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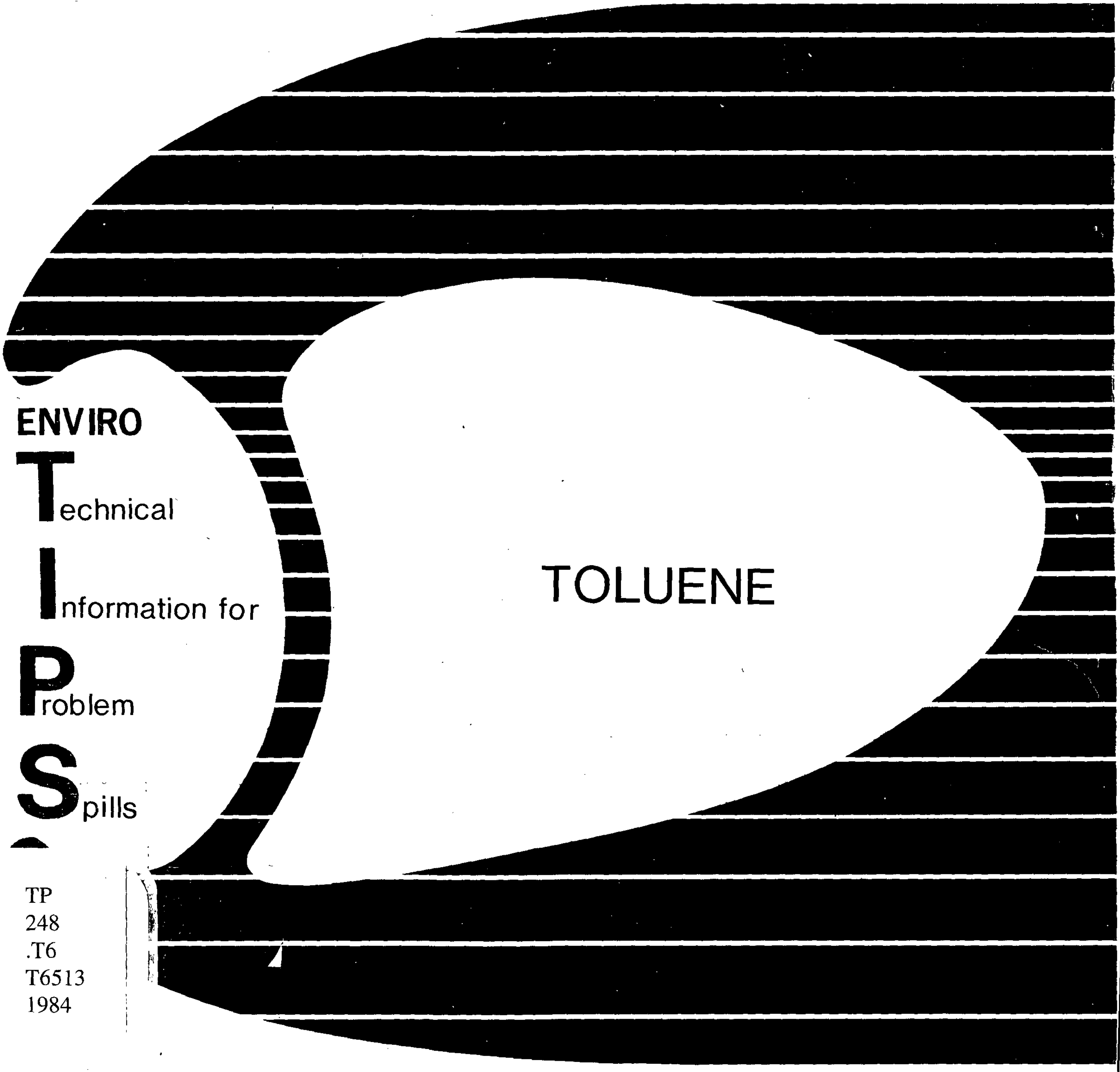

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Technical
Information for
Problem
Spills

TOLUENE

March 1984

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ENVIRONMENTAL AND TECHNICAL INFORMATION FOR PROBLEM SPILLS MANUALS

Environmental and Technical Information for Problem Spills (EnviroTIPS) manuals provide detailed information on chemical substances. This information is intended to assist the reader in designing countermeasures for spills and to assess their impact on the environment. The manual has been reviewed by the Technical Services Branch, Environmental Protection Service, and approved for publication. Approval does not necessarily signify that the contents reflect the views and policies of the Environmental Protection Service. Mention of trade names or commercial products does not constitute endorsement for use.

TOLUENE

ENVIRONMENTAL AND TECHNICAL INFORMATION FOR PROBLEM SPILLS

Technical Services Branch
Environmental Protection Programs Directorate
Environmental Protection Service
Environment Canada

March 1984

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FOREWORD

The Environmental and Technical Information for Problem Spills (EnviroTIPS) manuals were initiated in 1981 to provide comprehensive information on chemicals which were spilled frequently in Canada. The manuals are intended to be used by spill specialists for designing countermeasures for spills and to assess their effects on the environment. The major focus of TIPS manuals is environmental. The manuals are not intended to be used by first-response personnel because of the length and technical content; a number of manuals intended for first-response use are available. The information presented in this manual was largely obtained from literature review. Efforts were made, both in compilation and in review, to ensure that the information is as correct as possible. Publication of these data does not signify that these data are recommended by the Government of Canada, nor by any other group.

ACKNOWLEDGEMENTS

The final version was prepared by the staff of the Environmental Protection Service who rewrote the text, drafted illustrations and incorporated all comments and additions.

The draft of this manual was prepared under a contract with Environment Canada by M.M. Dillon Consulting Engineers and Planners, Concord Scientific Corporation and Waterloo Engineering Limited. The level of detail present was made possible by the many individuals, organizations and associations who provided technical data and comments throughout the compilation and subsequent review.

