INEL-95/0055

Calculations of Protective Action Distance for Toxic Chemical Spills Using Nomographs

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Introduction

This document was produced for emergency use following a spill of liquid gas or finely divided solid (<100 micron) toxic chemicals. The information on the next few pages was kept deliberately terse and is limited to data and graphic aids needed for calculation of plume distance (protective action distance). All supporting material is provided as Appendices.

Input Data Needed for the Calculation

The information needed for the calculation are:

Wind speed and direction

Area or flow rate of the spill

Identity of the chemical

Sky conditions (Clear/Cloudy - Day/Night)

All other information can be found in Tables 1 and 2.

The chemicals listed in Tables 1 and 2 include all those for which ERPG, EEGLs, SPEGLs, and CEGLs values have been published to date

Table 1 lists the vapor pressure and molecular weight for each chemical. Chemical formula and CAS Number are included for convenience.

Table 2 lists ERPG and PEL-TWA concentrations for all the chemicals found in Table 1.

Instruction for Using the Nomographs

Once the input data are collected, the nomographs can be used for calculation of plume distance. There two sets of nomographs. One set covers gas releases and finely divided solids (Figures 1,2 and 3) while the other set is used for liquid spills and boiling liquids (Figures 4,5 and 6).

There are three types of nomographs per set, one for each atmospheric stability class. The choice of which stability class selected, (based on sky conditions) determines the length of the center line of the chemical plume. "A" stability class "CLEAR DAY" is the first nomograph. The "D" stability class for day or night "CLOUDY-D/N" is second and "F" stability class "CLEAR NIGHT" is last.

Referring to the liquid spill nomographs, merely mark the data points on the scales and connect these points with straight lines that overshoot the scales to the "tie lines".

- The wind speed value on the first left scale is connected to the molecular weight scale and this connecting line is extended to the tie line scale that has no numbers on it. This tie line was scaled down so the next scale could fit on the page. This scaling down is represented by the uniform lines between this tie line and the next shorter parallel tie line.

- The next scale contains the range of vapor pressure values. A line is drawn from the scaled down tie line point through the proper vapor pressure value to the next tie line. This tie line has a scale down similar to the first one.

- From the second scaled down tie line point draw a line through the chemical airborne concentration (ERPG-2 is typically used for determining protective action distance) scale to the next tie line. This tie line did not need to be scaled down.

- In a similar manner, extend the line from the final tie line point through the area of the spill scale to plume distance scale and read the result.

The gas/solid aerosol nomographs are actually a simplified version of the liquid nomographs and are used the same way.

Examples of nomograph solutions are given in Appendix D at the end of this document.

Plotting the Plume

Once the protective action distance is determined by use of the appropriate nomograph, the plume width can be determined from Table 3 or Figure 7. The map of the area surrounding the site (Figure 8) may be used to determine the affected area. The plume plots (Figure 7) are printed to the same scale as the map (2Km/in) and can be used as an overlay if they are copied onto transparent overhead slide material.

Table 1
List of Chemicals for which Limit Parameters were Analyzed

CHEMICAL NAME	Chemical formula	Physical State	CAS NO.	Vapor Pressure (mm/Hg)	Molecular Weight
Acetone	CH3.CO.CH3	L	67-64-1	180	58.1
Acrolein	CH2=CHCHO	L	107-02-8	210	56.1
Acrylic Acid	H2C=CHCOOH	L	79-10-7	141	72.1
Acrylonitrile (Ca)	CH2=CHCN	L	107-13-1	83	53.1
Allyl Chloride	CH2=CH.CH2.Cl	L	107-05-1	295	76.5
Aluminum Oxide	Al2O3	S	1344-28-1	NA	101.9
Ammonia	NH3	G	7664-41-7	760	17.0
Arsenic (Inorganic) as As (Ca)	As inorg. cmpds.	S	7440-38-2	NA	74.9 (As)
Arsenic (Organic compounds) as As	As org. cmpds.	S	7440-38-2	130-250	74.9 (As)
Arsine (Ca)	AsH3	G	7784-42-1	760	77.9
Benzene(Ca)	C6H6	L	71-43-2	75	78.1
Beryllium (Ca)	Be	S	7440-41-7	NA	9.0
Bromine	Br	L	7726-95-6	172	159.8
Bromotrifluoromethane	CBrF3	G	75-63-8	760	148.9
1 ,3-Butadiene (Ca)	CH2=CHCH=CH2	G	106-99-0	760	54.1
Carbon Disulfide	CS2	L	75-15-0	297	76.1
Carbon Monoxide	CO	G	630-08-0	760	28.0
Carbon Tetrachloride (Ca)	CCl4	L	56-23-5	91	153.8
Chlorine	Cl2	G	7782-50-5	760	70.9
Chlorine Trifluoride	ClF3	G>11.7C	7790-91-2	760	92.5
Chloroacetyl Chloride	Cl.CH2.COCl	L	79-04-9	45	113.0
Chloroform (Ca)	CH.Cl3	L	67-66-3	160	119.4
Chloropicrin	C.Cl3.NO2	L	76-06-2	20	164.4
Chlorosulfonic Acid	Cl.SO2.OH	L	7790-94-05		116.5
Chlorotrifluoroethylene	Cl.FC=CF2	G	79-38-9	760	116.5
Crotonaldehyde (Ca)	CH3.CH=CHCHO	L	4170-30-3		70.1
Dichlorodifluoromethane (FC12)	C.Cl2.F2	G	75-71-8	760	120.9
Dichlorofluoromethane (FC21)	CH.CL2.F	G>8.9C	75-43-4	760	102.9
Dichlorotetrafluoroethane (FC114)	CF4.C.Cl2	G>3.8C	76-14-2	760	170.9
Diketene	CH2=CC.H2.C(O)O	L	674-82-8		84.1
Dimethylamine	(CH3)2.NH	G	124-40-3	760	45.1
Dimethylformamide	HCON.(CH3)2	L	68-12-2	4	73.1
1,1-Dimethylhydrazine (Ca)	(CH3)2.NN.H2	L	57-14-7	157	60.1
Epichlorohydrin (Ca)	C3.H5.O.Cl	L	106-89-8	13	92.5

CHEMICAL NAME	Chemical formula	Physical State	CAS NO.	Vapor Pressure (mm/Hg)	Molecular Weight
Ethanolamine	NH2.CH2.CH2.OH	L>10.6C	141-43-5	0.4	61.1
Ethylene Glycol	CH2.OH.CH2.OH	L	107-21-1		62.1
Ethylene Oxide (Ca)	CH2.O.CH2	G>10.6C	75-21-8	760	44.1
Fluorine	F2	G	7782-41-4	760	38.0
Formaldehyde (Ca)	HCHO	G	50-00-0	760G/1Aq	30.0
Hexachlorobutadiene	Cl2.C=C.Cl.C.Cl=C.Cl2	L	87-68-3		260.8
Hydrazine (Ca)	H2.N=N.H2	L	302-01-2	10	32.1
Hydrogen Chloride	HCl	G	7647-01-0	760/42 Aq	36.5
Hydrogen Fluoride	HF	G	7664-39-3	760/130 Aq	20.1
Hydrogen Peroxide (30%)	H2.O2	L	7722-84-1	5	34.0
Hydrogen Sulfide	H2.S	L	7783-06-4	760	34.1
Isobutyronitrile	(CH3)2.CH.CN	L	78-82-0	50	69.1
Isopropyl Alcohol	(CH3)2.CH.OH	L	67-63-0	33	60 1
Lithium Bromide	LiBr	S	7550-35-8	NA	86 9
Lithium Chromate	Li2.CrO4	S	14307-35-8	NA	129.9
Lithium Hydroxide	Li.OH	S	1310-65-2	NA	24.0
Mercury Vapor (as Hg)	Hg	G	7439-97-6	0.0012	200.6
Methane	CH4	G	74-82-8	760	16.0
Methanol	CH3.OH	L	67-56-1	100	32.0
Methyl Chloride (Ca)	CH3.CI	G	74-87-3	760	50.5
Methyl Fluoride (as Fluoride)	CH3.F	G	593-53-3	760	34.0
Methyl Iodide (Ca)	CH3.I	L	74-88-4	400	142.0
Methyl Mercaptan	CH3.SH	G	74-93-1	760	48.1
Monomethylamine	CH3.NH2	G	74-89-5	760	31.1
Monomethylhydrazine (Ca)	CH3.NH.NH2	L	60-34-4	50	46.1
NickelCarbonyl (asNi) (Ca)	Ni.(CO)4	L	13463-39-3	315	170.7
Nitric Acid	HNO3	L	7697-37-2	48	63.0
Nitrogen Dioxide	NO2	G	10102-44-0	760	46.0
Nitrous Oxide	N2.O	G	10024-97-2	760	44.0
Ozone	O3	G	10028-15-6	760	48.0
Perchloroethyene	Cl2C=CCl2	L	127-18-4	14	165.8
Perfuoroisobutylene	(CF3)2.C=CF2	G	382-21-8	760	200.0
Phenol	C6.H5.OH	S	108-95-2	0.4	94.1
Phosgene	CO.Cl2	G>8.2C	75-44-5	760	98.9
Phosphine	PH3	G	7803-51-2	760	34.0
Phosphoric Acid	H3.PO4	L/S	7664-38-2	0.03	98.0

CHEMICAL NAME	Chemical formula	Physical State	CAS NO.	Vapor Pressure (mm/Hg)	Molecular Weight
Phosphorous Pentoxide	P2.O5	S	1314-56-3	NA	142.0
Sodium Hydroxide	NaOH	S	1310-73-2	NA	40.0
Sodium Monoxide	Na2.O	S	12401-86-4	NA	62.0
Sodium Peroxide	Na2.O2	S	1313-60-6	NA	78.0
Styrene (Ca)	C6.H5.CH=CH2	L	100-42-5	5	104.2
Sulfur Dioxide	SO2	G	7446-09-5	760	64.1
Sulfuric Acid (Oleum,Sulfur Trioxide)	H2.SO4	L	7664-93-9	1	98.1
Tetrafluoroethylene	F2.C=CF2	G	116-14-3	760	100.0
Titanium Tetrachloride	Ti.Cl4	S	7550-45-0	NA	189.7
Toluene	C6.H5.CH3	L	108-88-3	20	92.1
Trichloroethylene (Ca)	CH.Cl=C.Cl2	L	79-01-6	58	131.4
Trichlorofluoromethane (FC11)	C.Cl3.F	G>23.7C	75-69-4	760	137.4
Trichlorotrifluroethane (FC113)	CF3.C.Cl3	L	76-13-1	285	197.5
Trimethylamine	(CH3)3.N	G	75-50-3	54	59.1
Uranium Hexafluoride	U.F6	S	7783-81-5	NA	352.0
Vinyl Acetate	CH2=CHOC(O).CH3	L	108-05-4	93	86.1
Vinylidene Chloride	CH2=C.Cl2	L	75-35-4		97.0
Xylene	C6.H4.(CH3)2	L	1330-20-7	9	106.2

