UNITED
NATIONS

ST

Secretariat

Distr.
GENERAL

ST/SG/AC.10/C.3/1999/49
20 April 1999

Original: ENGLISH

COMMITTEE OF EXPERTS ON THE
TRANSPORT OF DANGEROUS GOODS

Sub-Committee of Experts on the
Transport of Dangerous Goods
(Sixteenth session,
Geneva, 5-16 July 1999,
agenda item 5 (g))

MISCELLANEOUS DRAFT AMENDMENTS TO THE MODEL REGULATIONS ON THE TRANSPORT OF DANGEROUS GOODS

Toxic by inhalation substances

Packaging of substances that are toxic by inhalation

Transmitted by the Expert from the United States of America

1. The Sub-Committee at its fifteenth session agreed to delay further discussion on requirements for substances that are toxic by inhalation until the 1999-2000 biennium. While there are several papers on this topic that carry over from the previous biennium, the expert from the United States believes that the issue of toxic by inhalation should be addressed in steps. An important first step is to have clear criteria and to identify substances meeting those criteria.

2. In adopting special packaging requirements (packing instruction P601 and P602) for substances that are known to be assigned to Division 6.1, packing group I on the basis of inhalation toxicity (hereafter referred to as toxic by inhalation substances), the Sub-Committee recognized that special requirements for substances meeting these inhalation criteria are appropriate. However, there are substances that are known to meet the criteria but which have not been assigned to the same packing instructions.

3. It is the opinion of the expert from the United States that a first step in dealing with toxic by inhalation substances in this biennium is to consistently apply the packing instruction requirements to these substances on the basis of criteria. While the Division 6.1, packing group I inhalation toxicity criteria define the group of substances that are assigned to P601 and P602, the criteria for assigning substances to these two packing instructions have yet to be clarified.

Volatility to the LC_{50} Ratio Used to Assign Substances to P 601 and P 602

4. Ratios of volatility to the LC_{50} have long been used in the Model Regulations for classifying inhalation hazard substances to packing groups in Division 6.1 (see 2.6.2.2.4.3). While the decision to assign P601 or P602 was made on the basis of existing packaging requirements, it can be seen that substances were generally assigned to P601 when the toxicity was 200 ppm or less (the Globally Harmonized System also includes a classification level at LC_{50} 200 ppm (1 hour)) and the ratio of vapour pressure to toxicity (VP/LC_{50}) was 2000 or more. This is illustrated in the list of the substances shown in Annex 1, Table 1.

5. While the criteria may be derived from packaging instruction assignments, the expert from the United States believes that criteria for assigning substances to P601 need to be clearly defined so that all substances posing similar degrees of risk are treated consistently. In previous papers, the expert from the United States proposed that a ratio of volatility to the LC_{50} of 500 or more be used to differentiate between substances that are assigned to P601 and P602. The expert from the United States evaluated the significance of selecting a ratio of 500 versus a ratio of 2000 using vapor dispersion modelling. A description of the analysis and the results are provided in Annex 2. While it was necessary to make a number of assumptions in carrying out the analysis, it provides a comparison of the degrees of risk for these two volatility ratios. The analysis also illustrates the comparative risks between flammability and inhalation toxicity with toxicity posing a risk several orders of magnitude higher.

6. Clearly, the decision to use a ratio of 500 or 2000 is a subjective decision. However, on the basis of the data provided, the expert from the United States considers that significant safety enhancements can be provided by ensuring that substances with a ratio of volatility to the LC_{50} of 500 or more and an LC_{50} of 200 ppm or less are required to be packaged in packagings in accordance with P601. It is proposed that these criteria be used in assigning substances to P601.

7. Adopting a ratio of 500 would result in some of the substances currently assigned to P602 being reassigned to P601. These substances include UN 1238, UN 1239, UN 1244, and UN 1834 see Annex 1, Table 2).

Proposal

8. It is proposed that for UN 1238, UN 1239, UN 1244, and UN 1834 column 8 in the Dangerous Goods list be revised to read "P601".

9. Based on the criteria for assigning substances to P601 proposed in paragraph 6 above, UN 2482 and 2484 (data provided in Annex 1, Table 2) which are currently assigned to P001 should be reassigned to P601.

Proposal

10. It is proposed that for UN 2482 and UN 2484 column 8 in the Dangerous Goods list be revised to read "P601".

11. Based on the proposal in paragraph 6, criteria for substances assigned to P602 are substances with an LC_{50} of less than 1000 ppm and a ratio of volatility to the LC_{50} of less than 500 but equal to or more than 10. There are a number of substances that are currently assigned to P001 which meet these criteria. Relevant data for these substances is provided in Annex 1, Table 3.

Proposal

12. It is proposed that for UN 2644, UN 1809, UN 1143, UN 1810, UN 1722, UN 1829, UN 2442, UN 1695, UN 2487, UN 2232, UN 2488, UN 2382, UN 2485, UN 3079, UN 2407, UN 1838, UN 1135, UN 1754, UN 2826, UN 2438, UN 2606, UN 3023, UN 2477, UN 1752, UN 2646, UN 2337, UN 2521, UN 3246 column 8 in the Dangerous Goods list be revised to read "P602".

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ANNEX 1
List of substances meeting the Division 6.1, PG I inhalation toxicity criteria

Table 1 - Substances currently assigned to P601

UN No		Name	LC_{50}	SVC	SVC/LC_{50}
1259	P601	Nickel carbonyl	18	422000	23444.44
2480	P601	Methyl isocyanate	22	458000	20818.18
1380	P601	Pentaborane	12	225000	18750.00
1251	P601	Methyl vinyl ketone	5	93400	18680.00
1092	P601	Acrolein, inhibited	25	289000	11560.00
1994	P601	Iron pentacarbonyl	6	30300	5050.00
1185	P601	Ethyleneimine, inhibited	76	217000	2855.26
1744	P601	Bromine	113	237000	2097.35
1605	P601	Ethylene dibromide	650	11300	17.38
1744	P601	Bromine solutions	--	--	--
3294	P601	Hydrogen cyanide, solution in alcohol	--	--	--
1613	P601	Hydrocyanic acid, aqueous solutions	--	--	--
3281	P601	Metal carbonyls, n.o.s. (liquid)	--	--	--

Table 2 - Substances proposed to be assigned to P601

UN No	Packing instruction		Name	LC_{50} (ppm)	SVC (ppm)	SVC/LC_{50}	Data Source	RTECS #
	Current	Proposed						
1238	P602	P601	Methyl chloroformate	88	135000	1534.09	R	FG3675
1239	P602	P601	Methyl chloromethyl ether	160	210000	1312.50	R*	KN6650
1244	P602	P601	Methylhydrazine	68	50300	739.71	R*	MV5600
1834	P602	P601	Sulfuryl chloride	131	142000	1083.97	A	WT4870
2482	P001	P601	n-Propyl isocyanate	44	69700	1584.09	A	NR0190
2484	P001	P601	tert-Butyl isocyanate	22	19700	895.45	A	NQ8300

A Data obtained by the U.S. Competent Authority from correspondence with affected industries
R Data obtained from the RTECS.
* LC value converted to 1 hour.