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1 SUMMARY

TOLUENE ($C_6H_5CH_3$)

Colourless, watery liquid with an aromatic odour

SYNONYMS

Toluol, Methylbenzene, Phenylmethane

IDENTIFICATION NUMBERS

UN. No. 1294; CAS No. 108-88-3; OHM-TADS No. 7216928; STCC No. 4909305

GRADES & PURITIES

Nitration grade, 99.99 percent purity; Industrial grade, 98 percent purity

IMMEDIATE CONCERNS

Fire: Flammable liquid. Vapour forms explosive mixtures with air. Flashback may occur along vapour trail

Human Health: Toxic via inhalation, ingestion, and skin contact

Environment: Toxic to aquatic life

PHYSICAL PROPERTY DATA

State (15°C, 1 atm): liquid
Boiling Point: 110.6°C
Melting Point: -95°C
Flammability: flammable
Flash Point: 4°C (CC)
Density: 0.867 g/cm^3 (20°C)
Vapour Pressure: 3.7 kPa @ 25°C

Solubility (in water): 0.05 g/100 mL (20°C)
Behaviour (in water): floats
Behaviour (in air): vapour forms explosive mixtures with air
Odour Threshold: 0.17 ppm
Odour Threshold Range: 0.17 to 40 ppm

ENVIRONMENTAL CONCERNS

Toluene is toxic to aquatic life. It may be hazardous to waterfowl and animals through ingestion or contact. Toluene has no food chain concentration potential. Harmful to some species at concentrations as low as 10 mg/L.

HUMAN HEALTH

TLV®: 100 ppm (375 mg/m^3)
IDLH: 2,000 ppm (7,648 mg/m^3)

Exposure Effects

Inhalation: Inhalation of vapour causes headache, slight drowsiness at 500 ppm, nausea, and difficult breathing. Breathing high concentrations of toluene may cause death by paralysis of the respiratory centre

Contact: Toluene is absorbed to produce symptoms similar to those mentioned above. Prolonged skin exposure causes irritation. Eye contact yields irritation from liquid or high vapour concentrations, and can produce corneal burns

IMMEDIATE ACTION

Spill Control

Restrict access to spill site. Issue warning: "FLAMMABLE". Call fire department and notify manufacturer. Eliminate sources of ignition including traffic and equipment. Stop the flow and contain spill, if safe to do so. Avoid contact with liquid and vapour; stay upwind of release. Keep contaminated water from entering sewers or watercourses.

Fire Control

Use foam, dry chemical or carbon dioxide to extinguish. Cool fire-exposed containers with water. Stay clear of tank ends.

COUNTERMEASURES

Emergency Control Procedures in/on

Soil: Construct barriers to contain spill or divert to impermeable surfaces. Remove material with pumps or vacuum equipment. Adsorb residual liquid on natural or synthetic sorbents, shovel into metal containers with covers. All equipment should be spark- or explosion-proof

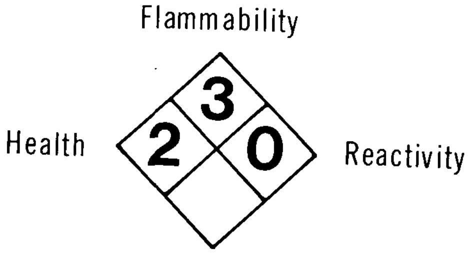
Water: Contain with booms, weirs or natural barriers. Use (oil) skimming equipment or suction hoses to remove slick, followed by the application of sorbents. All equipment should be spark- or explosion-proof

Air: Use water spray to disperse flammable vapour. Control runoff for later treatment and/or disposal

NAS HAZARD RATING

Category	Rating
Fire	3
Health	
Vapour Irritant	1
Liquid or Solid Irritant	1
Poison	2
Water Pollution	
Human Toxicity	1
Aquatic Toxicity	3
Aesthetic Effect	2
Reactivity	
Other Chemicals	1
Water	0
Self-reaction	0

NFPA
HAZARD
CLASSIFICATION



2 PHYSICAL AND CHEMICAL DATA

Physical State Properties

Appearance	Colourless liquid (Dow ERIS 1979)
Usual shipping state	Liquid
Physical state at 15°C, 1 atm	Liquid
Melting point	-95°C (CRC 1980; Kirk-Othmer 1983)
Freezing point	-95°C (Dow ERIS 1979; Kirk-Othmer 1983)
Boiling point	110.6°C (CRC 1980)
Vapour pressure	3.7 kPa (25°C) (Dow MSDS 1979) 7.9 kPa (40°C) (Kirk-Othmer 1983)

Densities

Density	0.867 g/cm^3 (20°C) (Kirk-Othmer 1983)
Specific gravity	0.872 (20°/4°C) (Dow MSDS 1979)
Vapour density	3.14 (Dow MSDS 1979)

Fire Properties

Flammability	Flammable liquid (NFPA 1978)
Flash point, CC OC	4°C (NFPA 1978) 13°C (CHRIS 1978)
Autoignition temperature	480°C (NFPA 1978) 480-496°C (API 1982)
Burning rate	5.7 mm/min (CHRIS 1978)
Upper flammability limit	7.1 percent (v/v) (NFPA 1978)
Lower flammability limit	1.4 percent (v/v) (NFPA 1978)
Flame speed	37 cm/s (Lange's Handbook 1979)
Heat of combustion	3,909 kJ/mole (20°C) (CRC 1980)
Combustion products	Carbon dioxide and water (CRC 1980)
Flashback potential	Vapour may travel considerable distance to a source of ignition and flash back (NFPA 1978)
Explosiveness	Vapours form explosive mixtures with air (NFPA 1978)
Behaviour in a fire	May explode if ignited in enclosed areas (NFPA 1978)
Electrical ignition hazard	May be ignited by electrical discharge