Table 2

Chemical Limits Based on ERPG or Hierarchy-based Alternative Concentrations

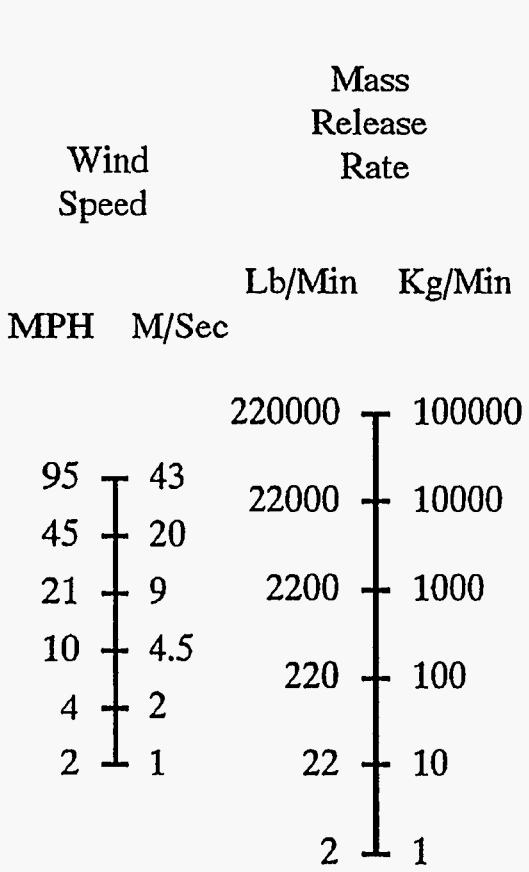
CHEMICAL NAME	PEL-TWA (mg/M^3)	ERPG-1 (mg/M^3)	ERPG-2 (mg/M^3)	ERPG-3 (mg/M^3)
Acetone	1815	2420	20570	48400
Acrolein	0.233	0.233	1.165	6.99
Acrylic Acid	5.897	5.897	147.4	2211.7
Acrylonitrile (Ca)	4.42	22.1	110.5	1105
Allyl Chloride	3.18	9.54	127.2	954
Aluminum Oxide	10	15	15	25
Ammonia	17.75	17.75	142	710
Arsenic (Inorganic) as As (Ca)	0.01	0.6	1.4	100
Arsenic (Organic compounds) as As	0.2	0.2		
Arsine (Ca)	0.162	3.24	3.24	16.2
Benzene(Ca)	3.25	16.25	162.5	9750
Beryllium (Ca)	0.002	0.006	25	100
Bromine	0.664	1.328	6.64	33.2
Bromotrifluoromethane	6090		152249	243599
1 ,3-Butadiene (Ca)	22.5	22.5	112.5	11250
Carbon Disulfide	3.16	3.16	158	1580
Carbon Monoxide	40.6	464	464	870
Carbon Tetrachloride (Ca)	12.78	127.8	639	4792
Chlorine	1.475	2.95	8.85	59
Chlorine Trifluoride		0.385	3.85	38.5
Chloroacetyl Chloride	0.231	0.462	4.62	46.2
Chloroform (Ca)	9.92	148.8	496	4960
Chloropicrin	0.683	1.366	1.366	20.49
Chlorosulfonic Acid		2	10	30
Chlorotrifluoroethylene		95.3	476.5	1429
Crotonaldehyde (Ca)	5.92	5.92	29.1	145.5
Dichlorodifluoromethane (FC12)	5030	15090	50300	251500
Dichlorofluoromethane (FC21)	42.8	128.4	428	214000
Dichlorotetrafluoroethane (FC114)	6990	20969	69900	349489
Diketene		3.44	17.2	172
Dimethylamine	1.87	1.87	187	935
Dimethylformamide	15.2	15.2	30.4	304

CHEMICAL NAME	PEL-TWA (mg/M^3)	ERPG-1 (mg/M^3)	ERPG-2 (mg/M^3)	ERPG-3 (mg/M^3)
1,1-Dimethylhydrazine (Ca)	1.25	3.75	12.5	125
Epichlorohydrin (Ca)	7.7	7.7	77	385
Ethanolamine	7.62	15.24	127	2540
Ethylene Glycol	10.16		101.6	152.4
Ethylene Oxide (Ca)	1.83	5.49	91.5	915
Fluorine	0.158	3.16	11.85	15.8
Formaldehyde (Ca)	1.23	1.23	12.26	30.7
Hexachlorobutadiene	0.213	32	106.6	320
Hydrazine (Ca)	0.133	0.399	1.06	13.3
Hydrogen Chloride	0.76	4.56	30.4	152
Hydrogen Fluoride	2.49	4.15	16.6	41.5
Hydrogen Peroxide (30%)	1.41	4.23	35.25	70.5
Hydrogen Sulfide	14.2	14.2	42.6	142
Isobutyronitrile		28.26	141.3	565.2
Isopropyl Alcohol	1000	1000	1000	30000
Lithium Bromide	1		15	
Lithium Chromate			0.1	
Lithium Hydroxide	0.025	0.05	0.1	0.5
Mercury Vapor (as Hg)	0.05	0.15	0.2	28
Methane	3272		3272	
Methanol	261.8	261.8	1308.8	6544
Methyl Chloride (Ca)	105	210	840	2100
Methyl Fluoride (as Fluoride)	2.5	7.5	12.5	
Methyl Iodide (Ca)	11.8	147.5	295	737.5
Methyl Mercaptan	1	1	50	200
Monomethylamine	12.7	12.7	127	636
Monomethylhydrazine (Ca)	0.452		0.94	94.3
NickelCarbonyl (asNi) (Ca)	0.0071	0.355	0.355	49.7
Nitric Acid	5.24	5.24	39.3	78.6
Nitrogen Dioxide	3.82	3.82	28.6	57.3
Nitrous Oxide	90	270	17996	35992
Ozone	0.2	0.6	2	20
Perchloroethyene	169.5	678	1356	3391
Perfuoroisobutylene			0.818	2.45
Phenol	19.2	38.5	192.4	769.7
Phosgene	0.41	0.82	0.82	4.1
Phosphine	0.42	1.14	70.5	141

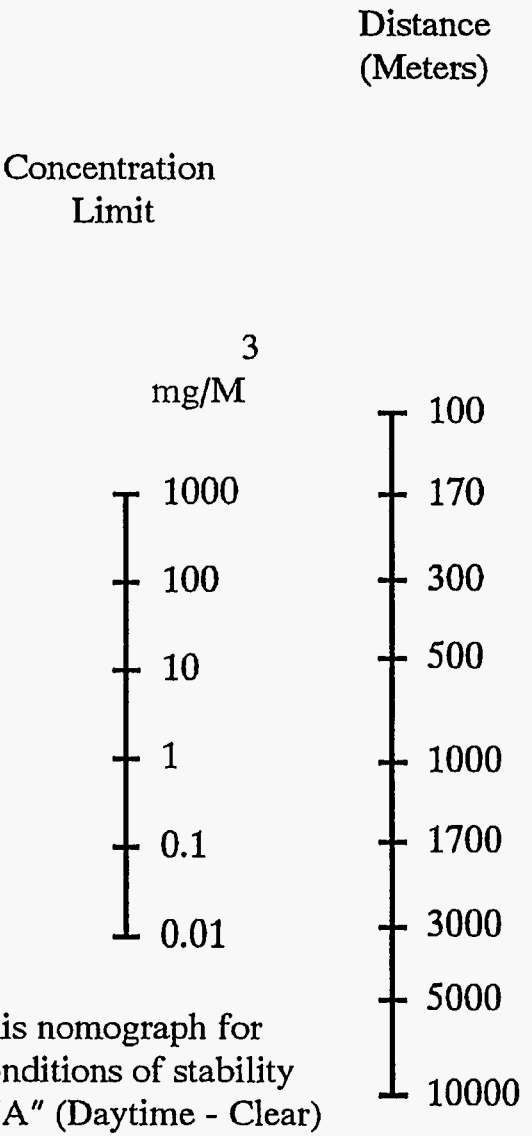
CHEMICAL NAME	PEL-TWA (mg/M^3)	ERPG-1 (mg/M^3)	ERPG-2 (mg/M^3)	ERPG-3 (mg/M^3)
Phosphoric Acid	1	3	5	10000
Phosphorous Pentoxide		5	25	100
Sodium Hydroxide		2	40	100
Sodium Monoxide				
Sodium Peroxide				
Styrene (Ca)	216.5	433	866	3464
Sulfur Dioxide	0.80	0.80	8	40
Sulfuric Acid (Oleum,Sulfur Trioxide)	1	2	10	30
Tetrafluoroethylene		818	4090	40900
Titanium Tetrachloride		5	20	100
Toluene	383	574.5	1149	7660
Trichloroethylene (Ca)	273	546	2730	5460
Trichlorofluoromethane (FC11)	562		8429	56196
Trichlorotrifluroethane (FC113)	7790	9738	11685	35055
Trimethylamine	24.2	24.2	242	1209
Uranium Hexafluoride	2.88	14.4	144	288
Vinyl Acetate	17.6	17.6	264	1761
Vinylidene Chloride	3.97	39.7	39.7	
Xylene	441	661.5	882	4410