Table 3 Substances proposed to be assigned to P602

UN No	Packing instruction		Name	LC_{50} (ppm)	SVC (ppm)	SVC/LC_{50}	Data Source	RTECS #
	Current	Proposed						
2644	P001	602	Methyl iodide	448	414000	924.11	R*	PA9450
1809	P001	602	Phosphorus trichloride	208	125000	600.96	R*	TH3675
1143	P001	602	Crotonaldehyde, stabilized	93	42100	452.69	R*	GP9499
1810	P001	602	Phosphorus oxychloride	96	35500	369.79	R*	TH4897
1722	P001	602	Allyl chloroformate	61	20400	334.43	A	LQ5775

Table 3 Substances proposed to be assigned to P602								
UN No	Packing instruction		Name	LC_{50} (ppm)	SVC (ppm)	SVC/LC_{50}	Data Source	RTECS #
	Current	Proposed						
1829	P001	602	Sulfur trioxide, inhibited	347	98700	284.44	A	WT4830
2442	P001	602	Trichloroacetyl chloride	128	22700	177.34	R*	A07140
1695	P001	602	Chloroacetone, stabilized	262	41900	159.92	R	UC0700
2487	P001	602	Phenyl isocyanate	16	2470	154.38	A	DA3675
2232	P001	602	2-Chloroethanal (Chloroacetaldehyde)	160	24300	151.88	A	AB2450
2488	P001	602	Cyclohexyl isocyanate	15	2170	144.67	A	NQ8650
2382	P001	602	Dimethylhydrazine, symmetrical	680	92000	135.29	A*	MV2625
2485	P001	602	n-Butyl isocyanate	105	13900	132.38	A	NQ8250
3079	P001	602	Methacrylonitrile, inhibited	656	84200	128.35	R*	UD1400
2407	P602	602	Isopropyl chloroformate	299	36800	123.08	A	LQ6475
1838	P001	602	Titanium tetrachloride	119	12800	107.56	R*	XR1925
1135	P001	602	Ethylene chlorohydrin	74	6450	87.16	A	KK0875
1754	P001	602	Chlorosulfonic acid	16	1320	82.50	A	FX5730
2826	P001	602	Ethyl chlorothioformate	138	10900	78.99	A	LQ6950
2438	P001	602	Trimethylacetyl chloride	507	35500	70.02	A	AO7200
2606	P001	602	Methyl orthosilicate	200	13300	66.50	A	VV9800
3023	P001	602	tert-Octyl mercaptan	102	5000	49.02	R*	MJ1500
2477	P001	602	Methyl isothiocyanate	635	27400	43.15	A	PA9625
1752	P001	602	Chloroacetyl chloride	660	24600	37.27	A	AO6475
2646	P001	602	Hexachlorocyclopentadiene	3	100	33.33	R*	GY1225
2337	P001	602	Phenyl mercaptan	66	1450	21.97	R*	DC0525
2521	P001	602	Diketene, inhibited	551	10500	19.06	A	RQ8225
3246	P001	602	Methanesulfonyl chloride	205	2760	13.46	A	--

A Data obtained by the U.S. Competent Authority from correspondence with affected industries
R Data obtained from the RTECS.
* LC value converted to 1 hour.

ANNEX 2
A risk assessment for Division 6.1, PG I
Toxic-by-inhalation (TIH) materials

Introduction

The purpose of this assessment is to evaluate the relative risks of substances having a vapor pressure to LC50 ratio of 500 versus a ratio of 2000 for toxic by inhalation substances with an LC50 of 200 ppm or less.

This paper assesses the relative risk through an analysis of the consequences of spilling selected Division 6.1, PG I inhalation hazard substances. The objective of this assessment is to compare the impacts of accidental spills of the selected chemicals on affected populations. Some of the substances are also flammable and upon release could ignite. This paper also compares the health impacts with flammability impacts. Flammability results in fatalities or injuries due to thermal radiation and explosion shock waves or blast waves.

Approach

An accident scenario including a spill, vaporization and subsequent atmospheric dispersion was assumed. Since the release and vaporization rate will vary considerably depending upon the accident scenario assumed, it is necessary to assume the characteristics of the release scenario.

The release rate depends on the manner in which the fluid is discharged from the container, the pressure in the container due to the substances vapor pressure, and the temperature of the substance. For this analysis, two temperature conditions were considered, 20 °C and 55 °C.

Before dispersion modeling is used to estimate exposures to the downwind populations, the amount of the substance evaporating from the spilled liquid pool into the air, or releasing from the container into the air must be estimated. The emission rate varies with the type and size of container, the conditions of the fluid in the container, temperature, pressure, the pool size for a liquid spill, wind speed and stability conditions, the height of the spill relative to the breathing zone, the container leaking potential from an accident, etc. Since this study is for the purpose of comparing health effect consequences for the selected liquids at different vapor pressure and acute toxicity values (LC50 in this case), assumptions made need to be uniformly applied across the analyses.

Choice of the best method for estimating the emission rate for a given scenario also depends upon the above factors affecting it. This analysis used several computer models available for prediction of source strengths from spills of materials in liquid form or flashing gaseous form. These models include DOT's "Automated Resource for Chemical Hazard Incident Evaluation" (ARCHIE) and EPA's ALOHA™.