Other Properties

Molecular weight of pure substance	92.15 (CRC 1980)
Constituent components of typical commercial grade	Industrial grade: 98 percent toluene (Dow ERIS 1979) Nitration grade: 99.99 percent toluene (Kirk-Othmer 1983)
Refractive index	1.4961 (20°C) (CRC 1980)
Viscosity	0.590 mPa·s (20°C) (CRC 1980)
Liquid interfacial tension with air	28.5 mN/m (20°C) (CRC 1980) 27.9 mN/m (25°C) (Kirk-Othmer 1983)
Liquid interfacial tension with water	36.1 mN/m (25°C) (CHRIS 1978)
Latent heat of fusion	6.6 kJ/mole (at melting point) (CRC 1980)
Latent heat of sublimation	38.0 kJ/mole (25°C) (Lange's Handbook 1979) 33.18 kJ/mole (110.6°C) (Kirk-Othmer 1983)
Latent heat of vaporization	35.9 kJ/mole (at boiling point) (CRC 1980)
Heat of formation	12.1 kJ/mole (liquid at 25°C) (Sussex 1977; Kirk-Othmer 1983) 50.0 kJ/mole (gas at 25°C) (Kirk-Othmer 1983)
Entropy	219.6 kJ/K (liquid) (Kirk-Othmer 1983) 319.7 kJ/K (gas) (Kirk-Othmer 1983)
Ionization potential	8.82 eV (Rosenstock 1977)
Heat capacity	
constant pressure (C_p)	1.125 J/(g·K) (ideal gas) (Kirk-Othmer 1983) 156 J/(mole·°C) (25°C) (CRC 1980)
constant volume (C_v)	1.970 J/(g·K) (liquid at STP) (Kirk-Othmer 1983) 143 J/(mole·°C) (25°C) (CRC 1980)
Critical pressure	4,215 kPa (CRC 1980) 4,109 kPa (Kirk-Othmer 1983)
Critical temperature	320.8 °C (CRC 1980) 318.6°C (Kirk-Othmer 1983)
Coefficient of thermal expansion	1.099 x 10^{-3}/°C (20°C) (Lange's Handbook 1979)
Thermal conductivity	4.91 J/(h·cm·°C) (17°C) (CRC 1980)
Saturation concentration	110 g/m^3 (20°C) (Verschueren 1977) 184 g/m^3 (30°C) (Verschueren 1977)
Diffusivity	0.076 cm^2/s (0°C) (Perry 1973)
Log_{10} octanol/water partition coefficient	2.69 (20°C) (Chiou and Schmedding 1982)

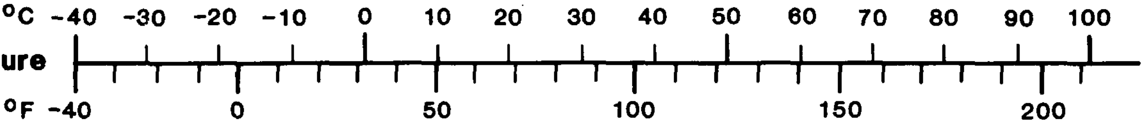
Solubility

In water	0.05 g/100 mL (20°C) (Texaco MSDS) 0.047 g/100 mL (16°C) (Verschueren 1977) 0.0528 g/100 mL (20°C) (Verschueren 1977)
In other common materials	Miscible in ethanol, diethyl ether and benzene. Soluble in acetone and carbon disulphide (CRC 1980)
Azeotropes	With water, 45 percent (w/w) toluene, BP = 95.3°C (Kirk-Othmer 1983) With methanol, 31 percent (w/w) toluene, BP = 63.8°C (Kirk-Othmer 1983) With ethanol, 32 percent (w/w) toluene, BP = 76.7°C (Kirk-Othmer 1983)
Vapour Weight to Volume Conversion Factor	1 ppm = 3.824 mg/m^3 (20°C) (Verschueren 1977)

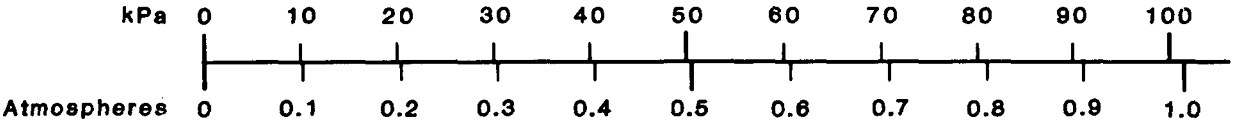
TABLE 1

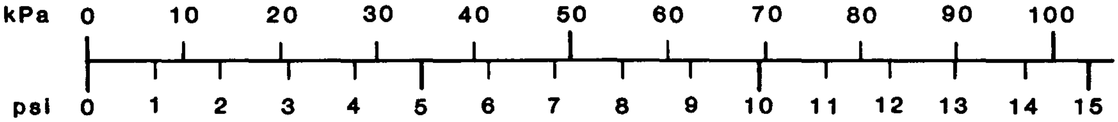
CONVERSION NOMOGRAMS

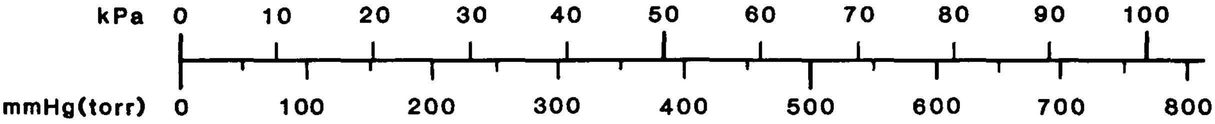
Temperature



Pressure 1 kPa = 1,000 Pa







Viscosity

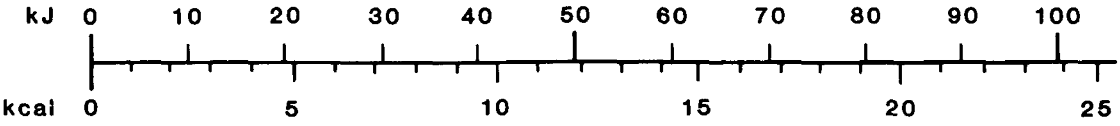
Dynamic 1 Pa·s = 1,000 centipoise (cP)