All units are mg/M^3

Values were converted from PPM by the relationship: $mg/M^3 = PPM * MW/24.45$

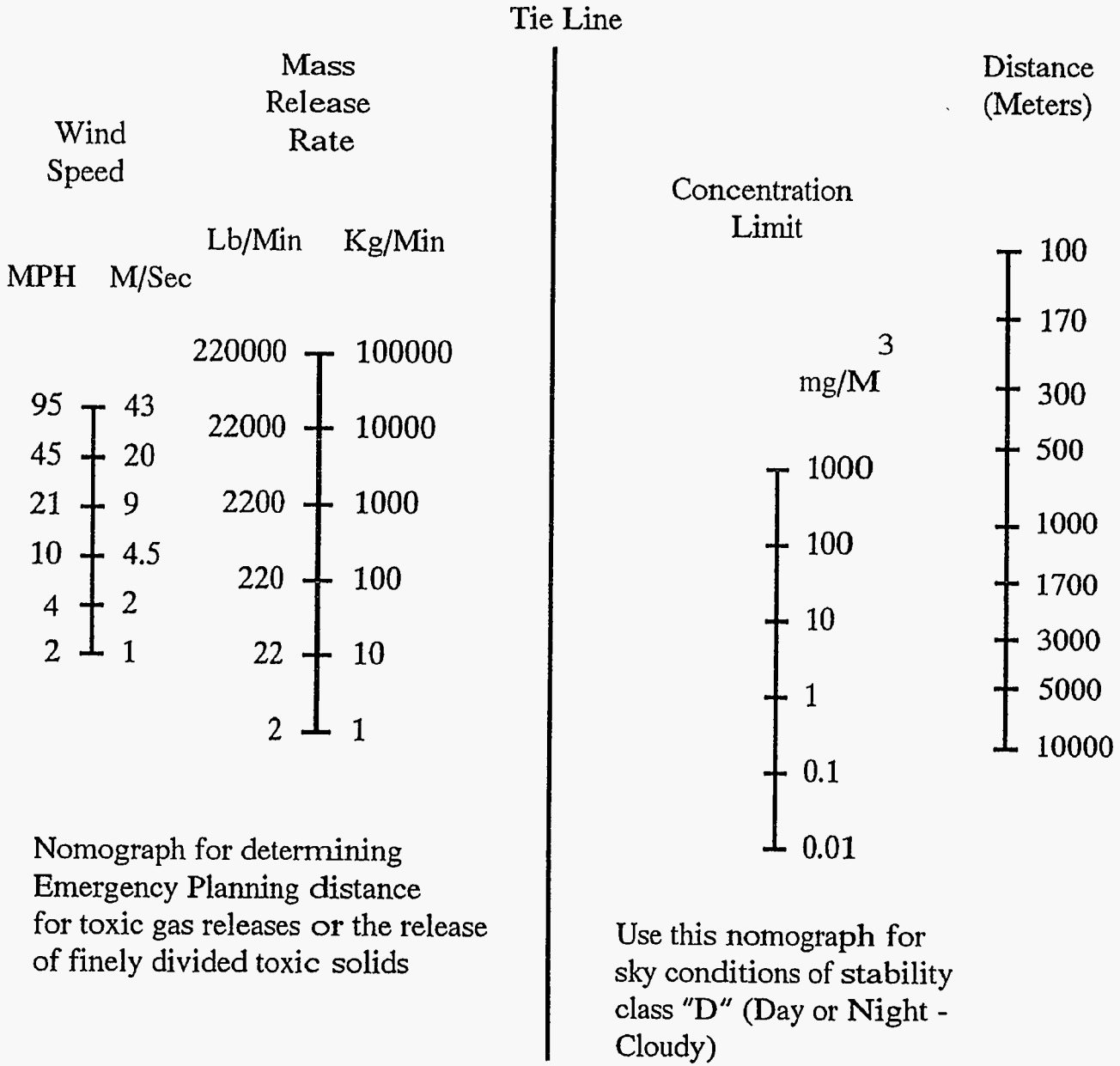


Nomograph for determining Emergency Planning distance for toxic gas releases or the release of finely divided toxic solids



Use this nomograph for sky conditions of stability class "A" (Daytime - Clear)

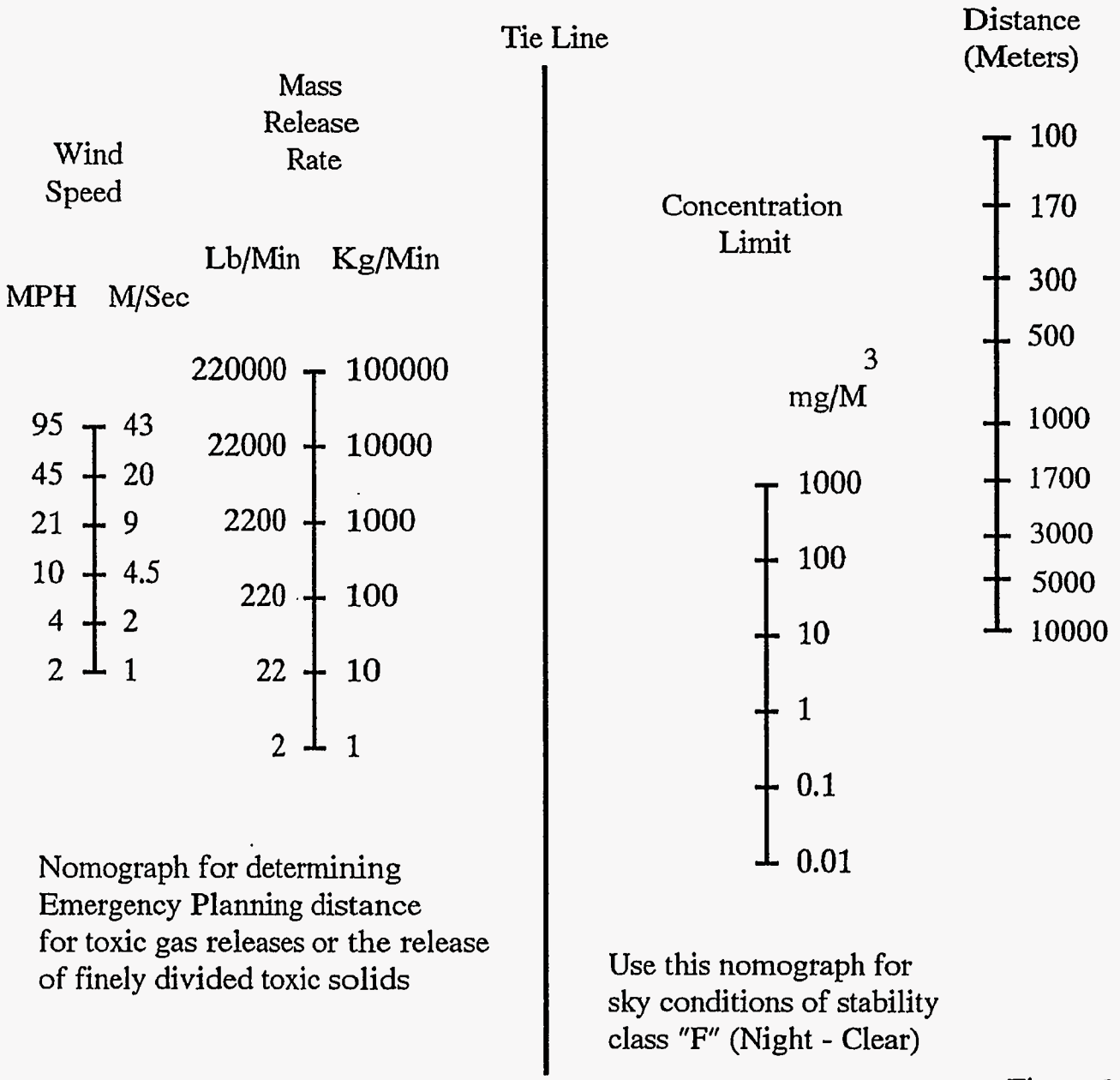
Figure 1



Nomograph for determining Emergency Planning distance for toxic gas releases or the release of finely divided toxic solids

Use this nomograph for sky conditions of stability class "D" (Day or Night - Cloudy)

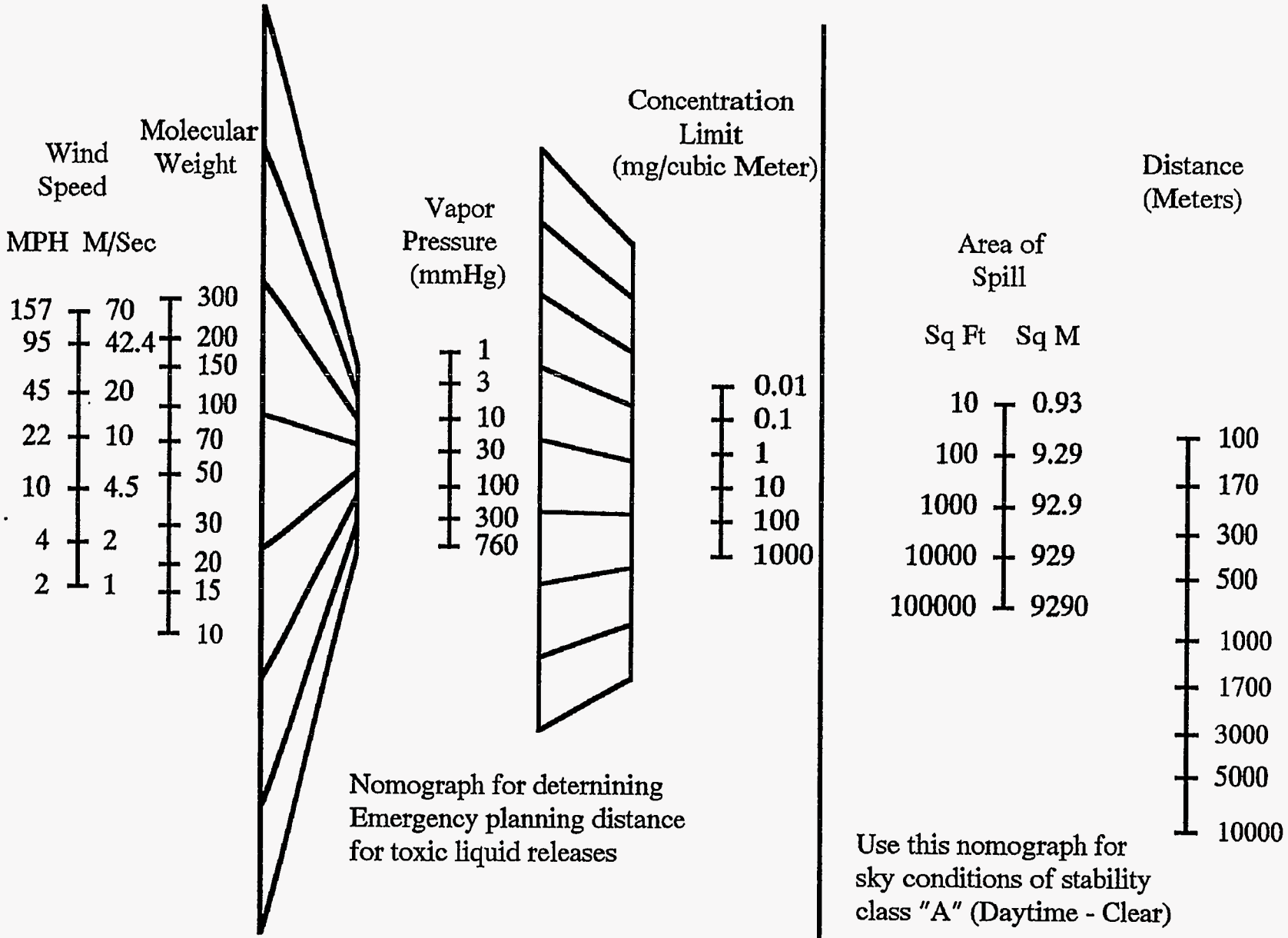
Figure 2



Nomograph for determining
Emergency Planning distance
for toxic gas releases or the release
of finely divided toxic solids

Use this nomograph for
sky conditions of stability
class "F" (Night - Clear)

