PLG-0370

for

General Public Utilities

Probabilistic Risk Assessment of Offsite Releases Initiated by a Toxic Chemical Release

FINAL REPORT

by

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1.0 INTRODUCTION AND SCOPE OF STUDY

Pursuant to Section 2.2.3 of the Standard Review Plan, an assessment has been made of the likelihood of core damage and a resulting release of radiation in excess of the limits of 10CFR100 initiated by a toxic chemical release. The offsite toxic chemical releases considered in this report consist of either the rupture of a fixed ammonium hydroxide storage tank or the rupture of one tank car on either of two rail lines adjacent to the plant, releasing the entire contents of the car instantaneously. Evaporation and meteorological models were developed and used to evaluate the propagation of the postulated releases from the release point to the TMI-1 control room. A list of the chemicals considered in this report is given in Table 1.1. A probabilistic model was made of the plant consequences of the release reaching the control room. The estimated frequency (per year) of all scenarios with consequences exceeding the 10CFR100 offsite dose rate initiated by an offsite hazardous chemical release can be calculated in the following way:

$$\lambda_{>10CFR100} = \sum_{i}^{M} \left[\lambda_{T_i} \; f^{*}_{R-T_i} \left\{ \sum_{j}^{N} f_{o_j} \right\} \cdot f_M \cdot f_{CF} \right] \qquad (1\text{-}1)$$

where

λ_{T_i} = frequency per year of a major offsite hazardous chemical releases of chemical i

= $\lambda_T \cdot n_i$

λ_T = frequency of major releases per tank-car-mile

n_i = number of tank cars shipped per year on either Shocks or Roy of chemical i

$f^{*}_{R-T_i}$ = integral over the track length of the conditional probability of exceeding the toxic limit given a major release of chemical i on either Shocks or Roy

f_{o_j} = total fraction of the time when operator action is required to mitigate the scenario caused by tank car rupture

f_M = fraction of all such operator actions which are unsuccessful and lead to core uncovery

f_{CF} = fraction of uncovered cores which lead to a 10CFR100 offsite dose rate

M = number of chemical-rail line combinations considered

N = number of mitigating actions possibly required

The variables in equation (1-1) are each calculated or discussed in this report as follows

λ_T in Section 2

n_i is from Reference 19

f_{R-T_i} in Section 3

f_{o_j}, f_m, and f_{CF} in Section 4

The last three of these variables will be calculated in detail in the TMI-1 PRA (TPRA) which is currently in process. The estimates used here are based on the TPRA Phase I results [Ref. 24] and on the MPRA [Ref. 25] results.

Certain physical phenomena which could be inferred to occur were not included in the model due to the unavailability of the data required to properly evaluate them. The primary example of this is the assumption that a hydrofluoric acid release would simply evaporate, rather than reacting chemically with the surface, when in fact it is highly reactive. The reason for this line of approach is that there is insufficient data on the composition of the roadbed, the reactions to be expected, the reaction rates, and a variety of other subjects to produce a valid model. Thus, the simplifying assumption was made that no reaction occurs. Since such a reaction would decrease the amount of hydrogen fluoride available for release, it is conservative.

TABLE 1.1 CHEMICALS ANALYZED IN THIS REPORT AND SOURCES OF RELEASE

Chemical	Sources*
Acetic Acid, Glacial	Roy, Shocks
Acetic Anhydride	Roy, Shocks
Acrylonitrile	Shocks
Ammonia, Anhydrous	Roy, Shocks
Ammonia, 29.4 w/% Aqueous	Manly-Regan
Bromine	Shocks
Chlorine	Shocks
Chromic Fluoride, 20 wt % in HF	Roy
Coal Tar, Light Oil	Shocks
Ethyl Acrylate	Roy, Shocks
Ethylene Oxide	Shocks
Formaldehyde, 37 wt % Aqueous	Shocks
Hexane	Shocks
Hydrochloric Acid, 36 wt % Aqueous	Shocks
Hydrofluoric Acid, anhydrous	Roy, Shocks
Phosphorus Oxychloride	Shocks
Propylene Oxide	Shocks
Vinyl Acetate	Shocks
Vinyl Chloride	Roy, Shocks

* The Roy line runs to the east of the plant. The Shocks lines to the west. The Manly-Regan tank is 4400 m N of the plant.

2.0 FREQUENCY OF A MAJOR RELEASE

In this section, the frequency of a toxic chemical release from the accidental rupture of a railroad tank car is calculated. This frequency was calculated from Accident/Incident Bulletins 146 (1977) and 151 (1982) [Ref. 20, 21]. Other data sources were considered but rejected because they were not sufficiently well defined. For instance, a study performed for the Department of Commerce by Systems Laboratory, Inc. [Ref. 22] and quoted in the Limerick PRA [Ref. 23] insufficiently documented the source of its numbers and, therefore, could not be used. Reference 24 provides data analyzed by Sandia National Laboratories which uses an accident rate of 1.5×10^{-6} per car-mile. It is also apparent that the quality of railroad tank cars is improving. However, the mix of new and old cars used by CONRAIL for shipments on the Shocks and Roy line is unknown. Therefore, national averages for track of the same type through 1982 were used. The historic data includes rail cars of all vintages used during that year, including the new cars. The mix of new and old cars is not expected to be any different on Shocks and Roy than elsewhere in the country. The statistics for 1983 and 1984, when available, are expected to be better as more new cars are brought into service.

Most track in the US (80%) is Class IV, therefore without more specific information it was assumed that the portions of Shocks and Roy considered here are also Class IV.

In the Midland PRA [Appendix H.2 of Ref. 25] the railroad car accidental release rate was estimated on per track-mile-year basis, and the same rate was used for every chemical. No data was available which specified the rate of shipment of specific chemicals. In TMI's case, CONRAIL provided GPUN with a list of shipping frequencies (number of tank cars) for an 18-month period from January 1978 to June 1979 [Ref. 19]. The availability of this list made it possible to calculate release frequencies for each chemical considered.

The frequency of a major release from a tank car rupture was calculated using the following relationship:

$$\lambda_T = \lambda_t \, n_{HMR} \, f_{RHM-M} \, / n_{HM} \qquad (2\text{-}1)$$

where

λ_t = total rate of accidents per train-mile

n_{HM} = number of cars of hazardous material per train

n_{HMR} = number of cars which release some or all of their contents per accident

f_{RHM-M} = fraction of such releases which are major

2.1 TOTAL RATE OF ACCIDENTS PER TRAIN-MILE (λ_t)

Data from Accident/Incident Bulletins were used to calculate the total rate per train mile of railroad accidents. Some of this data is reproduced in Appendix A. The latest data, for the years 1977 through 1982 shows a range of from 8 x 10^{-6} to 13.8 x 10^{-6} accidents per train mile based on a range of between 10,362 and 4,589 accidents and between 7.3 x 10^{8} and 5.7 x 10^{8} total train miles. These accidents usually (75% of the time) involve derailments and in about 40% of the time are due to track defects.

The data is also divided according to speed on three different track locations: main line, yard, and industry siding/unknown. In 1982, the fractions attributed to these types were 48%, 43% and 9%, respectively. Shocks and Roy were assumed to be main line track. For this year of main line data 32% of all accidents occurred when the trains were traveling at 10 miles per hour or less and 52% at 20 miles per hour or less.

During the period from 1968 to 1982 covered by References 20 and 21, the threshold for declaring a rail problem, an "accident," went up by a factor of three, from $750 to $4100. This probably had some effect in reducing the frequency of accidents per train mile. As shown in Table A-1, the rate of accidents varied from 9.2×10^{-6} in 1968 to a peak rate of 1.5×10^{-5} in 1978 back down to a rate of 8×10^{-6} in 1982 after the change in reporting criteria. Based on this data, a mean value of 1×10^{-5} was used for the total frequency of accidents per train-mile.

2.2 NUMBER OF CARS OF HAZARDOUS MATERIAL PER TRAIN (n_{HM})

The Accident/Incident Bulletin data excerpted in Appendix A shows that between 504 and 842 trains were involved in accidents during 1975-1982 while carrying hazardous materials. In these trains were a total of between 2,297 and 4,711 cars containing hazardous material. This produces an average 5 cars per train for this whole period, with a yearly average of between 4.6 and 7.4.

2.3 NUMBER OF CARS WHICH RELEASE HAZARDOUS MATERIALS PER ACCIDENT (n_{HMR})

From the 3,884 trains which transported hazardous materials between 1975 and 1982 and were involved in accidents, 850 cars produced releases. This results in an average over this period of 0.22 cars carrying hazardous materials releasing some or all of their contents per accident. The yearly average over this period varied between 0.18 and 0.23.

2.4 FRACTION OF TANK CAR RELEASES WHICH ARE MAJOR (f_{RHM-M})

Following the technique utilized in Appendix H.2 of the Midland PRA [Ref. 25], the fraction of tank car releases which are major was implied from the number which required evacuation of the area around the accident. From the data given in Reference 14, this ratio ranges from 10% to 26%, with a mean value of 18%. The mean value was used in this calculation.

The fact that a release was major, i.e., requiring evacuation, was used in turn to imply that the tank was not just leaking, it was ruptured and released its entire contents rapidly. The release rate from a tank car which was sufficient to prompt an evacuation would, of course, depend on the local authorities and on the toxicity of the chemical released. No site specific data of this type could be obtained for TMI.

2.5 SUMMARY

The numbers discussed in the last four sections are to be inserted into Equation 2-1 as follows:

$$\lambda_T = \lambda_t \, n_{HMR} \, f_{RHM-M} \, / n_{HM} \qquad (2\text{-}1)$$

$$= (1 \times 10^{-5}) \, (0.22) \, (0.18)/(5)$$

$$= 8.0 \times 10^{-8} \text{ per (car-mile)}$$

This number will be used in Section 4 to develop the frequency of exceeding the 10CFR100 offsite dose rate.

3.0 DETERMINATION OF THE CONDITIONAL PROBABILITY OF EXCEEDENCE OF CONTROL ROOM HABITABILITY STANDARDS, GIVEN A MAJOR RELEASE, FOR EACH CHEMICAL

In this section, the methodology, data, and procedures used to determine the habitability of the control room for various chemical releases and meteorological conditions will be discussed. These methods will then be used to determine the conditional probability that a major release will result in the exceedence of control room habitability standards. In the case of the fixed storage tank no more needs be done for this part of the calculation; however, for the cases involving rail cars, the conditional probability varies along the track. In the latter case, therefore, the conditional probability is integrated along the track to complete this phase of the calculation.

3.1 EVAPORATION AND DISPERSION MODELS

The evaporation and dispersion of contaminants resulting from a hazardous chemical spill are analyzed using a modification of the methods suggested in NUREG-0570[1] and Reg. Guide 1.78.[2] The most significant modifications are:

1. Plumes resulting from the spill of chemicals whose vapors are much lighter than air are treated as both buoyant and non-buoyant plumes.

2. Enhanced dispersion due to plume meandering during neutral and stable low wind speed meteorological conditions is accounted for.

3. Enhanced dispersion due to interaction of the plume with the reactor building complex is accounted for if tall structures are in the path of the plume as it travels from its source toward the control room air intake vent.

The various components of the evaporation and dispersion models are presented below. The modifications presented above are discussed in detail. It is shown that the modified models still provide conservative estimates of control room toxic vapor concentrations. The model assumes that the entire contents of a single railroad tankcar or stationary storage container is released to the environment instantaneously. Preliminary analysis showed that this assumption results in a "worst case" scenario in the control room.

3.1.1 Evaporation Models

The evaporation model contains the following components:

1. A model to calculate the time dependent surface area of a liquid spill.

2. A model to calculate the initial flashing of a compressed gas or pure low boiling point liquid release and the boil-off of the remaining liquid pool (Vaporization Class I).

3. A model to calculate the evaporation rate of a chemical that is a pure liquid at ambient conditions (Vaporization Class II).

4. A model to calculate the evaporation rate of the toxic components of a liquid mixture (Vaporization Class III).

3.1.1.1 Surface Area of Liquid Spill

The time dependent surface area of the liquid spill is calculated as suggested in NUREG-0570.[1] The suggested equation is due to Van Ulden.

$$A(t) = \Pi \left\{ r_o^2 + 2 \left[\frac{g v_o}{\Pi \rho_\ell} (\rho_\ell - \rho_a) \right]^{1/2} t \right\} \qquad (3\text{-}1)$$

where

r_o = initial radius of spill, cm

g = acceleration due to gravity = 980 cm/sec^2

V_o = volume of liquid spill, cm^3

ρ_ℓ = density of liquid, gm/cm^3

ρ_a = density of air, gm/cm^3

t = time, sec

The initial radius of the spill is given by

$$V_o = \Pi r_o^3 \qquad (3\text{-}2)$$

It should be noted that in the case of Vaporization Class I chemicals, V_o is the volume of the liquid that remains after instantaneous flashing to puff has taken place.

The maximum liquid spiii area is estimated from the initial liquid volume by assuming a final spill thickness of 1 cm. This is an extremely conservative assumption. The spill achieves its final thickness rapidly. Since the evaporation rate is directly proportional to spill area, the result is extremely high evaporation rates. Preliminary calculations showed that, in general, the higher the evaporation rate, the greater the impact of the resulting plume on the control room.

3.1.1.2 Vaporization of Compressed Gases and Low Boiling Point Liquids (Vaporization Class I)

According to NUREG-0570[1], the mass of chemical which is instantaneously flashed to form a puff release is calculated from

$$M_{vo} = M_T C_p (T_a - T_b)/H_v \qquad (3\text{-}3)$$

M_{vo} = mass of instantaneously vaporized (flashed) chemical, gm

M_T = total initial mass of spilled chemical, gm

C_p = liquid heat capacity of chemical, cal/gm-°C

T_a = ambient temperature, °C

T_b = normal boiling point of chemical, °C

H_v = heat of vaporization of chemical at normal boiling point, cal/gm

The portion of the release which does not flash to puff will form a liquid pool whose surface area is given by equation (3-1). This liquid (M_t - M_{vo}) will vaporize by absorption of atmospheric and solar radiation, convection of air and ground conduction. NUREG-0570 gives the following formula for calculating the vaporization (boil-off) rate:

$$\dot{M}_v(t) = \frac{A(t)}{H_v} \left[q_r + h_c (T_a - T_b) + 197 (T_E - T_b)/t^{1/2} \right] \qquad (3\text{-}4)$$

where

$\dot{M}_v(t)$ = vaporization rate, gm/sec

q_r = solar and atmospheric radiation fluxes, cal/m^2-sec

h_c = heat transfer coefficient for wind convection, cal/m^2-sec-°C

T_E = ground (earth) temperature, °C

T_b = chemical's normal boiling point, °C

$A(t)$ = liquid spill surface area, m^2

H_v = heat of vaporization, cal/gm

t = time after accident, sec

The wind convection heat transfer coefficient is conservatively assumed to equal 1.6 cal/m^2-sec-°C as suggested in NUREG-0570. Since radiation flux data were not available, q_r was conservatively assumed to equal 275 cal/m^2sec for unstable conditions as suggested in NUREG-0570. q_r was assumed equal to 200 cal/m^2-sec and 0 cal/m^2-sec for neutral and stable conditions, respectively, since the radiation flux for neutral atmosphere is less than that for unstable atmospheres and since stable conditions occur at night. The values used for h_c and q_r do not significantly affect the calculations in most cases since evaporation due to ground conduction (last term in brackets in equation 3-4) far outweighs that due to radiation and wind convection except at extremely long times after release. At these long times the concentration in the control room has usually passed its maximum.

3.1.1.3 Evaporation of Pure Chemicals which are Liquids at Ambient Conditions (Vaporization Class II)

The evaporation of a Vaporization Class II liquid in an open space with wind or in a confined area with good ventilation is given by Equations (2.1-18) and (2.1-20) of NUREG-0570:

$$\dot{M}_v(t) = h_d M_w A(t) (P_s - P_a)/R\ T_a \qquad (3\text{-}5)$$

where

h_d = forced convection mass transfer coefficient, cm/sec

M_w = molecular weight of chemical, gm/gm mol

T_a = absolute ambient temperature, °K

P_s = saturation partial pressure of chemical's vapor above liquid at temperature T_a, atm

P_a = partial pressure of chemical's vapor in ambient air, atm

R = universal gas constant = 82.05 cm^3-atm/gm mol-°K

For a pure liquid, the saturation partial pressure of its vapor is equal to its vapor pressure, P_v. In this study the concentration of the spilled chemical in ambient air was assumed to be negligible. Therefore, $P_a = 0$ resulting in conservative estimates of the evaporation rate. The forced convection mass transfer coefficient for a turbulent atmosphere is given by:

$$h_d = 0.037 \frac{D}{L} R_e^{0.8} S_c^{0.33} \qquad (3\text{-}6)$$

where

D = mass diffusivity of chemical in air, cm^2/sec

L = characteristic length of liquid spill, cm

R_e = $(L \bar{U} \rho_a)/\mu_a$ = Reynolds Number, dimensionless

S_c = $\mu_a/(\rho_a D)$ = Schmidt Number, dimensionless

$\bar{U}$ = mean wind velocity, cm/sec

ρ_a = density of ambient air, gm/cm^3

μ_a = viscosity of ambient air, gm/cm-sec

The characteristic length of the spill is taken as the spill diameter. Therefore:

$$L(t) = \left(\frac{4A(t)}{\pi}\right)^{1/2} \qquad (3\text{-}7)$$

3.1.1.4 Evaporation of Liquid Mixtures (Vaporization Class III)

Equations (3-5) to (3-7) also apply to the evaporation of liquid mixtures. The only difference in their application is that, in a strict sense, these equations must be applied to each mixture component, individually. M_w and P_s are then the molecular weight and saturation partial pressure, respectively, of a particular component. The total mixture evaporation rate is the sum of the evaporation rates of the individual components. Similarly, the total saturation pressure is the sum of the individual component partial pressures.

Several difficulties arise in the application of equations (3-5) to (3-7) to mixtures. Due to the different relative volatilities of the mixture component, each evaporates at a different rate; that is, the more volatile components evaporate initially while the higher boiling point components tend to remain in the liquid phase. As time passes, the liquid spill becomes depleted in its more volatile components and enriched in its less volatile components. The component saturation partial pressures are, among other things, a function of the mole fraction of the components in the liquid phase. As a result, the partial pressures and the total saturation pressure are a complex function of time.

In general, the individual component partial pressures are a function of temperature, composition (mole fraction) and the molecular interactions which occur between the different chemicals in the liquid mixture. It is therefore necessary to consider hydrocarbon mixtures, aqueous solutions and other solutions, separately.

3.1.1.4.1 Evaporation of Hydrocarbon Mixtures (Vaporization Class III-A)

Generally, all components of a hydrocarbon mixture are both volatile and toxic. Hydrocarbon mixtures consist of "similar chemicals", so it may be assumed that they exhibit ideal solution behavior, following Raoult's Law for ideal solutions:[3]

$$P_{si} = X_i \, P_{vi} \qquad (3\text{-}8)$$

where X_i = mole fraction of component i in liquid

P_{si} = partial pressure of component i above the liquid mixture, atm

The evaporation rate of each component may be found by applying equations (3-5) through (3-7). By taking time steps small enough that the composition of the mixture does not change appreciable over the time step, the remaining mass of each component and hence the mole fractions may be recomputed at each time step. Since each component of the mixture has a different toxicity level and molecular weight, the contribution of each component is normalized to the reference toxicity and molecular weight with the normalizing factor F_i, given by:

$$F_i = \frac{M_{W1} T_{L1}}{M_{Wi} T_{Li}} \qquad (3\text{-}9)$$

where

M_{Wi} = molecular weight of component i

T_{Li} = toxic limit of component i

The effective evaporation rate (referenced to component 1) is thus

$$\dot{M}_{VE}(t) = \sum_{i=1}^{N} F_i \dot{M}_{Vi}(t) \qquad (3\text{-}10)$$

where

$\dot{M}_{VE}(t)$ = effective evaporation rate, considered to be component 1.