One major part of a consequence analysis is a dispersion model to estimate the vapor dispersion concentration downwind. The appropriate model to be used when estimating atmospheric dispersions depends upon the physical properties of the chemical and the manner in which it is released. Gaussian dispersion models are used to estimate downwind concentrations for neutrally buoyant vapors or gases. When the chemical vapors are heavier than air, associated with high molecular weight or very cold vapors and in high concentrations, accurate modeling in the near field (less than 300 m) calls for use of a dense gas model. The computer software known as "DEGADIS," which is a dense gas dispersion model, is applicable to modeling atmospheric dispersion of ground level releases which include area sources which produce dense gas or aerosols. DEGADIS, like Gaussian dispersion models, generates predicted downwind concentrations which are strongly affected by the assumptions made relative to parameters such as stability class, surface roughness length, and averaging time. ALOHA™ which is also marketed as CAMEO™ has the features incorporating DEGADIS.

When flammable toxic substances being released from an accident encounter an ignition source, the pools of the liquid will either burn or the material in the container could explode if conditions are appropriate. If combustion or explosion occurs, it is assumed that toxic effects are no longer pertinent. Instead, impacts associated with flammability, or shock or blast waves might be appropriate. In this case, the consequence area refers to an area of fatality or injury zone associated with exposure to thermal radiation from flames or overpressure due to shock or blast waves. The consequence analyses presented in this study involve deriving the areas of fatality and injury using the unconfined vapor fire radiation model and explosion model available in ARCHIE.

Properties of Selected Chemicals

Table 1 lists the nine (9) TIH materials selected for this study. All of the substances are assigned to Division 6.1, PG I, have vapor pressure to LC50 ratios ranging from 452 to about 21,000, and have an LC50 of 200 ppm or smaller. Table 1 also shows the vapor pressures (VP) at 20 °C, atmospheric boiling points, molecular weights, and the vapor pressure to LC50 ratio (VP/LC50).

Assumptions to the Consequence Analysis

For acutely toxic endpoints, the chemical concentrations in the air resulting in human fatalities and injuries are LC50 and ERPG-2, respectively. LC50 as used in the Model Regulation is the concentration of vapor which, administered by inhalation for one hour to both male and female young adult albino rats, causes death within 14 days in half the animals tested. ERPG-2 is defined as "the maximum airborne concentration below which it is believed nearly all individuals could be exposed for up to one-hour without experiencing or developing irreversible or other serious effects, or symptoms which could impair an individual's ability to take protection." These toxic end points for the selected chemicals are listed in Table 1.

UN No	Chemical	LC50 (ppm)	VP @ 20 °C (ppm)	VP/LC50	ERPG-2 (ppm)	Boiling Point (°C)	Molecular Weight
1051	Hydrogen Cyanide	40	842000	21050.0	10	26.0	27.03
2480	Methyl Isocyanate	22	458000	20818.2	0.5	39.1	57.05
1092	Acrolein	25	289000	11560.0	0.5	52.5	56.06
1185	Ethyleneimine *	76	217000	2855.3	0.8	56.0	43.07
2482	n-Propyl isocyanate *	44	69700	1584.1	0.44	83.0	85.11
1239	Methyl chloromethyl ether *	160	210000	1312.5	1.6	59.1	80.51
1834	Sulfuryl chloride *	131	142000	1084.0	1.3	69.1	135
1244	Methylhydrazine *	68	50300	739.7	0.7	87.5	46.1
1143	Crotonaldehyde	93	42100	452.7	10	104.0	70.05

Table 1. List of Selected Chemicals and Pertinent Physical and Toxicological Properties.
*Note: * in the table denotes that the ERPG-2 values are approximated by assuming 1/100 of the LC50 values.*

For flammable toxic substances being considered, this assessment followed recommendations by the American Institute of Chemical Engineers and the U. S. Environmental Protection Agency in selecting the thermal radiation exposure levels resulting in fatalities and bodily injuries due to thermal radiation. The thermal radiation levels used are 20 KW/m^2 and 5 KW/m^2 exposed for 40 seconds for estimating the effects resulting in fatality and injury, respectively. In the case of an explosion scenario, the levels of overpressure used as indicators of fatality or injury are 5 psi and 1 psi, respectively, as recommended by the EPA (1996).

To simulate the temperature effect, two temperature levels are assumed and the resulting consequences were separately evaluated. The two temperature levels are 20 °C and 55 °C. It was assumed that each substance was contained in a single 210 litre drum which ruptured instantaneously forming a pool of liquid from which vapors evaporate and disperse in the air.

Meteorological conditions assumed for purposes of this study include the use of F stability with a 1.5 meters per second (3.4 MPH) wind speed which could represent a night time condition. Generally, the stable meteorological conditions (little mixing or turbulence) are designated by stability class E or F. The terrain geometry was assumed to be an urban surrounding. Personal protection such as sheltering or evacuation was not assumed. Other meteorological and terrain conditions can be assumed. Although the different assumptions could be used, their selection is not critical as the purpose of this study is to assess relative risks.

In the case of estimating human impacts associated with thermal radiation, it is assumed that vapors evaporating from the liquid pool, or the vapors and aerosols emanating from the container can catch fire. In the case of explosion, explosive properties of the material in the container were assumed.

An assumed population density is needed to estimate the number of fatalities and injuries once the areas of these zones are estimated from the appropriate consequence and dispersion models (ARCHIE and ALOHA™). For this study the population densities delineating rural, suburban

urban area ranges from 3326 to 15000 persons per square mile, and that in a suburban area ranges from 326 to 3326 persons per square mile.

Results

The consequence analyses that were performed for toxicological effects, effects from thermal radiation, or effects from blast or shock waves are presented in this section. These effects do not occur simultaneously. If one occurs, the other does not. For example, when there is no fire, only toxicological effects are appropriate; and when a fire results, then the toxicological effect is assumed eliminated and effects from thermal radiation are appropriate.

Table 2 below shows the radii of the fatality and injury zones for the selected materials assuming that the content temperature is at 20 °C when the container rupture occurs. These results are obtained from the application of ARCHIE and ALOHA™. Except for hydrogen cyanide, all other materials being evaporated from the spilled pool of liquid behave as a dense gas because of their densities in the vapor phase and their boiling points. The table shows the distances up to which the chemical concentration upon dispersion into the air is equal to or exceeds the LC50 or ERPG-2 concentration. These concentration levels are transient in nature because a finite amount of the materials is assumed to be spilled. Figures 1 and 2 show plume maps obtained from the output of ALOHA™ and provides the plume boundaries corresponding to the methyl isocyanate and methyl hydrazine releases at 20 °C. These maps indicate the distances at which the plumes end at the toxicological end points as they travel downwind. Within the plume distances shown, the chemical concentrations are expected to exceed the LC50s.