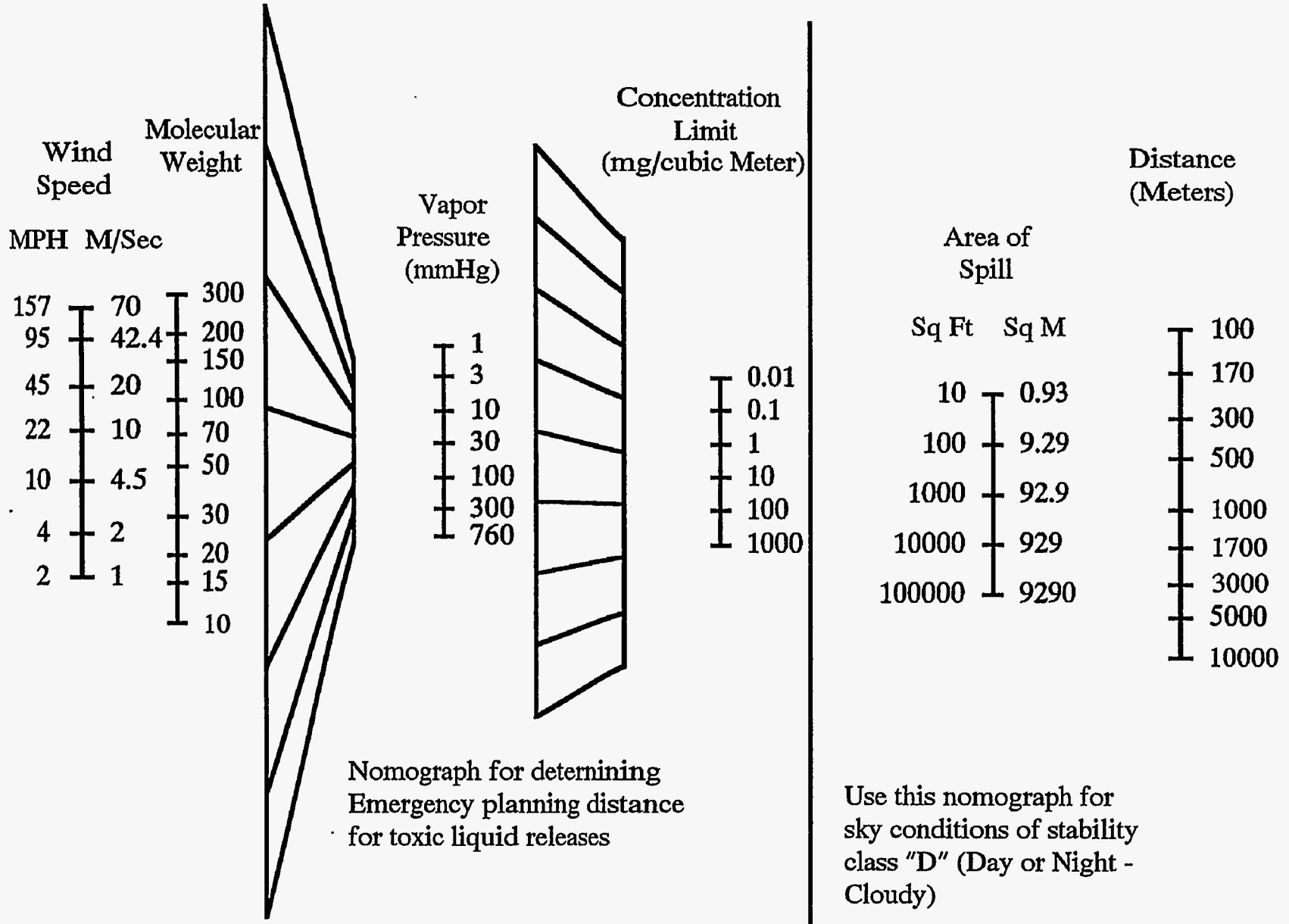
Figure 3



Nomograph for determining Emergency planning distance for toxic liquid releases

Use this nomograph for sky conditions of stability class "A" (Daytime - Clear)

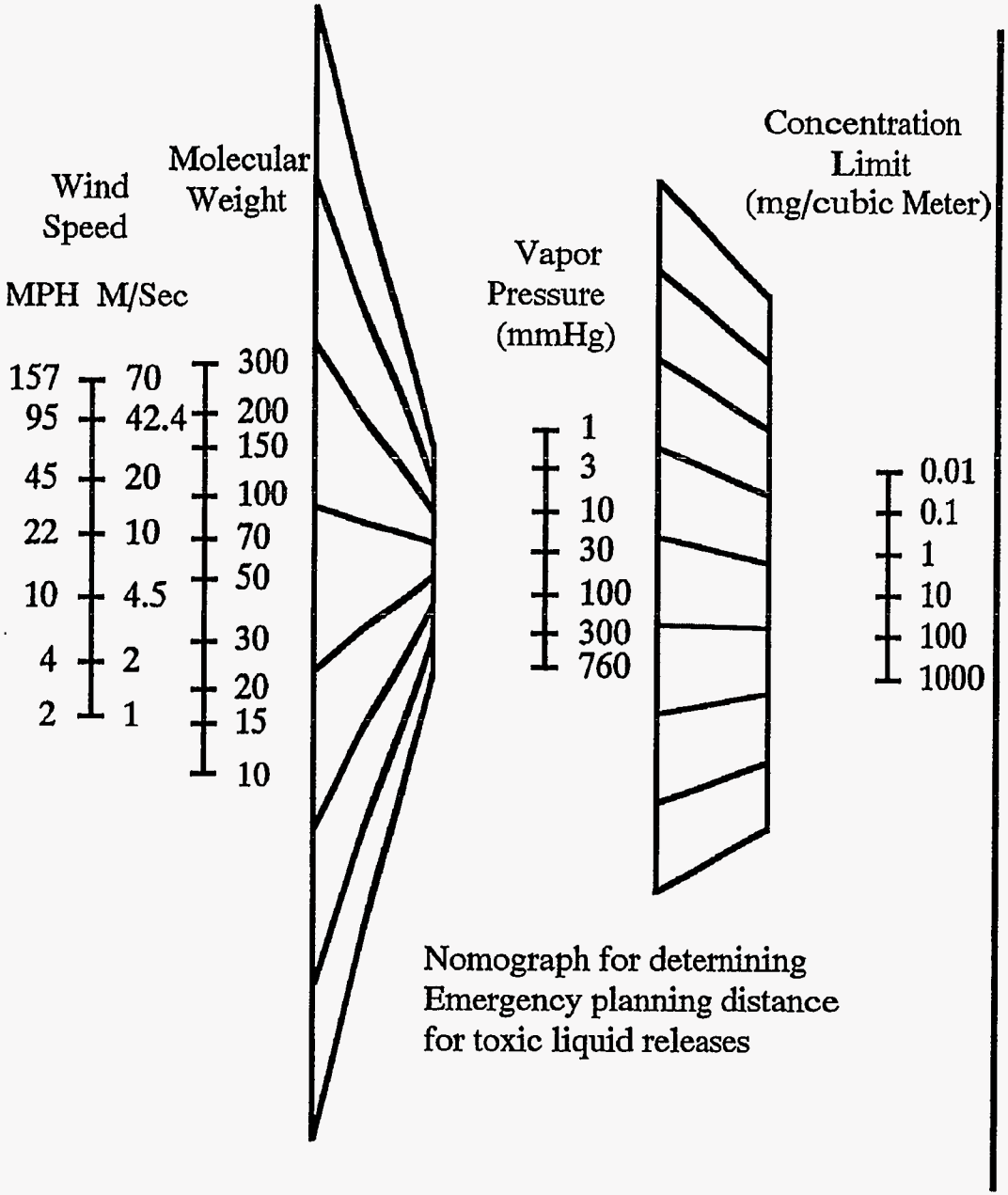
Figure 4



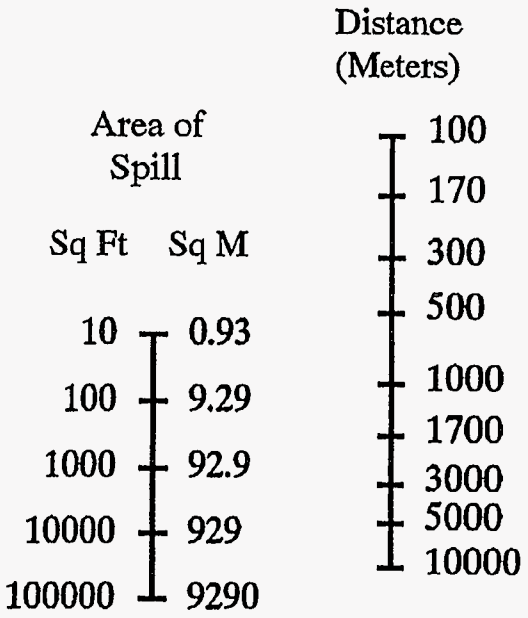
Nomograph for determining Emergency planning distance for toxic liquid releases

Use this nomograph for sky conditions of stability class "D" (Day or Night - Cloudy)

Figure 5



Nomograph for determining Emergency planning distance for toxic liquid releases



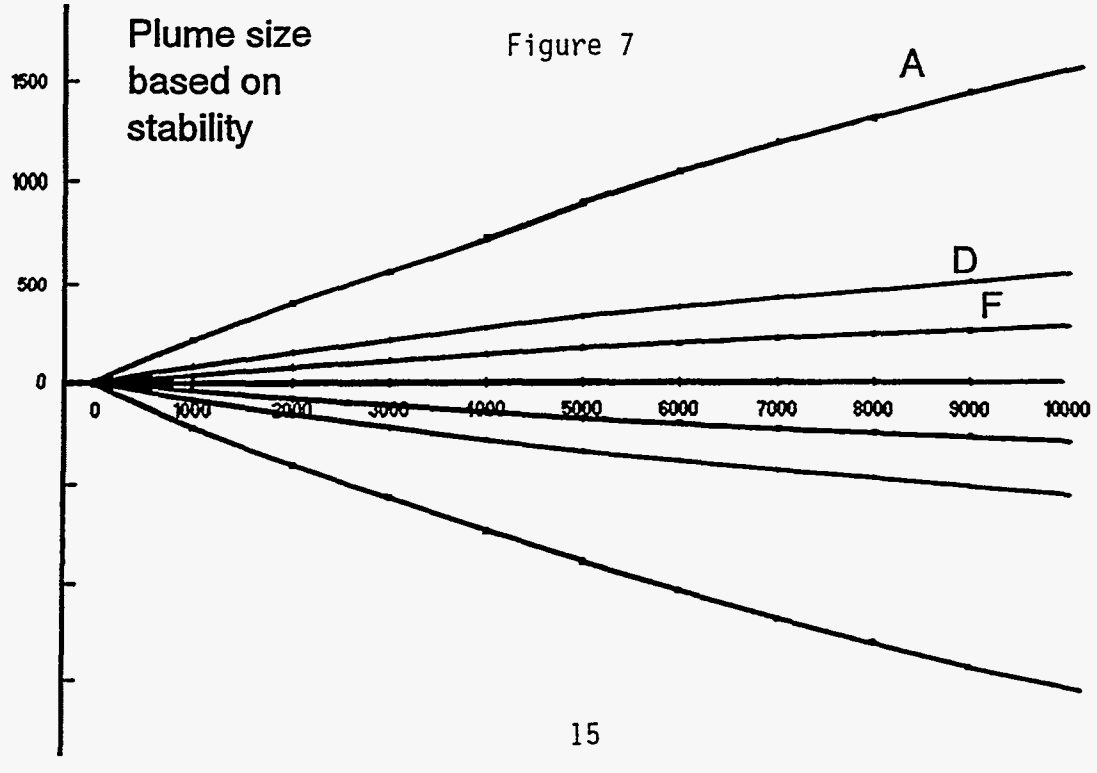
Use this nomograph for sky conditions of stability class "F" (Night - Clear)