$\dot{M}_{Vi}(t)$ = evaporation rate of component i.

The only chemical considered in this category is Coal Tar-Light Oil.

3.1.1.4.2 Evaporation of Aqueous Solutions (Vaporization Class III-B)

The aqueous solutions considered in this study are ammonium hydroxide, hydrochloric acid and formaldehyde solutions. The basic method discussed in the previous section is used with two exceptions. First, the solutions are not ideal, so actual partial pressure data is used. Second, only one component is considered toxic.

In the case of ammonium hydroxide and hydrochloric acid, good, accurate partial pressure data is available.[4] Formaldehyde is shipped either in aqueous solution or in solution with both water and methanol. The methanol inhibits polymerization of the formaldehyde with water to form methylene glycol and its polymers. Although complete data is not available on the ternary solution, it is known that the methanol serves to increase the partial pressure of formaldehyde over the solution. Also, the toxic limit for methanol is forty times that for formaldehyde, so it can safely be ignored (except for the increase in formaldehyde partial pressure). Thus, the formaldehyde is treated as an aqueous solution (for which adequate data does exist) but with the partial pressure of formaldehyde increased by an appropriate factor to account for the presumed presence of methanol.

3.1.1.4.3 Evaporation of Solutions with Solvents Other Than Water (Vaporization Class III-C)

The only chemical in this class is Chromic Fluoride solution. The only solvent for Chromic Fluoride is Hydrogen Fluoride. Chromic Fluoride is a non-volatile salt which is solid at ambient temperatures. Although part of the hydrogen fluoride solvent will flash at temperatures above its boiling point, only about 10% will flash at the highest temperatures occuring at TMI-1. Any chromic fluoride in the fraction which flashes should thus be entrained in the remaining hydrogen fluoride, which would evaporate leaving the chromic fluoride behind. Thus, the chromic fluoride solution is treated as pure hydrogen fluoride, and the chromic fluoride is ignored in the calculation.

3.1.2 Dispersion Models

Gaussian plume models are employed in this study to account for the dispersion of the instantaneous puff formed by instantaneous flashing of a Vaporization Class I chemical and the continuous plume formed from boil-off evaporation of the liquid spills. The models presented in NUREG-0570 are modified to account for plume rise, meandering and plume-building wake interactions.

3.1.2.1 Instantaneous Puff Model

In applying the instantaneous puff model, it is assumed that the wind is always blowing from the accident source directly toward the control room air intake vent. The concentration at the air intake vent is given by (NUREG-0570):

$$C_{puff}(t) = \frac{M_{vo}}{(2\Pi)^{3/2}\ \sigma_{XI}\sigma_{YI}\sigma_{ZI}} \exp\left[-\frac{1}{2}\left(\frac{X_o - \bar{U}t}{\sigma_{XI}}\right)^2\right]$$

$$\left\{\exp -\frac{1}{2}\left(\frac{Z-H}{\sigma_{ZI}}\right)^2 + \exp -\frac{1}{2}\left(\frac{Z+H}{\sigma_{ZI}}\right)^2\right\} \quad (3\text{-}11)$$

$$\sigma_{XI} = \left(\sigma_X^{\ 2} + \sigma_I^{\ 2}\right)^{1/2}$$

$$\sigma_{YI} = \left(\sigma_Y^{\ 2} + \sigma_I^{\ 2}\right)^{1/2} \quad (3\text{-}12)$$

$$\sigma_{ZI} = \left(\sigma_Z^{\ 2} + \sigma_I^{\ 2}\right)^{1/2}$$

$$\sigma_I = \left(\frac{2\ M_{vo}}{(2\Pi)^{\ 3/2}\ \rho_v}\right)^{1/3} \quad (3\text{-}13)$$

where

$C_{puff}(t)$ = concentration of toxic vapor at the air intake vent at time t, gm/m^3

$\sigma_X, \sigma_Y, \sigma_Z$ = standard deviations of the puff concentration in the along-wind, cross-wind, and vertical directions, respectively, as given in Reg. Guide 1.78,[2] meters

$\sigma_{XI}, \sigma_{YI}, \sigma_{ZI}$ = standard deviations adjusted to account for the initial puff dimensions, meters

X_o = downwind distance from accident source to air intake vent, meters

$\overline{U}$ = mean wind speed, m/sec

t = time after accident, sec

Z = height of air intake vent above grade at the accident source, meters

H = height of puff centerline, meters

ρ_V = density of pure toxic vapor at ambient temperature, gm/m^3

3.1.2.2 Continuous Plume Model

In applying the continuous plume model, it is assumed that the wind is always blowing from the accident source directly toward the air intake vent. The concentration at the air intake vent is given by (NUREG-0570).

$$C_{plume}(t) = \frac{M_v(t-t_o)}{2\Pi\sigma_y\,\sigma_Z\,\overline{U}}\left[\exp -\frac{1}{2}\left(\frac{Z-H(x_o,t-t_o)}{\sigma_Z}\right)^2 + \exp -\frac{1}{2}\left(\frac{Z+H(x_o,t-t_o)}{\sigma_Z}\right)^2\right] \tag{3-14}$$

$$\sigma_Y = \left[\sigma_Y^{\,2} + \sigma_o\,(t-t_o)^2\right]^{1/2}$$

and (3-15)

$$\sigma_o(t-t_o) = \frac{A(t-t_o)^{1/2}}{4.3}$$

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where

σ_Y, σ_Z = crosswind and vertical continuous plume standard deviations as given by Turner[5] evaluated at X_o, meters

σ_Y = crosswind standard deviation adjusted for the finite size of the liquid spill, meters

σ_o = initial value of σ_Y (at chemical spill), meters

$C_{plume}(t)$ = concentration at air intake vent at time t, gm/m^3

t_o = time at which continuous plume initially reaches vent, sec.

It should be noted that $A(t-t_o)$ is interpreted as A evaluated at time $t-t_o$. A similar interpretation should be given to all variables followed by $(t-t_o)$. $H(x_o, t-t_o)$ means H evaluated at distance x_o and time $t-t_o$.

The time at which the continuous plume first reaches the vent is given by:

$$t_o = X/\overline{U} \quad (3\text{-}16)$$

At time t_o, the plume source strength at the vent is equal to the spill evaporation rate at time zero, that is $M_v(t=o)$. Therefore, at any time $t > t_o$, the source strength of the plume segment in contact with the vent is given by $M_v(t-t_o)$. The same line of reasoning applies to the adjusted crosswind plume standard deviation, σ_Y and the plume centerline height, H. Therefore, all plume parameters are adjusted to account for the finite travel time interval, t_o, between the accident source and the vent as indicated by equations (3-14) and (3-15). Such adjustment is necessary so that the instantaneous puff (if it occurs) and the continuous plume equations can be applied simultaneously. Note that the height of the continuous plume centerline may also be a function of travel distance, X_o, if credit for plume rise is taken.

3.1.2.3 Plume Rise

3.1.2.3.1 Vapors Much Lighter Than Air

For toxic vapors much lighter than air, such as ammonia, the rise of the continuous plume centerline was calculated using the Briggs plume rise formulae (References 8 to 12). These are:

Neutral and Unstable Atmospheres:

$$\Delta h_1 = 1.6\ F(t)^{1/3}\quad X_o^{2/3}\ \overline{U}^{-1}$$

(3-17a)

$$\Delta h_2 = 1.6\ F(t)^{1/3}\quad (3.5\ x^*)^{2/3}\ \overline{U}^{-1}$$

$$x^* = 14\ F^{5/8} \qquad F \leq 55\ m^4/sec^3$$

$$x^* = 34\ F^{2/5} \qquad F \geq 55\ m^4/sec^3$$

(3-17b)

$$H(X_c,t) = h_s + Min(\Delta h_1,\ \Delta h_2)$$

Stable Atmospheres

$$\Delta h_3 = 1.6\ F(t)^{1/3}\quad X_o^{2/3}\ \overline{U}^{-1}$$

$$\Delta h_4 = 2.6\ \ F(t)/\overline{U}S)^{1/3}$$

(3-18)

$$\Delta h_5 = 4.0\ \ F(t)^{1/4}\ S^{-3/8}$$

$$S = \frac{g}{T_a}\ \frac{\partial\theta}{\partial Z}$$

$$H\ (X_o,t) = h_s + Min\ (\Delta h_3,\ \Delta h_4,\ \Delta h_5)$$

where

$F(t)$ = plume buoyancy flux at time t, m^4/sec^3

h_s = height of release, meters

S = stability parameter, sec^{-2}

$\partial\theta/\partial Z$ = gradient of atmospheric potential temperature, °C/m

The plume buoyancy flux is given by

$$F(t) = (1 - \rho_v/\rho_a) \frac{M_v(t)\ g}{\pi \rho_v} \qquad (3\text{-}19)$$

Equation (3-19) follows logically from the development given in Reference 6.

For all buoyant releases considered in this study, the release height, h_s, was assumed equal to zero. The gradient of potential temperature was assumed equal to .02, .0375 and .05 °C/m for E, F and G stabilities, respectively. For instantaneous puff releases, the plume centerline height was assumed equal to continuous plume centerline height at time zero. This is a conservative assumption for the cases considered since the instantaneous puff has considerably more buoyant potential than the continuous plume.

It should be noted that no credit was taken for plume meandering or plume-building wake interactions for buoyant plumes which rise above the reactor building complex (to be discussed later).

3.1.2.3.2 Non-Buoyant Vapors

For vapors much heavier than air, the plume centerline was assumed to be at ground level. For vapors whose density does not differ significantly from that of air, the plume centerline height was assumed equal to the air intake vent height. These assumptions are not substantially different since the TMI Unit 1 air intake vent is only about 16 feet above ground level.

3.1.2.4 Plume Meandering

There is ample evidence to confirm the existence of plume meandering in the vicinity of the TMI site during stable, low wind speed conditions. A series of SF_6 tracer gas atmospheric diffusion experiments were conducted on Three Mile Island during 1971. The results of these experiments are reported in Reference 7. They confirm the existence of plume meandering for releases in open areas and for releases affected by building wake interactions. As a result, the continuous plume dispersion model was modified to account for plume meandering as prescribed in Regulatory Guide 1.145.[8] According to Reg. Guide 1.145, σ_y in equations (3-14) and (3-15) is replaced by Σ_y where

$$\Sigma_y = (M-1)\,\sigma_{y800} + \sigma_y \qquad X_o \geq 800 \text{ meters} \tag{3-20}$$

$$\Sigma_y = M\,\sigma_y \qquad X_o \leq 800 \text{ meters}$$

where

σ_{y800} = value of σ_y at a distance of 800 meters, meters

σ_y = value of σ_y at distance X_o, meters

M = plume meander factor given in Figure 3 of Reg. Guide 1.145

Plume meander factors were not applied to the instantaneous puff model since the effect of meandering on puff dispersion is not presently well understood.

3.1.2.5 Plume-Building Wake Interactions

Figure 3-1, a plan view of the TMI Nuclear Station, gives the location of the Unit 1 control room air intake vent relative to the reactor building complex and natural draft cooling towers. The figure shows that plumes approaching the vent from the west and south are unobstructed while plumes approaching from the other directions must pass around or over some portion of the reactor building complex and cooling towers in order to reach the vent. Dispersion in the vicinity of these structures are too complex to model accurately. As a result, a relatively simple but conservative modification was applied to the instantaneous puff and continuous plume dispersion models. The modification involves adjusting the plume standard deviations (sigmas) to reflect interaction with the reactor-building complex. No credit is taken for interaction with the cooling towers even though they can significantly enhance plume dilution. The sigmas are adjusted as follows:

1. Instantaneous Puff Release

   σ_{XI} remains unchanged

   $$\sigma_{YI} = \text{MAX}\ (\sigma_{YI},\ W_b/4.3) \qquad (3\text{-}21)$$

   $$\sigma_{ZI} = \text{MAX}\ (\sigma_{ZI},\ H_b/2.15)$$

2. Continuous Plume

   $$\sigma_{Y} = \text{MAX}\ (\sigma_{Y},\ W_b/4.3) \qquad (3\text{-}22)$$

   $$\sigma_{Z} = \text{MAX}\ (\sigma_{Z},\ H_b/2.15)$$

where

W_b = projected width of reactor building complex in direction normal to the wind, meters

H_b = projected height of reactor building complex in direction normal to the wind, meters

It is seen from equation (3-22) that credit can only be taken for plume-building wake interactions or meandering, but not both simultaneously. For buoyant plumes, no building wake credit is taken if the plume centerline height is greater than or equal to H_b.

In applying the dispersion models, credit for plume-building wake interactions can be taken for spills occuring on the East Bank ("Roy") train line and at stationary storage tanks located onsite and offsite north and east of TMI. No credit can be taken for spills occuring on the West Bank ("Shocks") train line.

3.1.2.6 Other Considerations

It is seen that the instantaneous puff dispersion model takes credit for buoyant plume rise or plume-wake interactions but not both, simultaneously. The continuous plume dispersion model accounts for aonly one of buoyant plume rise, meandering, or plume-wake interactions. The phenomenon accounted for is the one that results in the greatest plume dilution. No attempt was made to account for interactions of a spill with rain, or Susquehanna river water or for chemical reactions that the spilled chemical may undergo in the environment.

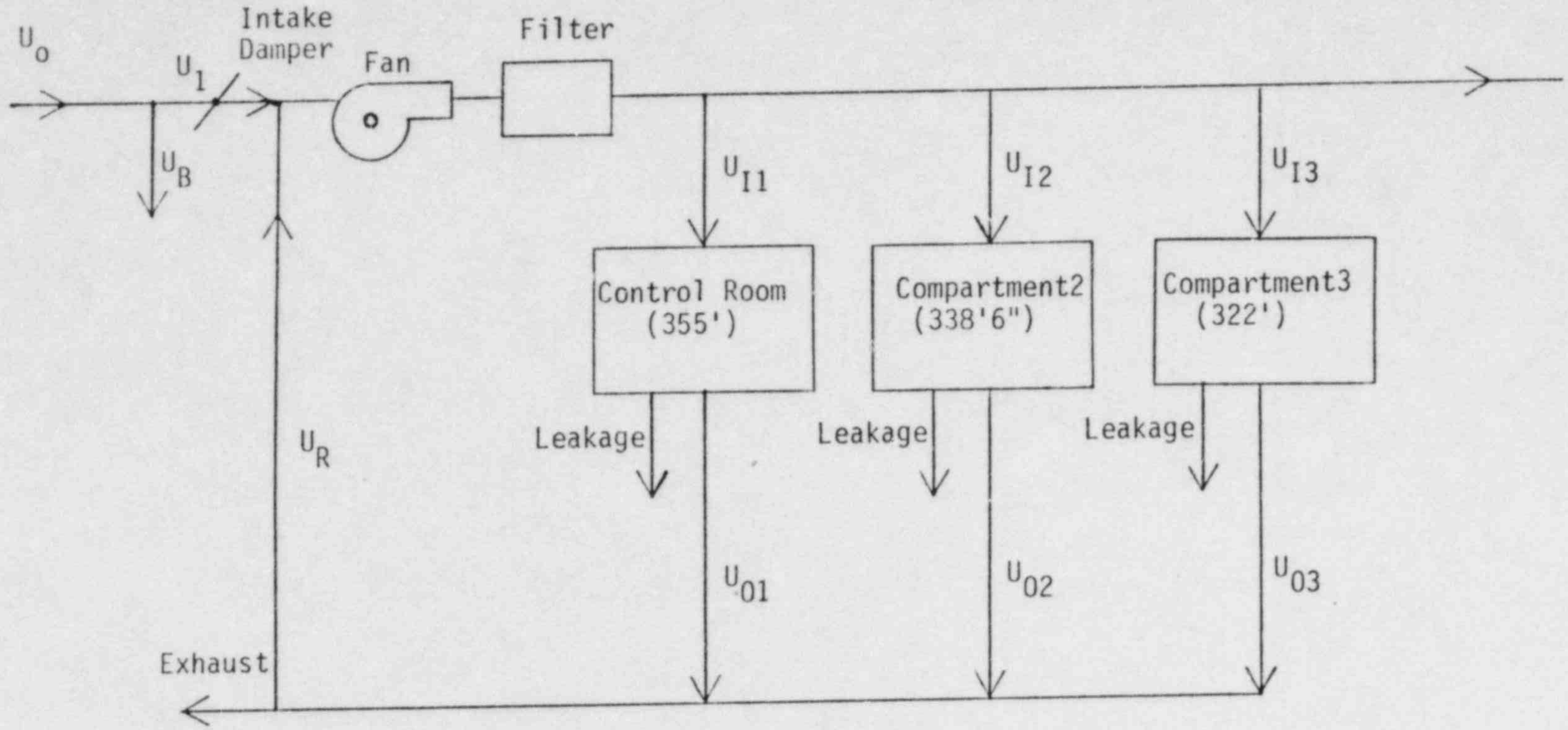
3.1.3 Modeling of Toxic Gas Concentrations in the Control Room Isolation Zone

The model for toxic gas concentrations in the control room isolation zone is shown in Figure 3-1.

A variety of possible configurations may be analyzed with the computer code used for this analysis. The code's capabilities include the following:

1) Ability to alarm at the source, at the mouth of the intake tunnel, and in the control room.
(2) Ability to activate two separate actions (changes in flow rates or filtration parameters or backflushing the intake tunnel) at specified times after reaching the alarm setpoint. This is necessary to model automatic action followed by operator response.
(3) Ability to model flow through the intake tunnel including changes in flow rates.
(4) Ability to correct the input centerline atmospheric dilution factors to average values for large intake flow rates.

Figure 3-1 Model for Toxic Gas Concentration



The first two items entail the use of logic models which check the concentrations at the three locations specified at each time step and, if specified concentration is passed (either increasing or decreasing) setting an initial (automatic) response time equal to the current time plus delays before the actions are completed. When this time is passed, a control card is read (a separate card is specified for each possible alarm source, separately for increasing and decreasing past the limit) which may change flow parameters, filtration or may specify backflushing of the intake tunnel. Optionally, an operator response may be selected in a similar manner after a delay time specified on the card for the automatic response.

The intake tunnel model converts the rate of introduction of the toxic gas (evaporation or leakage in grams per second) into a concentration at the mouth of the intake tunnel at a later time, the delay being equal to the ratio of the distance between the source and the mouth of the intake tunnel to the wind speed. This concentration is tracked from the mouth of the tunnel to the intake damper, moving forward by a volume equal to the product of the length of the time step and the intake flow rate. If this volume is greater than the intake tunnel volume, the appropriate time delay is used instead. At the intake damper, a portion of the flow, U_B, is diverted to the halls and machine shop, while the remainder, U_1 goes into the control room ventilation system.

The final modification is used to correct for the fact that the intake tunnel may be drawing air from a volume over which the concentration varies greatly. If no correction is performed, the amount of toxic gas can, under some circumstances, be overestimated to the point that more gas would be taken in than was actually released. To alleviate this problem, the conservative approach shown below was used.