		Distances in meters corresponding to					
UN No	Chemical	Fatality from toxicity (LC50)	Injury from toxicity (ERPG-2)	Fatality from fire	Injury from fire	Fatality from explosion	Injury from explosion
1051	Hydrogen cyanide	427	482	--	--	--	--
2480	Methyl isocyanate	517	4661	23.2	39.1	24	68.8
1092	Acrolein	422	3850	2.7	3.9	3	6
1185	Ethyleneimine	167	2615	3	3.9	3	6
2482	n-Propyl isocyanate	103	2054	2	2.6	2	5
1239	Methyl chloromethyl ether	94.7	1800	2	2	2	5
1834	Sulfuryl chloride	94	1690	--	--	--	--
1244	Methyl hydrazine	81	1181	2	2	2	5
1143	Crotonaldehyde	31	247	2	2	2	5

Table 2. Fatality and Injury Zones associated with Toxicological Endpoints, Fire, or Explosion when the content is released at 20 °C.

Figure 1. Plume Map showing the Air Concentration corresponding to the LC50 of Methyl Isocyanate released from a Drum at 20 °C

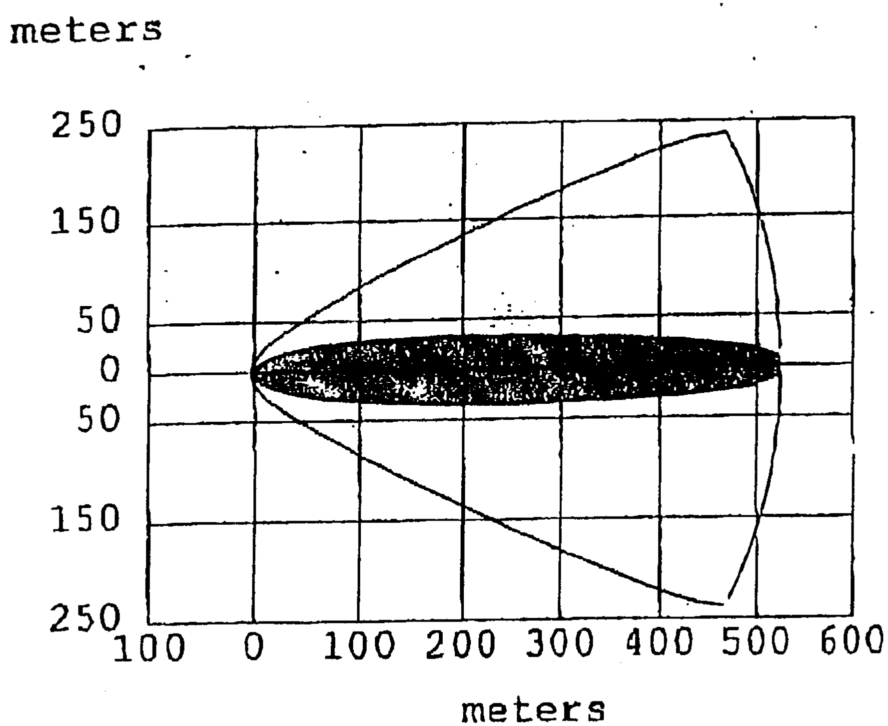


Figure 2. Plume Map showing the Air Concentration corresponding to the LC50 of Methyl Hydrazine released from a Drum at 20 °C

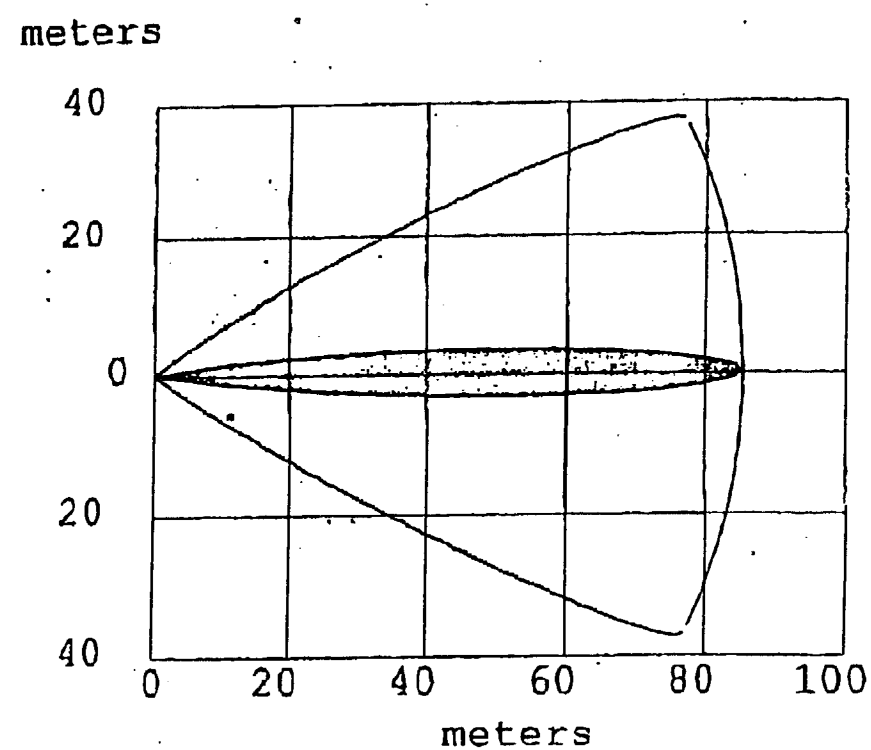


Table 3 summarizes the radii of the fatality and injury zones associated with releases of the selected chemicals assumed to occur at 55 °C. At that temperature, the contents of some materials are stored at the temperature above their boiling points. These materials include hydrogen cyanide, methyl isocyanate, and acrolein. The release mechanism will involve a direct discharge of aerosols and gases into the air instead of forming a liquid pool from which vapors will evaporate. The aerosols formed will be rapidly vaporized into the air.