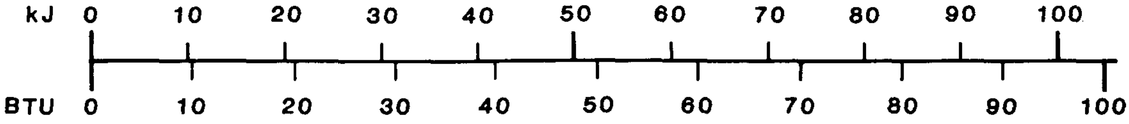
Kinematic 1 m²/s = 1,000,000 centistokes (cSt)

Concentration (in water)

1 ppm ≅ 1 mg/L

Energy (heat) 1 kJ = 1,000 J





Density

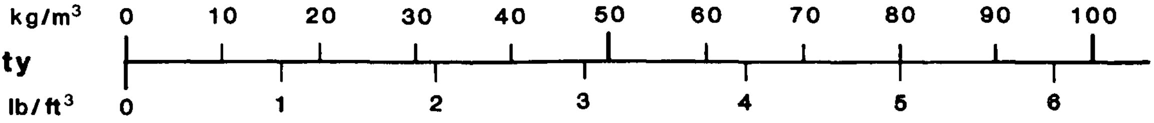


FIGURE 1

TOLUENE