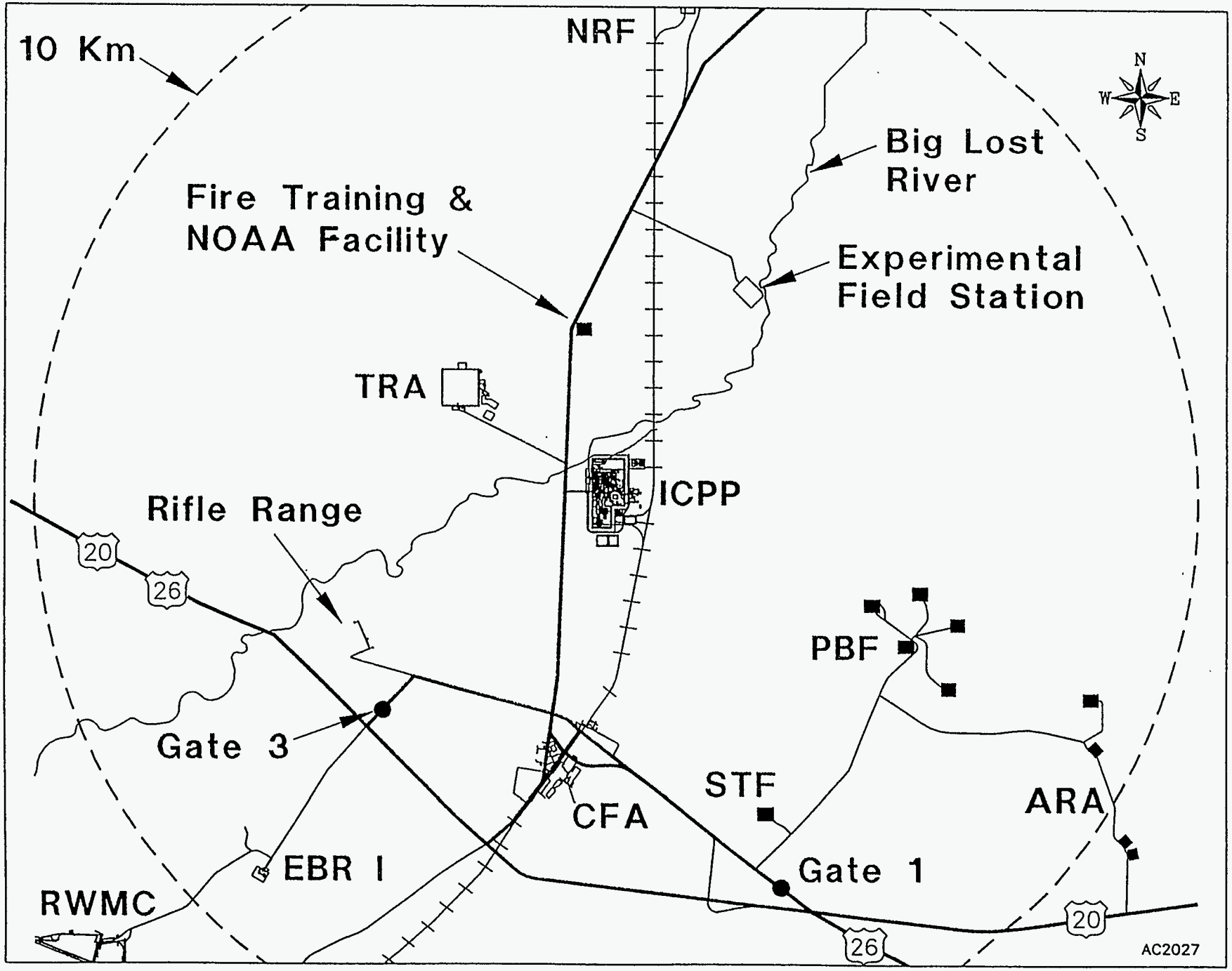
Figure 6

Table 3 Widths of plume for each class of stability as a function of distance from source

Distance (M)	"A" Width (M)	"D" Width (M)	"F" Width (M)
100	43.78	15.92	7.96
200	87.13	31.68	15.84
300	130.1	47.30	23.65
400	172.6	62.76	31.38
500	214.7	78.07	39.04
600	256.4	93.24	46.62
700	297.8	108.3	54.14
800	338.7	123.2	61.58
900	379.3	137.9	68.96
1000	419.5	152.6	76.28
2000	803.3	292.1	146.1
3000	1158	421.0	210.5
4000	1487	540.9	270.4
5000	1796	653.2	326.6
6000	2087	758.9	379.5
7000	2362	859.0	429.5
8000	2624	954.1	477.0
9000	2873	1045	522.3
10000	3111	1131	565.7

Figure 7




10 Km
NRF
N
W
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S
Big Lost
River
Fire Training &
NOAA Facility
Experimental
Field Station
TRA
ICPP
Rifle Range
20
26
PBF
Gate 3
CFA
STF
ARA
EBR I
Gate 1
RWMC
20
26
AC2027

Figure 8

Appendix A

Listing and Analysis of Limit Parameters Found for 88 Chemicals

The selection of chemicals and their concentration limits were based on the results of guidelines established by the Westinghouse M&O Subcommittee on Nonradiological risk (WSRC 1993). The material that follows is edited from their report.

The chemicals listed in Table A-1 include all those for which ERPG values have been published to date, all additional chemicals for which the Committee on Toxicology of the National Research Council, National Academy of Sciences, has developed EEGLs, SPEGLs, and CEGLs for the US military, and all chemicals for which ERPG values are either in the process of being developed, or which have been identified, by a subcommittee of DOE's Emergency Management Advisory Committee, as having a high priority for ERPG-value development.

All concentrations found for all 88 chemicals for the fifteen concentration limit parameters in Appendix C were compared. In making these comparisons, it must be clearly understood that each limit parameter was developed for a different purpose, addressing different populations, different time periods, and different toxicologic endpoints. At times the organizations responsible for development of chemical-specific values derived values that had nothing to do with toxicity and/or available data. For example, about 12% of IDLH values are based upon the chemical's lower explosive limit, since no evidence could be found to the effect that exposure to the chemical concerned was "immediately dangerous to life and health" at lower concentrations.

Ratios of individual pairs of values were calculated along with their mean, standard deviation, and standard deviation as a percentage of their mean. This was done, first, for all the pairs found (N = total number of pairs of parameters available for comparison), and then excluding a few ratios judged to be outliers (n = number of ratios used for the statistics). This judgement was made on the basis of large deviations of particular ratios from the mean value for a particular comparison. The results of these comparisons were used to develop the hierarchy of recommended alternative guidelines presented in Table 2. The various alternative guidelines are plotted against the primary guidelines. These recommendations differ somewhat from those already in use (see Tables 1 and 2). For example, the mean ratio of ERPG-2 to IDLH values is $0.26 \pm 169\%$ for $n = N = 34$, whereas the mean ratio of ERPG-3 to IDLH values is $1.04 \pm 174\%$ for $n = N = 34$ and $0.79 \pm 112\%$ for $n = 32$ (i.e., $n < N$). The comparison between IDLH and ERPG-3 values is clearly much better, which is to be expected since both these parameters are associated with life-threatening effects. Another difference concerns the use of SPEGL (60 min) values. D.O.E.'s Emergency Management Guide (Guidance for Hazard Assessment, 6-26-92) recommends use of the 1-hour SPEGL value in place of ERPG-2 (p. 37). However, SPEGLs were developed for only 5 chemicals: 3 hydrazine compounds, hydrogen chloride, and nitrogen dioxide. In every case, the SPEGL value compares better with the PEL-TWA or TLV-TWA (see below). Of these, only hydrogen chloride has EEGL and CEGL values.

The M&O subcommittee initially considered recommending the use of PEL-STEL or TLV-STEL values as the primary guidelines instead of ERPG-1 values, since the latter are not based exclusively on toxicologic considerations. Some ERPG-1 values are based on odor or perception threshold concentrations. In some instances, the ERPG-1 value would be equal to or greater than the ERPG-2 value, i.e., severe or irreversible health effects could occur at concentrations lower than those at which the chemicals would be perceived. For these chemicals, no ERPG-1 value has been developed. For some other

particularly odiferous chemicals (e.g., the amines and sulfides), the ratio of ERPG-2 to ERPG-1 values is large. In addition, there are 4 chemicals (1,3-butadiene, hydrogen sulfide, methyl mercaptan and trimethylamine) for which the ERPG-1 value is one-hundredth of the PEL-TWA value, which is the permissible exposure limit for an 8-hour workday, 5 days a week. However, the M&O subcommittee recommended use of ERPG-1 values as primary guidelines for consistency, but also recommended that short-term exposure limit values (the more conservative of PEL-ST and TLV-STEL) be used for particularly odiferous chemicals. These chemicals include carbon disulfide, hydrogen sulfide, sulfur dioxide, and trimethylamine. Methyl mercaptan lacks short-term exposure limits, so the remaining hierarchy parameter (TLV-TWA x 3) was used in place of ERPG-1.

For reasons already explained, the M&O subcommittee did not, in general, consider it appropriate to use fixed fractions or fixed multiples of parameters that have been developed with specific toxicologic endpoints in mind. It is for this reason that they did not used IDLH x 0.5, even though the values compare quite well with ERPG-3s. However, an exception has been made for chemicals that do not have short-term exposure limit or ceiling values, in which case they are included in the alternative parameter hierarchy, TLV-TWA x 3 for ERPG-1 and TLV-TWA x 5 for ERPG-2. The justification for this recommendation is contained in the ACGIH 1991-1992 Threshold Limit Value booklet.