It is assumed that a cross-section of the plume taken in the crosswind plane at the intake has a gaussian distribution with standard deviations σ_y in the horizontal direction and σ_z in the vertical direction traveling at windspeed $\bar{V}$. Since the plume is reflected by the ground, it will have a dilution factor as a function of horizontal distance y and vertical distance z of

$$\frac{\chi}{Q} = \frac{1}{\pi \bar{V} \sigma_y \sigma_z} \exp -\left(\frac{y^2}{2\sigma_y^2} + \frac{z^2}{2\sigma_z^2}\right). \tag{3-23}$$

Isopleths of constant concentration will thus be given by

$$\left(\frac{y}{\sigma_y}\right)^2 + \left(\frac{z}{\sigma_z}\right)^2 = S^2. \tag{3-24}$$

Bearing in mind that $z \geq 0$, this isopleth is a semiellipse with an area of

$$A = \frac{1}{2} \pi \sigma_y \sigma_z s^2 \tag{3-25}$$

It is assumed that the intake flow is taken from the area bounded by such an isopleth, thus conservatively maximizing the amount of toxic gas taken in. The required area is

$$A = \frac{U}{\bar{V}} \tag{3-26}$$

where U is the intake flow rate. Setting the areas in (3-25) and (3-26) equal,

$$s^2 = \frac{2U}{\pi \bar{V} \sigma_y \sigma_z} = \frac{2\chi_o U}{Q} \tag{3-27}$$

where χ_o/Q is the value of (3-23) at y=z=o, the centerline atmospheric dilution factor. Integrating (3-27) over the area bounded by the isopleth (3-24) and multiplying by the windspeed $\bar{v}$ yields the fraction R of toxic gas which is introduced into the vent:

$$R = 1 - \exp(-s^2/2) = 1 - \exp(-\chi_o U/Q). \tag{3-28}$$

It is seen that, in accordance with physical reality, this fraction varies from zero to one as U increases from zero to infinity. Dividing R by the uncorrected flow rate into the tunnel gives the required correction factor

$$F_c = \frac{1-\exp(-x_o U/Q)}{(x_o U/Q)} \qquad (3\text{-}29)$$

which reduces to unity for small flow rates.

The data input by the user consists of the volume (V_i) of each compartment, the volumetric flow rate (u_i) into that compartment, the volumetric flow rate from that compartment into the recirculation loop (u'_j), the intake volumetric flow rate (u_o), the filter efficiency (η), and the volume of the intake duct (V_D). Other pertinent variables are the intake concentration in the intake duct ($C_o(t)$) and the concentration of the chemical in each compartment as a function of time ($C_i(t)$). The concentrations are then governed by the equations

$$\frac{dC_i}{dt} = \sum_{j=1}^{3} \gamma_{ij}\, C_j\,(t) + v_i C_o(t) \qquad (3\text{-}30)$$

where

$$\lambda_i = u_i/V_i \qquad (3\text{-}31)$$

$$u_R = \sum_{i=1}^{3} u'_i \qquad (3\text{-}32)$$

$$\alpha_i = u'_i/u_R \qquad (3\text{-}33)$$

$$\beta = \frac{u_R}{u_R + u_o} \qquad (3\text{-}34)$$

$$\gamma_{ij} = (1-\eta)\,\beta\,\lambda_i\,\alpha_j - \lambda_i\,\sigma_{ij} \qquad (3\text{-}35)$$

and

$$v_i = (1-\eta)\,(1-\beta)\,\lambda_i. \qquad (3\text{-}36)$$

The set of equations (3-30) has a particular solution and three linearly independent homogeneous solutions. It is assumed the $C_o(t)$ may be adequately represented in some time interval k beginning at t_k by

$$C_o(t) = A_k \exp[\lambda_k (t-t_k)] \qquad t_k < t < t_{k+1} \tag{3-37}$$

The particular solution then has the form

$$C_{Ii}(t) = F_i \exp[\lambda_k (t-t_k)] \tag{3-38}$$

Substituting this expression into equation (3-30) at t_k yields

$$\sum_{j=1}^{3} (\gamma_{ij} - \lambda_k \sigma_{ij}) F_j = v_i A_k \tag{3-39}$$

This set of linear equations is solved in CRCONI by Gauss-Jordan elimination. In order to find the homogeneous solution which matches the boundary conditions (the concentration in each compartment at time t_k, computed in the previous time step), the characteristic equation of the matrix $[\gamma_{ij}]$ is first solved for the eigenvalues of $[\gamma_{ij}]$, W_j, and the corresponding eigenvectors. Let E_{ij} be the element of eigenvector j corresponding to compartment i. The solution in interval k is then given by

$$C_i(t) = \sum_{j=1}^{3} E_{ij}^{-1} \left[B_j e^{W_j (t-t_k)}\right] + F e^{W_k (t-t_k)} \tag{3-40}$$

Using the known concentrations at time t_k, the unknown values B_j may be found by solving the set of linear equations

$$\sum_{j=1}^{3} E_{ij} B_j = C_i(t_k) - F_i \tag{3-41}$$

In CRCONI, since the operation is carried out many times for each matrix E_{ij}, the inverse matrix E_{ij}^{-1} is found, and the unknowns B_j are found in each time step by using

$$B_j = \sum_{i=1}^{3} E_{ji}^{-1} [C_i(t_k) - F_i] \qquad (3\text{-}42)$$

This process is repeated at each time step, yielding the time dependent concentration.

3.2 METHODOLOGY EMPLOYED TO FIND THE CONDITIONAL PROBABILITY OF EXCEEDENCE

The methodology used to determine the conditional probability of exceedence is discussed below.

The maximum concentration of a chemical in the control room atmosphere after a spill is a strong function of four meteorological variables; wind direction, wind speed, stability and temperature. The evaporation rate is a function of temperature and, in many cases, windspeed. The dispersion of the plume is determined by the stability and windspeed, while the plume rise, for chemicals lighter than air, is determined by windspeed, stability and evaporation rate. Finally, the difference in the wind direction and the direction from the spill to the intake, along with the dispersion of the plume, determine what fraction of the peak concentration is present at the intake. A method has been developed to systematically take these factors into account in determining the conditional probability of exceeding the toxic limits in the control room given a chemical spill of a given amount of a given chemical at a given location.

Two methods are used for determining the ambient temperature at the time of the spill. The conservative method assumes that the evaporation takes place at the highest temperature consistant with the stability; 100°F for stability classes A through D, and 80°F for stability classes E through G. A more realistic method, used only for hydrofluoric acid spills, is to find the control room concentrations as a function of temperature. For both methods, the peak concentrations are found as a function of windspeed for a fixed atmospheric dilution factor.

The assessment of the condition probability of exceedence will be considered first for the conservative method. For each combination of wind speed and stability, the peak control room concentration, C_{max}, evaluated at an atmospheric dispersion factor of $(X/Q)_{ref}$, is compared to the toxic limit for that chemical, C_{lim}. The limiting value of the atmospheric dispersion factor, $(X/Q)_{lim}$, is found using

$$(X/Q)_{lim} = \frac{(X/Q)_{ref} \, C_{lim}}{C_{max}} \qquad (3\text{-}43)$$

Only atmospheric dispersion factors greater than $(X/Q)_{lim}$ at the vent will result in exceedence of the toxic limit in the control room. Using the meteorological methods in Reference 2, the plume standard deviations σ_y and σ_z, and the atmospheric dilution factor at the vent height and plume centerline, $(X/Q)_{CL}$ are found. If this value is less than $(X/Q)_{lim}$, the plume presents no possibility of exceeding the toxic limit for this stability and windspeed. Otherwise, a further step is required. The atmospheric dispersion factor, X/Q, has the following function form in the cross-wind direction:

$$X/Q = (X/Q)_{CL} \exp \left[-y^2/2\sigma_y{}^2\right] \qquad (3\text{-}44)$$

where y is the lateral distance between the plume centerline and the vent, measured perpendicular to the wind direction at the vent height, and X/Q is the atmospheric dilution at that point. Thus the plume only presents a hazard within a band within y_{lim} of the centerline, where y_{lim} is the solution of (3-2) at $(X/Q)_{lim}$:

$$y_{lim} = \sigma_y \;\; 2 \, \ell n \left[(X/Q)_{CL}/(X/Q)_{lim}\right]^{1/2} \qquad (3\text{-}45)$$

The half-width of the sector of the plume for which exceedences occur is thus

$$A = \tan^{-1} (y_{lim}/x) \qquad (3\text{-}46)$$

where x is the distance from the spill to the intake. Let the wind direction which would carry the vapor directly toward the vent be B. The wind directions between B-A and B+A lead to exceedences. Using meteorological data for a sample year, tabulated in the form of the number of occurrences of a given stability with a given range of windspeeds and a given range of directions, the number of occurances of wind directions between B-A and B+A for the given stability and windspeed are found. These results are summed over all windspeeds and stabilities and the sum divided by the total number of hours of meteorological data in the sample year, yielding the conditional frequency of exceedence of toxicity limits in the control room, given a spill.

For the more realistic method, the same procedure is followed, except that meteorological data is grouped in to 10°F ranges, and the conditional probability is found for that temperature range. These are multiplied by the probabilities of their respective groups and summed over all temperature groups to give the conditional frequency of exceedence.

For the rail sources (as opposed to the fixed source), the track is broken into segments, with each segment represented by its central point. The conditional probability of exceedence at that point is multiplied by the length of the segments, and the resulting values summed over the length of the rail line considered. The portion of the track considered is that within 5 miles of the plant.[2] The resulting line integral of the conditional probability is multiplied by the frequency of major releases of that chemical per mile per year to find the frequency of exceedence for that chemical.

TABLE 3.1 PROPERTIES OF CHEMICALS CONSIDERED

Chemical	Formula	Toxic Limit (ppm)	Odor Threshold (ppm)	Quantity Shipped, Tons		Molecular Weight
				Roy	Shocks	
Acetic Acid, Glacial	CH_3COOH	20	1.0	73.1	79.9	60.05
Acetic Anhydride	$(CH_3CO)_2O$	10	0.14	91.3	79.4	102.1
Acrylonitrile	CH_2CHCN	40	--	--	65.8	53.06
Ammonia, Anhydrous	NH_3	100	46.8	40.9	73.5	17.03
Ammonium Hydroxide, 29.4 wt % aqueous(1)	NH_4OH/H_2O	(2)	(2)	--	--	(2)
Bromine	Br_2	0.3	3.5	--	29.6	159.83
Chlorine	Cl_2	15	3.5	--	85.0	70.91
Chromic Fluoride, 20 wt % in HF	CrF_3/HF	(3)	(3)	96.7	--	(3)
Coal Tar, Light Oil	(4)	(4)	(4)	--	71.5	(4)
Ethyl Acrylate	$CH_2CHCOOC_2H_5$	50	.00024	81.7	76.8	100.12
Ethylene Oxide	$(CH_2)_2O$	200	--	--	78.6	44.05
Formaldehyde	HCHO	10	0.8	--	93.1	30.03
Hexane	$CH_3(CH_2)_4CH_3$	200	--	--	73.8	86.17
Hydrochloric Acid, 36 wt % aqueous	HCl/H_2O	100	1-5	--	92.5	36.47
Hydrogen Fluoride, anhydrous	HF	6	--	78.2	84.6	20.01
Phosphorus Oxychloride	$POCl_3$	0.5	--	--	33.5	153.39
Propylene Oxide	OCH_2CHCH_3	200	200	--	68.8	58.08
Vinyl Acetate	$CH_3COOCHCH_2$	20	0.12	--	79.5	86.05
Vinyl Chloride	CH_2CHCl	1000	260	39.9	92.6	62.56

Chemical	Boiling Point (1 atm)°C	Relative Vapor Density	Liquid Density gm/cm^3	Liquid Heat Capacity cal/gm-°C	Heat of Vaporization cal/gm	Diffusivity at 0°C cm^2/sec
Acetic Acid, Glacial	118.1	2.07	1.05	.490	96.75	0.106
Acetic Anhydride	140.	3.52	1.08	0.398	92.2	0.074
Acrylonitrile	77.3	1.83	0.806	0.500	173.68	0.082
Ammonia, Anhydrous	-33.4	0.597	0.674	1.10	327.4	0.169
Ammonium Hydroxide, 29.4 wt % aqueous(1)	92.4	(2)	.897	--	--	(2)
Bromine	58.73	5.5	2.93	0.107	44.9	0.085
Chlorine	-34.5	2.49	1.57	0.226	68.8	0.114
Chromic Fluoride, 20 wt % in HF	(3)	(3)	(3)	(3)	(3)	(3)
Coal Tar, Light Oil	(4)	(4)	(4)	(4)	(4)	(4)
Ethyl Acrylate	99.8	3.45	0.941	0.450	20.9	0.070
Ethylene Oxide	10.7	1.52	0.897	0.476	138.5	0.106
Formaldehyde	97.	1.07	1.1	--	--	0.142
Hexane	68.7	2.97	0.660	0.541	87.5	0.060
Hydrochloric Acid, 36 wt % aqueous	-84.8	1.268	1.179	--	--	0.158
Hydrogen Fluoride, anhydrous	19.54	0.69	0.967	0.61	80.5	0.167
Phosphorus Oxychloride	105.1	5.3	1.69	--	54.63	.072
Propylene Oxide	33.9	2.0	0.830	0.507	111.	0.088
Vinyl Acetate	73.	3.0	0.934	0.433	95.2	0.076
Vinyl Chloride	-13.4	2.15	0.92	0.38	79.8	0.096

Notes:

(1) 12,000 gallon tank 4400 m North of intake
(2) Use values for Ammonia
(3) Use values for Hydrogen Fluoride
(4) See Table 3.3

TABLE 3.2 VAPOR PRESSURES OF PURE SUBSTANCES (Atm)*

CHEMICAL NAME	0 F	10 F	20 F	30 F	40 F	50 F	60 F	70 F	80 F	90 F	100 F
ACETIC ACID, GLACIAL	0.001260	0.001896	0.002804	0.004081	0.005852	0.008322	0.011711	0.016198	0.022086	0.029886	0.040205
ACETIC ANHYDRIDE	0.000270	0.000435	0.000686	0.001062	0.001616	0.002418	0.003563	0.005175	0.007411	0.010474	0.014594
ACRYLONITRILE	0.015441	0.021729	0.030009	0.040653	0.054426	0.072208	0.094402	0.121956	0.156795	0.200151	0.253278
AMMONIA	2.154480	2.759291	3.497616	4.390771	5.462057	6.736758	8.242136	10.007402	12.063670	14.443903	17.182842
BENZENE	0.007719	0.012391	0.019282	0.029212	0.042705	0.059767	0.079557	0.104173	0.134999	0.172742	0.219097
BROMINE	0.024285	0.037962	0.056715	0.076822	0.102886	0.136127	0.177227	0.228449	0.291687	0.3690[illegible]4	0.463107
CHLORINE	1.961497	2.430244	2.984227	3.633887	4.390228	5.264782	6.269566	7.417034	8.720029	10.191735	11.845625
ETHYL ACRYLATE	0.003366	0.005101	0.007537	0.010817	0.015422	0.021900	0.030306	0.040847	0.054608	0.073782	0.096711
ETHYLENE OXIDE	0.286759	0.375391	0.485931	0.619283	0.779800	0.973083	1.203970	1.477712	1.799976	2.176838	2.614781
HEXANE	0.020966	0.029508	0.041016	0.056116	0.075165	0.099420	0.130063	0.167488	0.213614	0.269907	0.336869
HYDROGEN FLUORIDE	0.214830	0.275437	0.354646	0.451944	0.568187	0.703007	0.862720	1.050565	1.270004	1.524720	1.818604
INDENE	0.000113	0.000177	0.000270	0.000405	0.000598	0.000870	0.001247	0.001764	0.002463	0.003398	0.004634
NAPHTHALENE	0.000001	0.000002	0.000004	0.000008	0.000015	0.000027	0.000048	0.000082	0.000140	0.000234	0.000383
PHOSPHORUS OXYCHLORIDE	0.003491	0.005172	0.007537	0.010817	0.015301	0.021352	0.029170	0.038791	0.051043	0.066744	0.086364
PROPYLENE OXIDE	0.095184	0.129985	0.172503	0.226154	0.293313	0.376585	0.478870	0.601215	0.746645	0.919974	1.125115
STYRENE	0.000597	0.000904	0.001347	0.001974	0.002850	0.004054	0.005691	0.007829	0.010587	0.014173	0.018825
TOLUENE	0.002591	0.003860	0.005655	0.008173	0.011652	0.016300	0.022445	0.030432	0.040654	0.053731	0.070160
VINYL ACETATE	0.013351	0.019075	0.026837	0.036960	0.050254	0.067588	0.089920	0.118397	0.154501	0.199828	0.256088
VINYL CHLORIDE	0.841472	1.069301	1.345306	1.676753	2.071519	2.538081	3.085510	3.723452	4.462104	5.312195	6.284951
XYLENE	0.000624	0.000964	0.001463	0.002182	0.003203	0.004631	0.006601	0.009211	0.012695	0.017296	0.023305

* Interpolated and extrapolated from Perry and Chilton, Chemical Engineers Handbook, Tables 3-7 and 3-8. Values greater than 1 atmosphere may be subject to considerable error, but are not used in the report.

TABLE 3.3 COMPONENTS OF COAL TAR-LIGHT OIL

Chemical	Formula	Weight Fraction	Toxic Limit (ppm)	Molecular Weight	Liquid Density	Diffusivity at 0°C cm^2/sec
Benzene	.7808	C_6H_6	60	78.1	.8794	.077
Indene	.0169	C_9H_8	24	116.2	.9968	.0608
Nophthalene	.0132	$C_{10}H_8$	22.5	128.6	1.162	.0513
Sturene	.0120	C_8H_8	145	104.14	.9074	.0652
Toluene	.1456	C_7H_8	235	92.1	.866	.076
Xylene	.0315	C_8H_{10}	475	106.2	.87	.0645

TABLE 3.4 PARTIAL PRESSURES OF FORMALDEHYDE AND WATER OVER AQUEOUS SOLUTIONS OF FORMALDEHYDE*

Temperature °C	Weight % Formaldehyde	Partial Pressure of Formaldehyde, mm of hg
0	7.97	0.056
0	15.0	0.102
0	19.4	0.118
0	28.6	0.157
20	9.25	0.340
20	18.6	0.575
20	27.2	0.780
20	28.6	0.795
20	36.2	1.025
35	1.08	0.166
35	5.10	0.695
35	11.4	1.29
35	18.3	1.80
35	19.7	1.94
35	28.6	2.48
35	35.6	2.81
45	10.5	2.30
45	19.4	3.79
45	27.1	4.72
45	35.5	5.60

* 9% Methanol increases all formaldehyde partial pressures by a factor of 1.56. P_w is given by

$$P_w = 10^{8.677-2168/T_a}$$

where P_w is the partial pressure of water in mm of mercury and T_a is the ambient temperature in degrees kelvin.

