

It should be noted that V_0 is the volume of the liquid spill remaining after instantaneous flashing to puff has taken place and is given by:

$$V_0 = \frac{m_T - m_V}{p_l} \quad (2.3-3)$$

A.3 VAPOR DISPERSION

The vapor from instantaneous flashing (puff) and from continuous vaporization of evaporation (plume) moves in the direction of the wind, and disperses by diffusion into the atmosphere. The dispersion is assumed to follow a Gaussian distribution for short travel times (a few minutes to one hour). That is, an individual puff may or may not be well-described by a Gaussian formulation, but an ensemble of puffs is assumed to disperse in a Gaussian function. This diffusion model is applicable only to the vapors whose densities do not differ greatly from that of air (Slade). The wind is assumed to be in the direction from the source of spill to the control room air intake. It should be noted that the topography between the source and receptor is ignored in this treatment.

A.3.1 Instantaneous (Puff) Release

The diffusion equation for an instantaneous puff with a finite initial volume and a receptor at the air intake is given by the following equation (NUREG-0570, p. 18)

$$\frac{\chi}{Q} (\text{puff}) = (2\pi)^{-3/2} (\sigma_{XI}\sigma_{YI}\sigma_{ZI})^{-1} \exp \left\{ -\frac{1}{2} \left(\frac{x^2}{\sigma_{XI}^2} + \frac{y^2}{\sigma_{YI}^2} \right) \right\} \\ \cdot \left\{ \exp \left(-\frac{1}{2} \frac{(z-h)^2}{\sigma_{ZI}^2} \right) + \exp \left(-\frac{1}{2} \frac{(z+h)^2}{\sigma_{ZI}^2} \right) \right\} \quad (3.1-1)$$

χ/Q (puff) is given in m^{-3}

σ_{XI} , σ_{YI} , σ_{ZI} = adjusted standard deviations of the puff concentration in the horizontal along-wind (X), horizontal cross-wind (Y), and vertical cross-wind directions (Z), respectively (m).

x, y, z = distances from the puff center in the X, Y, and Z directions, respectively (m). z is also the effective above-ground elevation of the receptor, e.g., the fresh-air intake of a control room.

h = effective above-ground elevation of the source.

To account for the initial volume of the puff, it is assumed that

$$\sigma_{XI}^2 = \sigma_{XI}^{\prime 2} + \sigma_o^2 \quad (3.1-2)$$

$$\sigma_{YI}^2 = \sigma_{YI}^{\prime 2} + \sigma_o^2 \quad (3.1-3)$$

$$\sigma_{ZI}^2 = \sigma_{ZI}^{\prime 2} + \sigma_o^2 \quad (3.1-4)$$

$$\sigma_{XI}^2 = \sigma_{YI}^2 \quad (3.1-5)$$

and letting $x = x_o - ut$

$$\sigma_o = \left[\frac{m_{vo}}{(2^{1/2} \pi^{3/2} \rho_v)} \right]^{1/3}$$

where

σ_o = initial standard deviation of the puff (m)

σ_{XI}^{\prime} , σ_{YI}^{\prime} , σ_{ZI}^{\prime} = standard deviation of puff concentration in the X, Y, and Z directions, respectively (m)

m_{vo} = mass of the instantaneously released puff (g)

ρ_v = density of the puff (g/m^3)

x_o = ground distance between the source of spill and receptor (m)

u = wind speed (m/sec)

t = time after release (sec)

The density of the puff is calculated using the ideal gas law.

$$PV = nRT \quad (3.1-6)$$

and the relation between density and volume

$$\rho_v = \frac{M \cdot n}{V} \quad (3.1-7)$$

which leads to:

$$\rho_v = \frac{M \cdot P}{RT} \quad (3.1-8)$$

where

M = molecular weight (gm/mole)

P = atmospheric pressure (atm)

n = number of moles

R = universal gas constant $8.205 \times 10^{-5} \frac{\text{atm} \cdot \text{m}^3}{\text{mole} \text{ } ^\circ\text{K}}$

T = ambient temperature, $^\circ\text{K}$

V = volume (m^3)

Then, Eq. (3.1-1) may be used for the calculation of the center-line concentration where $y = 0$.

Since the control room air intakes are located 36.5 meters above ground level, heavier than air vapor must overcome gravity to rise to the intake, while lighter than air vapors will reach the intake easily. To account conservatively for this effect, the puff dispersion, Eq. (3.1-1) is modified as follows:

For the vapors much heavier than air, the puff centerline is assumed to move up the hill to the ground level elevation of the plant. Dilution will occur due to the puff rising up the hill, but no credit was taken to account for this effect, $z=h=0$ is used in Eq. (3.1-1). For vapors much lighter than air, the puff centerline is assumed to move directly to the level of the air intake, therefore h is replaced by z in Eq. (3.1-1).