VAPOUR PRESSURE vs TEMPERATURE

Reference: Chem. Eng. 1975

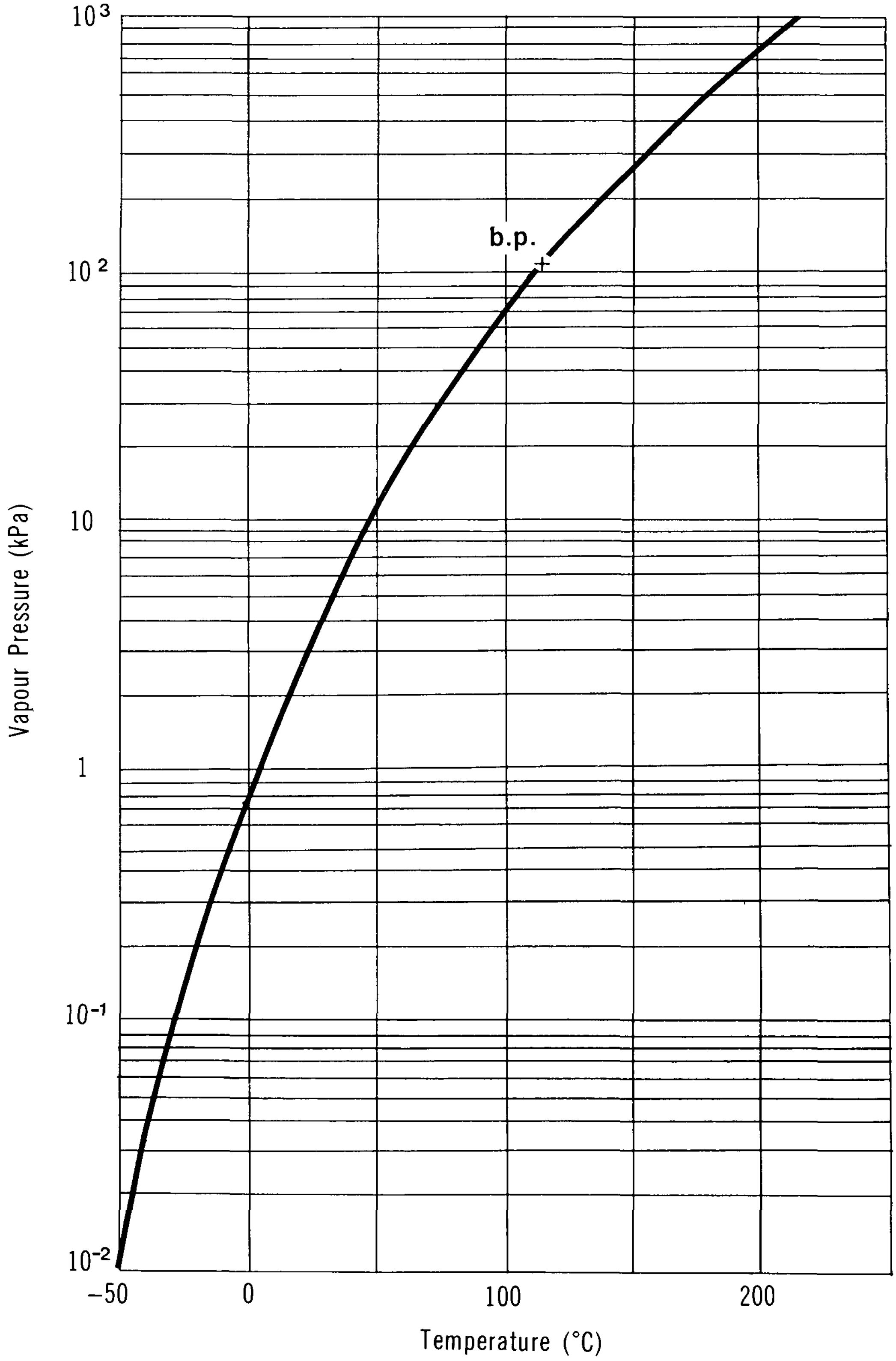


FIGURE 2

TOLUENE

LIQUID DENSITY vs TEMPERATURE

Reference: Chem. Eng. 1975

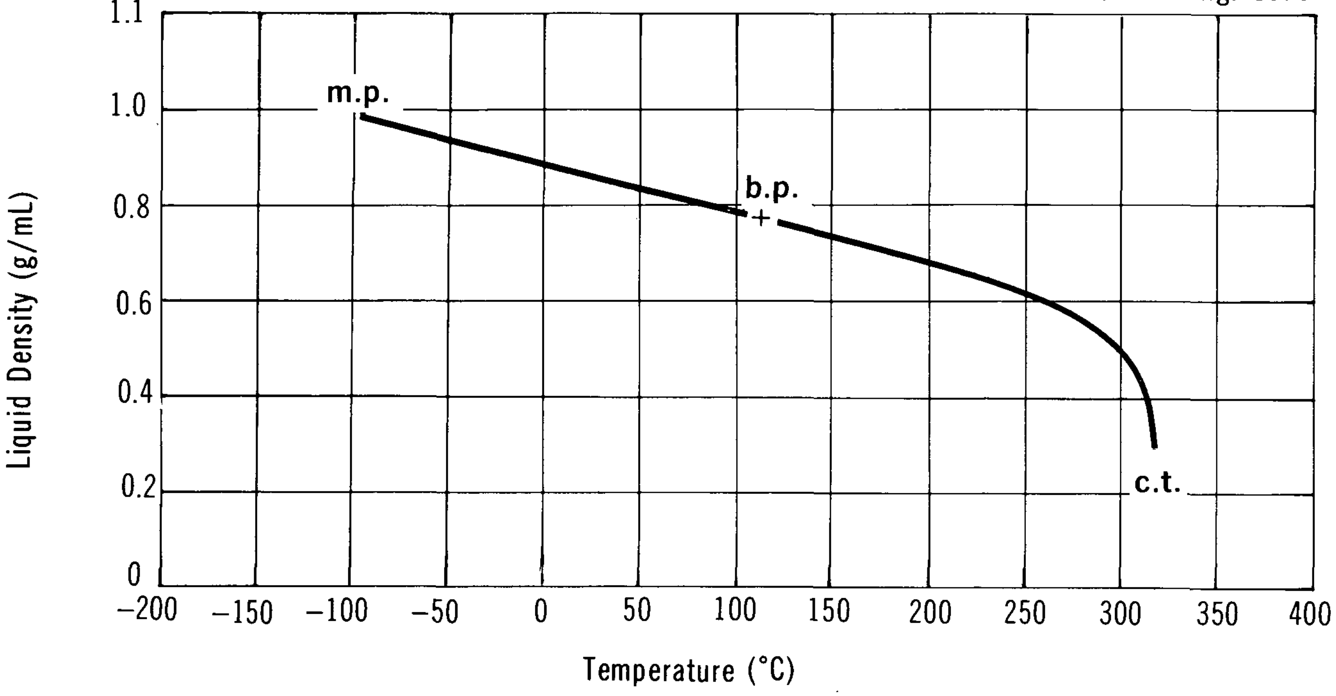


FIGURE 3

TOLUENE

SATURATED VAPOUR DENSITY vs TEMPERATURE