TABLE 3.5 JOINT FREQUENCY TABLE - NUMBER OF OCCUPANCES OF WIND SPEED AND DIRECTION FOR EACH STABILITY CLASS

1982 DATA BELOW 5 DEGREES F

STABILITY A

SPEED	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
CALM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
18.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	3	2	0	0
24.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	4	2	0	0
24.6+MPH	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0

STABILITY B

SPEED	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
CALM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4.5 MPH	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
5.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18.5 MPH	0	0	0	0	0	0	0	0	0	0	0	2	2	2	0	0
24.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24.6+MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

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TABLE 3.5 (continued)

STABILITY C

SPEED	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
CALM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4.5 MPH	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
5.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6.5 MPH	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
7.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18.5 MPH	0	0	0	0	0	0	0	0	0	0	1	0	2	0	0	0
24.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
24.6+MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

STABILITY D

SPEED	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
CALM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.5 MPH	0	0	0	0	1	0	1	1	0	0	1	0	1	0	0	0
4.5 MPH	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
5.5 MPH	0	0	0	0	1	0	0	0	0	1	0	0	1	0	0	0
6.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12.5 MPH	0	0	0	0	0	0	0	0	0	0	0	2	2	0	0	0
18.5 MPH	0	0	0	0	0	0	0	0	0	0	0	4	1	5	0	0
24.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	0
24.6+MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 3.5 (continued)

STABILITY E

SPEED	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
CALM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.5 MPH	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0
3.5 MPH	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
4.5 MPH	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
5.5 MPH	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
6.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
7.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
18.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24.6+MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

STABILITY F

SPEED	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
CALM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24.6+MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 3.5 (continued)

STABILITY G

SPEED	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
CALM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7.5 MPH	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
12.5 MPH	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
18.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24.6+MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

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TABLE 3.6 JOINT FREQUENCY TABLE - NUMBER OF OCCURANCES OF WIND SPEED AND DIRECTION FOR EACH STABILITY CLASS

1982 DATA FROM 5 TO 15 DEGREES F

STABILITY A

SPEED	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
CALM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
4.5 MPH	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6.5 MPH	0	0	0	0	0	0	0	0	0	0	[illegible]	0	0	0	0	0
7.5 MPH	0	0	0	0	0	0	0	0	0	0	[illegible]	0	0	0	0	0
12.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0
18.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
24.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	4	1	0	0
24.6+MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

STABILITY B

SPEED	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
CALM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
12.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
24.6+MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

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TABLE 3.6 (continued)

STABILITY C

SPEED	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
CALM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	C	0	0	0
3.5 MPH	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
4.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
12.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
18.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0	0
24.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0
24.6+MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

STABILITY D

SPEED	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
CALM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5 MPH	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	1
2.5 MPH	3	2	2	2	2	0	0	0	0	1	0	1	0	0	0	0
3.5 MPH	1	1	0	0	1	1	0	0	0	0	1	0	0	0	0	0
4.5 MPH	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0
5.5 MPH	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0
6.5 MPH	0	0	0	0	1	0	0	0	0	0	0	0	2	0	0	0
7.5 MPH	1	0	0	0	1	0	1	0	0	0	0	0	0	0	0	1
12.5 MPH	0	0	0	0	0	2	1	0	0	0	0	2	7	1	0	1
18.5 MPH	0	0	0	0	0	0	0	0	0	0	0	2	5	3	0	0
24.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
24.6+MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

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TABLE 3.6 (continued)

STABILITY E

SPEED	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
CALM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5 MPH	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
2.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.5 MPH	0	0	1	0	1	0	1	1	0	0	0	0	0	0	0	0
4.5 MPH	2	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
5.5 MPH	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
6.5 MPH	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
7.5 MPH	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1	0
12.5 MPH	0	0	0	0	0	0	0	0	0	0	0	1	2	2	0	0
18.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24.6+MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

STABILITY F

SPEED	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
CALM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
5.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0	1
6.5 MPH	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	1
7.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
12.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
18.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
24.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24.6+MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

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TABLE 3.6 (continued)

STABILITY G

SPEED	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
CALM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5 MPH	0	0	0	0	1	0	1	0	0	0	0	0	1	0	0	0
2.5 MPH	0	0	0	1	0	0	1	2	2	4	1	0	0	0	0	0
3.5 MPH	0	0	0	2	4	0	1	0	0	1	0	1	0	0	0	1
4.5 MPH	0	0	0	0	0	1	2	1	0	0	0	0	1	1	0	0
5.5 MPH	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0
6.5 MPH	0	0	0	0	0	1	0	0	0	0	0	1	0	0	1	0
7.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
18.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24.6+MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 3.7 JOINT FREQUENCY TABLE - NUMBER OF OCCURANCES OF WIND SPEED AND DIRECTION FOR EACH STABILITY CLASS

1982 DATA FROM 15 TO 25 DEGREES F

STABILITY A

SPEED	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
CALM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
2.5 MPH	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
3.5 MPH	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	0
4.5 MPH	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0
5.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
6.5 MPH	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
7.5 MPH	0	0	0	0	0	0	1	0	0	1	0	1	0	3	0	0
12.5 MPH	1	0	0	0	0	0	0	0	0	0	0	1	3	6	4	5
18.5 MPH	1	0	0	0	0	0	0	0	0	0	0	0	1	0	7	3
24.5 MPH	1	0	0	0	0	0	0	0	0	0	0	0	2	2	2	4
24.6+MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0

STABILITY B

SPEED	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
CALM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
5.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
7.5 MPH	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0
12.5 MPH	1	0	0	0	0	0	0	0	0	0	0	0	1	2	1	0
18.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	3	1	2
24.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	1	4	0	0
24.6+MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0

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TABLE 3.7 (continued)

STABILITY C

SPEED	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
CALM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.5 MPH	1	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0
3.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
4.5 MPH	0	1	1	1	0	0	0	0	0	0	0	1	0	0	0	0
5.5 MPH	0	0	0	1	1	0	1	0	1	0	0	0	0	0	2	0
6.5 MPH	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
7.5 MPH	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1
12.5 MPH	1	0	0	0	0	0	0	0	0	0	0	0	0	3	1	0
18.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	2	4	3
24.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0	0
24.6+MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

STABILITY D

SPEED	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
CALM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.5 MPH	1	1	2	1	3	0	0	0	1	0	1	0	1	1	1	2
3.5 MPH	2	3	2	0	2	3	1	3	0	0	0	1	2	1	2	1
4.5 MPH	2	3	2	3	3	3	1	2	2	0	0	1	1	1	0	0
5.5 MPH	1	0	8	1	0	3	0	0	0	0	0	0	2	0	3	1
6.5 MPH	6	1	1	0	1	5	1	0	1	0	0	1	2	0	2	1
7.5 MPH	3	0	1	2	2	6	3	0	0	0	0	0	2	1	0	1
12.5 MPH	4	2	0	3	1	3	6	0	1	0	0	0	3	14	7	7
18.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	3	17	4	2
24.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	3	2	1
24.6+MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

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TABLE 3.7 (continued)

STABILITY E

SPEED	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
CALM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5 MPH	1	1	0	1	0	0	1	0	2	1	2	0	0	0	0	0
2.5 MPH	1	0	2	3	0	0	1	0	0	2	1	0	0	0	0	0
3.5 MPH	2	1	2	1	2	3	0	0	0	0	0	1	0	3	0	1
4.5 MPH	3	0	0	0	2	1	0	0	1	1	0	1	1	0	1	1
5.5 MPH	2	0	0	0	1	0	0	0	0	0	0	0	1	0	0	1
6.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
7.5 MPH	1	0	0	0	1	0	0	0	0	0	0	0	3	0	0	0
12.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	6	2	0
18.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1
24.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24.6+MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

STABILITY F

SPEED	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
CALM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5 MPH	0	0	0	0	3	1	2	0	0	0	1	0	0	0	1	0
2.5 MPH	0	1	1	0	1	2	2	0	1	1	0	0	1	0	0	0
3.5 MPH	0	0	1	0	0	0	0	1	1	0	0	0	0	0	0	0
4.5 MPH	3	0	0	0	0	1	0	0	0	0	0	0	2	1	0	0
5.5 MPH	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
6.5 MPH	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24.6+MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 3.7 (continued)

STABILITY G

SPEED	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
CALM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5 MPH	0	0	0	2	0	2	1	1	2	3	1	2	0	0	0	0
2.5 MPH	3	0	1	1	1	0	2	1	2	0	2	1	0	1	2	0
3.5 MPH	0	0	0	0	1	2	0	1	0	0	0	0	1	0	0	1
4.5 MPH	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
5.5 MPH	1	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0
6.5 MPH	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
7.5 MPH	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24.6+MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 3.8 JOINT FREQUENCY TABLE - NUMBER OF OCCURANCES OF WIND SPEED AND DIRECTION FOR EACH STABILITY CLASS

1982 DATA FROM 25 TO 35 DEGREES F

STABILITY A

SPEED	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
CALM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.5 MPH	0	0	0	0	0	0	0	0	0	1	1	1	0	1	2	1
3.5 MPH	1	1	0	0	0	0	0	2	0	0	1	0	0	1	2	1
4.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5.5 MPH	1	0	0	0	1	0	1	0	2	1	0	0	1	0	0	3
6.5 MPH	0	0	1	1	0	0	0	0	0	0	0	0	1	0	1	1
7.5 MPH	0	0	0	0	0	0	1	0	1	0	1	0	0	1	2	1
12.5 MPH	1	0	1	0	0	1	0	0	1	0	4	3	6	6	4	13
18.5 MPH	6	0	0	0	0	0	0	0	0	0	0	0	1	4	13	10
24.5 MPH	3	0	0	0	0	0	0	0	0	0	0	0	0	3	6	4
24.6+MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1

STABILITY B

SPEED	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
CALM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.5 MPH	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
3.5 MPH	0	0	0	0	0	1	0	0	0	1	0	0	0	0	1	1
4.5 MPH	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	1
5.5 MPH	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0
6.5 MPH	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0
7.5 MPH	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0
12.5 MPH	0	0	0	0	1	1	0	0	0	0	0	0	2	4	0	0
18.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	0
24.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0
24.6+MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0

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TABLE 3.8 (continued)

STABILITY C

SPEED	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
CALM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5 MPH	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
2.5 MPH	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
3.5 MPH	1	0	0	0	0	0	2	1	0	0	0	0	0	0	0	0
4.5 MPH	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0
5.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
6.5 MPH	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
7.5 MPH	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
12.5 MPH	0	0	0	0	2	3	1	0	0	1	0	0	2	1	0	2
18.5 MPH	1	0	0	0	0	0	0	0	0	0	1	0	0	1	5	1
24.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0
24.6+MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

STABILITY D

SPEED	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
CALM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5 MPH	1	3	1	2	1	3	1	0	0	0	1	0	2	0	0	2
2.5 MPH	1	2	2	7	5	2	3	3	1	1	0	0	3	1	1	5
3.5 MPH	5	3	4	6	14	4	5	5	2	2	1	1	2	2	2	4
4.5 MPH	2	4	5	7	6	15	4	2	6	2	2	0	1	2	3	2
5.5 MPH	0	0	3	2	9	13	6	3	2	0	1	1	1	4	1	3
6.5 MPH	1	0	2	3	7	9	6	2	4	0	2	0	0	2	7	6
7.5 MPH	1	1	3	2	1	12	6	1	1	1	0	0	5	6	3	4
12.5 MPH	9	3	5	6	3	10	10	3	0	2	3	0	6	18	16	9
18.5 MPH	2	0	0	0	1	0	0	0	0	0	0	0	2	24	31	6
24.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
24.6+MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

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TABLE 3.8 (continued)

STABILITY E

SPEED	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
CALM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5 MPH	3	0	1	2	0	3	3	2	7	1	5	3	0	2	2	1
2.5 MPH	7	2	0	1	5	4	4	1	3	5	1	3	2	1	3	3
3.5 MPH	1	8	1	3	3	3	1	1	2	4	0	0	1	1	2	7
4.5 MPH	5	2	2	2	2	5	4	1	0	1	1	2	0	1	2	2
5.5 MPH	3	0	1	1	1	5	2	0	0	1	1	3	0	4	1	3
6.5 MPH	3	0	0	0	0	0	0	1	0	0	5	1	0	1	1	3
7.5 MPH	3	0	0	0	0	0	1	0	1	0	0	3	3	3	0	4
12.5 MPH	0	0	0	0	0	0	0	0	0	1	5	2	4	10	2	2
18.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
24.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24.6+MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

STABILITY F

SPEED	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
CALM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5 MPH	1	1	3	2	2	2	3	2	2	5	0	0	1	1	2	0
2.5 MPH	2	2	4	1	2	4	6	3	6	3	2	4	2	3	0	1
3.5 MPH	3	1	0	1	4	4	2	2	1	5	0	4	1	1	0	5
4.5 MPH	2	0	1	1	4	1	0	1	0	0	0	0	1	0	2	1
5.5 MPH	1	0	0	1	2	2	0	0	0	0	1	0	2	0	0	3
6.5 MPH	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
7.5 MPH	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
12.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
18.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24.6+MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 3.8 (continued)

STABILITY G

SPEED	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
CALM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5 MPH	0	0	0	0	0	1	0	0	1	2	0	0	1	0	0	0
2.5 MPH	0	1	1	0	0	1	0	2	3	2	3	0	0	0	1	0
3.5 MPH	0	0	0	1	1	1	2	0	0	0	0	0	0	0	0	0
4.5 MPH	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
5.5 MPH	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
6.5 MPH	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0
7.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24.6+MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 3.9 JOINT FREQUENCY TABLE - NUMBER OF OCCURANCES OF WIND SPEED AND DIRECTION FOR EACH STABILITY CLASS

1982 DATA FROM 35 TO 45 DEGREES F

STABILITY A

SPEED	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
CALM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5 MPH	0	0	0	0	0	0	1	0	1	0	0	1	0	0	0	0
2.5 MPH	1	0	0	0	0	0	0	2	1	1	0	2	3	1	1	1
3.5 MPH	5	0	0	0	1	1	2	1	2	3	0	1	0	1	1	0
4.5 MPH	0	0	0	0	0	0	3	1	0	1	3	0	1	0	1	1
5.5 MPH	1	0	0	0	0	4	1	0	0	0	0	1	0	1	0	3
6.5 MPH	1	0	0	0	0	0	1	0	1	0	0	0	0	0	3	1
7.5 MPH	1	0	0	0	0	0	0	0	0	0	1	2	0	0	0	2
12.5 MPH	1	0	0	0	0	0	0	0	4	1	2	1	11	10	9	4
18.5 MPH	2	0	0	0	0	0	0	0	0	0	0	0	5	5	3	1
24.5 MPH	1	0	0	0	0	0	0	0	0	0	0	0	1	1	4	1
24.6+MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

STABILITY B

SPEED	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
CALM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5 MPH	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
2.5 MPH	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	2
3.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
4.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
5.5 MPH	0	0	0	0	2	1	0	0	0	1	0	0	0	1	0	1
6.5 MPH	0	0	0	0	1	0	1	1	0	0	0	0	0	0	0	1
7.5 MPH	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0
12.5 MPH	0	0	0	0	0	0	2	0	1	0	0	0	1	1	2	0
18.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	3	1	0	0
24.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0
24.6+MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

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TABLE 3.9 (continued)

STABILITY C

SPEED	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
CALM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4.5 MPH	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0
5.5 MPH	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0
6.5 MPH	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0
7.5 MPH	0	0	0	0	0	1	0	0	1	0	0	1	0	0	0	1
12.5 MPH	0	0	0	0	0	0	0	1	1	0	0	0	0	0	1	0
18.5 MPH	0	0	0	0	0	0	0	0	0	0	0	1	0	9	1	1
24.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1
24.6+MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

STABILITY D

SPEED	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
CALM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5 MPH	0	0	1	0	1	2	0	1	1	0	0	0	0	1	0	1
2.5 MPH	2	3	3	0	2	1	2	0	0	0	0	1	0	1	0	0
3.5 MPH	1	4	2	4	8	13	10	2	2	2	0	0	1	0	0	1
4.5 MPH	1	1	3	4	6	16	4	3	6	1	1	0	1	1	3	1
5.5 MPH	1	4	3	2	5	8	3	3	3	2	1	1	2	3	1	2
6.5 MPH	3	1	4	2	4	8	7	7	7	1	0	2	1	2	1	2
7.5 MPH	0	1	4	2	1	4	2	2	1	1	2	1	4	3	1	2
12.5 MPH	2	1	2	0	2	4	2	1	1	1	0	0	12	38	46	9
18.5 MPH	3	0	0	0	0	0	1	0	0	0	1	0	8	31	35	13
24.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	8	9	6	6
24.6+MPH	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0

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TABLE 3.9 (continued)

STABILITY E

SPEED	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
CALM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5 MPH	1	0	3	1	2	0	1	0	3	2	2	0	1	1	0	0
2.5 MPH	1	2	1	6	4	6	3	1	1	1	2	1	5	2	1	2
3.5 MPH	8	2	4	2	10	6	5	2	4	2	0	3	2	4	4	7
4.5 MPH	3	0	2	2	3	2	1	3	4	0	1	4	7	2	4	7
5.5 MPH	2	4	0	1	5	1	2	1	4	2	3	4	5	3	1	4
6.5 MPH	3	1	3	0	3	3	1	0	3	0	0	0	5	2	1	5
7.5 MPH	3	0	0	0	3	2	0	1	1	0	0	1	1	2	2	1
12.5 MPH	2	0	0	0	0	1	0	0	0	0	0	0	2	13	10	14
18.5 MPH	1	0	0	0	0	0	0	0	0	0	0	0	0	1	3	5
24.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24.6+MPH	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0

STABILITY F

SPEED	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
CALM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5 MPH	0	1	1	0	3	3	2	4	2	2	0	0	1	0	0	1
2.5 MPH	0	4	2	2	2	1	4	5	4	6	2	6	3	5	3	3
3.5 MPH	0	1	1	4	5	5	2	2	1	2	2	2	3	2	0	4
4.5 MPH	3	0	0	0	0	2	3	0	0	0	0	0	2	1	0	4
5.5 MPH	1	1	0	1	0	0	0	1	0	0	0	2	1	1	1	0
6.5 MPH	1	0	0	0	0	0	0	0	0	0	0	2	1	0	1	2
7.5 MPH	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	3
12.5 MPH	0	0	0	0	0	0	1	0	0	0	0	0	0	0	4	2
18.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24.6+MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

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TABLE 3.9 (continued)

STABILITY G

SPEED	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
CALM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5 MPH	3	0	0	2	2	0	1	1	1	3	0	1	1	2	1	2
2.5 MPH	1	1	0	2	4	2	2	4	7	2	3	4	1	1	1	1
3.5 MPH	0	2	0	0	0	1	2	0	2	1	1	0	2	5	3	0
4.5 MPH	1	1	0	2	0	1	2	0	1	2	0	0	1	0	1	3
5.5 MPH	0	0	0	0	1	0	1	0	1	0	0	0	1	0	1	1
6.5 MPH	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
7.5 MPH	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	1
18.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
24.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24.6+MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 3.10 JOINT FREQUENCY TABLE - NUMBER OF OCCURANCES OF WIND SPEED AND DIRECTION FOR EACH STABILITY CLASS

1982 DATA FROM 45 TO 55 DEGREES F

STABILITY A

SPEED	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
CALM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5 MPH	0	0	0	0	0	0	0	0	0	2	0	1	0	0	0	0
2.5 MPH	0	0	0	0	0	3	0	1	0	0	0	2	1	0	0	1
3.5 MPH	1	0	0	0	0	0	0	1	0	1	0	0	1	0	0	4
4.5 MPH	0	0	0	0	0	0	1	1	1	1	1	0	0	1	0	1
5.5 MPH	1	0	0	0	0	1	1	0	1	1	0	0	0	0	0	2
6.5 MPH	0	0	0	0	0	1	1	0	1	1	1	1	0	0	0	2
7.5 MPH	2	0	0	0	0	0	0	1	1	2	0	0	2	0	0	3
12.5 MPH	5	0	1	3	2	3	3	1	2	1	1	0	6	9	9	12
18.5 MPH	2	0	0	0	0	0	0	0	0	1	0	0	1	11	13	5
24.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0
24.6+MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