A.3.2 Continuous Plume Diffusion

The diffusion equation for the continuous release of a plume with a finite initial volume and a receptor at z above the ground level is given by the following equation (Slade, p. 99):

$$X/Q(\text{cont}) = (2\pi u \sigma_y \sigma_z)^{-1} \cdot \exp \left\{ \frac{-y^2}{2\sigma_y^2} \right\} \left\{ \exp \left[-\frac{(z-h)^2}{2\sigma_z^2} \right] + \exp \left[-\frac{(z+h)^2}{2\sigma_z^2} \right] \right\} \quad (3.2-1)$$

where

$X/Q(\text{cont})$ is given in sec/m^3

σ_y, σ_z = standard deviations of the plume concentrations in the y and z direction, respectively.

To give credit for the finite initial size of the spill, σ_y here is replaced by $(\sigma_y^2 + \sigma_{y0}^2)^{1/2}$, where σ_{y0} is the effective width of the spill. Although the distribution of a circular spill of a liquid in the cross-wind direction is not a normal function (it is of the form $P = (1 - F^2)^{1/2}$, where $-1.0 \leq F \leq 1.0$), σ_{y0} may be approximated by the following method (NUREG-0570, p. 20).

$$\sigma_{y0} \approx r \pi^{1/2} / 4.3 \quad (3.2-2)$$

where r = radius of the spill. Similarly, σ_z may be replaced by $(\sigma_z^2 + \sigma_{z0}^2)^{1/2}$ to account for the building effect, σ_{z0}^2 may be approximated by the following method:

$$\sigma_{z0}^2 = \frac{.5z^2}{\pi} \quad (3.2-3)$$

Again, to account for the differences for heavier than air and lighter than air vapors, $z = h = 0$ is used in Eq. (3.2-2) for vapors heavier than air. For vapors lighter than air, h is replaced by z in Eq. (3.2-1).

A.3.3 Standard Deviations and Stability Conditions

The stability categories, i.e., the Pasquill's types of weather conditions, are defined as:

<u>Pasquill's Stability Category</u>	<u>Weather Condition</u>
A	extremely unstable
B	moderately unstable
C	slightly unstable
D	neutral
E	slightly stable
F	moderately stable
G	extremely stable

Although the Pasquill-Gifford curves are appropriate only for plumes, they may be assumed to be applicable for estimating the puff dispersion coefficients. Using the Pasquill-Gifford curves (Slade, pp. 102 and 103) a functional dependence for σ_y and σ_z was developed of the form:

$$\log_{10}\sigma = A + B \log_{10}x + C(\log_{10}x)^2 + D (\log_{10}x)^3 \quad (3.3-1)$$

where x is the distance from the spill to the control room air intake in km

The coefficients are as follows:

Coefficients for σ_y

Pasquill Stability	A	B	C	D
A	2.3237	0.89182	0.00028741	-0.01228
B	2.1556	0.91347	0.028256	-0.02334
C	2.0142	0.91977	-0.0022985	-0.008289
D	1.8288	0.92394	-0.0056984	-0.0062276
E	1.7006	0.92826	-0.0017835	-0.009115
F	1.5289	0.92159	-0.011057	-0.0032318
G(x in m)	-1.6212	1.0648	-0.014857	-0.0020555

Coefficients for σ_z

Pasquill Stability	A	B	C	D
A	2.7301	2.6383	1.68666	0.59749
B	2.1003	1.3655	0.407576	0.0888029
C	1.8087	0.87272	-0.06512	0.00184558
D	1.4901	0.72583	-0.093465	0.011157
E	1.3284	0.67969	-0.10332	-0.0005092
F	1.1391	0.65602	-0.12889	0.0037608
G(x in m)	-1.8981	1.1243	-0.036447	-0.0086351

A.4 CONTROL ROOM CONCENTRATIONS

The concentrations of the toxic chemical, C_{CR} , in g/m^3 , in the control room, at any instant, is calculated by solving the following differential equation:

$$\frac{dC_{CR}(t)}{dt} = \lambda_I X(t) - \lambda_O C_{CR}(t) \quad (4-1)$$

where

- λ_I is the control room air inflow rate, (sec^{-1})
- λ_O is the control room air exhaust rate (sec^{-1})
- $X(t)$ is the concentration outside the air intake (g/m^3)
- $C_{CR}(t)$ is the concentration in the control room (g/m^3)
t in seconds

The control room air inflow rate, λ_I , is given by:

$$\lambda_I = \frac{F_I}{V_{CR} \cdot 60} \quad (4-2)$$

and similarly, λ_O , is given by:

$$\lambda_O = \frac{F_O}{V_{CR} \cdot 60} \quad (4-3)$$

where

- V_{CR} is the control room volume (ft^3)
- F_I is the control room air intake flow (cfm)
- F_O is the control room air exhaust flow (cfm)

The concentration of the toxic chemical, $X(t)$, at the air intake just outside the control room is the sum of the puff and plume concentration at any instance and is given by:

$$X(t) = m_{VO} \frac{X}{Q} \text{puff}(t) + \left(\frac{d_{mv}}{dt}\right) \frac{X}{Q} \text{cont}(t) \quad (4-4)$$

where m_{VO} is given by Eq. (2.1-1), $\frac{X}{Q} \text{puff}(t)$ is given Eq. (3.1-1).