Reference: CHRIS 1978

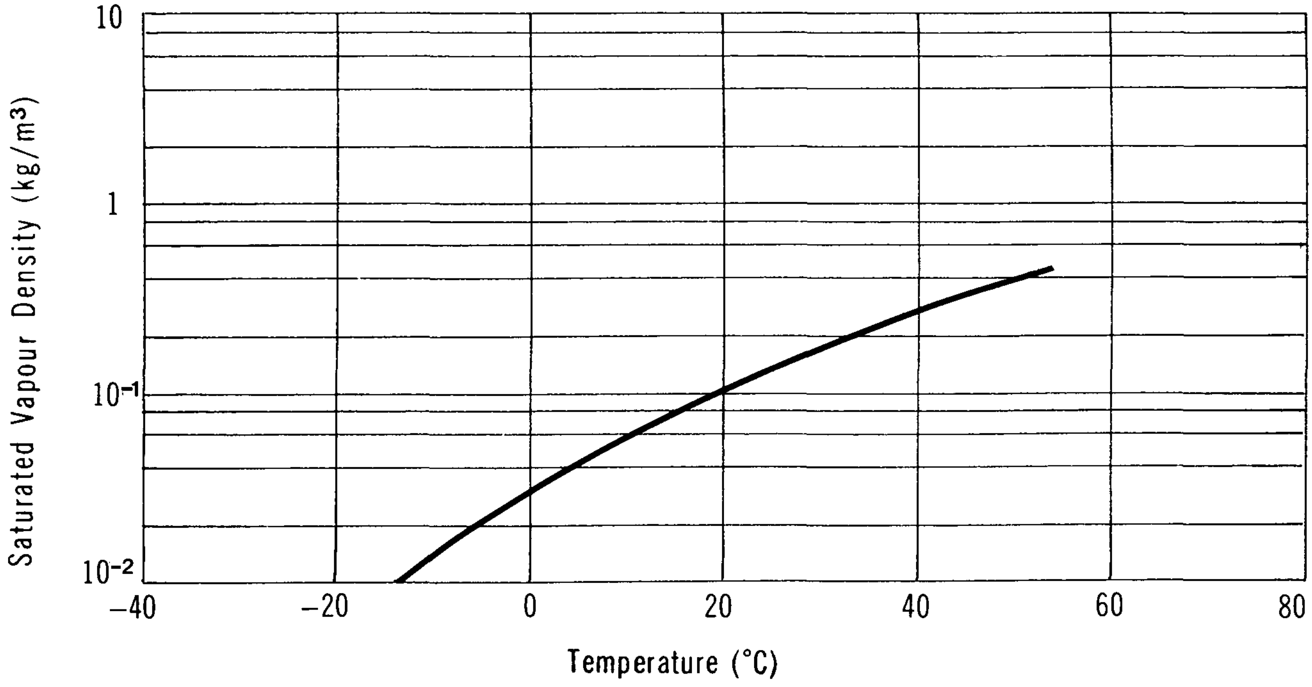


FIGURE 4

TOLUENE

VAPOUR VISCOSITY vs TEMPERATURE

Reference: Chem: Eng. 1975

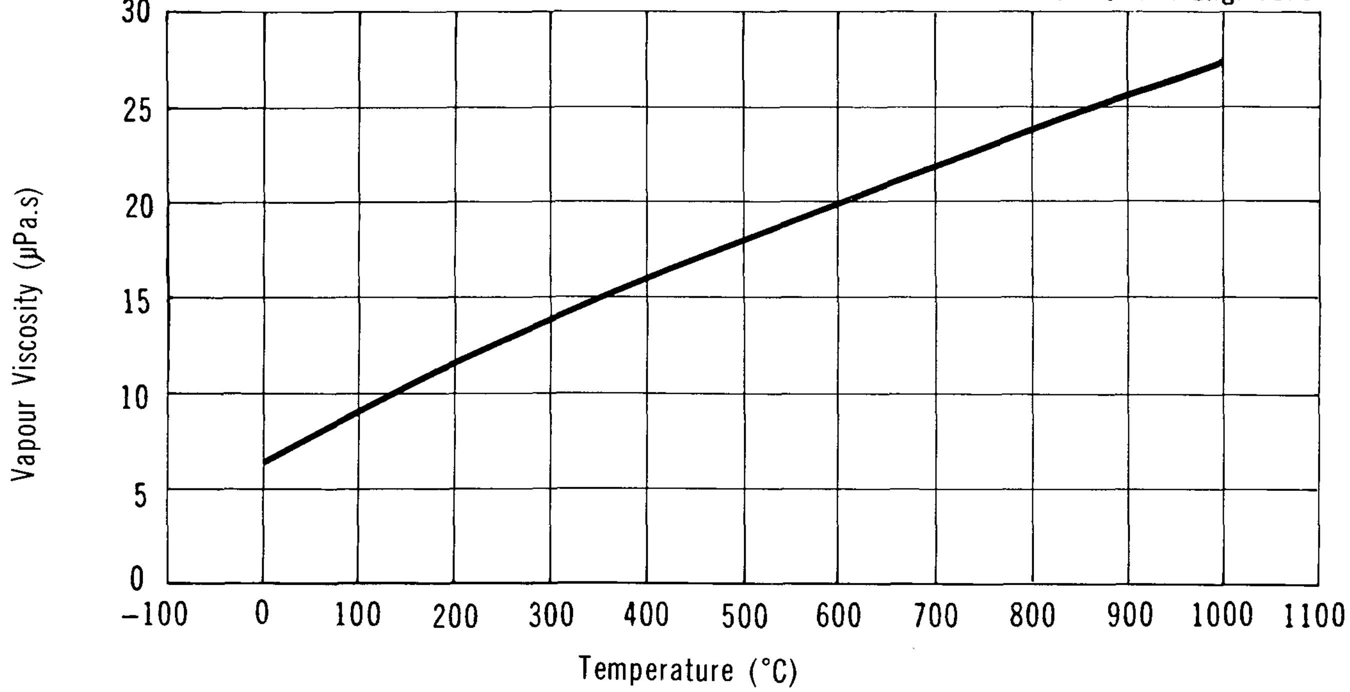
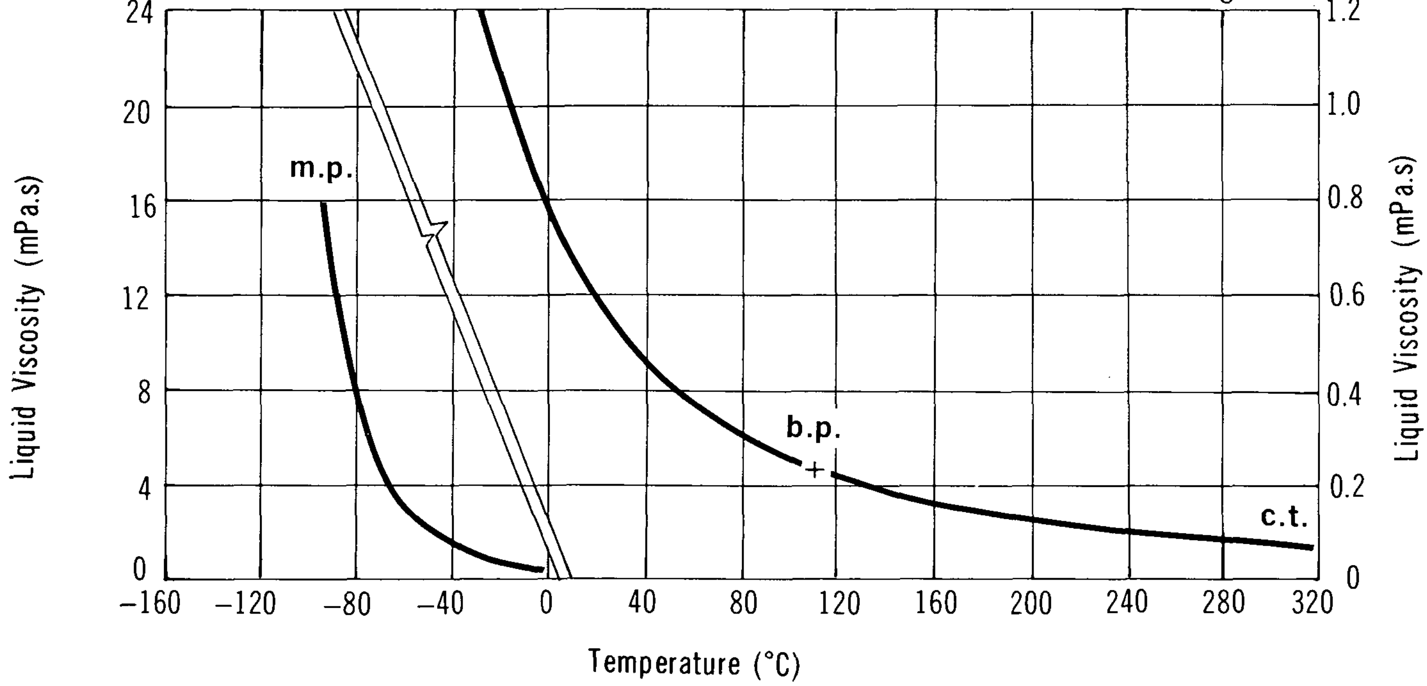