STABILITY B

SPEED	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
CALM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.5 MPH	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
3.5 MPH	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
4.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5.5 MPH	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0
6.5 MPH	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
7.5 MPH	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0
12.5 MPH	1	0	1	0	0	1	0	1	1	0	0	0	1	2	1	0
18.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	1	2	2	2
24.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	2	4	0
24.6+MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

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TABLE 3.10 (continued)

STABILITY C

SPEED	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
CALM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5 MPH	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0
2.5 MPH	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0
3.5 MPH	0	0	1	0	0	0	1	1	1	0	0	0	0	0	0	0
4.5 MPH	0	0	0	0	1	0	1	1	0	0	0	0	1	0	0	0
5.5 MPH	0	0	0	0	0	2	1	0	1	0	0	0	0	0	0	0
6.5 MPH	0	0	0	0	0	1	0	1	0	0	0	0	0	0	1	0
7.5 MPH	1	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0
12.5 MPH	1	0	0	0	1	2	0	0	1	0	0	0	1	0	1	2
18.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	3
24.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
24.6+MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

STABILITY D

SPEED	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
CALM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5 MPH	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0
2.5 MPH	4	1	1	0	1	1	3	2	0	0	1	0	1	0	0	1
3.5 MPH	0	0	1	1	1	3	2	3	1	0	0	0	3	1	1	0
4.5 MPH	3	1	2	0	4	5	3	4	4	0	0	0	1	1	1	2
5.5 MPH	1	3	3	2	2	6	4	3	2	0	1	1	0	1	3	0
6.5 MPH	1	0	5	8	5	6	0	5	2	0	0	1	1	1	1	0
7.5 MPH	0	0	2	7	8	4	1	3	2	0	0	0	3	2	2	1
12.5 MPH	4	2	3	7	17	8	0	2	2	1	2	1	7	17	16	6
18.5 MPH	3	0	0	0	1	0	0	0	0	1	0	0	2	23	17	7
24.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	1	1	8	0
24.6+MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0

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TABLE 3.10 (continued)

STABILITY E

SPEED	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
CALM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5 MPH	0	1	1	3	2	2	1	1	3	1	0	3	4	1	0	0
2.5 MPH	3	0	1	7	5	4	3	2	3	0	3	0	6	1	3	3
3.5 MPH	3	2	3	1	6	9	2	2	2	2	3	3	1	2	2	6
4.5 MPH	4	0	1	1	2	9	5	7	1	1	0	3	1	1	2	2
5.5 MPH	2	1	0	2	2	13	8	7	1	2	1	2	2	1	3	0
6.5 MPH	4	0	0	1	1	1	7	6	4	2	0	2	1	3	4	6
7.5 MPH	1	0	0	0	0	6	8	3	1	3	1	2	5	1	6	2
12.5 MPH	2	0	0	0	1	1	3	3	7	1	7	2	16	16	15	3
18.5 MPH	0	0	0	0	0	1	0	0	2	0	0	0	10	6	11	1
24.5 MPH	0	0	0	0	0	0	0	0	0	0	0	2	0	1	1	1
24.6+MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

STABILITY F

SPEED	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
CALM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5 MPH	0	0	0	2	2	2	2	2	7	2	1	3	2	0	0	0
2.5 MPH	3	2	0	0	4	3	7	6	2	2	4	3	2	1	6	2
3.5 MPH	2	0	0	0	5	5	5	1	0	1	1	1	0	1	1	4
4.5 MPH	3	1	0	0	2	5	3	0	0	0	0	0	0	0	2	5
5.5 MPH	1	1	0	0	1	4	2	2	0	1	0	0	1	0	0	1
6.5 MPH	3	0	0	0	0	2	0	0	0	0	0	1	2	0	0	0
7.5 MPH	1	0	0	0	0	0	1	0	0	0	0	0	1	0	1	1
12.5 MPH	3	0	0	0	0	0	1	0	0	0	0	1	0	2	0	4
18.5 MPH	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
24.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24.6+MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 3.10 (continued)

STABILITY G

SPEED	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
CALM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5 MPH	0	0	0	0	2	1	3	3	6	3	3	2	2	1	0	1
2.5 MPH	2	2	0	0	4	3	2	3	5	1	1	3	3	2	4	2
3.5 MPH	0	0	0	1	2	7	3	2	1	1	0	1	1	1	1	0
4.5 MPH	1	0	0	0	1	1	1	0	0	0	0	2	0	0	1	0
5.5 MPH	1	0	0	0	0	5	1	1	0	1	0	0	0	0	0	1
6.5 MPH	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
7.5 MPH	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
12.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
18.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24.6+MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 3.11 JOINT FREQUENCY TABLE - NUMBER OF OCCURANCES OF WIND SPEED AND DIRECTION FOR EACH STABILITY CLASS

1982 DATA FROM 55 TO 65 DEGREES F

STABILITY A

SPEED	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
CALM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5 MPH	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
2.5 MPH	0	3	1	0	0	3	1	1	3	0	0	2	2	2	0	3
3.5 MPH	1	1	0	0	3	1	0	0	1	0	0	1	1	3	8	7
4.5 MPH	2	0	0	1	0	0	0	0	0	0	1	0	2	0	1	6
5.5 MPH	2	0	0	1	0	4	0	0	1	1	0	0	0	2	4	3
6.5 MPH	4	1	0	2	1	0	0	1	1	3	1	0	0	2	1	5
7.5 MPH	0	1	0	0	0	1	0	1	0	0	0	0	0	1	5	5
12.5 MPH	5	1	1	0	0	1	1	1	4	7	0	1	3	0	20	10
18.5 MPH	2	0	0	0	0	2	0	0	1	0	0	0	1	0	3	11
24.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
24.6+MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

STABILITY B

SPEED	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
CALM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.5 MPH	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0
3.5 MPH	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0
4.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
5.5 MPH	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0
6.5 MPH	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	1
7.5 MPH	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0
12.5 MPH	0	0	0	0	0	0	0	1	1	1	0	0	1	1	1	0
18.5 MPH	0	0	0	0	0	1	0	0	0	0	1	0	2	5	2	0
24.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24.6+MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

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TABLE 3.11 (continued)

STABILITY C

SPEED	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
CALM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5 MPH	C	0	0	0	0	0	0	0	0	0	0	0	0	0	C	0
2.5 MPH	1	0	0	0	0	0	0	0	0	0	0	0	2	0	0	1
3.5 MPH	1	0	0	0	0	0	0	C	0	0	0	0	0	0	1	1
4.5 MPH	0	0	1	0	0	1	0	0	0	0	0	0	C	0	1	0
5.5 MPH	2	0	0	0	2	0	1	0	0	0	0	0	0	0	0	0
6.5 MPH	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1
7.5 MPH	0	0	0	0	1	0	1	0	0	1	0	0	0	0	0	0
12.5 MPH	0	0	0	0	0	0	0	0	1	0	0	0	2	3	0	0
18.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0
24.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
24.6+MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

STABILITY D

SPEED	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
CALM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5 MPH	1	2	1	1	3	2	1	1	2	0	0	0	0	0	0	0
2.5 MPH	7	2	1	5	2	4	0	2	1	0	1	2	4	4	0	2
3.5 MPH	4	2	3	6	10	8	4	1	1	2	1	1	3	3	1	4
4.5 MPH	5	2	2	3	8	11	7	10	1	4	2	2	0	3	4	3
5.5 MPH	2	3	1	5	18	11	6	1	7	0	0	0	2	0	3	4
6.5 MPH	5	3	4	8	9	6	3	4	4	2	0	0	3	2	2	2
7.5 MPH	2	0	6	9	5	4	3	1	2	4	1	0	1	1	1	2
12.5 MPH	2	0	3	7	18	10	2	9	16	3	1	3	13	7	8	2
18.5 MPH	0	0	0	0	3	0	0	1	3	2	0	0	3	4	7	2
24.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1
24.6+MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

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TABLE 3.11 (continued)

STABILITY E

SPEED	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
CALM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5 MPH	1	4	5	2	2	3	1	7	4	1	2	5	0	1	0	1
2.5 MPH	6	3	7	10	7	12	7	3	6	3	3	7	9	10	2	9
3.5 MPH	3	3	8	11	23	14	9	5	5	7	3	2	8	6	4	3
4.5 MPH	11	5	5	12	25	7	10	7	11	0	2	0	5	9	3	6
5.5 MPH	11	2	3	3	6	13	5	10	3	9	2	2	1	6	4	7
6.5 MPH	13	2	0	2	1	2	1	5	4	3	2	2	3	1	3	5
7.5 MPH	1	5	1	0	3	4	1	2	4	3	0	1	1	4	3	2
12.5 MPH	8	2	2	2	0	1	0	9	10	6	6	9	9	18	12	8
18.5 MPH	1	0	0	0	0	0	0	0	0	4	2	1	8	4	5	5
24.5 MPH	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0
24.6+MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

STABILITY F

SPEED	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
CALM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5 MPH	1	0	0	0	4	6	8	10	8	7	5	7	3	3	2	3
2.5 MPH	1	2	1	2	5	11	10	6	5	5	9	4	4	4	3	4
3.5 MPH	3	3	0	0	7	12	5	3	5	4	0	6	1	4	7	6
4.5 MPH	4	1	2	2	9	8	2	3	2	1	0	0	3	4	3	8
5.5 MPH	2	0	1	2	2	3	2	0	1	1	0	1	3	3	3	5
6.5 MPH	2	0	1	0	0	1	0	0	0	1	1	1	3	2	3	3
7.5 MPH	1	0	0	0	0	2	0	0	0	0	0	0	1	3	1	3
12.5 MPH	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	7
18.5 MPH	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
24.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24.6+MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 3.11 (continued)

STABILITY G

SPEED	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
CALM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5 MPH	1	0	0	0	3	3	2	4	5	3	1	3	0	0	2	0
2.5 MPH	0	1	1	2	3	3	6	2	8	4	5	0	2	0	1	1
3.5 MPH	1	0	0	2	4	10	4	4	2	2	1	3	0	0	1	0
4.5 MPH	0	0	0	0	1	3	3	1	2	1	1	0	0	1	1	1
5.5 MPH	0	0	1	0	1	0	1	0	1	0	0	0	1	1	3	0
6.5 MPH	0	0	0	0	1	0	0	0	0	0	0	0	0	0	3	1
7.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
12.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24.6+MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 3.12 JOINT FREQUENCY TABLE - NUMBER OF OCCURANCES OF WIND SPEED AND DIRECTION FOR EACH STABILITY CLASS

1982 DATA FROM 65 TO 75 DEGREES F

STABILITY A

SPEED	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
CALM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.5 MPH	3	1	0	0	0	0	0	0	0	1	0	2	3	3	2	7
3.5 MPH	8	0	1	0	0	0	3	4	3	4	5	3	3	4	10	12
4.5 MPH	5	3	0	0	1	1	3	1	0	3	5	0	0	4	2	9
5.5 MPH	5	2	2	1	2	0	1	1	0	1	3	2	2	2	2	7
6.5 MPH	4	3	2	1	2	0	2	2	2	3	2	0	1	4	7	7
7.5 MPH	4	0	0	0	0	0	1	0	1	2	2	0	0	4	4	9
12.5 MPH	9	2	0	0	0	1	0	0	3	5	3	3	3	17	44	21
18.5 MPH	1	0	1	0	0	0	0	0	0	0	0	0	0	0	6	7
24.5 MPH	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
24.6+MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

STABILITY B

SPEED	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
CALM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.5 MPH	0	0	0	0	0	0	0	0	2	0	0	2	0	2	1	2
3.5 MPH	1	0	0	0	1	1	0	0	1	0	0	0	0	0	0	0
4.5 MPH	0	0	0	1	0	2	0	2	1	2	0	1	0	0	0	0
5.5 MPH	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	1
6.5 MPH	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1
7.5 MPH	1	1	0	0	0	0	0	0	0	1	0	0	0	0	1	0
12.5 MPH	0	0	1	0	0	1	0	0	2	1	0	0	1	0	2	0
18.5 MPH	0	0	0	0	0	0	0	0	1	1	0	0	1	1	0	0
24.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24.6+MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

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TABLE 3.12 (continued)

STABILITY C

SPEED	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
CALM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5 MPH	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
2.5 MPH	0	0	1	0	0	0	0	0	0	0	1	0	2	1	1	1
3.5 MPH	1	0	0	0	0	1	0	0	1	4	0	0	0	0	0	3
4.5 MPH	0	0	0	0	0	0	0	0	0	0	1	0	0	1	2	0
5.5 MPH	0	0	2	1	0	0	2	0	0	0	0	0	0	0	0	0
6.5 MPH	0	0	0	0	0	0	0	0	1	2	0	0	0	0	0	0
7.5 MPH	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
12.5 MPH	0	0	0	0	1	1	0	0	2	0	0	0	0	0	2	1
18.5 MPH	0	0	0	0	0	0	0	0	2	1	0	0	0	1	0	0
24.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24.6+MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

STABILITY D

SPEED	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
CALM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5 MPH	0	1	0	0	0	0	0	0	1	0	0	0	3	0	0	0
2.5 MPH	4	4	1	2	3	1	3	0	2	1	2	3	2	4	2	5
3.5 MPH	1	1	0	4	4	3	7	2	6	2	4	2	4	0	2	6
4.5 MPH	3	1	1	0	4	6	8	9	4	4	3	1	1	0	3	1
5.5 MPH	0	1	0	0	1	3	8	12	7	2	0	0	0	2	0	0
6.5 MPH	1	2	1	1	2	5	3	5	3	3	0	0	1	2	2	2
7.5 MPH	0	0	0	2	2	2	3	3	4	2	0	0	1	2	1	1
12.5 MPH	2	0	0	2	3	5	3	25	16	6	1	0	2	5	7	3
18.5 MPH	4	0	0	0	0	0	0	0	4	2	0	0	0	3	2	0
24.5 MPH	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1
24.6+MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

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TABLE 3.12 (continued)

STABILITY E

SPEED	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
CALM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5 MPH	1	0	2	0	2	2	2	1	0	1	0	2	2	0	2	0
2.5 MPH	5	1	1	1	7	2	1	5	8	4	4	9	8	2	4	4
3.5 MPH	5	6	3	1	14	9	6	3	15	15	8	13	5	6	3	1
4.5 MPH	5	1	3	3	4	9	10	10	11	8	11	3	3	4	3	7
5.5 MPH	3	4	1	1	5	5	4	13	11	8	1	1	1	3	4	4
6.5 MPH	4	3	2	1	1	0	6	8	5	7	3	2	0	4	4	2
7.5 MPH	3	1	0	0	1	1	2	4	4	0	0	0	1	1	7	1
12.5 MPH	6	2	0	0	0	0	3	3	11	5	2	1	4	7	12	8
18.5 MPH	1	0	0	0	0	0	0	0	4	4	0	0	1	0	4	1
24.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24.6+MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

STABILITY F

SPEED	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
CALM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5 MPH	2	0	2	1	3	3	2	3	7	7	2	2	5	1	1	2
2.5 MPH	2	1	1	0	6	10	8	4	5	5	9	3	6	3	1	3
3.5 MPH	1	1	0	3	4	5	7	3	1	2	2	3	2	1	3	2
4.5 MPH	1	1	1	2	2	4	6	3	1	3	1	1	4	3	2	3
5.5 MPH	0	1	0	0	1	1	3	2	1	0	0	1	1	2	2	2
6.5 MPH	0	0	1	0	0	0	0	1	0	0	0	0	1	1	2	2
7.5 MPH	4	0	0	0	1	0	0	0	0	0	0	0	1	1	1	0
12.5 MPH	0	0	0	0	0	0	0	0	0	0	1	0	0	0	2	2
18.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
24.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24.6+MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 3.12 (continued)

STABILITY G

SPEED	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
CALM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5 MPH	0	0	0	0	2	0	1	2	1	0	0	2	3	0	0	1
2.5 MPH	0	1	0	0	4	5	1	3	5	2	1	1	1	1	0	2
3.5 MPH	0	0	0	0	0	5	3	3	3	1	1	0	0	2	0	0
4.5 MPH	0	0	0	0	0	3	0	0	0	0	0	0	2	0	1	0
5.5 MPH	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
6.5 MPH	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0
7.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
18.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24.6+MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 3.13 JOINT FREQUENCY TABLE - NUMBER OF OCCURANCES OF WIND SPEED AND DIRECTION FOR EACH STABILITY CLASS

1982 DATA FROM 75 TO 85 DEGREES F

STABILITY A

SPEED	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
CALM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.5 MPH	2	0	1	0	2	0	0	0	0	1	0	1	1	5	3	1
3.5 MPH	4	3	0	0	1	1	0	0	5	1	5	2	8	6	8	11
4.5 MPH	4	0	2	1	C	1	0	1	3	3	3	1	3	0	5	8
5.5 MPH	3	1	1	0	1	1	1	2	0	2	3	2	5	3	4	8
6.5 MPH	2	1	0	0	2	1	3	1	2	9	2	1	0	1	7	7
7.5 MPH	0	1	0	0	0	0	0	0	0	4	4	0	1	0	3	2
12.5 MPH	3	0	0	0	0	0	4	2	6	8	4	0	2	2	14	5
18.5 MPH	0	0	0	0	0	0	2	0	0	0	0	0	1	0	0	0
24.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24.6+MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

STABILITY B

SPEED	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
CALM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.5 MPH	1	0	0	0	0	0	0	0	0	1	0	0	0	2	0	1
3.5 MPH	0	0	1	0	0	1	0	1	0	1	1	0	0	0	1	1
4.5 MPH	1	0	0	0	0	1	2	0	0	0	0	1	0	0	0	0
5.5 MPH	0	0	0	0	0	0	1	1	1	0	1	0	1	0	0	0
6.5 MPH	0	0	0	0	0	0	2	0	0	1	0	0	0	1	0	0
7.5 MPH	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0
12.5 MPH	1	0	0	0	0	0	1	0	3	6	1	1	0	1	2	0
18.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
24.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24.6+MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

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TABLE 3.13 (continued)

STABILITY C

SPEED	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
CALM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.5 MPH	1	0	1	0	0	0	0	0	0	0	0	0	0	0	2	1
3.5 MPH	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
4.5 MPH	1	0	0	0	0	0	2	0	1	0	0	0	0	1	0	0
5.5 MPH	0	0	1	0	0	1	0	1	1	0	0	1	0	1	0	0
6.5 MPH	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0
7.5 MPH	0	0	0	0	0	0	2	1	1	0	0	0	0	0	0	0
12.5 MPH	0	0	0	0	0	0	1	1	2	1	1	0	1	0	1	1
18.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
24.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24.6+MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

STABILITY D

SPEED	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
CALM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5 MPH	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0
2.5 MPH	2	0	0	1	1	0	0	0	1	0	1	2	2	5	3	3
3.5 MPH	0	1	0	0	0	2	0	1	1	2	1	2	1	2	1	3
4.5 MPH	2	0	0	0	0	0	2	4	2	0	2	2	2	0	1	2
5.5 MPH	1	0	0	2	1	2	4	2	3	3	2	2	0	0	2	1
6.5 MPH	0	1	0	0	0	0	4	9	0	7	1	1	0	2	1	0
7.5 MPH	1	0	0	0	1	0	4	1	4	1	0	1	0	3	3	1
12.5 MPH	0	0	0	0	0	0	5	5	6	10	7	2	6	6	3	0
18.5 MPH	0	0	0	0	0	0	1	0	0	3	0	0	0	0	0	0
24.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24.6+MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

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TABLE 3.13 (continued)