$\frac{d_{mv}}{dt}$ is zero for $t < \frac{D}{u}$ and is given by Eq. (2.1-7) for any time thereafter. $\frac{X}{Q} \text{cont}(t)$ is also zero for $t < \frac{D}{u}$ and is given by Eq. (3.2-1) for any time thereafter.

The concentration of the toxic chemical at any time, t , in the control room is given by the following solution of Eq. (4-1):

$$C_{CR}(t) = e^{-\lambda_0 t} \int_0^t e^{\lambda_0 t'} \lambda_I X(t') dt \quad (4-5)$$

A.5 CONCENTRATIONS IN PARTS PER MILLION (ppm)

A convenient method of presenting concentrations of toxic gases in the atmosphere is in units of parts per million (ppm).

To convert to ppm from gm/m³, we use the ideal gas law:

$$PV = nRT \quad (5-1)$$

where for a volume V, n moles of total gases are present. The number of moles of toxic gases is given by:

$$n_i = \frac{C(\text{gm/m}^3) \cdot V}{MW} \quad (5-2)$$

where C (gm/m³) is the concentration in gm/m³
V is the volume in consideration, m³
MW is the gram-molecular weight of the substance (gm/mole)

The concentration in ppm is then given by:

$$C(\text{ppm}) = \frac{n_i \times 10^6}{n} = \frac{C(\text{gm/m}^3) \cdot R \cdot T \times 10^6}{MW \cdot P} \quad (5-3)$$

where R = gas constant $8.205 \times 10^{-5} \frac{\text{atm-m}^3}{\text{mole-}^\circ\text{K}}$

T = ambient temperature, °K.

P = atmospheric pressure (1 atm).

A.6 REFERENCES

D. H. Slade, "Meteorology and Atomic Energy", TID-24190, U.S. Atomic Energy Commission, Washington, D.C. (1968).

J. Wing, "Toxic Vapor Concentrations in the Control Room Following a Postulated Accidental Release", NUREG-0570, U.S. NRC, Washington, D.C. (1979).

R. B. Byrd, W. E. Stewart, W. N. Lightfoot, "Transport Phenomena", John Wiley & Sons, N. Y. (1960).

APPENDIX B

Included in Appendix B are control room and other system characteristics required by NUREG-0737 Section III.D.3.4, Attachment 1 related to the toxic chemical study to aid in an independent evaluation as required by NUREG-0737.