		Distances in meters corresponding to					
UN No	Chemical	Fatality from toxicity (LC50)	Injury from toxicity (ERPG-2)	Fatality from fire	Injury from fire	Fatality from explosion	Injury from explosion
1051	Hydrogen cyanide	409	503	--	--	--	--
2480	Methyl isocyanate	548	7400	24.4	38.5	24	68.8
1092	Acrolein	439	6931	14.3	29.6	14	58
1185	Ethyleneimine	554	5800	5.7	8.3	5	14
2482	n-Propyl isocyanate	479	4850	5	8	5	14
1239	Methyl chloromethyl ether	286	2800	5	8	5	14
1834	Sulfuryl chloride	94275	2366	--	--	--	--
1244	Methyl hydrazine	411	5468	5	8	5	14
1143	Crotonaldehyde	233	1058	5	8	5	14

Table 3. Fatality and Injury Zones associated with Toxicological Endpoints, Fire, or Explosion when the content is released at 55 °C.

The areas of estimated fatality and injury zone distances shown in Tables 2 and 3 are converted to the areas of fatality and injury impact zones. These areas are multiplied by the population densities assuming a suburban area with a population density of 3326 persons per square mile. The estimated fatalities and injuries obtained for this population density are shown in Tables 4 and 5. These tables are presented in the form of charts in Figures 3 through 6 for the potential fatalities associated with inhalation of toxic gases in the air for three different levels of population density. It can be noted that only the potential fatality portion of the consequence values are used in preparing Figures 3-6. Figures 4 and 6 are an enlargement of a portion of Figures 3 and 5, respectively, and show the potential fatalities at the values of VP/LC50 ratios between approximately 500 and 2000, along with regression lines.

		Potential Fatalities or Injuries associated with toxicological effects, thermal radiation or explosion effects when the content is released at 20 °C (estimated number of persons)					
UN No	**Chemical**	**Fatalities from toxicity (LC50)**	**Injuries from toxicity (ERPG-2)**	**Fatality from fire**	**Injury from fire**	**Fatality from explosion**	**Injury from explosion**
1051	Hydrogen cyanide	189	240.8	--	--	--	--
2480	Methyl isocyanate	277	22519	0.6	1.6	0.6	4.9
1092	Acrolein	184.6	15364	.0076	.016	.0093	.037
1185	Ethyleneimine	28.9	7088	.0093	.016	.0093	.037
2482	n-Propyl isocyanate	11	4373	.0042	.0073	.0042	.026
1239	Methyl chloromethyl ether	9.3	4373	.0042	.0042	.0042	.026
1834	Sulfuryl chloride	9.2	3358	--	--	--	--
1244	Methyl hydrazine	6.8	1446	.0042	.0042	.0042	.026
1143	Crotonaldehyde	1.0	63	.0042	.0042	.0042	.026

Table 4. The number of potential fatalities and injuries associated with toxicological endpoints, thermal radiation, or shock blast waves of explosion when accidental releases occur at 20 °C.

		Potential Fatalities or Injuries associated with toxicological effects, thermal radiation or explosion effects when the content is released at 55 °C (estimated number of persons)					
UN No	**Chemical**	**Fatalities from toxicity (LC50)**	**Injuries from toxicity (ERPG-2)**	**Fatality from fire**	**Injury from fire**	**Fatality from explosion**	**Injury from explosion**
1051	Hydrogen cyanide	173.4	262	--	--	--	--
2480	Methyl isocyanate	311	56760	0.6	1.5	0.6	4.9
1092	Acrolein	200	49794	0.2	0.9	0.2	3.5
1185	Ethyleneimine	318	34869	.034	.071	.026	0.2
2482	n-Propyl isocyanate	238	24382	.026	.066	.026	0.2
1239	Methyl chloromethyl ether	85	8126	.026	.066	.026	0.2
1834	Sulfuryl chloride	78.4	5803	--	--	--	--
1244	Methyl hydrazine	175.1	30991	.026	.066	.026	0.2
1143	Crotonaldehyde	56.3	1160	.026	.066	.026	0.2

Table 5. The number of potential fatalities and injuries associated with toxicological endpoints, thermal radiation, or shock or blast waves of explosion when accidental releases occur at 55 °C.