60-minute SPEGL values, which are not listed in Table A-1, are given below (NAS 1985):

Hydrazine	0.12 ppm
Hydrogen Chloride	1 ppm
Monomethylhydrazine	0.24 ppm
1,1 -Dimethylhydrazine	0.24 ppm
Nitrogen Dioxide	1 ppm

Table A-1
Chemical-Specific Primary or Hierarchy-based Alternative Concentrations
(based on October 1992 limits)

CHEMICAL NAME	PEL-TWA	ERPG-1	ERPG-2	ERPG-3	UNITS
Acetone	750	1000	8500	20000	ppm
Acrolein	0.1	0.1	0.5	3	ppm
Acrylic Acid	2*	2	50	750	ppm
Acrylonitrile (Ca)	2	10	50	500	ppm
Allyl Chloride	1	3	40	300	ppm
Aluminum Oxide	10	15*	15*	25	mg/m3
Ammonia	25	25	200	1000	ppm
Arsenic (Inorganic) as As (Ca)	0.01	0.6	1.4	*100*	mg/m3
Arsenic (Organic compounds) as As	0.2*	0.2			mg/m3
Arsine (Ca)	0.05	1*	(1)	(5)	ppm
Benzene (Ca)	1	5	50	3000	ppm
Beryllium (Ca)	0.002	*0.006*	(25)	(100)	mg/m3
Bromine	0.1	0.2	1	5	ppm
Bromotrifluoromethane	1000		25000	40000	ppm
1,3-Butadiene (Ca)	10*	10	50	5000	ppm
Carbon Disulfide	1*	1	50	500	ppm
Carbon Monoxide	35	400	400	750	ppm
Carbon Tetrachloride(Ca)	2	*20*	*100*	*750*	ppm
Chlorine	0.5	1	3	20	ppm
Chlorine Trifluoride		*0.1*	*1*	*10*	ppm
Chloroacetyl Chloride	0.05	0.1	1	10	ppm
Chloroform (Ca)	2	30	100	1000	ppm
Chloropicrin	0.1	0.2*	0.2	3	ppm
Chlorosulfonic Acid		2	10	30	mg/m3
Chlorotrifluoroethylene		20	100	300	ppm
Crotonaldehyde (Ca)	2	2	10	50	ppm
Dichlorodifluoromethane (FC12)	1000	3000	10000	50000	ppm
Dichlorofluoromethane (FC21)	10	30	100	50000	ppm
Dichlorotetrafluoroethane (FC114)	1000	3000	10000	50000	ppm
Diketene		1	5	50	ppm
Dimethylamine	1*	1	100	500	ppm
Dimethylformamide	5*	(5)	(10)	(100)	ppm
1,1-Dimethylhydrazine (Ca)	0.5	1.5	5	50	ppm
Epichlorohydrin (Ca)	2	2	20	100	ppm
Ethanolamine	3	6	50	1000	ppm
Ethylene Glycol	4		40	60	ppm
Ethylene Oxide (Ca)	1	3	*50*	*500*	ppm
Fluorine	0.1	2	7.5	10	ppm

CHEMICAL NAME	PEL-TWA	ERPG-1	ERPG-2	ERPG-3	UNITS
Formaldehyde (Ca)	1	1	10	25	ppm
Hexachlorobutadiene	0.02	3	10	30	ppm
Hydrazine (Ca)	0.1	0.3	(0.8)	(10)	ppm
Hydrogen Chloride	0.5	3	20	100	ppm
Hydrogen Fluoride	3	5	20	50	ppm
Hydrogen Peroxide(30%)	1	3	(25)	(50)	ppm
Hydrogen Sulfide	10	10**	30	100	ppm
Isobutyronitrile		10	50	200	ppm
Isopropyl Alcohol	400	400*	400	12000	ppm
Lithium Bromide	1		15		mg/m3
Lithium Chromate			0.1		mg/m3
Lithium Hydroxide /Hydride	0.025	*0.05*	*0.1*	*0.5*	mg/m3
Mercury Vapor (as Hg)	0.05	0.15	0.2	28	mg/m3
Methane	5000		5000		ppm
Methanol	200	*200*	*1000*	*5000*	ppm
Methyl Chloride (Ca)	50	100	*400*	*1000*	ppm
Methyl Fluoride (as fluoride)	2.5	7.5	12.5		mg/m3
Methyl Iodide (Ca)	2	25	50	125	ppm
Methyl Mercaptan	0.5	0.5**	25	100	ppm
Monomethylamine	10	10	100	500	ppm
Monomethylhydrazine (Ca)	0.24		0.5	50	ppm
Nickel Carbonyl (as Ni) (Ca)	0.001	0.05*	0.05	7	ppm
Nitric Acid	2	(2)	(15)	(30)	ppm
Nitrogen Dioxide	2*	(2)	(15)	(30)	ppm
Nitrous Oxide	50	150	10000	20000	ppm
Ozone	0.1	0.3	1	10	ppm
Perchloroethylene	25	100	200	500	ppm
Perfuoroisobutylene			0.1	0.3	ppm
Phenol	5	10	50	200	ppm
Phosgene	0.1	0.2*	0.2	1	ppm
Phosphine	0.3	1	(50)	(100)	ppm
Phosphoric Acid	1	3	5	10000	mg/m3
Phosphorous Pentoxide		5	25	100	mg/m3
Sodium Hydroxide		(2)	(40)	(100)	mg/m3
Sodium Monoxide					mg/m3
Sodium Peroxide					mg/m3
Styrene (Ca)	50	100	200	500	ppm
Sulfur Dioxide	0.3*	0.3	3	15	ppm
Sulfuric Acid (Oleum,Sulfur Trioxide)	1	2	10	30	mg/m3
Tetrafluoroethylene		200	1000	10000	ppm
Titanium Tetrachloride		5	20	100	mg/m3
Toluene	100	150	300	2000	ppm
Trichloroethylene (Ca)	50	(100)	(500)	(1000)	ppm

CHEMICAL NAME	PEL-TWA	ERPG-1	ERPG-2	ERPG-3	UNITS
Trichlorofluoromethane (FC11)	100		1500	10000	ppm
Trichlorotrifluroethane (FC113)	1000	1250	1500	4500	ppm
Trimethylamine	10	10**	**100**	**500**	ppm
Uranium Hexafluoride	0.2	**(1)**	**(10)**	**(20)**	ppm
Vinyl Acetate	5*	**5**	**75**	**500**	ppm
Vinylidene Chloride	1	10*	10		ppm
Xylene	100	150	200	1000	ppm
Number of Guideline Values	74	78	85	79	

Note: Bold numbers are ERPG values, bold numbers in parentheses are draft ERPG values, numbers in bold itallics are new.

Notes for Table A-1: Chemical-Specific or hierarchy-based Alternative Concentrations:

Values given as alternatives in the absence of ERPG values were selected from the concentration-limit parameters using the hierarchy presented in Table 4.

(Ca) indicates that chemical is a confirmed or suspected human carcinogen.

At least one guideline value was found for all but 2 (sodium monoxide and sodium peroxide) of the 88 chemical substances on this list. Neither is listed among over 2000 chemicals on the ILO-CIS data base of exposure limits (ILO 1991). Values from 15 major countries are included in this list. It is concluded that the above two substances do not qualify as being "extremely hazardous".

* Values adjusted downwards to next higher range value. For example, the PEL-STEL for isopropyl alcohol is 500 ppm, whereas the EEGL-60 is 400 ppm. Therefore, the ERPG-1-equivalent value is adjusted downwards to 400 ppm.

** For three chemicals, ERPG-1 values that are odor-based have been adjusted upwards. The higher PEL-STEL is used instead of the ERPG-1 value because the ERPG-1 value is based on perception rather than health effects. ERPG-1 values for compounds like carbon disulfide and sulfur dioxide could also have been adjusted upwards, but since the adjustment was small (less than a factor of 10), this was not done. For each of the three chemicals below, the adjustment involved a factor of 100. Without adjustment, the hierarchy values for hydrogen sulfide, methyl mercaptan, and trimethylamine would have been as follows:

Chemical	Formula	TLV-TWA (ppm)	ERPG-1 (ppm)	ERPG-2 (ppm)	ERPG-3 (ppm)
Hydrogen Sulfide	H2S	10	(0.1)	30	100
Methyl mercaptan	CH3SH	0.5	(0.005)	15	100
Trimethyl-amine	(CH3)3N	10	(0.1)	1500	4500

Note: The ERPG-1 values that have been adjusted, using the hierarchy values from Table A-2, are in parentheses.

Table A-2
Recommended Hierarchy Of Alternative Concentration-Limit Parameters

Primary Guideline	Hierarchy Group	Hierarchy of Alternative Guidelines	Source of Concentration Parameter
ERPG-3	1	EEGL (30-min) IDLH	AIHA 1991 NAS 1985 NIOSH 1990
ERPG-2	2	EEGL (60-min) LOC PEL-C TLV-C TLV TWA x 5*	AIHA 1991 NAS 1985 EPA 1987 CFR 29:1910.1000 ACGIH 1992 ACGIH 1992
ERPG-1	3	PEL-STEL TLV-STEL TLV-TWA x 3*	AIHA 1991 CFR 29:1910.1000 ACGIH 1992 ACGIH 1992
PEL-TWA	4	TLV-TWA SPEGL (60-min) CEGL	CFR 29:1910.1000 ACGIH 1992 NAS 1985 NAS 1985

Notes: * Applicable only to chemicals whose effects are dose-dependent.

The protocol is to use the primary guidelines first and then the alternative guidelines in the order presented for each hazard level when the primary guideline does not exist.

If application of this hierarchy to a particular chemical gives rise to a value for a lower hazard class that is higher than the value for the next higher hazard class (e.g., ERPG-1-equivalent value greater than ERPG-2-equivalent value), then that value should be adjusted downwards to match that of the next higher hazard class (see Table A-1 for examples).

References:

WSRC 1993 "Toxic Chemical Hazard Classification and Risk Acceptance Guidelines for use in D.O.E. Facilities", Recommendations of the Westinghouse M & O Nuclear Facility Safety Committee Subcommittee on Nonradiological Risk Acceptance Guidelines Development,(April 20, 1993), WSRC-MS-92-206, REV. 1

Appendix B

Development of Plume Distance Nomograph for Protective action

I. Introduction

The protective action nomograph used for determining chemical plume distance was developed by placing several three line nomographs together to predict the centerline plume distance. The nomograph scales on the lines are all logarithmic so the values can be multiplied or divided as required in the gaussian plume equation.

II. Plume Distance Equations

The various equations used to construct the NOMOGRAPH EQUATION were taken from the EPA/FEMA/DOT "Technical Guidance to Hazards Analysis - Emergency Planning for Extremely Hazardous substance" (EPA 1987). They are presented in Table B-1. The LIQUID FACTORS equation contains the chemical specific parameters relevant to a pool evaporation generation of vapors. The DIKED AREAS equation is used because the surface area of the liquid pool is known. The STEADY STATE CONCENTRATION DOWNWIND equation relates the generation rate to the chemical air concentration and the Pasquill stability (meteorological factors). The UNIT CONVERSION equations convert units in the various equation to common units. The PASQUILL STABILITY equations and the constants were solved in terms of the other variables in the NOMOGRAPH EQUATION liquid pool and mass release scenarios. Table B-2 contains the value for various distances of the PASQUILL STABILITY equations plus the value of the linearized constant (7.9836 for the liquid pool release and -3.8451 for the mass release).