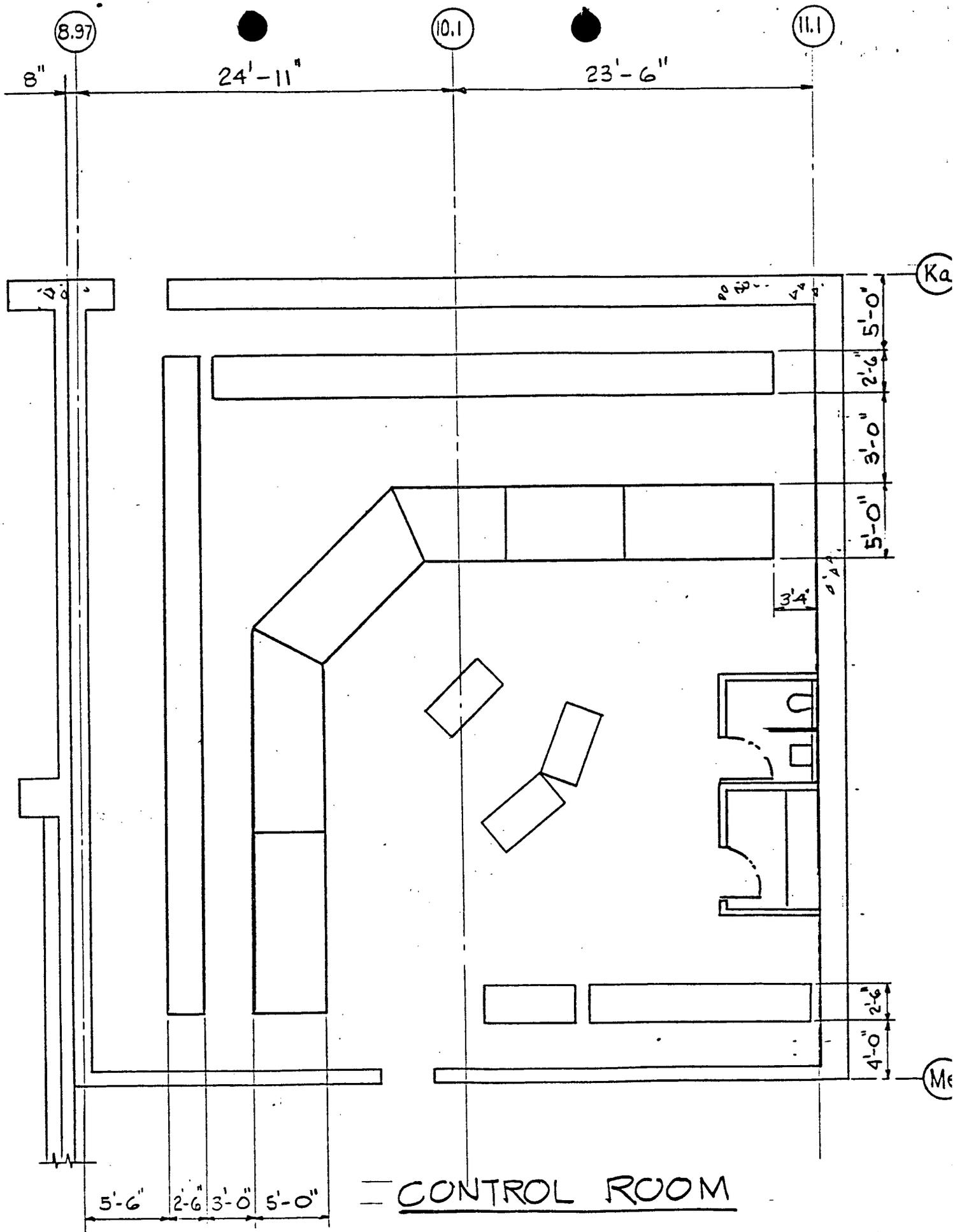
Control room characteristics

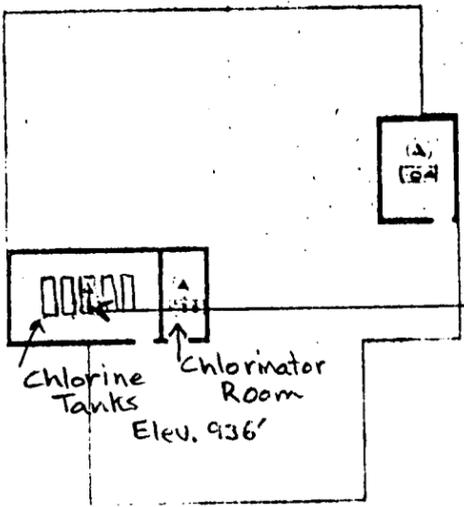
- air volume control room - 26,000 ft³ to ceiling.
32,500 ft³ including plenum space
air volumes do not allow for equipment volume
- infiltration leakage rate - zero in normal and high radiation condition (control room is pressurized). Zero (est.) in isolation mode, 100% recir., no pressurization. (Control room has no walls or doors exposed to the outside air.)
- high efficiency particulate air (HEPA) filter and charcoal absorber efficiencies - HEPA 99.97% on 0.3 micron particles
Charcoal Adsorber-Elemental Iodine 95%
- Organic Iodine 95%
(Both charcoal adsorber efficiencies per 2" bed depth)

Closest distance between containment and air intake - 7 ft.
from main control room air
intake to reactor building wall.

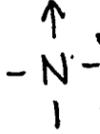
Automatic isolation capability - damper closing time, damper
leakage and area - damper closing time - 7.5 - 15 sec.

at 1" W.G.	{	16" dia - 1.4ft ² , intake opening - leakage = 19 cfm
		25" x 30" - 5.2 ft ² , " " " = 52 cfm
		26" x 20" - 3.6 ft ² exhaust opening- " = 36 cfm



