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SURRY ONSITE TOXIC CHEMICAL
RELEASE ANALYSIS


Prepared For
VIRGINIA ELECTRIC AND POWER COMPANY

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1.0 INTRODUCTION AND SUMMARY

The chemicals stored onsite at the Surry Nuclear Power Station and their storage locations are shown in Figure 1-1. Chemicals classified as potentially hazardous are: morpholine, dimethylamine, acetone, cyclohexylamine, sulfuric acid, ammonium hydroxide, carbon dioxide, diesel fuel, chlorine and hydrazine. An analysis of the consequences of releasing the contents of a single container of these chemicals was performed. The analysis considered the release of the chemical, its atmospheric dispersion and subsequent buildup in the control room air. The quantities of each chemical considered, the toxicity limit and the estimated cloud center concentration at the control room air intake are listed in Table 1-1. It can be observed from this table, that morpholine, acetone, cyclohexylamine, sulfuric acid, ammonium hydroxide and diesel fuel present no hazard to control room personnel. Since the cloud center concentration for dimethylamine, carbon dioxide, chlorine and hydrazine exceed their toxicity limits, the buildup in the control room was determined. The results of this analysis revealed that the control room concentration also exceeds the toxicity limit.

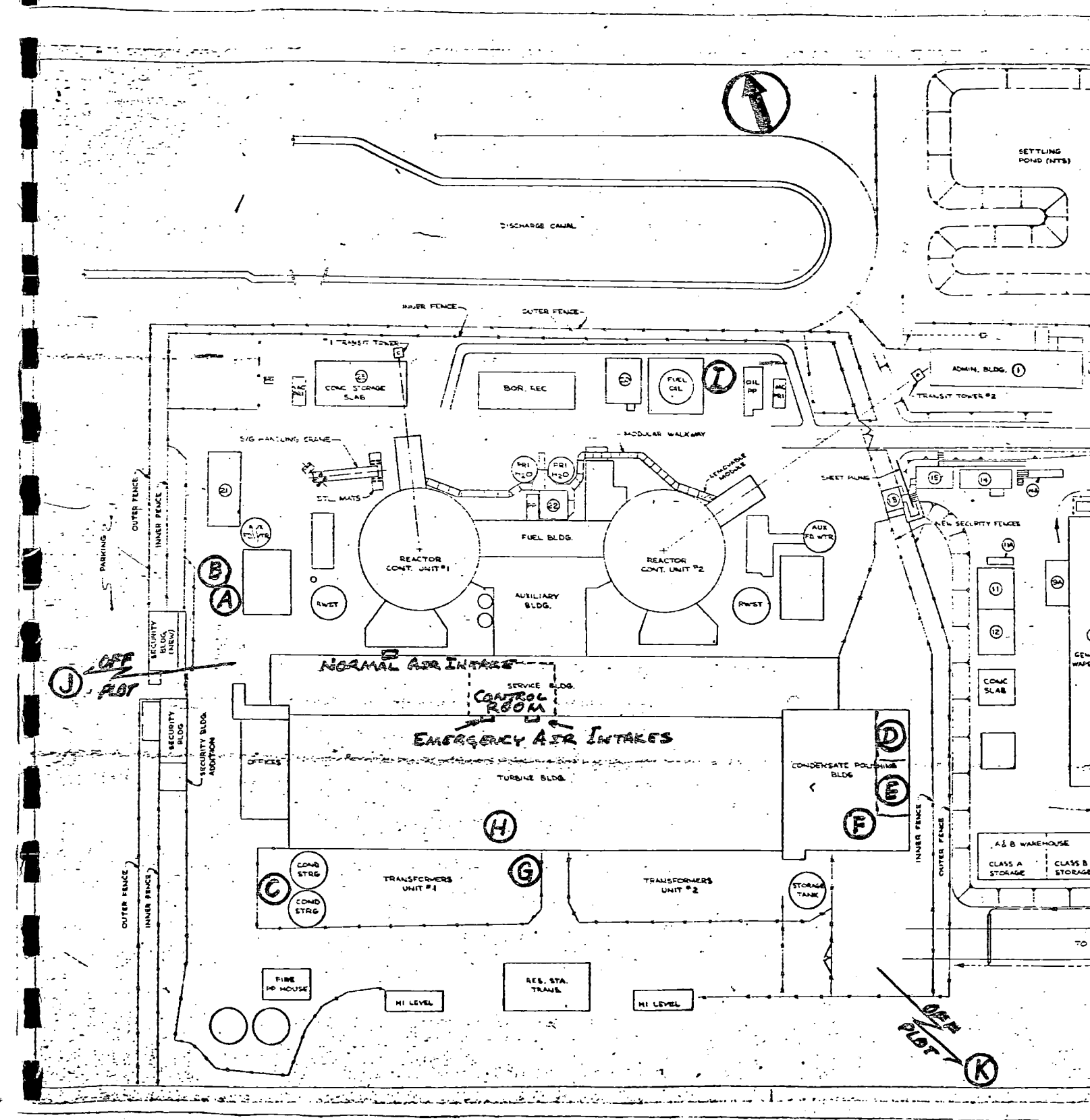
TABLE 1-1

SURRY ONSITE CHEMICALS

Chemical	Quantity Spilled	Toxicity Limit (mg/m ³)	Cloud Center Concentration (mg/m ³)
Morpholine	55 gal	105 ^a	1
Acetone	55 gal	4800 ^b	27
Cyclohexylamine	55 gal	40 ^a	1
Sulfuric Acid	8,000 gal	2 ^b	0.004
Ammonium Hydroxide	3,000 gal	70 ^b	3.8
Carbon Dioxide	17 tons	18000 ^b	1.8x10 ⁶
Diesel Fuel	210,000 gal	1355 ^a	50
Chlorine	64 lbs	45 ^b	1x10 ⁵
Hydrazine	55 gal	0.3 ^a	21
Dimethylamine	135 lbs	28 ^a	1.9x10 ⁶

a) Short Term Exposure Limit from ACGIH, Reference 1.

b) From Table C-1 of R.G. 1.78, Reference 2.



Chemical	Meters From Air Intake	Location
Dimethylamine, Argon, Helium, Hydrogen, Nitrogen, Oxygen, Carbon Dioxide, Acetylene, Breathing Air, Specialty Gas Mixes:	38	A) Outside NNW of Intake East of Security Building
Morpholine, Anhydrous Hydrazine Acetone, Sodium Hypochloride, Cyclohexylamine:	58	B) Outside NNW of Intake East of Security Building
Hydrogen Bank	84	C) Outside W of Intake, SW of Condensate Storage Tanks
Sulfuric Acid	125	D) Room Within Condensate Polishing Building, Berm Within Room, 2 (Self-Closing) Doors Between Emergency Intake. 173 m From Condensate Polishing Building HVAC Exhaust Stack to Normal Intake