STABILITY E

SPEED	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
CALM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5 MPH	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	1
2.5 MPH	4	1	0	2	1	0	0	0	1	1	3	2	2	3	2	2
3.5 MPH	0	1	1	0	0	2	2	0	4	4	4	3	0	1	0	1
4.5 MPH	0	1	1	0	1	4	4	6	4	3	4	5	3	2	0	0
5.5 MPH	1	1	1	1	1	1	2	3	6	10	2	3	0	2	5	1
6.5 MPH	0	1	1	0	0	0	1	1	4	2	0	1	2	0	1	1
7.5 MPH	0	0	0	0	0	0	2	2	3	7	2	2	1	3	2	1
12.5 MPH	0	0	0	0	0	0	0	0	5	3	1	1	3	4	4	0
18.5 MPH	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0
24.5 MPH	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
24.6+MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

STABILITY F

SPEED	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
CALM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5 MPH	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0
2.5 MPH	0	1	0	0	0	1	1	1	0	2	0	0	0	0	0	1
3.5 MPH	0	0	1	1	0	0	1	0	0	1	4	0	1	1	1	0
4.5 MPH	0	0	0	1	1	0	1	1	0	1	0	0	4	0	0	0
5.5 MPH	0	0	1	0	0	0	0	0	0	0	0	1	0	0	1	1
6.5 MPH	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
7.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
12.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
18.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24.6+MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 3.13 (continued)

STABILITY G

SPEED	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
CALM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5 MPH	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0
2.5 MPH	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0
3.5 MPH	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
4.5 MPH	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
5.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24.6+MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 3.14 JOINT FREQUENCY TABLE - NUMBER OF OCCURANCES OF WIND SPEED AND DIRECTION FOR EACH STABILITY CLASS

1982 DATA FROM 85 TO 95 DEGREES F

STABILITY A

SPEED	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
CALM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.5 MPH	0	0	0	0	0	0	0	0	0	1	2	3	1	1	2	1
4.5 MPH	1	0	0	0	0	0	0	0	0	1	2	0	1	0	0	1
5.5 MPH	1	0	0	0	0	0	0	0	0	1	0	2	1	2	0	2
6.5 MPH	0	0	0	0	0	0	0	0	0	0	0	1	2	0	0	1
7.5 MPH	0	0	0	0	0	0	0	0	0	1	0	1	1	1	2	0
12.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	0
18.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24.6+MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

STABILITY B

SPEED	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
CALM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.5 MPH	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6.5 MPH	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
7.5 MPH	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
12.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
18.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24.6+MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

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TABLE 3.14 (continued)

STABILITY C

SPEED	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
CALM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.5 MPH	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0
4.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5.5 MPH	0	0	0	0	0	0	0	2	0	1	0	0	0	0	0	0
6.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7.5 MPH	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0
12.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24.6+MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

STABILITY D

SPEED	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
CALM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
3.5 MPH	0	0	0	0	0	0	0	0	0	1	1	0	0	1	0	0
4.5 MPH	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0
5.5 MPH	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
6.5 MPH	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0
7.5 MPH	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0
12.5 MPH	0	0	0	0	0	0	0	0	1	4	0	0	0	0	0	0
18.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24.6+MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 3.14 (continued)

STABILITY E

SPEED	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
CALM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4.5 MPH	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
5.5 MPH	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
6.5 MPH	0	0	0	0	0	0	0	0	0	2	1	0	0	0	0	0
7.5 MPH	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0
12.5 MPH	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0
18.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24.6+MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

STABILITY F

SPEED	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
CALM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
18.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24.6+MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 3.14 (continued)

STABILITY G

SPEED	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
CALM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24.6+MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 3.15 JOINT FREQUENCY TABLE - NUMBER OF OCCURANCES OF WIND SPEED AND DIRECTION FOR EACH STABILITY CLASS

JULY 1976-JUNE 1977 ALL TEMPERATURES

STABILITY A

SPEED	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
CALM	1	0	1	0	0	0	1	0	0	1	0	0	0	0	0	2
1.5 MPH	3	2	0	0	0	0	3	1	0	1	3	7	3	2	5	8
2.5 MPH	10	6	4	0	0	1	3	0	2	2	3	5	7	8	11	10
3.5 MPH	7	7	2	2	5	2	1	4	1	2	4	6	4	6	5	14
4.5 MPH	18	12	1	2	4	4	3	2	3	2	11	17	14	5	7	17
5.5 MPH	24	7	3	1	0	2	4	5	4	2	10	8	9	9	13	13
6.5 MPH	15	14	5	5	3	2	1	6	2	3	6	13	12	5	14	15
7.5 MPH	13	6	3	1	1	0	0	4	2	3	6	9	9	7	19	18
12.5 MPH	57	17	7	6	4	3	7	7	7	29	38	26	49	65	86	79
18.5 MPH	24	4	1	0	0	1	2	5	1	7	13	7	32	40	56	38
24.5 MPH	4	1	0	0	0	0	0	0	0	0	0	0	0	6	17	7
24.6+MPH	6	1	0	0	0	0	0	0	0	0	0	0	0	1	3	5

STABILITY B

SPEED	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
CALM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.5 MPH	1	2	0	0	0	0	0	0	0	0	0	0	1	1	0	0
2.5 MPH	1	0	1	1	0	0	0	0	0	0	1	2	2	0	0	2
3.5 MPH	1	1	0	0	0	0	1	1	2	0	1	1	0	1	4	1
4.5 MPH	1	0	0	0	0	0	2	0	1	1	1	3	2	0	0	3
5.5 MPH	0	2	0	0	0	1	3	1	2	2	0	2	1	2	1	0
6.5 MPH	2	0	2	2	0	0	1	1	2	1	0	0	0	3	2	5
7.5 MPH	1	0	0	0	0	0	1	0	0	0	1	1	0	1	1	1
12.5 MPH	2	0	0	3	1	0	2	1	1	7	7	4	10	8	10	12
18.5 MPH	3	2	0	0	0	0	1	0	0	0	1	2	5	6	9	9
24.5 MPH	1	0	0	0	0	0	1	0	0	0	0	0	0	2	4	5
24.6+MPH	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1

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TABLE 3.15 (continued)

STABILITY C

SPEED	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
CALM	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0
1.5 MPH	0	0	0	0	0	0	0	0	1	1	1	1	0	0	1	0
2.5 MPH	0	1	0	0	0	1	1	0	0	0	2	0	1	0	1	0
3.5 MPH	0	1	1	0	1	1	0	0	1	1	1	0	0	1	0	1
4.5 MPH	1	0	0	0	0	0	0	1	1	1	3	1	2	0	1	0
5.5 MPH	0	0	1	1	0	1	0	1	0	2	2	2	1	1	0	0
6.5 MPH	0	0	0	1	0	2	0	0	2	1	3	3	0	1	0	1
7.5 MPH	0	0	0	0	1	1	0	1	1	3	2	1	1	1	1	2
12.5 MPH	4	3	1	1	1	1	1	0	2	6	3	0	4	6	8	4
18.5 MPH	4	0	0	0	0	0	0	0	0	3	2	0	3	4	4	4
24.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	2	9	2
24.6+MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	0

STABILITY D

SPEED	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
CALM	0	0	3	0	1	0	0	0	0	1	0	1	0	0	1	0
1.5 MPH	5	6	7	5	5	3	3	4	4	5	3	3	5	5	4	5
2.5 MPH	5	8	11	14	8	7	3	7	2	4	6	4	9	6	8	9
3.5 MPH	18	11	7	5	14	13	10	11	8	10	10	13	8	6	12	10
4.5 MPH	13	9	8	10	12	15	13	9	16	16	14	11	10	10	8	17
5.5 MPH	7	12	4	9	14	18	11	16	16	15	14	14	5	9	12	11
6.5 MPH	11	9	8	8	13	16	18	14	19	17	13	13	11	12	7	5
7.5 MPH	11	6	5	4	11	14	14	8	14	9	7	10	14	15	14	10
12.5 MPH	16	9	9	8	18	45	21	18	34	40	27	27	63	95	125	55
18.5 MPH	12	3	0	0	1	2	5	0	2	12	19	9	27	87	93	46
24.5 MPH	2	1	0	0	0	0	0	1	0	1	1	0	6	36	48	12
24.6+MPH	0	0	0	0	0	0	0	0	0	0	0	0	2	13	15	2

TABLE 3.15 (continued)

STABILITY E

SPEED	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
CALM	0	1	2	1	3	0	1	1	0	1	0	1	2	2	3	1
1.5 MPH	16	8	9	9	10	5	11	5	4	5	10	10	17	4	8	9
2.5 MPH	12	11	15	8	11	15	9	11	7	5	10	12	10	13	10	14
3.5 MPH	17	19	15	12	19	18	20	16	18	19	22	21	24	12	18	21
4.5 MPH	24	15	22	14	23	12	13	25	23	15	19	22	26	22	19	27
5.5 MPH	19	12	8	8	17	14	21	27	19	19	23	28	46	25	23	30
6.5 MPH	17	11	14	4	12	13	15	10	15	22	21	23	45	21	23	27
7.5 MPH	14	16	7	6	11	13	14	6	24	26	15	20	35	36	18	23
12.5 MPH	27	22	10	6	10	12	19	11	28	60	43	32	73	119	103	73
18.5 MPH	15	3	0	0	1	0	0	1	2	9	5	3	18	54	52	20
24.5 MPH	1	2	0	0	0	0	0	1	0	0	0	0	3	14	9	3
24.6+MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0

STABILITY F

SPEED	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
CALM	0	1	4	0	2	2	2	1	1	2	1	1	1	2	2	0
1.5 MPH	5	13	8	9	11	10	8	4	11	10	11	6	15	10	11	4
2.5 MPH	11	1	5	10	12	9	10	9	5	11	11	12	12	13	17	10
3.5 MPH	7	9	5	7	6	14	11	4	11	9	11	13	17	8	9	16
4.5 MPH	16	8	7	5	5	9	8	9	11	10	22	14	27	8	17	13
5.5 MPH	10	4	8	5	3	2	2	7	1	8	10	7	10	12	8	9
6.5 MPH	3	7	1	1	4	0	3	4	3	7	10	8	12	4	3	11
7.5 MPH	4	1	0	1	3	0	0	1	3	2	2	3	9	8	6	5
12.5 MPH	12	3	0	0	2	3	2	0	2	3	4	8	8	3	4	7
18.5 MPH	1	0	0	0	0	0	0	0	0	1	0	0	0	2	0	1
24.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24.6+MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 3.15 (continued)

STABILITY G

SPEED	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
CALM	0	3	5	0	0	2	1	1	2	0	1	1	0	2	0	0
1.5 MPH	5	2	8	4	6	4	2	5	9	9	11	6	11	2	6	3
2.5 MPH	5	3	4	3	13	12	8	7	3	5	12	4	7	3	10	4
3.5 MPH	3	6	8	10	13	11	3	7	9	5	9	12	14	11	7	8
4.5 MPH	4	7	5	1	2	3	2	5	11	6	8	7	9	4	10	6
5.5 MPH	4	1	1	0	5	3	2	1	1	5	4	2	4	1	3	9
6.5 MPH	4	0	0	2	0	2	0	2	3	5	1	2	1	1	1	3
7.5 MPH	7	0	0	0	1	1	0	0	0	0	0	1	2	1	0	2
12.5 MPH	3	0	0	0	1	0	0	1	0	0	0	2	0	2	0	3
18.5 MPH	1	0	0	0	0	0	0	0	0	0	0	0	[illegible]	0	1	1
24.5 MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24.6+MPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 3.16 FRACTION OF HOUR IN EACH TEMPERATURE RANGE IN 1982 METEOROLOGICAL DATA

Temperature Range, °F	Fraction in Range
<5	0.007620
5-15	0.017702
15-25	0.056038
25-35	0.129191
35-45	0.147479
45-55	0.141266
55-65	0.218288
65-75	0.185346
75-85	0.088042
85-95	0.009027
>95	0.000000

TABLE 3.17. CONTROL ROOM FLOW AND VOLUME DATA

Flow Rates (cfm)	
U_O	69667
U_B	25383
U_{I1}	13600
U_{I2}	15810
U_{I3}	8074
U_{O1}	0
U_{O2}	0
U_{O3}	0

Compartment Volumes (cubic feet)	
V_1	114900
V_2	70400
V_3	70400

Volume 1 contains the control room

TABLE 3.18 CONDITIONAL PROBABILITY OF EXCEEDENCE OF TOXIC LIMITS IN CONTROL ROOM, GIVEN A MAJOR RELEASE, INTEGRATED OVER TRACK WITHIN FIVE MILES OF TMI-1

Chemical	Roy	Shocks
Acetic Acid, Glacial	.010934	.002872
Acetic Anhydride	.000679	.000000
Acrylonitrile	--	.014661
Ammonia, Anhydrous	.026145	.023608
Bromine	--	.082288
Chlorine	--	.078189
Chromic Fluoride	.102293	--
Coal Tar, Light Oil	--	.003605
Ethyl Acrylate	.004377	.000227
Ethylene Oxide	--	.023453
Formaldehyde	--	.000001
Hexane	--	.000000
Hydrochloric Acid	--	.002672
Hydrogen Fluoride, Anhydrous	.102293	.094398
Phosphorus Oxychloride	--	.079749
Propylene Oxide	--	.012521
Vinyl Acetate	--	.034216
Vinyl Chloride	.015827	.009610

4.0 CONDITIONAL PROBABILITY OF A 10CFR100 RELEASE GIVEN A CONTROL ROOM CONCENTRATION IN EXCESS OF TOXIC LIMITS

Following the calculation of λ_T and f_{R-T_i} from Equation (1-1) in Sections 2 and 3, respectively, the final steps are to calculate the conditional probability that a 10CFR100 release will occur. This calculation requires evaluating f_{o_j}, f_m, and f_{CF} and using n_i values from Reference 19.

The frequency of shipment of all chemical/rail line combinations that passed the screening test described in Section 3 were multiplied by the values from Reference 19 divided by 1.5 as shown in Table 4-1. The 1.5 factor was applied because the data was the total for 18 months. As seen in Table 4-1, the frequency of shipment of the chemicals of concern ranged between 26 and 2900 per year with a total of about 5900 per year.

Table 4-1

NUMBER OF SHIPMENTS PER YEAR OF THE IMPORTANT HAZARDOUS CHEMICALS (n_i)

Chemical	Line	Shipments per Year
Acetic Acid	Shocks	79.3
	Roy	26
Acetic Anhydride	Shocks	34.7
	Roy	34.7
Acrylonitrile	Shocks	134.7
Ammonia, Anhydrous	Shocks	180
	Roy	46
Bromine	Shocks	47.3
Chlorine	Shocks	1046
Chromic Flouride	Roy	127.3
Coal Tar, Light Oil	Shocks	118.7
Ethyl Acrylate	Shocks	334.7
Ethylene Oxide	Shocks	236.7
Formaldehyde, 37 wt%	Shocks	50.7
Hydrofluoric Acid, Anhydrous	Shocks	96
	Roy	42.7
Phosporous Oxychloride	Shocks	41.3
Propylene Oxide	Shocks	236.7
Vinyl Acetate	Shocks	32
Vinyl Chloride	Shocks	2888.7
	Roy	42

4.1 TOTAL FRACTION OF THE TIME WHEN OPERATOR ACTION IS REQUIRED TO MITIGATE TOXIC CHEMICAL RELEASE INITIATED SCENARIOS ($\Sigma_j f_{oj}$)

In the scenarios considered so far a railroad car filled with a toxic chemical has ruptured and the resulting toxic plume has made it to the control room air intake and has infiltrated the control room in a concentration in excess of the toxic limit value. In order to be concentrated enough the toxic plume half width will be between 50 and 150 feet. For many of these chemicals, the operator will isolate the control room prior to the TLV being reached based on smell or skin irritation. In some cases, however, he will not be aware of the situation in time. It was estimated that depending on the chemical the conditional probability of failing to isolate ranges between 1.0 and 0.1; the mean value appears to be approximately 0.3. For convenience, this factor is considered as part of the failure of the operator to recover as described in Section 4.2.

In cases where the control room remains unisolated, two situations may evolve from the operator's extreme discomfort at being exposed to the TLV:

i. most likely the operator will trip the plant because of his apprehension about his ability to perform <u>or</u>

ii. he will become incapacitated prior to being able to trip the plant.

If the operator trips the plant, normally operating systems will insert the control rods, trip the turbine, rampback the feedwater, and dump steam thereby leveling off at the steam dump and feed flow rates required to remove decay heat. No operator action is required. If the plant continues to run, it will do so until some onsite or offsite disturbance causes the plant to trip automatically. On the average, this happens 8-10 times per year which means that the likelihood per operating hour of the plant tripping is about 1.6×10^{-3}, not nearly as likely as the operator tripping manually. In either case, one of the systems which must respond automatically will need to fail in order for operator response to be required to prevent a 10CFR100 release. It was assumed that the operator tripped the plant.

In the process of performing Phase I of the TMI-1 PRA [Ref. 28] an event tree was developed for the case where an automatic or manual turbine/reactor trip occurs. This event tree is shown in Figure 4-1; the top events and their conditional split fractions are defined in Table 4-2. As can be seen from comparing Figure 4-1 and Table 4-2, if no systems (top events) fail, as in scenario 1, end state "0" (for success) results without operator intervention. Among the top events in this tree EF+, EF-, TH, BF, RE, CD, HL and DH require manual actuation of important systems. These actions (except for TH*) are only required if some other automatically actuated system has failed. Preliminary estimates made for Phase I of the TMI-1 Probabilistic Risk Assessment (based on the current plant design) showed that the most likely of these systems to fail would be the main feedwater system failing to rampback in response to a turbine/reactor trip (MF-, MF+; see scenarios 15-32 in Figure 4-1). This rampback is done under control of the ICS. If this rampback fails, given the current plant design, operator action will be required to reestablish feedwater flow to a steam generator (EF). This action must be performed within approximately 1 hour to prevent core uncovery and the onset of core damage. Based on the detailed ICS analysis performed for the Midland PRA and used in the TPRA Phase I analysis, the total of likelihood of all automatic actuation failures which could lead to the requirement for operator response is 0.05. This number is dominated by failure to rampback feedwater but also includes SD, MF+ and the others.

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*TH was found to be unnecessary unless an excessive cooldown initiating event occurs.