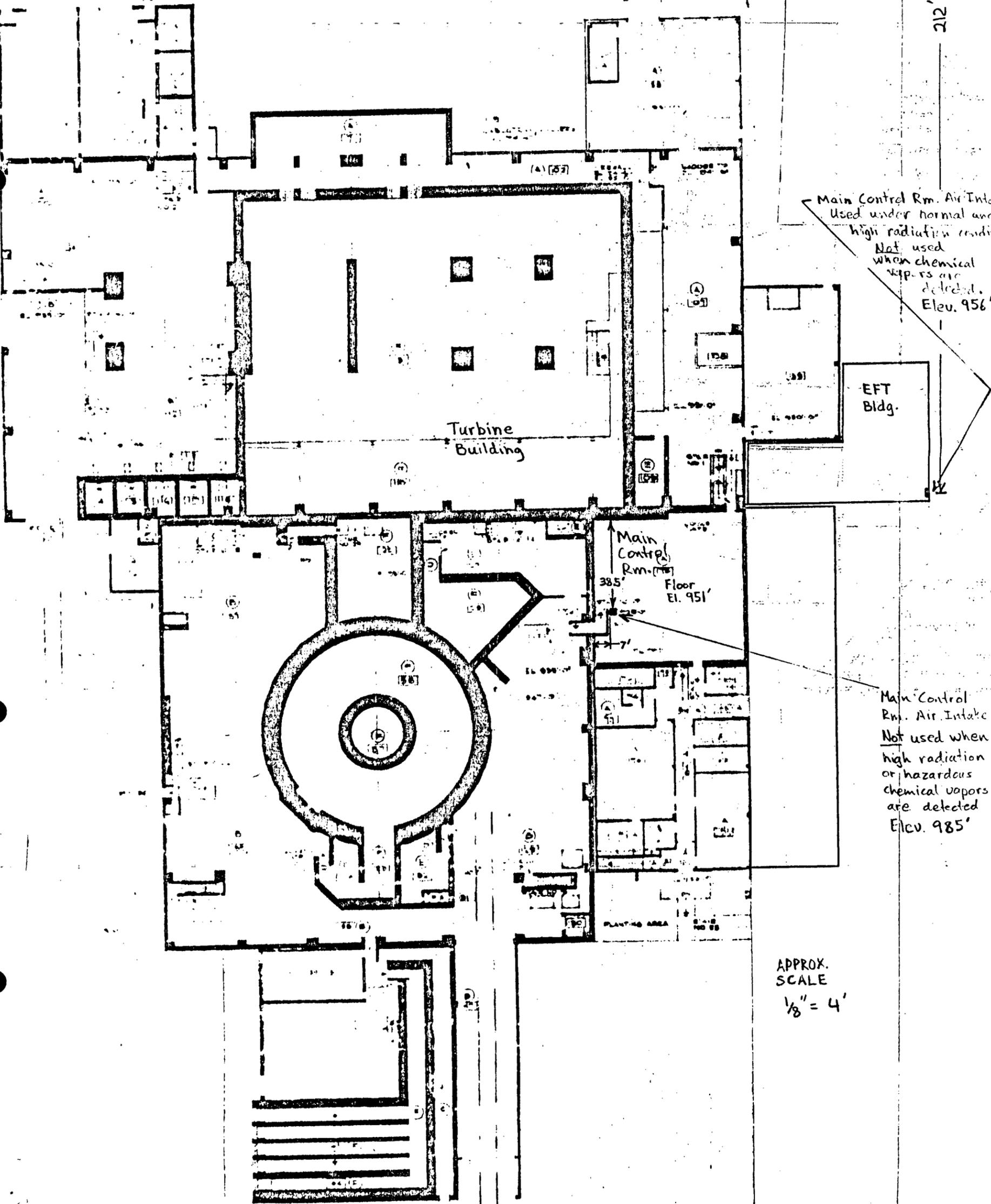


228'



Chlorine Tanks
Chlorinator Room
Elev. 936'

212' B-5



Main Control Rm. Air Intake
Used under normal and
high radiation conditions
Not used
when chemical
vapors are
detected.
Elev. 956'

EFT
Bldg.

Turbine
Building

Main
Control
Rm. Floor
El. 951'

Main Control
Rm. Air Intake
Not used when
high radiation
or hazardous
chemical vapors
are detected
Elev. 985'

APPROX.
SCALE
1/8" = 4'

DESIGN REPORT

ON

MONTICELLO MCR/TSC VENTILATION PROJECT

DESIGN REPORT
on MCR/TSC Ventilation Project

CONTENTS

1. Scope of work - Include preliminary drawings
2. Design Basis to include comparison of FSAR and current design

Building

Ventilation

Piping

3. DBA Dose Evaluation
4. Engineering and Construction Schedule

1. SCOPE OF WORK

The following modifications and additions are included; construction of a building adjacent the turbine building and boiler room which will contain the Emergency Filtration Train (EFT), addition of a permanent ventilation system which includes particulate and charcoal filters, connecting ducting to the Technical Support Center (TSC) and Main Control Room (MCR) and addition of connecting piping from the emergency service water system to the EFT building.

2. DESIGN BASIS

2.1 EFT Building

2.1.1 Seismic - The Emergency Filtration Train building (EFT) will be Seismic Category I. The seismic spectrum used will be the ground motion spectrum given in the FSAR. A single stick model will be used to develop the various floor spectrum and shear and moment diagrams for each elevation. The single stick model will include soil-structure interaction based on the information in the FSAR.

2.1.2 Tornado - The building will be designed for tornado pressure loads and external tornado missiles as defined in the FSAR.

2.1.3 The flooding criteria will be the same as included in the FSAR. The design of the building is such that it will not float and doors below elevation will be water tight or allow for sandbagging.

2.2 Heating, Ventilation and Air Conditioning.

2.2.1 Seismic - All mechanical components designated as Q items are given in Table I and indicated on the attached P&ID. The seismic spectrum to be used for OBE and SSE will equal or exceed the seismic criteria in the FSAR. Those components which are unique to the TSC will not be seismic category I. However, the seismic category II over I interface will be applied where failure of the non seismic equipment would jeopardize the operation of the Seismic I portion of the system. The entire H&V system will be connected to the emergency power supply using Class IE components as defined by the FSAR.

2.3 Electrical

2.3.1 Seismic - All electrical components which are used to interface between both the Q and non Q components of the EFT will be Class IE as defined by the FSAR.

The seismic spectrum used in the qualification test and/or analysis of the electrical components will meet or exceed the spectrum defined in the FSAR or the floor spectrum to be developed for the EFT building as described in paragraph 2.1.1.