FIGURE 5

TOLUENE

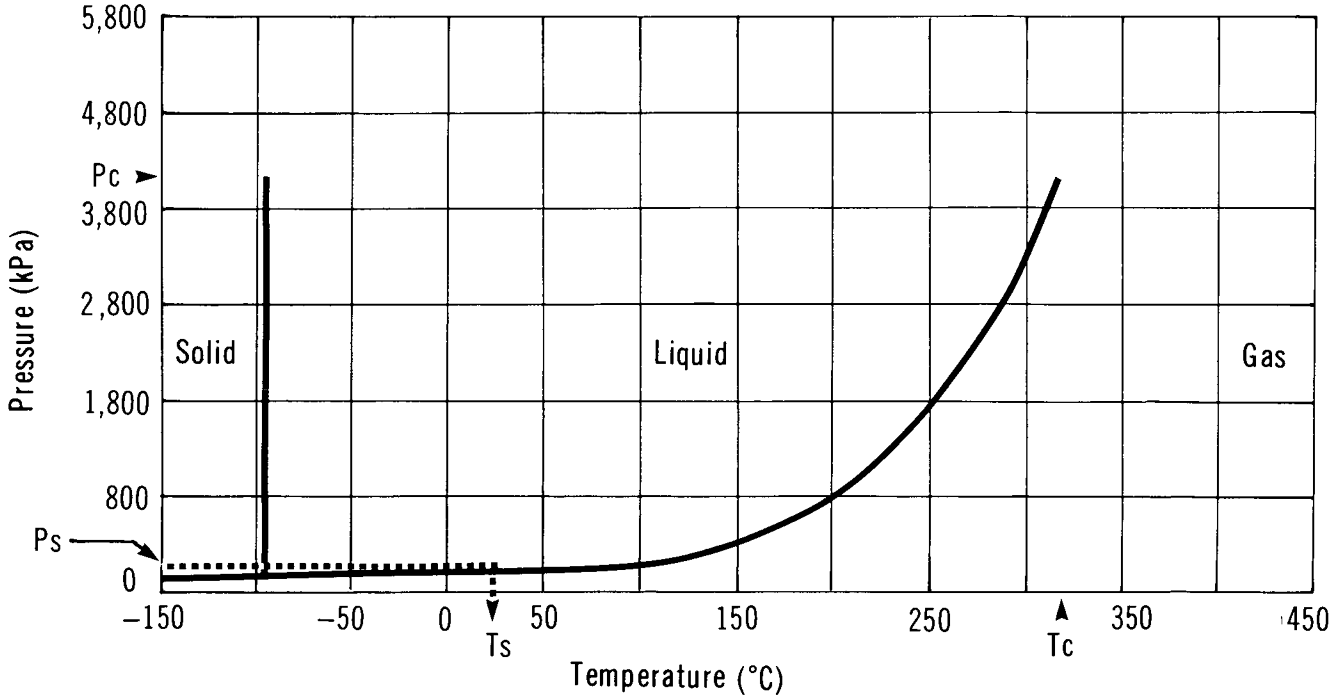
LIQUID VISCOSITY vs TEMPERATURE

Reference: Chem: Eng. 1975



TOLUENE

PHASE DIAGRAM



3 COMMERCE AND PRODUCTION

3.1 **Grades, Purities** (Finachem PI 1979; Corpus 1983)

Toluene is sold in a nitration grade with a purity of 99.99 percent, or as an industrial grade with a purity of 98 percent. It is also sold as a mixture with xylenes.

3.2 **Domestic Manufacturers** (Corpus 1983; CBG 1980; CCPA 1981)

These are corporate headquarters addresses and are not intended as spill response contacts.

Esso Chemical Canada
2300 Yonge Street
Toronto, Ontario
M5W 1K3
(416) 488-6600

Gulf Canada Ltd.
800 Bay Street
Toronto, Ontario
M5S 1Y8
(416) 924-4141

Petro-Canada
1 Place Ville Marie
Montreal, Quebec
H3B 4A9
(514) 866-3911
(514) 866-2094

Petrosar Ltd.
P.O. Box 3060
Sarnia, Ontario
N7T 7M1

Shell Canada Ltd.
505 University Avenue
Toronto, Ontario
M5G 1X4
(416) 866-7111

Sunchem, Division of Sunoco Inc.
56 Wellesley Street West
Toronto, Ontario
M5S 2S4
(416) 924-4111

Texaco Canada Inc.
90 Wynford Drive
Don Mills, Ontario
M3C 1K4
(416) 443-7811

3.3 **Other Suppliers** (Corpus 1983)

Dow Chemical Canada Inc. (Captive)
Box 1012, Modeland Road
Sarnia, Ontario
N7T 7K7
(519) 339-3131

Kalama Chemical (Direct)
U.S.A.