Figure 3. POTENTIAL FATALITIES @ VARIOUS VP/LC50 RATIOS FOR SELECTED 6.1 TIHs @ 20 °C

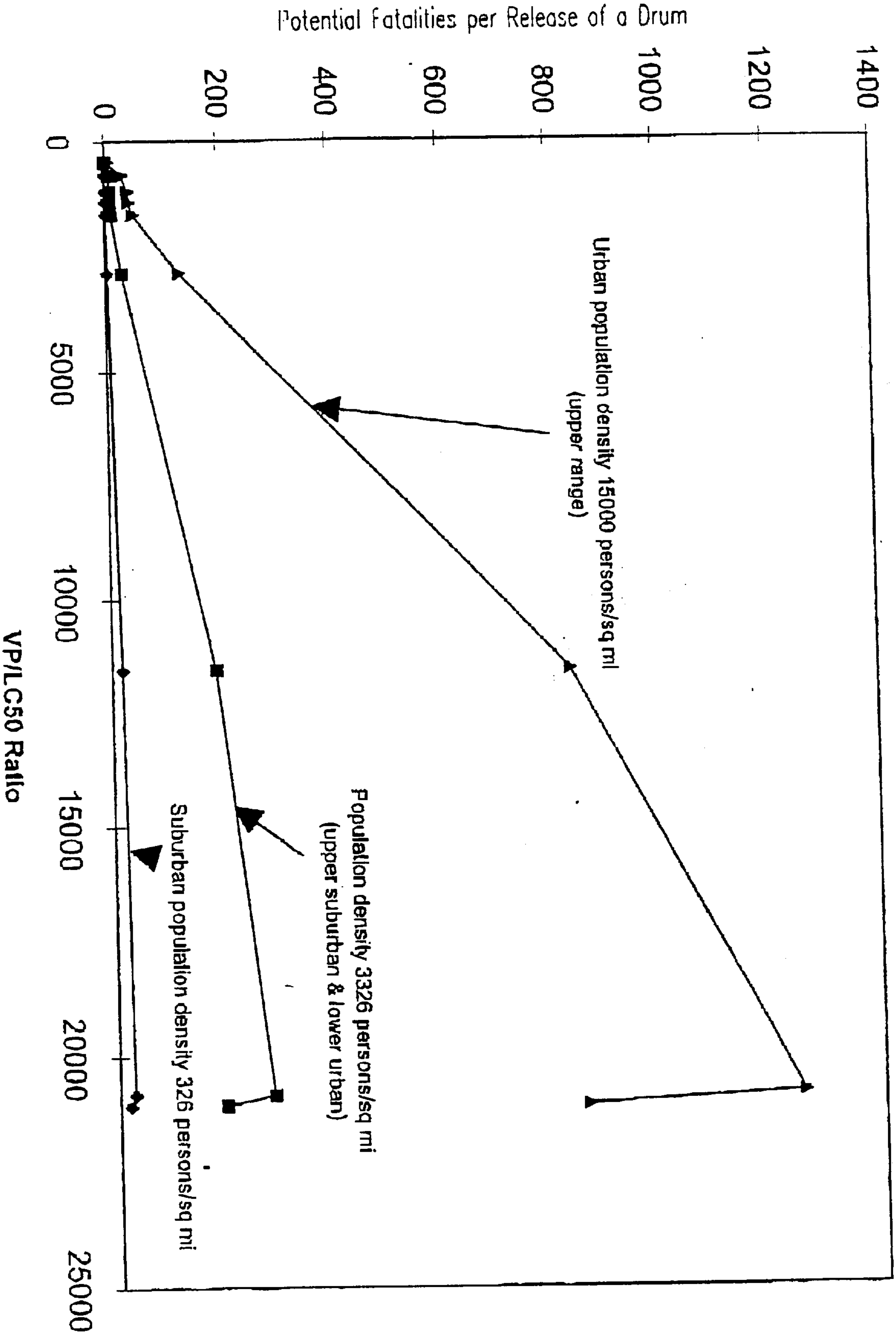


Figure 4. POTENTIAL FATALITIES @ VP/LC50 RATIOS FOR SELECT 6.1 TIHs @ 20 °C

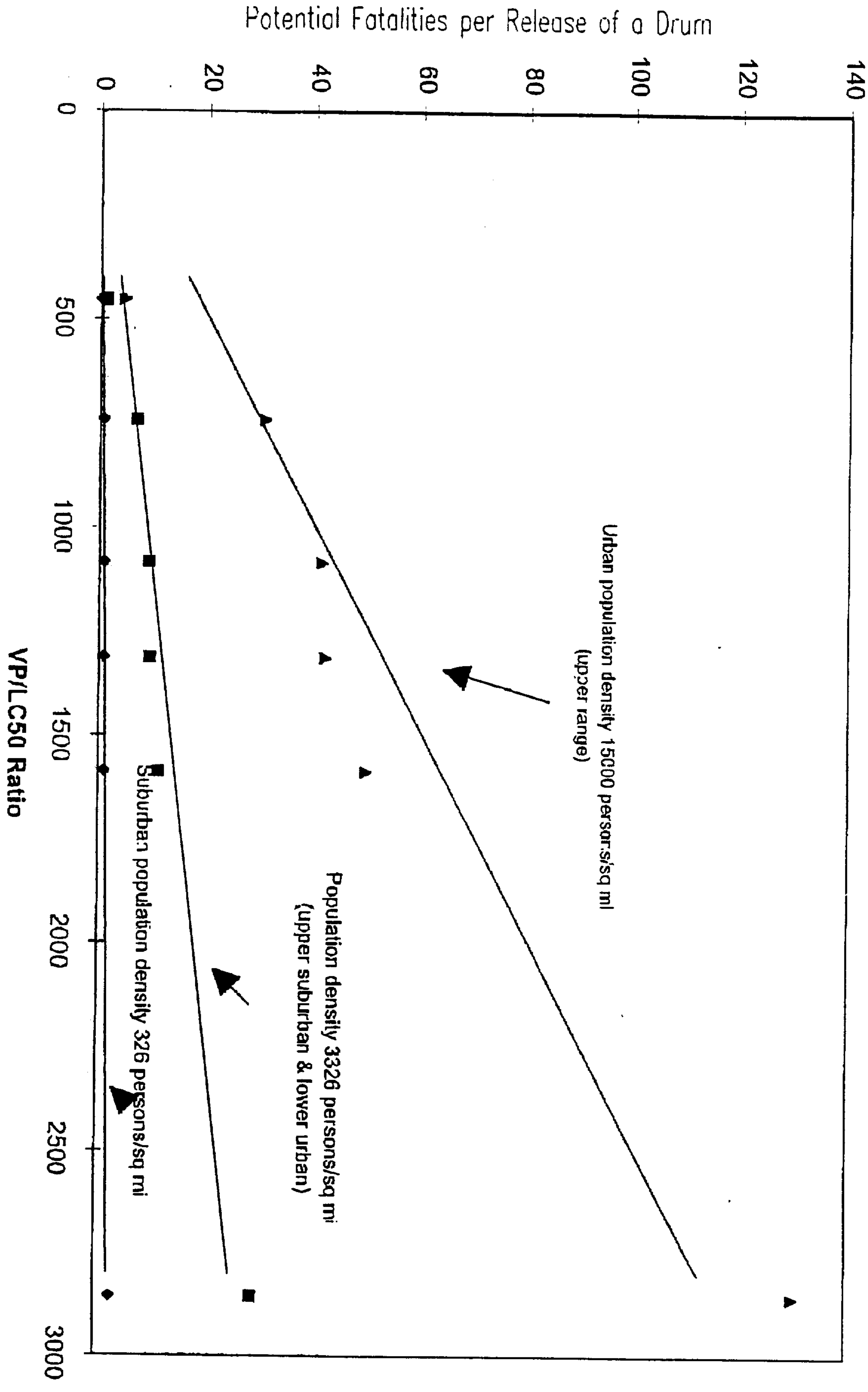


Figure 5. POTENTIAL FATALITIES @ VARIOUS VP/LC50 RATIOS FOR SELECTED 6.1 TIHs @ 55 °C

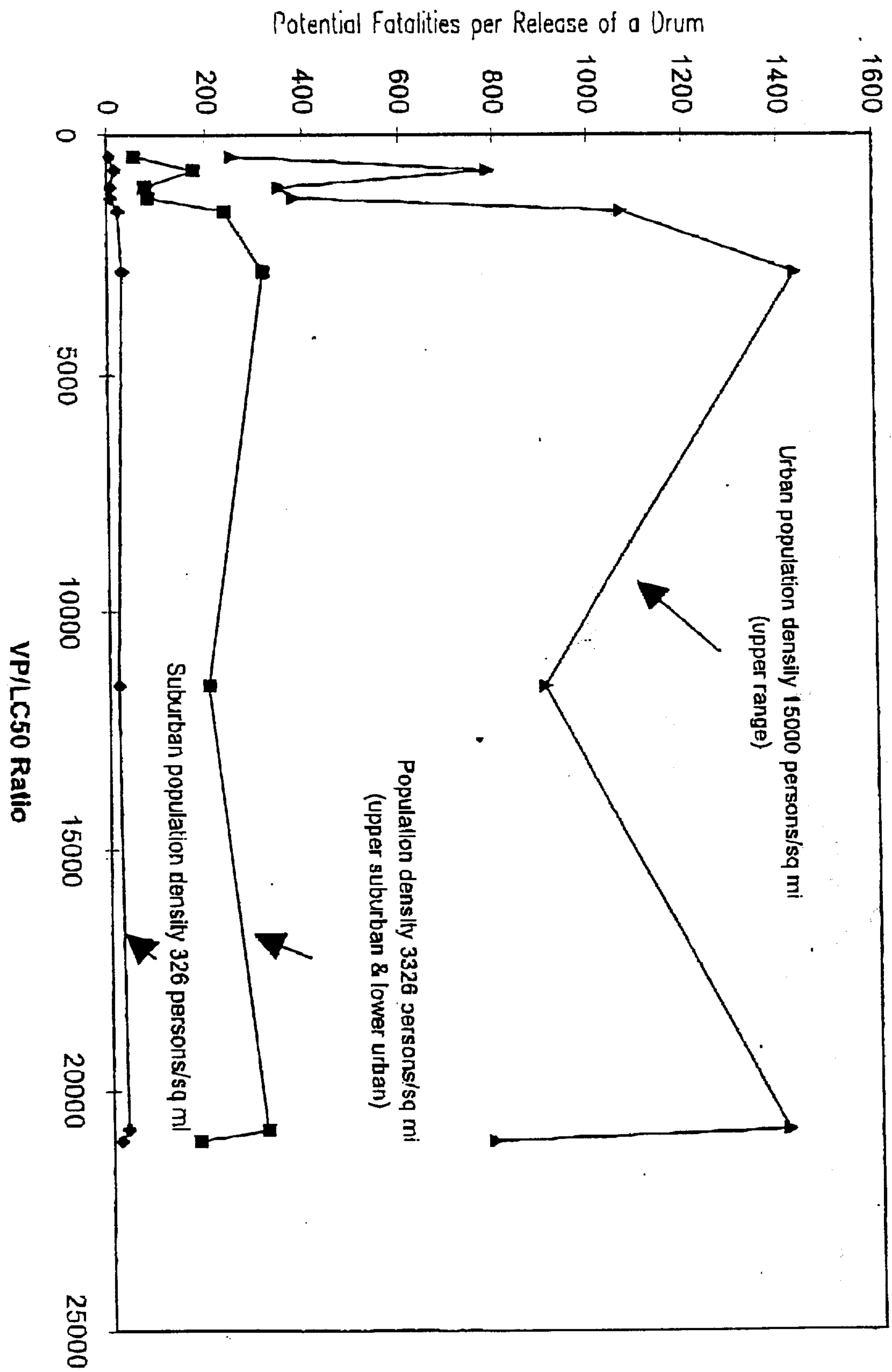


Figure 6. POTENTIAL FATALITIES @ VARIOUS VP/LC50 RATIOS FOR SELECTED 6.1 TIHs @ 55 °C

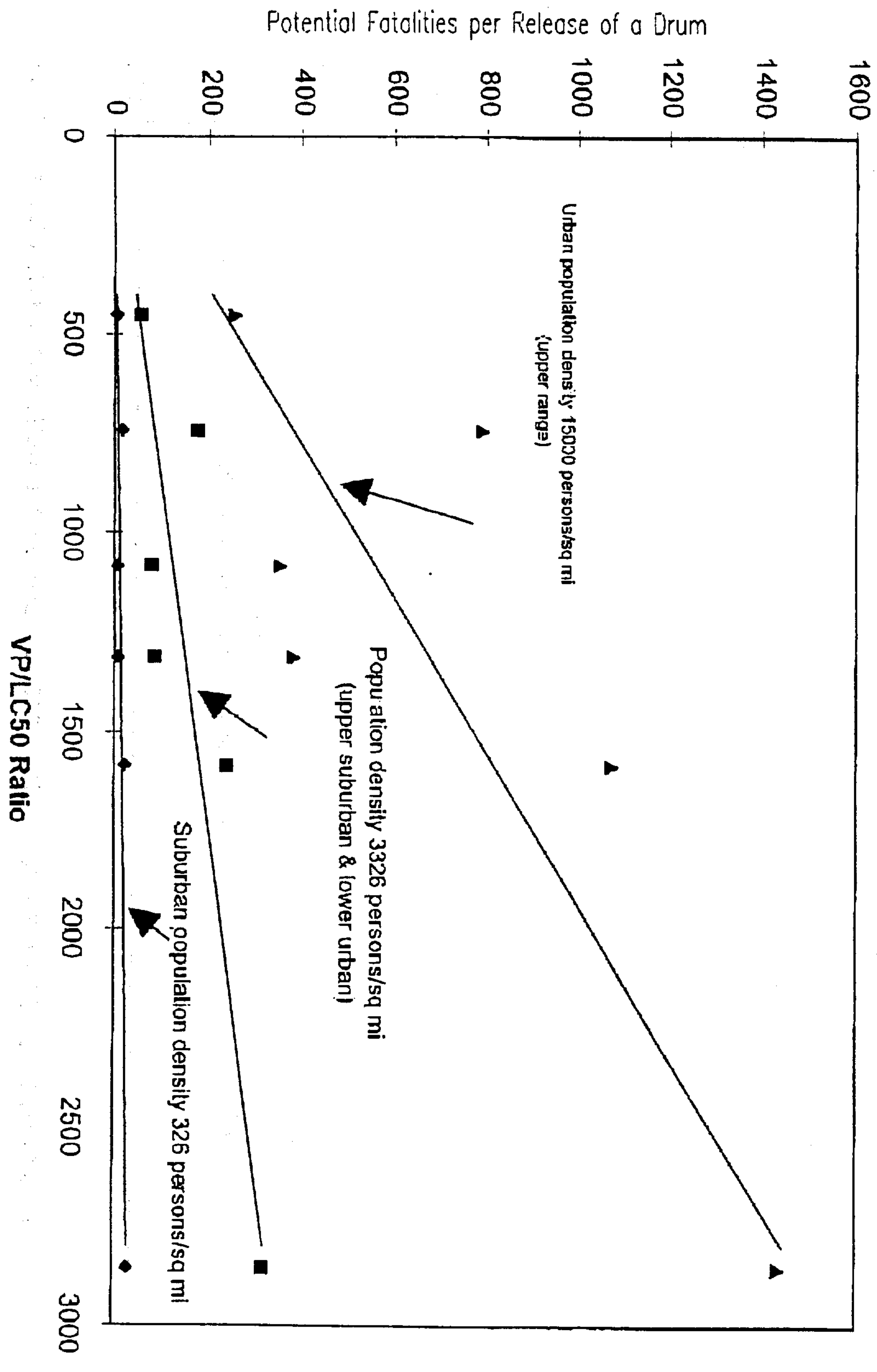
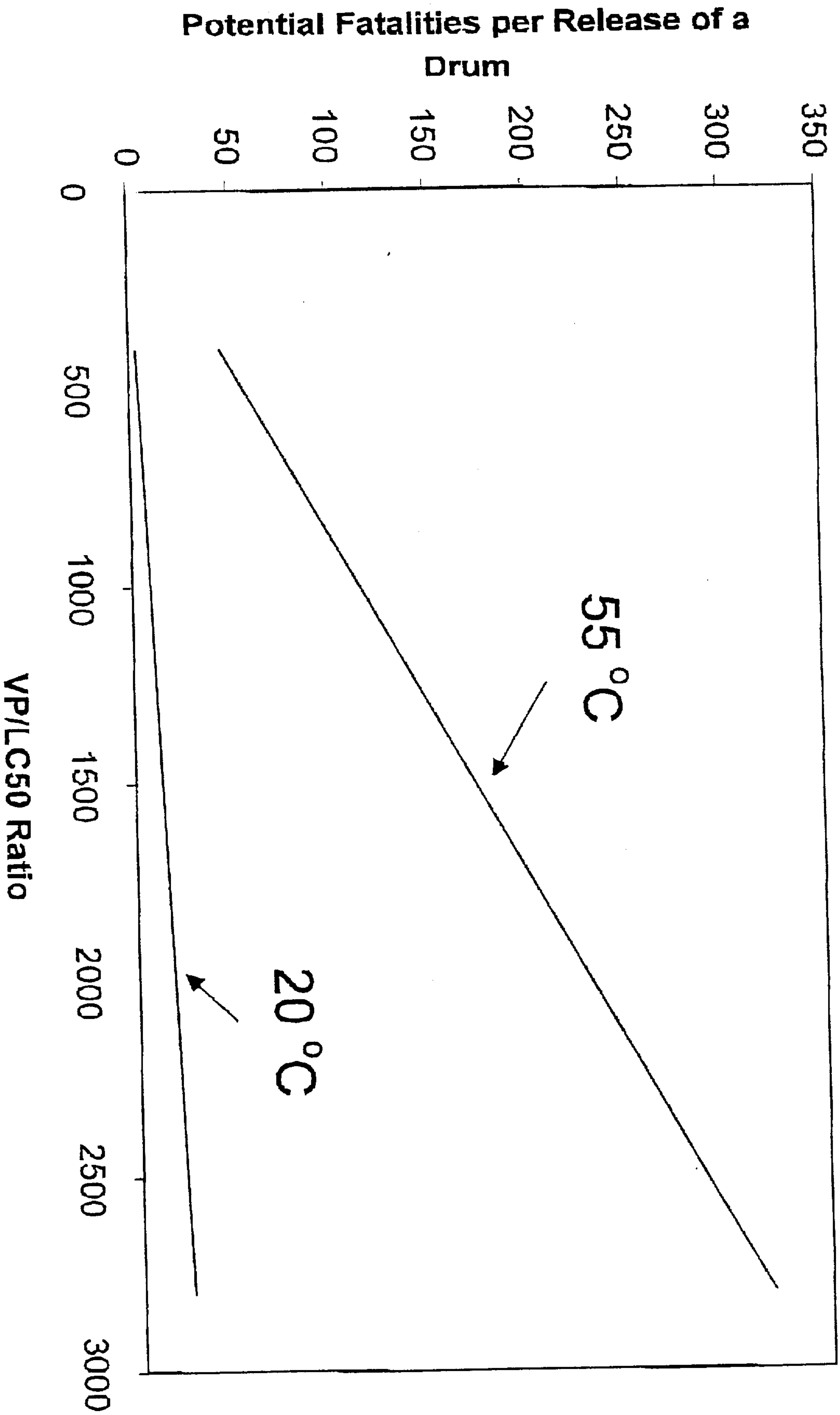


Figure 7. Effect of Release Temperature on Potential Fatality Estimates @ Population Density of 3326 persons/sq. mi



It should be noted that the values of VP/LC50 ratio for n-Propyl isocyanate, Methyl chloromethyl ether, Sulfuryl chloride, and Methyl chloride are between 500 and 2000. An examination