- 2.4 Piping and Ducting - All ducting except for those portions unique to the TSC will be seismically qualified per the FSAR. The portions of the H&V system to be seismic qualified to the FSAR spectrum are shown in drawing NF 92284. All ducting in the EFT Building will be Seismic I.

The emergency service water piping to the EFT shown in drawings P-1000 to P-1004 will be Seismic Category I qualified to seismic criteria equal to or exceeding the levels specified in the FSAR or the floor spectrum to be developed for the EFT building as described in paragraph 2.1.1.

- 2.5 Emergency service water will be provided by the screen wash pumps that will be connected to the diesel-generator for Class 1E power.

3. DBA DOSE EVALUATION

3.1 General Licensing Consideration

The requirements to show acceptable post LOCA doses in the Technical Support Center (TSC) (NUREG-0578, Section 2.2.2b) and in the Control Room (CR), (NRC's letter of 5/7/80) result in the need to evaluate the DBA-LOCA and the subsequent pathways including MSIV leakage for release of radioactivity. In the FSAR the Monticello plant and the control room were licensed on the basis that all containment leakage was collected by the SGTS and released through the main stack.

In 1975, NRC issued Regulatory Guide 1.96 on the subject of MSIV Leakage Collection Systems (LCS). R.G. 1.96 indicated that operating plants (Monticello) may continue operation without an MSIV-LCS unless recurring leakage indicates a significant problem.

The dose calculations were performed to show compliance of the Control Room (CR) and Technical Support Center (TSC) with GDC 19.

It should be noted that several natural mechanisms will reduce or delay the radioactivity prior to release to the environment. However, no credit has been taken for the mechanisms in the analysis. These mechanisms are discussed in section 3.2.4.

3.2 Methodology

The guidelines given in SRP 6.4 and R. G. 1.3 were used with an exception of the X/Q 's for CR and TSC. Atmospheric dispersion factors are based on the Halitsky Methodology for Meteorology and Atomic Energy 1968, as discussed in Section 3.2.2.

3.2.1 Assumptions and Bases

Regulatory Guide 1.3 was used to determine activity levels in the containment following a DBA-LOCA. Activity releases are based on a containment leakage rate of 1.2% per day. Table 1 lists the assumptions and parameters used in the analysis and dose point locations. The majority of the containment leakage will be collected in the reactor building and exhausted to the atmosphere through the 95% efficient SGTS filters as an elevated release from the main stack. However, there exist certain release pathways from the containment which will bypass the SGTS filters. The bypass leakage was quantified by assuming that all four MSIV's leak at the technical specification limit of 11.5 scfh. After adjusting this to DBA-LOCA temperature and pressure conditions, the total bypass was rounded up to 25% of the containment leak rate in order to account for potential bypass in the feedwater and other similar lines.

Radioactivity leaking past the isolation valves could be released through the outboard MSIV stems into the steam tunnel, or continue down the steam lines to the stop valves and into the turbine condenser complex. Leakage into the steam tunnel is exhausted by the SGTS filtration system, thus eliminating it as a bypass pathway. Leakage down the steam lines is subject to plateout and delay within the lines. Reference 7, Section 5.1.2, discusses iodine removal rates which can be applied to calculate plateout on the piping and turbine condenser surfaces. Elemental and particulate iodine DFs of over 100 can be calculated for small travel distances and large travel times down the steam lines, considering the small volumes of leakage which leak past the valves. It was assumed that the bypass leakage is confined to the steam line, turbine condenser volume complex from which it will leak at 1% of the turbine condenser volume per day. This leak rate is consistent with the assumptions used for the CRDA in SRP 15.4.9. The volumetric leakage from the condenser would be approximately the same as in leakage. Furthermore, the bypass leakage will be cooling and

condensing as it travels down the lines. Therefore, it is not anticipated that the turbine condenser volume would pressurize.

Leakage within the turbine building would be exhausted by the HVAC system if it was working. Additional plate-out on ductwork, fans and fancoolers would further minimize the iodine releases. Should the HVAC not be working, then any bypass leakage would tend to collect in the building and be subject to additional decay and plateout. Leakage from the turbine building into the control building is minimized by the separate HVAC systems in each building, and by maintaining the interconnecting doors in their normally closed positions. Within the control building, the control room/TSC pressurization system will assure that leakage is from the protected area towards the other parts of the building, thus further minimizing the possibility of contaminating the protected areas.

The TSC and main control room pressurized volume consists of the second floor of the control building and the HVAC equipment room on the roof of the building. An 1/8 inch WG positive pressure is maintained in the TSC and main control room by introducing 1000 cfm of outside air through a redundant 99% efficient filtration system.

The activity which enters the TSC or main control room may be the result of either bypass leakage or SGTS exhaust in the outside air. However, due to the locations of these sources with respect to the ventilation intake it is not possible for the intake to be exposed to activity from both sources at the same time. Since the SGTS exhaust is elevated the concentrations from this source at the intake will be less than those due to bypass leakage. This analysis, therefore, conservatively assumes that the activity concentration at the intake is due to bypass leakage for the duration of the event.