Ammonium Hydroxide	130	E) Room Within Condensate Polishing Building, 2 (Self-Closing) Doors Between Emergency Intake. 189 m From Ammonium Room Exhaust Stack to Normal Intake
Hydrazene	114	F) Condensate Polishing Building, 1 (Self-Closing) Door Between Emergency Intake
Carbon Dioxide	48	G) Outside Adjacent to Double Doors South Side of Turbine Building
Sulfuric Acid	40	H) Inside Turbine Building Across From Emergency Intake
Diesel Fuel	122	I) Outside Separate Tank 60'x60'x9' Dike
Chlorine	144	J) Inside Sewerage Treatment Building - Off Plot
Hydrazine Ammonium Hydroxide	450	K) Inside Warehouse Building - Off Plot

FIGURE 1-1
PLOT PLAN SURRY 1 & 2
TOXIC CHEMICAL SOURCE LOCATIONS

2.0

METHOD OF ANALYSIS

The release and subsequent atmospheric dispersion of dimethylamine, chlorine and carbon dioxide were calculated assuming an instantaneous puff release of the total amount stored. The release and subsequent dispersion of ammonium hydroxide is calculated for boiling from a pool of liquid formed by spillage of the total amount in storage. An evaporation model was chosen for all other chemicals since their boiling points are well above ambient temperatures, and they have moderate vapor pressures at ambient conditions.

2.1

Release to Atmosphere

The rate at which material is released to the atmosphere is dependent on the size of the pool of liquid formed, the physical characteristics of the material, and the meteorological conditions at the time of the spill. The release of materials which have a boiling point greater than the ambient temperature will be limited by mass transfer considerations. Those materials with boiling points at or below the ambient temperature will have their release rate governed by heat transfer considerations. A brief description of the models used is given below. These models are based on the concepts presented by Bird, Stewart and Lightfoot⁽³⁾ for mass transfer limited models, and by Krieth⁽⁴⁾ for heat transfer limited models.

The size of pool of liquid formed by the spill is estimated by assuming a square shaped pool with a minimum depth of one centimeter. The lateral extent of the pool is limited by the topography when berms or other size restrictions exist.

The evaporation rates for liquids with boiling points above the ambient temperature were calculated as:

$$W_a = M_a A D_{ab}^{2/3} \sqrt{\frac{u}{L}} \ln \left(\frac{P_a}{P - P_a} + 1 \right) \quad (2-1)$$

or

$$W_a = M_a A D_{ab}^{2/3} (2.305 u^{0.8} L^{-0.2} - 12800/L) \ln \left(\frac{P_a}{P - P_a} + 1 \right) \quad (2-2)$$

Equation 2-1 is applicable to laminar flow regimes ($Re < 5 \times 10^5$) while equation 2-2 is applicable to turbulent flow regimes. The symbols used in these equations are defined in Table 2-1 (Nomenclature).