of the figures, especially Figures 4 and 6, indicates that the potential fatalities associated with the inhalation of toxic vapors from releases at 20 °C ranges from approximately 7 to 11 persons assuming a population density of 3326 persons per square mile. If the release occurs at 55 °C, the potential fatalities are higher, ranging from approximately 78 to 238 persons. The injury figures are considerably higher as can be seen from these figures or from Tables 4 and 5. The effect of release temperature is shown in Figure 7 for one population density, based on the regression lines in Figures 4 and 6. This figure indicates that the potential fatalities increase considerably as the release temperature increased.

Tables 4 and 5 show that the potential fatalities associated with flammability or explosion accidents range from $4x10^{-3}$ at the release temperature of 20 °C and $2.6x10^{-2}$ at the release temperature of 55 °C. It can be seen that the toxicological health effects are far more significant than the other effects for the selected chemicals.

Conclusions

The risk assessment for the selected Division 6.1, PG I substances shows that the potential consequences associated with the materials with the VP/LC50 ratio between 500 and 2000 are significant. When the temperature effect is considered, the potential consequences become even more significant. The consequence associated with toxic health effects overwhelms that associated with flammability and explosive properties.

The present analysis assumes a release of one 210 litre drum. A quantity larger than one drum will result in more significant consequences.

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