3.2.2 Atmospheric Dispersion Factor (X/Q)

The following discussion is an explanation of the reasons for the use of the Halitsky X/Q methodology and a value of $K_c = 2$ instead of the Murphy methodology (Ref. 2) which SRP 6.4 suggests as an interim position.

Historically, the preliminary work on building wake X/Q_s was based on a series of wind tunnel tests by James Halitsky et al. Halitsky summarized these results

in Meteorology and Atomic Energy in 1968 (Ref. 1). In 1974 K. Murphy and K. Campe of NRC published their paper based on a survey of existing data. This X/Q methodology which presented equations without derivation or justification, was adopted as the interim methodology in SRP 6.4 in 1975. Since that time a series of actual building wake X/Q measurements have been conducted at Rancho Seco (Ref. 3) and several other papers have been published documenting the results of additional wind tunnel tests.

Reviews of the Murphy Eq. 6 and discussions with the author over the years have determined that the building wake correction factor, $(K+2)/A$, and $K=3/(S/d)^{1.4}$ were derived from the Halitsky data in Figure 37 of Ref. 2 from Murphy's paper. The Halitsky data was from wind tunnel tests on a model of the EBR-II rounded (PWR Type) containment and the validity of the data was limited to $.5 < s/d < 3$ (Ref. 1, Sect. 5.5.5.2). The origin and reason for the +2 in $K+2$ is not known. All other formulations use K only, and for situation where K is less than 1 the use of $K+2$ imposes an unrealistic limit on the X/Q .

For the Monticello plant, the building complex is composed of square edged buildings and not a round topped cylindrical containment as was used in the Halitsky experiments. For an HVAC intake located near the SE corner of the EFT addition to the roof of the control building, the intake will be subject to a building wake caused by a combination of the Reactor Building and the Turbine Building for any bypass leakage escaping from the turbine building. There will be no reactor building leakage because the building is kept at a negative pressure by the SGTs which exhausts from the main stack. Thus, an S/d ratio cannot be calculated with any meaning.

Since the Murphy methodology could not be applied, a survey of the literature was undertaken. It was found that the Halitsky wind tunnel test data (Ref. 1, Section 5.5.5) conservatively overestimated K values "by factors of up to possibly 10". Given this conservatism, it was felt that the use of a reasonable K value from the Halitsky data on square edged buildings should be acceptable. A review of Figures 5.27 from M&AE (Ref. 1) resulted in K values in the .5 to 2 range. A value of $K=2$ was chosen to get a X/Q of 8.6×10^{-4} . Information from other sources, as indicated below, has also shown that this should be a conservative value.

In a paper by Walker (Ref. 4), control room \bar{x}/Q 's were experimentally determined for floating power plants in wind tunnel tests. Different intake and exhaust combinations were considered. Using the data for intake 6, and stack A exhaust, (in Ref. 4) \bar{x}/Q values of 1.77×10^{-5} and 2.24×10^{-5} were found after adjusting the wind speed from 1.5 m/sec to 1 m/sec. These values are approximately one order of magnitude lower than the conservatively calculated value for Monticello.

In a wind tunnel test by Hatcher (Ref. 5), a model industrial complex was used to test dispersions due to the wake. Data obtained from their tests show that K has a value less than 1, and decreases as the test points are moved closer to the structure. Meroney and Yang (Ref. 6) in a study to determine optimum stack heights, show that for short stacks (6/5 of building height), K reaches a value of approximately 0.2 and decreases closer to the building. They concluded that the Halitsky methodology was "overly conservative". These recent experimental tests show that $K = 2$ used to determine the \bar{x}/Q for Monticello is a conservative estimate by, at least, a factor of 2 and possibly by 10 or more.

Field tests were made on the Rancho Seco facility (Ref. 3), and $\bar{u}\bar{x}/Q$ were obtained. Data from round topped containment releases and square edged auxiliary building releases were used to simulate the Monticello case. Measured $\bar{u}\bar{x}/Q$ values ranging from $8.07 \times 10^{-4} \text{ m}^{-2}$ to approximately 1×10^{-6} were found. Although most values of $\bar{u}\bar{x}/Q$ were in the 10^{-5} m^{-2} range for those cases approximating the Monticello configuration, the worst Rancho Seco case value of 8.07×10^{-4} at Pasquill G and 1.8 m/sec with a building area of 2050 m^2 is used for comparison purposes. When adjusted to the Monticello conditions with a wind speed of 1 m/sec and an area of 2314 m^2 , and including a reduction factor of 2 to account for the Rancho Seco containment being a cylinder instead of rectangular, (Halitsky's data indicates K_c for cylinders is from 3 to 5, for rectangular buildings $K_c = .5$ to 2) the worst case corrected \bar{x}/Q is 2×10^{-4} . This is a factor of 4 smaller than the Monticello value of 8.6×10^{-4} calculated using the Halitsky wind tunnel data.