The rate of vaporization of materials with boiling points at or below the ambient temperature is:

$$W_a = 126 M / \Theta \quad (2-3)$$

$$\Theta = \left[\frac{-b + \sqrt{b^2 + 4ac}}{2a} \right]^2 \quad (2-4)$$

$$a = \bar{h}_a (T_a - T_o) + 365 \quad (2-5)$$

$$b = 4.45 (T_c - T_o) \quad (2-6)$$

$$c = M h_{fg} / A \quad (2-7)$$

The film coefficient is given by

$$\bar{h}_a = 0.279 \sqrt{\text{Re}} / L \quad (2-8)$$

or

$$\bar{h}_a = 0.0151 (\text{Re}^{0.8} - 23200) / L \quad (2-9)$$

Equation 2-8 is applicable to laminar flows, while equation 2-9 is for turbulent flow.

2.2 Atmospheric Dispersion

An atmospheric dispersion analysis was performed for the control room habitability assessment for onsite releases of toxic chemicals at the Surry Nuclear Power Plant. The nature of these releases (i.e., near the reactor buildings complex and very short distances to the intakes) necessitated a more detailed and substantially different type of analysis than past evaluations concerning toxic chemicals. The analysis and assumptions, which provide a conservative assessment, are outlined below.

Continuous Releases

For those releases which occur in or near the building complex, χ/Q values were calculated utilizing the results of recent analyses of diffusion tests near buildings⁽⁵⁾. Onsite Surry meteorological data for the period 3/3/74 - 3/2/75 was evaluated to determine a representatively conservative meteorological condition (approximately worst 5% conditions) in order to provide the wind speed, σ_y and σ_z values needed. Because conditions of Pasquill Class G atmospheric stability and windspeeds less than 1.3 m/s (3 mph) occur nearly 10% of

the time at Surry, a meteorological condition of G and 0.5 m/s (1.1 mph) was selected for use in this analysis. The parameters used in the analysis are listed in Table 2-2.

Instantaneous Releases

Three locations were identified as having the potential for instantaneous or puff releases. The carbon dioxide and dimethylamine releases are within the building complex and therefore the selection of an adequate dispersion model for a puff release becomes very complicated. In order to conservatively assess releases from this location, σ_x , σ_y , and σ_z are taken as being zero. The initial puff size, σ_I , is calculated based on release characteristics as per Regulatory Guide 1.78. In essence, the building influences and the short distance (44m) render σ_{xI} , σ_{yI} , and σ_{zI} meaningless. The wind speed utilized is 0.5 m/s. It is assumed that the puff will not diffuse as it moves downwind.

The release location for chlorine is away from any building influences and is evaluated assuming G atmospheric stability ($\sigma_{x,y} = 3.8$ m, $\sigma_z = 2.0$ m) and 0.5 m/s wind speed, σ_I is calculated based on the particular release characteristics, using the formulations and data of R.G. 1.78.

2.3 Concentration Buildup in Control Room

The differential equation governing the concentration in the control room is:

$$V_R \dot{C}_R = qX - qC_R \quad (2-10)$$

after rearranging terms:

$$\dot{C}_R = \frac{q}{V_R} X - \frac{q}{V_R} C_R \quad (2-11)$$

(see Table 2-1 for description of terms)

This equation is solved numerically using a Runge-Kutta procedure derived by Gill (6).

TABLE 2-1
NOMENCLATURE

A	=	Area of spill (cm^2 or ft^2)
D_{ab}	=	Binary diffusivity of species a into species b (cm^2/s)
\bar{h}_a	=	Film coefficient for heat transfer from air ($\text{Btu/hr-ft}^2\text{-F}$)
h_{fg}	=	Latent heat of vaporization of liquid (Btu/lbm)
L	=	Characteristic length of spill (cm)
M	=	Mass of liquid spilled (lbm)
M_a	=	Molecular Weight of Material spilled (g/g-mole)
P	=	Atmospheric pressure (torr)
P_a	=	Vapor Pressure of material spilled (torr)
Re	=	Reynolds number = $u L/\gamma$
T_a	=	Ambient Air Temperature (F)
T_c	=	Initial temperature of concrete roadway (F)
T_o	=	Boiling point of material spilled (F)
u	=	Wind speed (cm/s)
W_a	=	Evaporation rate or boiling rate (mg/s)
γ	=	Kinematic viscosity of air (cm^2/s)
θ	=	Time required to completely vaporize the liquid (hr)
X	=	Concentration of chemical in air (mg/m^3)
q	=	Control room air intake rate (cfm)
V_R	=	Control room volume (cu ft)
C_R	=	Concentration of chemical in control room air (mg/m^3)