The constant term includes the numerical value of the constants from the various equations and the temperature factor of (273° C + T1) where T1 is set to 27° C. A temperature of 27° C was used because it is the temperature associated with the 95% weather at the ICPP and when added to 273° K it gives 300° K. The temperature was included in the constant because most degree changes would produce very small changes in the nomograph equation results due to the large 273° K value added to each temperature used. The 27° C would produce conservative results for conditions below 27° C at the ICPP.

The STEADY STATE DOWNWIND equation is good for downwind plumes releases from 10 minutes to 1 hour. The PASQUILL STABILITY equations are limited for use with distances ranging from 100 m to 10,000 m. The open country equations were selected because the site is located in open desert country. The A stability equation is used for clear days when there are no clouds in the sky or less than 10% cloud cover. The D stability equation is for cloudy (more than 10% cloud cover) days or nights. The F stability equation is used for clear (less than 10% cloud cover) nights. The stability equations provide an one hour average concentration. The HANNA CORRECTION FACTOR from "Handbook of Atmospheric Diffusion," (DOE/TIC-11223 1982) was used to adjust the concentration to a 15 minute average plume peak.

Table B-1. Nomograph Equations

EQUATION FACTOR	EQUATION	EPA 1987
LIQUID FACTORS	$LFA = (0.106 \times u^{0.78} \times MW^{2/3} \times 0.49 \times QS \times VP)/(82.05 \times (T1+273))$	10
DIKED AREAS	$QR_{lb/min} = (LFA \times (A\ ft^2) \times u^{0.78})/0.49$	14
STEADY STATE CONCENTRATION DOWNWIND	$(C\ gm/m^3) = QR_{g/sec}/(Pi \times \sigma\text{-}y \times \sigma\text{-}z \times u)$	15
UNIT CONVERSION	$QR_{lb/min} = 0.132 \times QR_{g/sec}$	NA
UNIT CONVERSION	$(Cmg/m^3) = 1/1000 \times (C\ gm/m^3)$	NA
PASQUILL A STABILITY (OPEN COUNTRY)	$\sigma\text{-}y\ \sigma\text{-}z = (0.22d(1+0.0001d)^{-1/2})(0.20d)$	EXHIBIT G-1
PASQUILL D STABILITY (OPEN COUNTRY)	$\sigma\text{-}y\ \sigma\text{-}z = (0.08d(1+0.0001d)^{-1/2})(0.06d(1+0.0015d)^{-1/2})$	EXHIBIT G-1
PASQUILL F STABILITY (OPEN COUNTRY)	$\sigma\text{-}y\ \sigma\text{-}z = (0.04d(1+0.0001d)^{-1/2})(0.016d(1+0.0003d)^{-1})$	EXHIBIT G-1
HANNA CORRECTION FACTOR	$(15_{min}/60_{min})^{.02} = 0.7579$	NA
LIQUID POOL NOMOGRAPH EQUATION	$(\sigma\text{-}y\ \sigma\text{-}z)(43.7718)(.7579) = MW^{2/3} \times VP \times A_{SQ\ FT} \times u^{-.22} \times (C\ MG/M^3)^{-1}$	
LIQUID POOL LINEARIZED NOMOGRAPH EQUATION	$LOG(\sigma\text{-}y\ \sigma\text{-}z)+1.5208 = LOG(MW\text{^}(2/3))+LOG(VP)+LOG(A_{sq\ ft})-.22LOG(u)-LOG(C\ mg/m^3)$	

EQUATION FACTOR	EQUATION	EPA 1987
MASS RELEASE RATE NOMOGRAPH EQUATION	$(\sigma\text{-}y\ \sigma\text{-}z)(1.88 \times 10^{-4}(0.7579) = QR_{kg/min} \times u^{-1} \times (C\ mg/m^3)^{-1}$	
MASS RELEASE RATE NOMOGRAPH EQUATION	$LOG(\sigma\text{-}y\ \sigma\text{-}z)\text{-}3.8451 = LOG(QR_{kg/min})\text{-}LOG(u)\text{-}LOG(C\ mg/m^3)$	

WHERE:
$QR_{lb/min}$ = Rate of release to air (lb/min)
$QR_{gm/sec}$ = Rate of release to air (gm/sec)
MW = Molecular weight (g/g-moles)
A ft^2 = Surface area of spilled material (ft^2)
VP = Vapor pressure of material (mm Hg)
82.05 = R of 82.05 atm cm^3/g-mole K
T1 = 27° C simplification for worst case weather condition
u = Windspeed (m/sec)
QS = Quantity spilled (lbs)
C gm/m^3 = Airborne concentration (gm/m^3)
C mg/m^3 = Airborne concentration (mg/m^3)
d = Centerline plume distance (m)
Pi = 3.141
σ-y = Dispersion deviation horizontally (m)
σ-z = Dispersion deviation vertically (m)

Table B-2. Stability Equation and Constant Values

DISTANCE, M	σ-y σ-z	LOG(σ-y σ-z)	INCLUDING CONSTANT (LIQUID POOL)	INCLUDING CONSTANT (MASS RELEASE)
F STABILITY FACTOR OPEN COUNTRY				
100	6.18276	0.7912	2.3120	-3.0539
1000	469.3970	2.6715	4.1923	-1.1736
10000	11313.7085	4.0536	5.5744	0.2085
D STABILITY FACTOR OPEN COUNTRY				
100	44.5381	1.6487	3.1695	-2.1964
1000	2894.5089	3.4616	4.9824	-0.3835
10000	84852.8137	4.9287	6.4494	1.0836
A STABILITY FACTOR OPEN COUNTRY				
100	437.81649	2.6413	4.1621	-1.2038
1000	41952.3539	4.6228	6.1435	0.7776
10000	3111269.8372	6.4929	8.0137	2.6478

III.Nomograph Patterns

Several three line nomographs were used to complete mathematical operations graphically. The three line nomograph has three vertical lines equally spaced. Input variable of the nomograph equation are located on the left two lines and the resultant calculation on the right most line. The calculation is completed by marking the value of input variables on the left two lines and connecting and projecting with a straight ruler to the right most line for the results. When connecting several nomographs in series the resultant line becomes the "tie line" to the next nomograph. Tie lines on nomographs typically do not show the calculated values, because the tie line is the first input line on a following three line nomograph. By restricting the distances between the nomograph lines to equal distances, the middle line linear increments used to construct the scales are always half the size of increments of the lines on either side. In the liquid pool release nomograph some of the three line nomographs were reduced in size to fit on the page. In this case two tie lines were placed next to each other with connecting lines from the first tie line to the next to guide the transition to a different scale three line nomograph.

The nomograph used in this project combines a series of three nomographs. Each three line nomograph will be called a nomograph patterns in this discussion. The liquid pool nomograph shown in figure B-1 combines four nomograph patterns. The mass release nomograph combines two nomograph patterns. Each nomograph starts at the left and finishes on the right.

Figure B-1 Protective action Plume Distance Nomograph

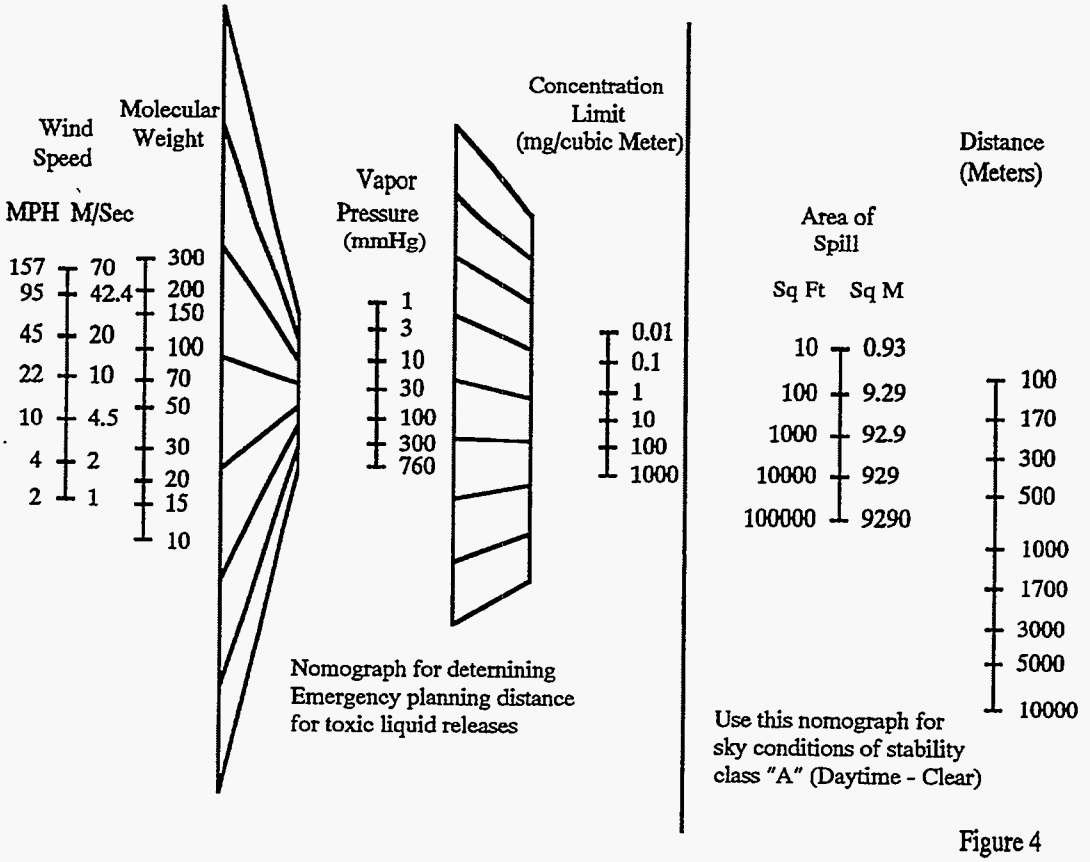

Figure 4

Three patterns were used in the construction of the liquid pool release protective action plume distance nomograph and two patterns were used in the mass release nomograph. These patterns include a multiplication pattern and two division patterns. The multiplication pattern was used for vapor pressure and area multiplication in the liquid pool nomograph. A division pattern was used to divide the chemical concentration into previous calculations in both the liquid pool nomograph and the mass release nomographs. Another division pattern was used to divide the wind speed raised to a fractional power into the molecular weight raised to a fractional power in the liquid pool nomograph and to divide the wind speed into the mass release rate in the mass release nomograph.