It was concluded that sufficient data and field tests exist to give a reasonable assurance that the chosen \bar{x}/Q is a conservative one, over and above the conservatism implied by using the 5th percentile wind speed and wind direction factors. In addition, the intake location, well below the source of activity but still close

to the building wall and high enough to avoid drifting snow problems, is perhaps the most optimal location, due to the apparent increases in concentrations as one moves further into the wake cavity.

3.2.3 Results

The radiological exposures in the CR and TSC are included in Table 2. These doses are within the GDC 19 guideline values.

3.2.4 Mechanisms for Reducing Iodine Releases

The following mechanisms could result in significant quantities of iodine being removed before they are released to the environment. However, no credit for these mechanisms was taken in the calculation of radiological consequences.

- o Drywell Sprays, Suppression Pool to Air Partitioning and Condensation Effects

Though manually operated, the drywell sprays will reduce the iodine source term if actuated. Even without the spray system, condensation will occur in the drywell and wetwell. The iodines in the air and suppression pool are expected to reach equilibrium due to this phenomenon. Since the iodines have a preference to stay in water due to the equilibrium partition factor of over 300 established by the physical conditions in the containment, the iodines available for release by air leakage will be reduced significantly.

- o Plateout on Pipe Surfaces

Although there is an implied factor of 2 iodine plateout in Regulatory Guide 1.3 source term, experimental evidence and the experience at TMI indicates that significantly larger plateout factors are common. During transport down the steam lines, the holdup time for leakage, and so contact time in the steam lines could be many hours and the iodines will see a large surface on which they can plateout prior to release. The results of experiments (reference 7) done under conditions very similar to those expected in the main steam lines following isolation indicate iodine reduction by a factor up to 100.

- o Removal Through Valves and Leakage Holes

Since the bypass leakage paths are through minute holes in valves and valve seats, the leakage will be subjected to filtration effects. Larger particulates could tend to plug the leak paths. (Reference 8).

- o Condensate Within Pipes

Condensation will occur within the pipes when the pipes cool down to ambient temperature. This would result in removal of iodines and particulates from the gas phase.

3.2.5 References

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TABLE 1

LOSS-OF-COOLANT ACCIDENT: PARAMETERS
TABULATED FOR POSTULATED ACCIDENT ANALYSES

		<u>DESIGN</u> <u>BASIS</u> <u>ASSUMPTIONS</u>	
I.	Data and Assumptions Used to Estimate Radioactive Sources from Postulated Accidents		
	A. Power Level (MWt)		1670
	B. Burnup		NA
	C. Fission Products Released from Fuel (fuel damaged)		100%
	D. Iodine Fractions		
	(1) Organic		0.04
	(2) Elemental		0.91
	(3) Particulate		0.05
II.	Data and Assumptions Used to Estimate Activity Released		
	A. Primary Containment Leak Rate (%/day)		1.2
	B. Secondary Containment Release Rate (%/day)		100
	C. Leak Rate Through MSIV (scfh)		11.5
	D. Main Condenser Leak Rate (%/day)		1.0
	E. Volume of Main Condenser (cu. ft.)		77,000
	F. Valve Movement Times		NA
	G. SGTS Adsorption and Filtration Efficiencies (%)		
	(1) Organic iodines		95
	(2) Elemental iodine		95
	(3) Particulate iodine		95
	(4) Particulate fission products		95
III.	Dispersion (sec/m ³):	<u>Ground Level</u>	<u>Elevated</u>
	A. TSC and CR - Building Wake \bar{X}/Q for Time Intervals of		
	(1) 0-8 hrs	8.6x10 ⁻⁴	2.5x10 ⁻¹¹
	(2) 8-24 hrs	5.1x10 ⁻⁴	3.7x10 ⁻¹¹
	(3) 1-4 days	3.2x10 ⁻⁴	7.3x10 ⁻¹²
	(4) 4-30 days	1.4x10 ⁻⁴	2.4x10 ⁻¹²

TABLE 1 (Continued)

DESIGN
BASIS
ASSUMPTIONS

IV. Data for CR/TSC:

A. Volume of CR/TSC (ft ³)	104,400
B. Filtered intake (cfm)	1,000
C. Efficiency of Charcoal (%) Adsorber	99
D. Unfiltered Inleakage (cfm)	10
E. Recirculation Flow Rate	0.0
F. Occupancy Factors:	
0-1 day	1.0
1-4 days	0.6
4-30 days	0.4

TABLE 2

DBA-LOCA Radiological Consequences

Dose Contributions to the CR/TSC	Whole Body	Doses (Rem)		Skin
			Thyroid	
a) Direct Shine from Reactor Building	(max.) 2.5	-	-	-
b) Plume Shine from Stack Release		.334	-	-
c) Plume Shine from Bypass Leakage		.168	-	-
d) Airborne Activity inside CR/TSC from 25% bypass leakage		.0031	20.2	.13
TOTAL	(max.) 3.		20.2	.13
GDC 19 Dose Guidelines		5	30	30

4.0 Engineering and Construction Schedule