TABLE 2-2

PARAMETERS FOR ATMOSPHERIC DISPERSIONS

<u>Release*</u> <u>Location</u>	<u>Meters From</u> <u>Release Point</u> <u>To The Intake</u>	<u>X/Q** (sec/M³)</u>
B	58	1×10^{-3}
E	189	8×10^{-5}
I	122	3×10^{-4}
D	173	1×10^{-4}
H	40	2×10^{-3}
K	457***	1.12×10^{-2}

NOTES:

* See Figure 1-1 for release locations.

** X/Q values were obtained from Figure 7 of Reference 1.

*** X/Q values for other locations utilize tests discussed in NUREG/CR-1394 which were done near buildings. Hence, these values include building wake and some meander credit. At Location K, large buildings are not present and assuming G conditions and no meander, X/Q is calculated using the continuous models of Reference 7 as:

$$X/Q = \frac{1}{\sigma_y \sigma_z \bar{u}}$$

3.0 RESULTS

The rate of evaporation of the six chemicals whose boiling points are above the ambient temperature are evaluated based on the models described in Section 2.1. The resultant evaporation rates at a wind speed of 0.5 m/sec are listed in Table 3-1 along with the parameters used in their determination.

For ammonium hydroxide, the boiling point is 86°F, and the boiling model described in Section 2.1 is used. The parameters used for this evaluation are air and concrete temperature 100°F, heat of vaporization 774 Btu/lbm, spill area 774 ft². The resulting boiling rate is 4.8×10^4 mg/sec at 0.5 m/sec wind speed.

For chlorine and carbon dioxide instantaneous puff releases of the entire contents of one container are assumed. The control room parameters used are 70,000 cubic foot volume, normal intake and exhaust rate = 1820 cfm including leakage. Emergency intake and exhaust rate = 1000 cfm. No credit was taken for the effects of filters.

The resulting peak concentration in the control room, and the time required to reach the toxicity limit are listed in Table 3-2.

The column labeled t_1 in Table 3-2 represents the amount of warning that control room personnel would have if leak detectors were present at the chemical storage location. This time includes the time required for the vapor cloud to drift to the air intake and then to build up to the toxicity limit in the control room. The column labeled t_2 represents the amount of warning available if detectors which can sense the specific chemical at its toxicity limit are placed at the air intake.

TABLE 3-1

EVAPORATION RATES

Chemical	Q	D _{ab}	M _a	P _a	A	W _a
Morpholine	55	0.2	87.12	10.0	2.2×10^2	9.43×10^2
Acetone	55	0.134	58.1	400	2.2×10^2	2.72×10^4
Cyclohexylamine	55	0.2	99.17	10	2.2×10^2	1.07×10^3
Sulfuric Acid	8,000	0.1038	98.08	0.005	3.3×10^4	4.34×10^1
Hydrazine	55	0.2	32.05	51.3	2.2×10^2	1.83×10^3
Diesel Fuel	210,000	0.09	170.3	155	3.6×10^3	1.73×10^5

NOTES:

- Q = quantity of chemical spilled (gallons)
 D_{ab} = diffusivity of chemical in air (cm²/sec)
 M_a = molecular weight of chemical (grams/gram-mole)
 P_a = vapor pressure of chemical (torr)
 A = spill area
 W_a = evaporation rate (mg/sec)

TABLE 3-2

PEAK CONCENTRATION OF CHEMICALS
IN CONTROL ROOM

Chemical	TL	C_R	t_1	t_2
Morpholine	105	9.4×10^{-1}	*	*
Acetone	4,800	2.7×10^1	*	*
Cyclohexylamine	40	1.1	*	*
Sulfuric Acid	2	4.3×10^{-3}	*	*
Hydrazine	0.3	2.1×10^1	946	36
Diesel Fuel	1,355	5.2×10^1	*	*
Ammonium Hydroxide	70	3.8	*	*
Carbon Dioxide	1.8×10^4	3.9×10^4	159	61
Carbon Dioxide	1.8×10^4	2.2×10^4 (E)	180 (E)	82 (E)
Chlorine	45	8.9×10^2	280	17
Dimethylamine	28	6.5×10^3	68	7

NOTES:

- TL = Toxicity limit (mg/m^3) See Table 1-1 for sources of data
- C_R = peak concentration in control room (mg/m^3)
- t_1 = time from spill until TL is reached in control room air (seconds), * indicates TL not reached
- t_2 = time from reaching TL at intake to reaching TL in control room
- E = emergency air intake

4.0 REFERENCES

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