In the multiplication pattern, the values for each multiplicand was placed on the left and center lines with the resultant calculation on the tie line. Unique to the multiplication pattern, the center and right line scales are opposite in increasing magnitude relative to the left line scale. In other words if the scale on the left line increases going vertically up the line then the values on the middle and right lines must decrease while moving up the lines.

For the first division pattern, the divisor values are place on the middle line of the three line nomograph pattern, the numerator values on the left line, and the resultant calculated on the right line. Unique to this division pattern, the values on the left and middle lines increased in magnitude in the same direction while the values on the right line decrease.

The second division pattern has the divisor values on the left line, the numerator values on the center line, and the resultant value on the right line. Unique to this pattern, all values increase in magnitude in the same direction on each line. The variables used in this pattern (wind speed and molecular weight) are raised to a power in the nomograph equation. These values were scaled before placing the values on the lines.

For figure B-1, the wind speed, u, raised to the 0.22 power on the first left line was divided into the molecular weight raised to the 2/3rd power on the second line using the second division pattern to give the resultant value on the tie line. This tie line was scaled down so the next pattern could be shown on the page. The next line contains the vapor pressure which is multiplied with a resultant on the tie line using the multiplication pattern. This tie line is scaled down before dividing by the chemical airborne concentration, C, on the next line using the first division pattern with results on the next tie line. This tie line does not need to be scaled down before multiplying by the area of the spill, A, to project the resultant stability classification distance on the last line. The log of the A Stability class value includes the constant from the nomograph equation which is used to locate the distance for the chemical plume.

For the mass release nomograph, the wind speed on the first line is divided into the mass release rate on the second line using the second division pattern. The resultant is the tie line or third line on the nomograph. The concentration on the fourth line is divided into the tie line using the first division pattern to give the resultant stability class distance on the last line of the nomograph.

The plotting tolerance can be as much 10% because the errors are only additive

due to the logarithmic or power nature of the scales. The RMS result of these combined errors is between 22 and 26%. With the inherent uncertainty of plume calculation models this should be acceptable.

References:

EPA 1987 U.S. Environmental Protection Agency, Federal Emergency Management agency, U.S. Department of Transportation, "Technical Guidance for Hazards Analysis - Emergency Planning for Extremely Hazardous Substances," December 1987.

Appendix C

Acronym Definitions

AGENCIES: (Listed alphabetically)

ACGIH	American Conference of Governmental Industrial Hygienists
AIHA	American Industrial Hygiene Association
EPA	Environmental Protection Agency
FEMA	Federal Emergency Management Agency
NAS	National Academy of Sciences
NIOSH	National Institute for Occupational Safety and Health
OSHA	Occupational Safety & Health Administration
USDOT	U.S. Department of Transportation

GUIDELINES

AIHA Terms (developed for emergency response purposes) (AIHA 1989):

ERPG-1 Emergency Response Planning Guideline 1: "The maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing other than mild transient adverse health effects or perceiving a clearly defined objectionable odor."

ERPG-2 Emergency Response Planning Guideline 2: "The maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action."

ERPG-3 Emergency Response Planning Guideline 3: "The maximum airborne concentration below which it is believed nearly all individuals could be exposed for up to 1 hour without experiencing or developing life threatening health effects."

NAS Terms (developed for military use) (NAS 1986):

EEGL Emergency Exposure Guidance Level "A concentration of a substance in air (as a gas, vapor, or aerosol) that may be judged by DOD to be acceptable for the performance of specific tasks during rare emergency conditions lasting for periods of 1-24 h. Exposure at an EEGL might produce reversible effects that do not impair judgement and do not interfere with proper responses to the emergency". The EEGL is "a ceiling guidance level for a single emergency exposure, usually lasting from 1 h to 24 h -- an occurrence expected to be infrequent in the lifetime of a person".

CEGL Continuous Exposure Guidance Level: "CEGLs are ceiling concentrations designed to avoid adverse health effects, either immediate or delayed, of more prolonged exposures and to avoid degradation in crew performance that might endanger the objectives of a particular mission as a consequence of continuous exposure for up to 90 days".

SPEGL Short-Term Public Emergency Guidance Level: "The SPEGL is defined as a suitable concentration for unpredicted, single, short-term, emergency exposure of the general public. In contrast to the EEGL, the SPEGL takes into account the wide range of susceptibility of the general public. This includes sensitive populations -- such as children, the aged, and persons with serious debilitating diseases".

OSHA Terms (developed for occupational safety) (CFR 29:1910.1000):

PEL Permissible Exposure Limit: Although the term PEL is not used in the "Final Rule Limits Columns" of Table Z-1-A and Table Z-2, it was used in the "Transitional Limits". It is also used in the compound-specific rules for various substances, e.g., #1910.1018 (Inorganic arsenic), #1910.1028 (Benzene), #1910.1045 (Acrylonitrile), #1910.1047 (Ethylene oxide), etc.

PEL-TWA Time-Weighted Average: "The employee's average airborne exposure in any 8-hour work shift of a 40-hour work week which shall not be exceeded". This is to be computed from the equation:
$E = (CaTa + CbTb + \ldots CnTn)/8$
where C is the concentration during any period of time T (in hours) where the concentration remains constant.

PEL-STEL Short-Term Exposure Limit: "The employee's 1-minute time weighted average exposure which shall not be exceeded at any time during a work day unless another time limit is specified ...".

PEL-C Ceiling: "The employee's exposure which shall not be exceeded during any part of the work day". If necessary from a monitoring point of view, C may be assessed as a 15-minute time weighted average.

EPA Terms (developed for emergency planning) (EPA 1987):

LOC Level of Concern: "The concentration of an extremely hazardous substance in air above which there may be serious irreversible health effects or death as a result of a single exposure for a relatively short period of time." (Also used by FEMA and US DOT)

ACGIH Terms (developed for workplace safety) (ACGIH 1992):

TLV-TWA Threshold Limit Value - Time-Weighted Average: "The time-weighted average concentration for a normal 8-hour workday and a 40-hour workweek, to which nearly all workers may be repeatedly exposed, day after day, without adverse effect."

TLV-STEL Threshold Limit Value - Short-Term Exposure Limit: "The concentration to which workers can be exposed continuously for a short period of time without suffering from 1) irritation, 2) chronic or irreversible tissue damage, or 3) narcosis of sufficient degree to increase the likelihood of accidental injury, impair self-rescue, or materially reduce work efficiency, and provided that the daily TLV-TWA is not exceeded." "A TLV-STEL is ...a ... 15-minute TWA exposure which should not be exceeded at any time during a workday even if the 8-hour TWA is within the TLV-TWA. Exposures above the TLV-TWA up to the STEL should not be longer than 15 minutes and should not occur more than four times per day. There should be at least 60 minutes between successive exposures in this range."

TLV-C Threshold Limit Value - Ceiling: "The concentration that should not be exceeded during any pan of the working exposure." "... if instantaneous monitoring is not feasible, then the TLV-C can be assessed by sampling over a 15-minute period except for those substances that may cause immediate irritation when exposures are short."

NIOSH Terms (developed for respirator use) (NIOSH 1990):

IDLH Immediately Dangerous to Life or Health: "The maximum concentration from which, in the event of respirator failure, one could escape within 30 minutes without a respirator and without experiencing any escape impairing (e.g., severe eye irritation) or irreversible health effects."

References:

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Appendix D

Example Solutions of Nomographs

Spill conditions and variable inputs:

Wind speed of 4 mph
Molecular weight of 50 g-moles
Vapor pressure of 760 mm Hg
Concentration in air of 1 mg/m^3
Spill area of 1000 ft^2
Sky contition is daytime - clear

The spill site wind speed, chemical molecular weight, chemical vapor pressure, chemical air concentration limit, and area of the spill are require for inputs to the nomograph. The nomograph for day - clear liquid spill (Figure 4) was selected. For this hypothetical chemical spill scenario the resultant plume distance would be less than 3000 meters.

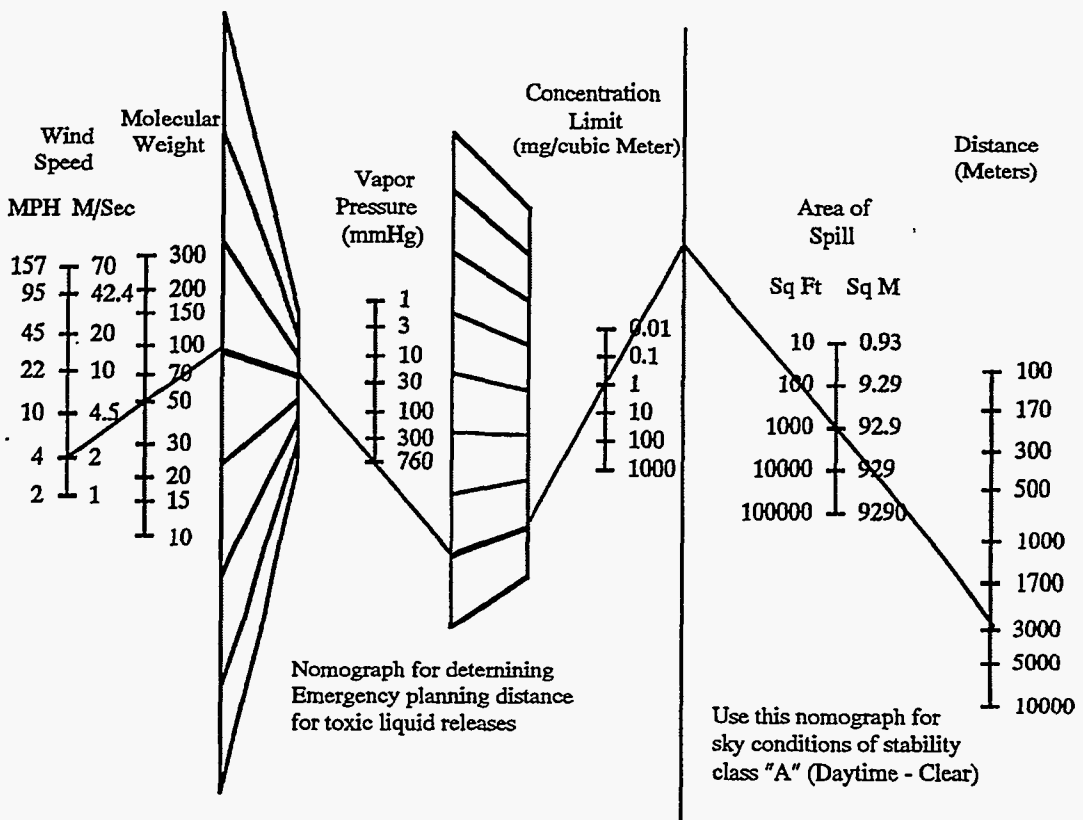

Figure 4