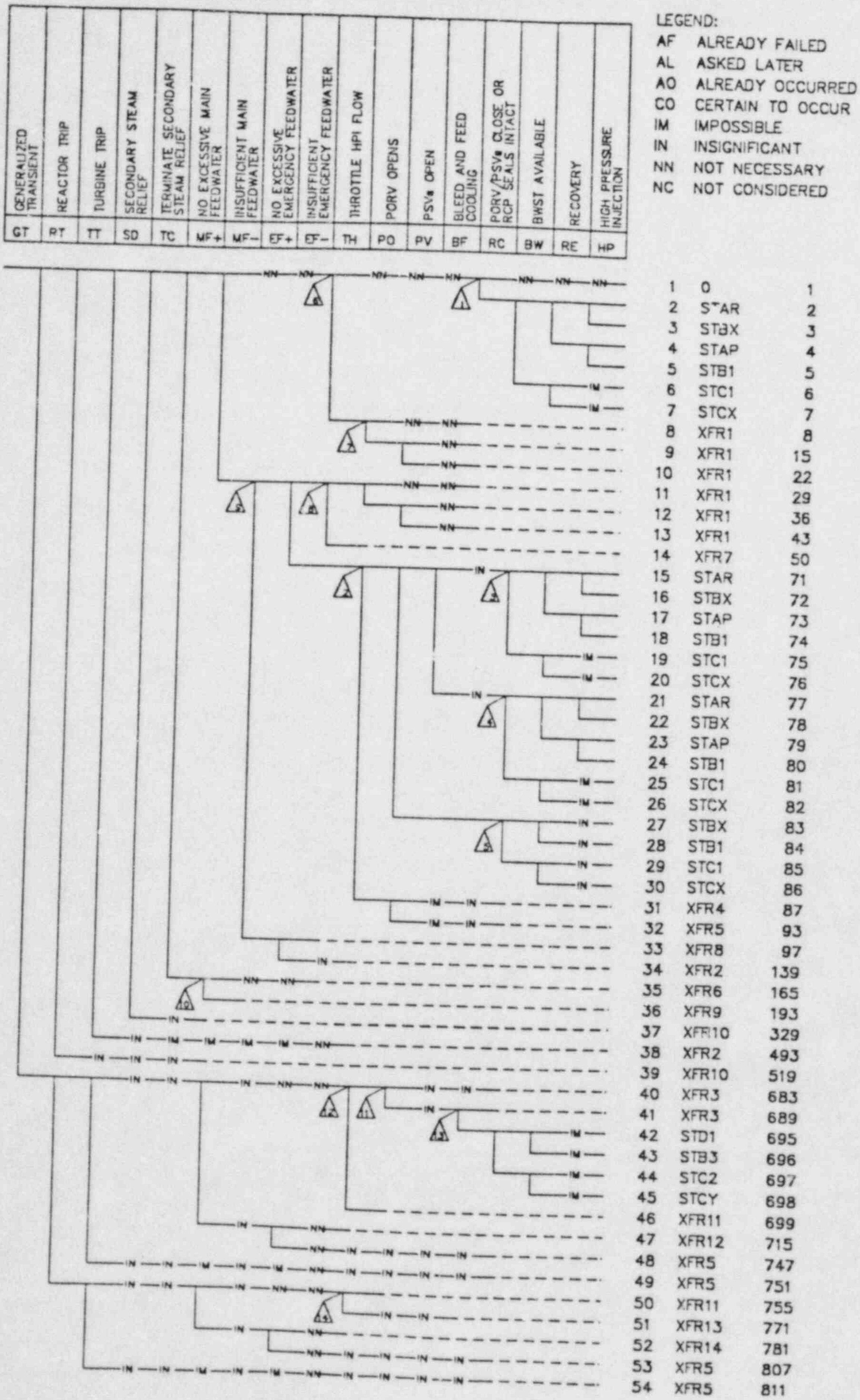

FIGURE 4-1 GENERAL TRANSIENT EVENT TREE (SHEET 1 of 4)

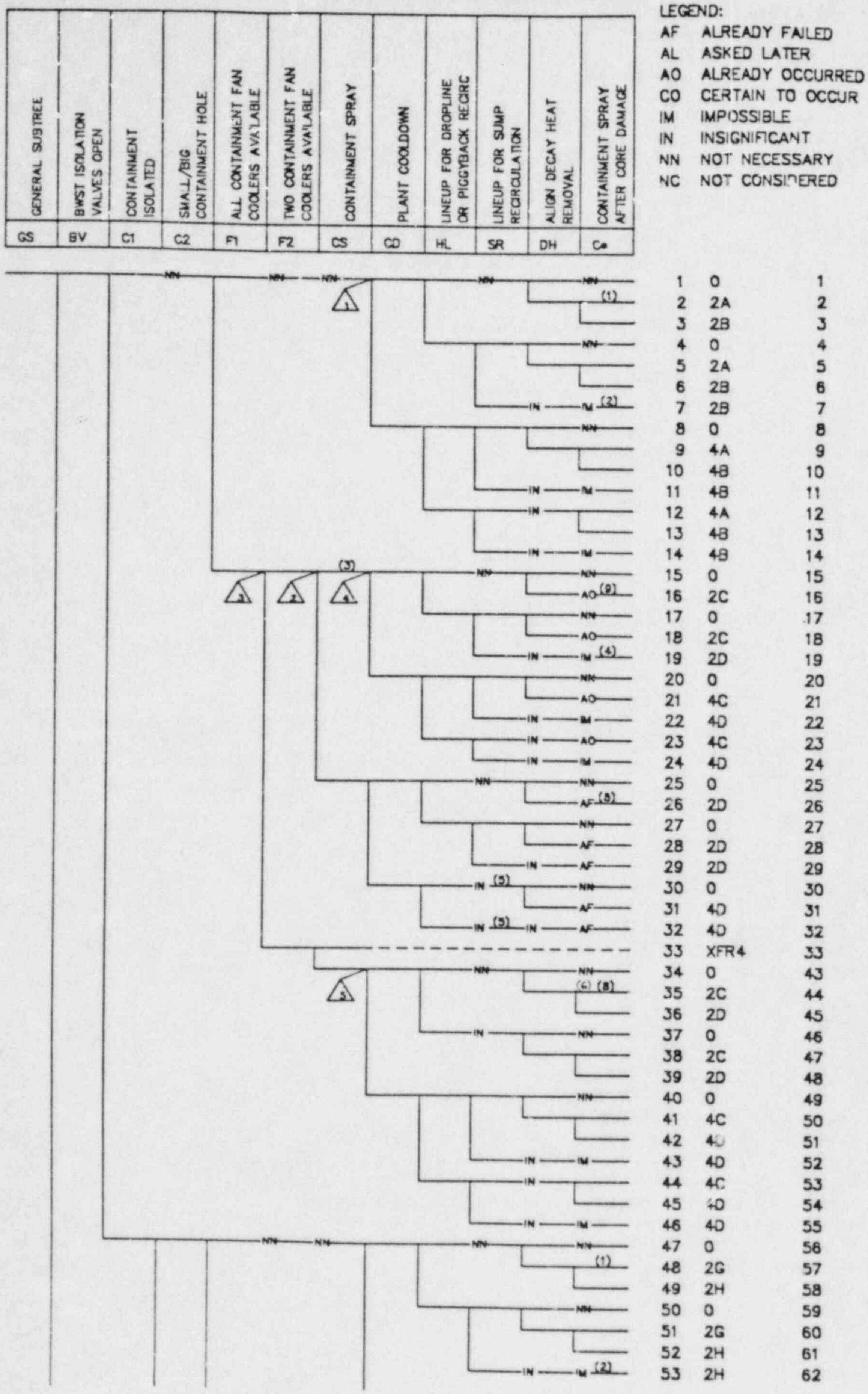

FIGURE 4-1. GENERAL SUBTREE STRUCTURE FOR A AND B SUBTREES
(Sheet 2 of 4)

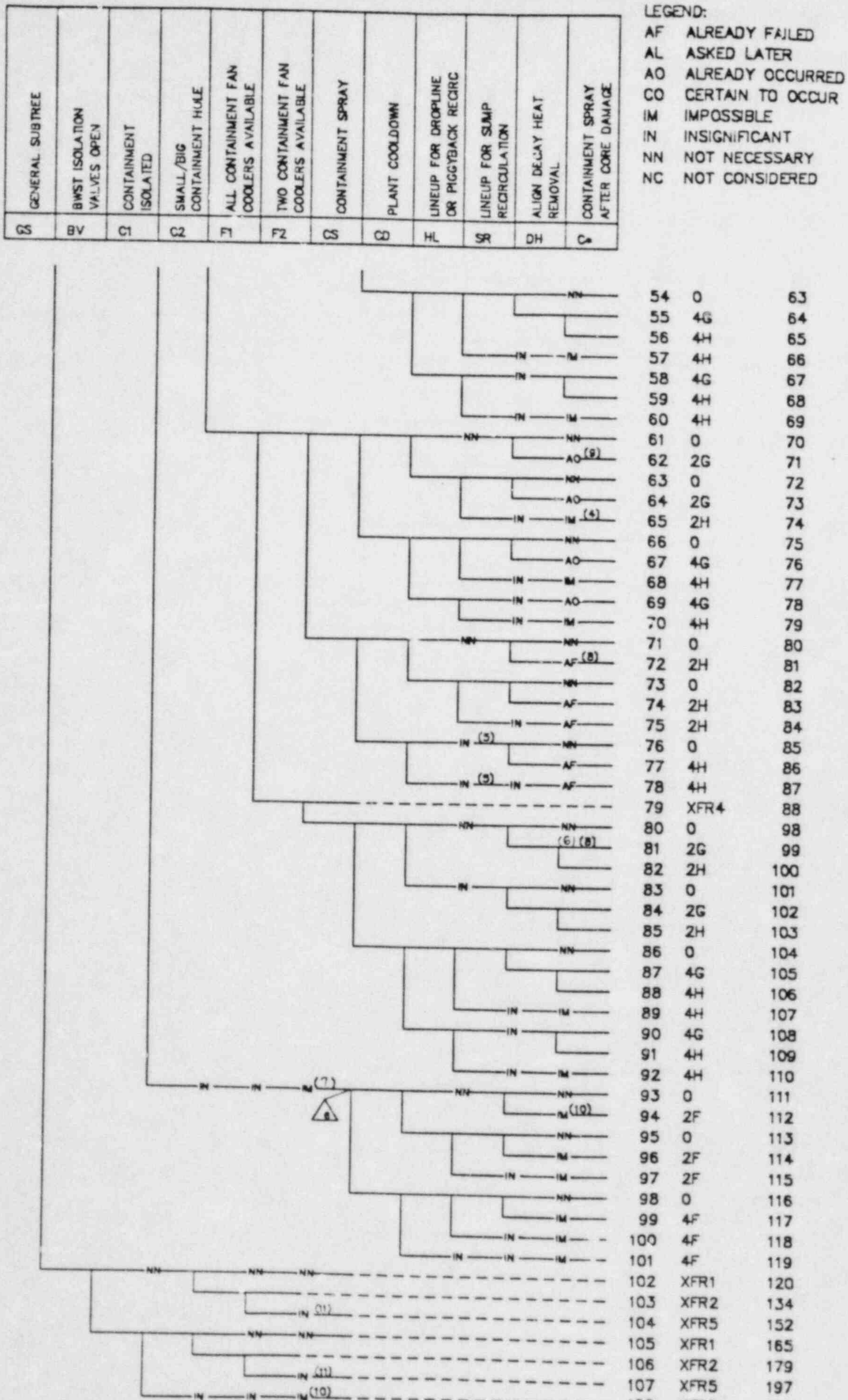

FIGURE 4-1 (continued)
(Sheet 3 of 4)

NOTES FOR FIGURE 4-1

1. Because core damage takes place after the BWST is empty, sprays are available and able to pump out of the sump. Sprays did not burn up early. They cannot remove heat from the containment because of DH failure; instead, the fans do it.

2. The sump is not available to the sprays, so they fail for the reasons noted in comment (1).

3. Sprays would be actuated before BWST empties and before containment fails (without sprays containment heat removal would occur at about the same time).

4. For success, the sprays must keep on working after recirculation switchover.

5. There is nothing left to take suction off of the sump. The sprays must work in order to do long term containment heat removal.

6. There is no containment heat removal after core damage here, the fans have failed, and the sump/spray water is not being cooled.

7. The big hole in containment will prevent containment pressure from reaching 4 psi or 30 psi until core damage.

8. If containment spray and DH fail, there is not enough containment heat removal when one train of containment fan cooler is down, but scrubbing could still work if at least one train of spray works. In the first scenario, neither train of sprays works; in the second scenario, one train works.

9. Since DH has failed, sprays cannot do long term containment heat removal.

10. With such a big hole in the reactor building, the pressure never goes high enough.

11. Because one train of containment spray has already failed, two out of two trains can never work; therefore, containment heat removal must fail.

FIGURE 4-1 (continued)
(Sheet 4 of 4)

TABLE 4-2. EVENT TREE TOP EVENTS

Event Tree Top Event Name	Systems Involved	Conditional Split Fraction Name	Description
AH	Pressurizer Heaters	 AH-1 AH-1($\overline{GA}/\overline{GB}$)	Operator regains pressurizer level and reestablishes subcooling such that core heat removal continues via subcooled natural circulation. • All support systems available. • Only one train of support available.
BF	PORV	BF-1	Operator holds open PORV for HPI cooling.
BV	BWST Discharge	BV-1	BWST discharge valves DH-V5A and DH-V5B remain open, check valves DH-V14A and DH-V14B open on demand, and flow is maintained through them for 24 hours.
BW	BWST	BW-1	Borated water is available from the BWST until recirculation. Also includes failure of both LPI/BS discharge valves (DH-V5A and DH-V5B and DH-V14A and DH-V14B) to open on demand.
C1/C2	Reactor Building Isolation	 C1-1 C1-1($\overline{GA}/\overline{GB}$) C1-1($\overline{EA}/\overline{EB}$) C1-1($\overline{GAGB}$) C2-1 C2-1($\overline{GA}/\overline{GB}$) C2-1($\overline{EA}/\overline{EB}$) C2-1($\overline{GAGB}$) C2-1($\overline{CI}$)	Isolation of reactor building purge supply and exhaust on demand and remain isolated until the demand is removed. • All support systems available. • Only one train of AC power available. • Train A of ESAS is unavailable. • No AC power is available. Given a failure of C1, the containment opening is small (< 3 inches). • All suport systems available. • Only one train of AC power is available. • Only one train of ESAS is available. • No AC power is available. • Small opening is given.

TABLE 4-2 (continued)

Sheet 2 of 9

Event Tree Top Event Name	Systems Involved	Conditional Split Fraction Name	Description
CD	Backup Instrument Air, ADVs, Pressurizer Spray, Decay Heat Removal Discharge Valves		Cooldown and depressurization of the RCS.
		CD-1	• Using ADVs and pressurizer spray or holding PORV open given HPI is available. Also includes opening of the DHR discharge valves (DH-V4A and DH-V4B).
		CD-2	• Using PORV, holding it open (given HPI is available). Also includes opening of the DHR discharge valves.
		CD-3	• Like CD-1 but for SGTR.
		CD-4	• Like CD-2 but for SGTR.
CS/C*	Reactor Building Spray		Provides containment energy removal function (only asked upon a failure of reactor building; emergency cooling).
		CS-1	• One of two trains of reactor building spray actuates automatically and operates for 24 hours.
		CS-1($\overline{GA}/\overline{GB}$) .	• One of one train of reactor building spray actuates automatically and operates for 24 hours.
		CS-2	• Two of two trains of reactor building spray actuate automatically and operate for 24 hours.
		CS-3	• One of two trains similar to CS-1 except add SR.
		CS-3 ($\overline{GA}/\overline{GB}$	• Similar to CS-3 except one of one train.
CV	Control Building Ventilation		Provides control building ventilation for 24 hours.
		CV-1	• One of two trains operates.
		CV-1($\overline{OP}$)	• Like CV-1 except offsite power is unavailable.
		CV-1($\overline{GA}/\overline{GB}$)	• Like CV-1 ($\overline{OP}$) except one diesel is unavailable.

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TABLE 4-2 (continued)

Event Tree Top Event Name	Systems Involved	Conditional Split Fraction Name	Description
DA,DB	DC Power, Vital AC Power		One train of DC power and vital AC power are available for 24 hours.
		DA/DB-1	• One of two trains is available.
		DA/DB-1($\overline{DB}/\overline{DA}$)	• Availability of one train given that the other train has failed.
DH	Decay Heat Removal		Decay heat removal manual actuation and operation for 24 hours.
		DH-1	• One of two trains actuates.
		DH-2	• One of two trains actuates in recirculation mode.
		DH-1($\overline{GA}/\overline{GB}$)	• One of one train actuates.
		DH-2($\overline{GA}/\overline{GB}$)	• One of one train actuates in recirculation mode.
		DH-3	• One of two trains actuates in piggyback recirculation mode.
		DH-3($\overline{GA}/\overline{GB}$)	• One of one train actuates in piggyback recirculation mode.
DT	Auxiliary Spray Line	DT-1	Operator must establish auxiliary spray flow to prevent long term boron concentration effects. Actions must be taken within 24 hours of the LORI.
EA/EB	ESAS		One train of engineered safeguard actuation is available upon demand.
		EA/EB-1	• One of two trains available.
		EA/EB-1($\overline{EB}/\overline{EA}$)	• Availability of one train given that the other train has failed.
EF+	Emergency Feedwater		Both trains of EFW are controlled to prevent overcooling the primary.
		EF+1	• Manual start and control.
		EF+2	• Automatic start and control.

TABLE 4-2 (continued)

Event Tree Top Event Name	Systems Involved	Conditional Split Fraction Name	Description
EF-	Emergency Feedwater		The emergency feedwater system is supplying sufficient feedwater to remove decay heat from the primary.
		EF-1	• Manual initiation (one of three pumps required).
		EF-2	• Automatic initiation (one of three pumps required).
		EF-2($\overline{GA}/\overline{GB}$)	• Like EF-2 but only one train of support is available.
		EF-2($\overline{GAGB}$)	• Like EF-2 but no AC power is available.
		EF-3	• Like EF-2 but requires turbine-driven pump or both motor-driven pumps.
		EF-4	• Like EF-3 except manual initiation.
		EF-3($\overline{GA}/\overline{GB}$)	• Like EF-3 but only one train of support is available.
		EF-5	• One out of two motor-driven pumps required after turbine-driven pump becomes unavailable (automatic initiation).
		EF-5($\overline{GA}/\overline{GB}$)	• Like EF-5 except only one support train is available.
F1/F2	Reactor Building Emergency Cooling		Provides containment energy removal function (in conjunction with top event [CS]).
		CF-1	• Requires all three reactor building emergency cooling coils and fan units operating, being supplied cooling water from at least one reactor river water pump (three of three work).

TABLE 4-2 (continued)

Sheet 5 of 9

Event Tree Top Event Name	Systems Involved	Conditional Split Fraction Name	Description
		CF-2	• Requires both remaining emergency cooling coils and fan units operating, being supplied cooling water from at least one reactor river water pump, given that one reactor building emergency cooling coil has failed (two of two remaining must operate).
GA/GB	Diesel Generators, All 1E AC Switchgear		Availability of power to one train of Class 1E switchgear from the diesel generators for 6 hours following a loss of offsite power.
		GA/GB-1	• Availability of a given train (A or B).
		GB-1($\overline{GA}$)	• Availability of one train given that the other train has failed.
HA/HB	Decay Heat River Water, Decay Heat, Closed Cycle Cooling		One train of cooling water to the decay heat closed cycle cooler is available for 24 hours.
		HA/HB-1	• One of two trains available.
		HB-1($\overline{HA}$)	• Availability of one train given that the other train has failed.
HL	Decay Heat Removal		Operator action to line up the DHR system for various modes of of operation.
		HL-1	• Open three of three dropline valves from control room and one of two manual valves locally. Valves must open on demand and remain open for 24 hours (includes long term water supply).
		HL-2	• Open both trains of piggyback valves (DH-V7A and DH-V7B).

TABLE 4-2 (continued)

Sheet 6 of 9

Event Tree Top Event Name	Systems Involved	Conditional Split Fraction Name	Description
HP	High Pressure Injection		Initiation of high pressure injection and continued operation for 24 hours.
		HP-1	• Automatic initiation of one of two trains through one injection path.
		HP-1$\overline{A}$/$\overline{B}$	• Automatic initiation of one of one train injecting through one injection path with only one train of support available.
		HP-2	• Automatic initiation of one of two trains injecting through two injection paths.
		HP-2$\overline{A}$/$\overline{B}$	• Like HP-2 except only one train of support is available.
		HP-3	• Like HP-1 except manual initiation.
		HP-3$\overline{A}$/$\overline{B}$	• Like HP-3 but only one train of support is available.
		HP-4	• Automatic initiation of two of two trains.
		HP-5	• Like HP-4 except manual initiation.
ID	Control Room Instrumentation	ID-1	Operator identifies a steam generator tube rupture as such; otherwise, operator is assumed to take it for a very small LORI.
LP	Low Pressure Injection	LP-1	One of two trains of LPI actuates automatically and injects for 24 hours.
		LP-1$\overline{A}$/$\overline{B}$	• Like LP-1 except only one train of support is available.
LT	Makeup to BWST/MUT	LT-1	Operator provides a long term water source for injection by either refilling the BWST or makeup tank within 8 hours.
		LT-2	• Like LT-1 but at least one PSV must be open for decay heat removal.

TABLE 4-2 (continued)

Sheet 7 of 9

Event Tree Top Event Name	Systems Involved	Conditional Split Fraction Name	Description
MF+1	Main Feedwater	MF+1	Both trains of main feedwater ramp back to the correct rate to prevent overcooling of the core.
MF-	Main Feedwater	MF-1	Main feedwater ramps back to no less than the proper flow on at least one steam generator to assure adequate heat removal from the primary.
		MF-2	Operator action to reestablish main feedwater flow after isolation by the steam line rupture detection system.
NS	Nuclear River Water, Nuclear Services Closed Cycle Cooling		Sufficient cooling to nuclear services closed cycle cooling system loads for 24 hours.
		NS-1	• One of two trains.
		NS-1($\overline{OP}$)	• One of two trains start and run after a loss of offsite power.
OP	Offsite Power	OP-1	Availability of offsite power following a turbine trip.
PO	PORV		PORV operation on demand for RCS pressure relief or RCS cooling, stays open until demand is removed.
		PO-1	• Automatic opening, passes steam.
		PO-2	• Automatic opening, passes water.
PV	PSVs		PSVs open on demand and remain open until demand is removed.
		PV-1	• One of two PSVs opens, passes steam.
		PV-2	• Two of two PSVs open, pass steam.
		PV-3	• Like PV-1 but passes water.
		PV-4	• Like PV-2 but pass water.

TABLE 4-2 (continued)

Sheet 8 of 9

Event Tree Top Event Name	Systems Involved	Conditional Split Fraction Name	Description
RC	PSVs, PORV		Both PSVs close after demand is removed.
		RC-1	• After passing steam.
		RC-2	• After passing water.
		RC-3	• After passing water and HPI is throttled.
			PORV closes after demand is removed.
		RC-4	• After passing steam.
		RC-5	• After passing water.
		RC-6	• After passing water and HPI is throttled.
			All PORV/PSVs close after demand is removed.
		RC-7	• After passing steam.
		RC-8	• After passing water.
		RC-9	• After passing water and HPI is throttled.
RE	River Water and Closed Cycle Cooling Water Intermediate RE-2 Closed Cooling Water	RE-1	Recover HPI flow after RCP seal failure but in time to prevent core damage.
			Operation of RCP thermal barrier cooling to prevent RCP seal leakage. • All support systems available. • One train of all support systems failed.
RT	Reactor Protection	RT-1	All control rod assemblies except one insert into the core on demand.
		RT-1($\overline{OP}$)	Like RT-1 except offsite power is lost.
SD	MSSVs		Suffi[illegible] MS[illegible]s on each steam gene[illegible] open on demand and remain open until the demand is removed.
		SD-1	• One of nine MSSVs per steam generator.
		SD-2	• Two of nine MSSVs per steam generator.

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TABLE 4-2 (continued)

Sheet 9 of 9

Event Tree Top Event Name	Systems Involved	Conditional Split Fraction Name	Description
SE	RCP Seals	SE-1 SE-2	Seal integrity is maintained. Pressure vessel integrity is maintained after an excessive cooldown transient.
SR	Reactor Sump		Reactor building sump must be
		SR-1	• Operator action to open sump isolation valves.
		SR-2	• Both sump isolation valves open manually (includes valve hardware failures).
TC	MSSVs ADVs TBVs	TC-1	All MSSVs, ADVs, and TBVs must close upon remcval of demand.
		TC-2	Like TC-1 but includes isolating steam to EFW pump turbine from generator after SGTR.
TH	HPI		Operator throttles HPI flow before pumping open PORV/PSVs with water.
		TH-1	• Throttle using MU-V217.
		TH-2	• Throttle using MU-V16A, MU-V16B, MU-V16C, and MU-V16D.
TT	Turbine Stop and Control Valves	TT-1	All turbine stop valves or all turbine control valves close on demand.

4.2 CONDITIONAL PROBABILITY THAT THE MANUAL ACTIONS REQUIRED TO BE MADE CAN BE (f_M)

In those situations requiring manual action after the control room concentration has exceeded the TLV, the operator may don a Scott-AirPack and still be able to act or operators not in the control building may enter it to help out. The plume half widths must be fairly narrow if the concentration is to exceed the TLV in the control room. Any operators outside the part of the plume which exceeds the TLV will not be incapacitated. Since the maximum plume half width is about 150 feet operators may come from most locations onsite other than the control building or from offsite. These operators would don breathing apparati and/or protective clothing and enter the control building to, for instance, actuate high pressure injection to keep the core covered.

Based on the time available to act, the distance from which the new operators must come and the stress involved in the situation an estimate of 0.1 for the conditional probability of failing to perform the required manual actuations was made. This number is comparable to the likelihood developed in Reference 25 for the operator failing to recover electric power during a station blackout wherein the same amount of time and comparable stress levels exist.

4.3 FRACTION OF UNCOVERED CORES WHICH LEAD TO A 10CFR100 OFFSITE DOSE RATE (f_{EF})

If manual actions fail and core is uncovered, it will be damaged, releasing the fission products from the fuel rods either through the primary safety valves or through the reactor vessel bottom. These fission products will be released to the containment atmosphere. The containment will be isolated and the sprays will scrub fission products from the air and the fan coolers will protect the containment integrity. All of this will happen automatically unless an automatic actuation fails. The small amount of fission products released will depend on the normally allowed containment leakage. Normally allowed containment leakage will not result in a 10CFR100 release, because this leak rate is set in order to assure that this does not happen given a design basis accident wherein 100% of the fission products are liberated from the fuel.

The likelihood that one of the containment safety features fails or that the containment fails from being overstressed is much less than 10^{-2} as shown in Reference 25 and 28. This number will probably be limited by the failure of the containment building sprays or fan coolers or by the loss of control building ventilation which will fail both.

5.0 TOTAL RESULTS

All of the data described in Sections 2-4 were combined using Equation 1-1 to form the results shown in Table 5-1. The table also sums these scenario results and subtracts out the frequency of scenarios involving chlorine releases. The chlorine gas monitor planned for installation in the control room air intake will isolate the control room before concentrations in excess of the TLV can be reached. The total frequency of all scenarios which might lead to offsite doses in excess of 10CFR100 limits is 3.3×10^{-10} per year. This means that on the average once in 3. billion years such an accident might occur.

It is very likely that other scenarios, with higher frequency, will dominate the risk from operating TMI Unit 1. The highest frequency such scenarios are expected to be between 1×10^{-7} and 3×10^{-7} per year, a full three orders of magnitude higher.

The Standard Review Plan 3.2.2 suggests that NRC reviewers use 10^{-6} per year to judge the acceptability of the frequency of scenarios such as these. This is a case where the "expected rate of occurrence of potential exposures in excess of 10CFR100 guidelines of approximately 10^{-6} per year is acceptable if... the realistic probability can be shown to be lower." In this case, the realistic probability would indeed be lower because:

a. Lack of an accurate and detailed ground absorption model has forced the use of a 1 cm. deep puddle for evaporation of any spill.

b. Lack of detailed information from CONRAIL about car types and current shipment frequencies have forced the use of 1982 data on car mixes and 1978-1979 data on shipment frequencies. Railcars have been improved somewhat in design and railroad shipping rates have been in steady decline since 1980 because of the general economic downturn.

c. Not all releases requiring evacuation necessarily involve the release of the entire contents of a tank car as assumed here. However, no data exists to further discriminate such cases.

d. GPUN has committed to changing the emergency feedwater (EFW) actuation system such that if the main feedwater ramps back too much ($\overline{MF}$-), EFW will be automatically actuated. This will make it even more unlikely that operator intervention is required after a turbine/reactor trip.

Table 5-1

Table showing Estimates of the Frequency of Scenarios Initiated by a Toxic Chemical Release which Result in a Radiation Release from TMI Unit 1 in Excess of the Dose Limits of 10CFR100

	Frequency of Exceedence, Per Year		
Chemical	Roy	Shocks	Total
Acetic Acid, Glacial	1.15×10^{-12}	9.23×10^{-13}	2.07×10^{-12}
Acetic Anhydride	0	0	0
Acrylonitile	-	8.00×10^{-12}	8.00×10^{-12}
Ammonia, Anhydrous	4.87×10^{-12}	1.72×10^{-11}	2.21×10^{-11}
Bromine	-	1.58×10^{-11}	1.58×10^{-11}
Chlorine	-	3.34×10^{-10}	3.34×10^{-10}
Chromic Fluoride	5.28×10^{-11}	-	5.28×10^{-11}
Coal Tar, Light Oil	-	1.46×10^{-12}	1.46×10^{-12}
Ethyl Acrylate	3.66×10^{-13}	3.08×10^{-13}	6.74×10^{-13}
Ethylene Oxide	-	2.25×10^{-11}	2.25×10^{-11}
Formaldehyde, 37 wt %	-	2.05×10^{-16}	2.05×10^{-16}
Hexane	-	0	0
Hydrochloric Acid 36 wt %	-	8.44×10^{-13}	8.44×10^{-13}
Hydrofluoric Acid, Anhydrous	1.71×10^{-11}	3.67×10^{-11}	5.38×10^{-11}
Phosphorous Oxychloride	-	1.33×10^{-11}	1.33×10^{-11}
Propylene Oxide	-	1.31×10^{-11}	1.31×10^{-11}
Vinyl Acetate	-	4.43×10^{-12}	4.43×10^{-12}
Vinyl Chloride	2.69×10^{-12}	1.12×10^{-10}	1.15×10^{-10}
Totals	7.90×10^{-11}	5.81×10^{-10}	6.60×10^{-10}
Without Chlorine	7.90×10^{-11}	2.47×10^{-10}	3.26×10^{-10}

Key: - Indicates no such shipments occur on the indicated line.
0 Indicates shipments made, but not in sufficient amounts per tank car to exceed the TLV in the control room from the rail line indicated.

6.0 REFERENCES

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APPENDIX A

Tank Car Accident Frequency (per car-mile)

OBJECTIVE: Determine site-specific distribution for λ_T, the frequency of tank car accidents/car-mile.

NOTES

1. Used 3.2×10^{-4}/track mile-year in Midland (for frequency of release). Obtained from range of 346-1500 releases (1971-1977), 325,500-334,932 miles. For one particular company, there were 7 major releases over 10,454 miles (1973). Ratio of evacuations to releases ~0.10 to 0.26 (mean = 0.18).

2. Accident/Incident Bulletin Data

Year	Accidents/ 10^6 Train-Miles	Derailments/ 10^6 Train-Miles	Accidents due to Track Defaults/ 10^6 Train-Miles	Train-Miles*
1977	13.82 (10,362)	10.76	5.78 (4,337)	7.50×10^8
1978	15.00 (11,277)	11.66	6.38 (4,797)	7.52×10^8
1979	12.76 (9,740)	9.80	5.31 (4,050)	7.63×10^8
1980	11.78 (8,451)	9.93	4.87 (3,492)	7.18×10^8
1981	8.55 (5,781)	6.46	3.36 (2,273)	6.76×10^8
1982	8.00 (4,589)	5.90	3.09 (1,769)	5.73×10^8

*Includes motor-train miles, yard-switching miles and locomotive-miles.

Accidents on Main Line Track

Speed	Total No.	Derailments	%	Track-Caused	%
Unknown	43	18	42	3	7
1-10	705	587	83	330	47
11-20	449	359	80	150	33
21-30	424	340	80	170	40
31-40	277	195	70	63	23
41-50	199	129	65	27	14
51-60	84	61	73	26	31
61-70	19	6	32	2	11
71-80	8	1	13	1	13
81-90	3	1	33	1	33
>91	2	-	-	1	50
	2213	1697	77	774	45

Accidents on Yard Track

Speed	Total No.	Derailments	%	Track-Caused	%
Unknown	76	28	37	6	8
1-10	1784	1259	71	752	42
11-20	84	47	56	21	25
21-30	8	2	25	1	13
31-40	4	2	50	1	25
41-50	2	2	100	1	50
	1958	1340	68	762	39

Accidents on Industry, Siding, or Unknown Track Type

Speed	Total No.	Derailments	%	Track-Caused	%
Unknown	11	2	18	1	9
1-10	355	305	86	193	54
11-20	42	34	81	17	40
21-30	4	2	50	-	-
31-40	5	3	60	2	40
41-50	1	-	-	-	-
	418	346	83	213	51

Accidents by Track Class

Speed	Total No.	%	Derailments	%	Track-Caused	%
Unknown	305	7	212	70	128	42
1	2172	47	1623	75	963	44
2	740	16	570	77	327	44
3	763	17	556	73	235	31
4	537	12	374	70	106	20
5	66	1	46	70	9	14
6	6	0.1	2	33	1	17
	4589		3383	74	1769	39

Accidents Involving Hazardous Materials

Year	Consists Carrying	In Consist	Continuing Hazardous Material	Damaged Hazardous Material	Releasing Hazardous Material	People Evacuated
1982	504	35,268	2,297	671	137	7,226
1981	601	41,197	2,770	773	109	18,720
1980	842	59,697	4,139	989	173	25,713

3. Special Routing of Spent Fuel Elements, Systems Technology Lab. Inc., Arlington, VA, 1982. (Performed for U.S. Department of Commerce, PBB3-101015).

References a report on tanker releases per car-mile as a function of track class: "The Geographical Distribution of Risk Due to Hazardous Materials Tank Car Transportation in the U.S.":

Class	Release Probability	
1	9.13×10^{-6}	
2	6.6×10^{-7}	
3	5.4×10^{-7}	
4	1.3×10^{-7}	(80% of U.S. track is Class 4)
5	1.3×10^{-7}	
6	3.31×10^{-6}	

4. Final Environmental Statement on the Transportation of Radioactive Material by Air and Other Modes, NUREG-0170, Dec. 1977.

Based on Sandia data, uses accident rate of 1.5×10^{-6} per car-mile.

PROCEDURE

Note 3 gives the desired result, but the source is not sufficiently defined. As a check, let

$$\lambda_T = \lambda_t \ f_R$$

where

λ_t = total rate of accidents/train-mile

f_R = conditional frequency of hazardous material release, given that a train carry H-M's is in an accident.

Table A-1

THRESHOLD ACCIDENT VALUE

λ_t x10^6	Year	Threshold	Source: Accident/Incident Bulletins 151 (1982 and 146 (1977)
9.2	1968	$ 750	
9.9	1969	750	
9.7	1970	750	
9.3	1971	750	
9.6	1972	750	
11.7	1973	750	
12.8	1974	750	
10.7	1975	1750	
13.2	1976	1750	
13.8	1977	2300	
15.0	1978	2600	
12.8	1979	2600	
11.8	1980	3200	
8.6	1981		
8.0	1982	4100	

For our purposes, a "mean" value of $\sim 1.0 \times 10^{-5}$ is good enough.

$$f_R = n_{HMR} / n_{HM}$$

where

n_{HM} = number of cars of hazardous material per hazardous material train

n_{HMR} = number of cars carrying hazardous materials which release some or all of their contents per accident

Year	Consists	Cars in Consist	Cars Containing Hazardous Matls.	Cars Releasing Hazardous Matls.
1982	504	35,268	2,297	137
1981	601	41,197	2,770	109
1980	842	59,697	4,139	173
1977	673	50,007	3,118	153
1976	627	45,363	2,642	152
1975	637	48,669	4,711	126
	3,884	280,201	19,677	850

Thus,

Year	$\bar{n}_{HM}$	$\bar{n}_{HMR}$
1982	4.6	0.27
1981	4.6	0.18
1980	4.9	0.21
1977	4.6	0.23
1976	4.2	0.24
1975	7.4	0.20

Using global averages, $\bar{n}_{HM} = 5$, $\bar{n}_{HMR} = 0.22$

$$\therefore \quad \lambda_T = 4.5 \times 10^{-7}/\text{car-mile}$$

ATTACHMENT 2

Minimum Time for Chemical to Reach Intake Structure in Concentration Sufficient to Cause Exceedence, Minutes

CHEMICAL	Roy Line (min)	Shocks Line (min)	TLV ppm
Acetic Acid, Glacial	2.32	8.76	20
Acetic Anhydride	3.33	-	10
Acrylonitrile	-	6.18	40
Ammonia, Anhydrous	2.32	6.[illegible]	100
Bromine	-	5.94	0.3
Chlorine	-	6.18	15
Chromic Fluoride in HF	2.43	-	6 as HF
Coal Tar, Light Oil	-	8.76	60 (Benzene)
Ethyl Acrylate	2.32	8.76	50
Ethylene Oxide	-	8.76	200
Formaldehyde	-	311.52	10
Hexane	-	-	200
Hydrochloric Acid	-	8.76	100
Hyd. Fluoride, Anhydrous	2.43	6.35	6
Phosphorus Oxychloride	-	6.18	0.5
Propylene Oxide	-	8.76	200
Vinyl Acetate	-	6.18	20
Vinyl Chloride	3.9[illegible]	8.76	1000

Attachment 3

Frequency of Exceedence of the Toxic Limit in the TMI-1 Control Room

Chemical	Frequency of Exceedence, Per Year		
	Roy	Shocks	Total
Acetic Acid	2.30×10^{-8}	1.85×10^{-8}	4.15×10^{-8}
Acetic Anhydride	1.79×10^{-9}	0	1.79×10^{-9}
Acrylonitrile	-	1.60×10^{-7}	1.60×10^{-7}
Ammonia	9.74×10^{-8}	3.44×10^{-7}	4.42×10^{-7}
Bromine	-	3.15×10^{-7}	3.15×10^{-7}
Chlorine	-	6.69×10^{-6}	6.69×10^{-6}
Chromic Fluoride	1.06×10^{-6}	-	1.06×10^{-6}
Coal Tar, Light Oil	-	2.92×10^{-8}	2.92×10^{-8}
Ethyl Acrylate	7.33×10^{-9}	6.15×10^{-9}	1.35×10^{-8}
Ethylene Oxide	-	4.50×10^{-7}	4.50×10^{-7}
Formaldehyde	-	4.10×10^{-12}	4.10×10^{-12}
Hexane	-	0	0
Hydrochloric Acid	-	1.69×10^{-8}	1.69×10^{-8}
Hydrofluoric Acid, Anhydrous	3.42×10^{-7}	7.34×10^{-7}	1.08×10^{-6}
Phosphorous Oxychloride	-	2.67×10^{-7}	2.67×10^{-7}
Propylene Oxide	-	2.62×10^{-7}	2.62×10^{-7}
Vinyl Acetate	-	8.87×10^{-8}	8.87×10^{-8}
Vinyl Chloride	5.38×10^{-8}	2.25×10^{-6}	2.30×10^{-6}
Total	1.58×10^{-6}	1.16×10^{-5}	1.32×10^{-5}
Without Chlorine	1.58×10^{-6}	4.94×10^{-6}	6.52×10^{-6}

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