3.4 **Major Transportation Routes**

Current Canadian production of toluene is located only in Quebec, Ontario and British Columbia. The major customers are located in the same areas and thus the major transportation routes are in the Toronto-Sarnia area, the Montreal area, and some in the Vancouver area. Minor amounts are transported across Canada generally.

3.5 **Production Levels** (Corpus 1983)

Company, Plant Location		Nameplate Capacity kilotonnes/yr (1982)
Esso Chemical Canada, Sarnia, Ont.		70
Esso Chemical Canada, Ioco, B.C.		38
Gulf Canada, Montreal, Que.		52
Petro-Canada, Montreal, Que.		158
Petrosar, Corunna, Ont.		60
Shell Canada, Corunna, Ont.		95
Sunchem, Sarnia, Ont.		160
Texaco Canada, Mississauga, Ont.		20
	TOTAL	653
Domestic Production (1982)		470
Imports (1982)		1.1
	TOTAL SUPPLY	471.1

3.6 Manufacture of Toluene

3.6.1 General. Toluene is primarily produced in Canada by catalytic reformation of naphthene-rich petroleum feedstock fractions, generally in conjunction with the manufacture of benzene and xylenes.

3.6.2 Manufacturing Process (Kirk-Othmer 1983; FKC 1975). Dehydrogenation of naphtha feedstock is the most common process used to produce toluene. The feedstock is preheated, vaporized, mixed with hydrogen-rich recycled gas, and passed through the reactor for a contact time of about 15 seconds. Cycloalkanes in the feedstock are catalytically reformed into aromatic hydrocarbons and hydrogen; a representative reaction is:

$$C_6H_{11}CH_3 \xrightarrow[\text{455-549°C, 1,000 to 300 kPa}]{\text{Molybdenum or Platinum on Alumina}} C_6H_5CH_3 + 3H_2$$

Conversion is usually around 80 percent. The process stream is cooled in heat exchangers and the liquid phase separated; the liquid is fractionated and the toluene-rich fraction is refined by further fractionation, and azeotropic distillation and washing sequences. The gas phase and toluene-poor phases are recycled to the process.

3.7 Major Uses in Canada (Corpus 1983; Finachem PDS 1981)

Toluene is used in the production of benzene, benzoic acid/phenol, trinitrotoluene, lacquers, resin solutions, lacquer thinners, as a gasoline component, and as a solvent in formulations of rubber cements, paints, inks and pesticides. In 1982, 39 percent was used for solvents, 25 percent for benzene production and 22 percent for benzoic acid/phenol production. This is expected to change by 1987 to be 68 percent for benzene production, 25 percent as solvents and an insignificant amount for benzoic acid/phenol production.

3.8 Major Buyers in Canada (Corpus 1983; CBG 1980)

A & K Petro-Chem Industries, Weston, Ont.
Almatex, London, Ont.
Anachemia Chemicals, Montreal, Que.
Apco Chemical, Toronto, Ont.
Ashland Chemical/Solvents, Division of Valvoline Oil & Chemicals, Mississauga, Ont.
Arliss Chemical, Montreal, Que.
Bate Chemical, Toronto, Ont.
Borden Chemical, Toronto, Ont.
C-I-L Paints, Toronto, Ont.
C-I-L, McMasterville, Que.
Canada Colors & Chemical, Toronto, Ont.
Canada Printing Inks, Toronto, Ont.
Color Your World, Toronto, Ont.
Cote Chemicals, Chateauguay, Que.
DeSoto Coatings, Toronto, Ont.
Dominion Cisco Industries, Toronto, Ont.
Du Pont Canada, Ajax, Corunna, Ont.
Ernchem Sales, Vancouver, B.C.
Ford Motor Canada, Oakville, Ont.
General Motors Canada, Oshawa, Ont.
Gulf Canada, Montreal, Que.
Harrisons & Crosfield, Toronto, Ont.
Hart Chemical, Guelph, Ont.
Industrial Adhesives, Toronto, Ont.; Montreal, Que.
Inmont Canada, Toronto, Brantford, Ont.
International Chemical, Brampton, Ont.
International Paints, Montreal, Que.
Lawter Chemicals Canada, Toronto, Ont.
3M, London, Ont.
Mallinckrodt, Pt. Claire, Que.
Mobil Chemical, Toronto, Ont.

PPG Industries Canada, Toronto, Ont.
Shefford Chemicals, Granby, Que.
Sherwin-Williams of Canada, Montreal, Que.
Sico, Quebec City, Montreal, Que.
Sinclair & Valentine, Toronto, Ont.
Stanchem (PPG Industries), Montreal, Que.
Syndel Labs, Vancouver, B.C.
Tonecraft, Toronto, Ont.
Toronto Star, Toronto, Ont.
USM Canada, Montreal, Que.
Van Waters & Rogers, Richmond, B.C.; Montreal, Que.
Wilchem, Willowdale, Ont.

4 MATERIAL HANDLING AND COMPATIBILITY

4.1 Containers and Transportation Vessels

4.1.1 Bulk Shipment. Transportation vessels and containers under this category have been grouped under the classifications of railway tank cars, highway tank vehicles, and portable tanks. Some toluene is transported in Canada by pipeline and occasionally by sea using tank containers.

4.1.1.1 Railway tank cars. Railway tank cars used to transport toluene are classified under the A-8 Class CTC/DOT 111A tank specification. Each specification is described in Table 2 (TCM 1979).

TABLE 2 RAILWAY TANK CAR SPECIFICATIONS

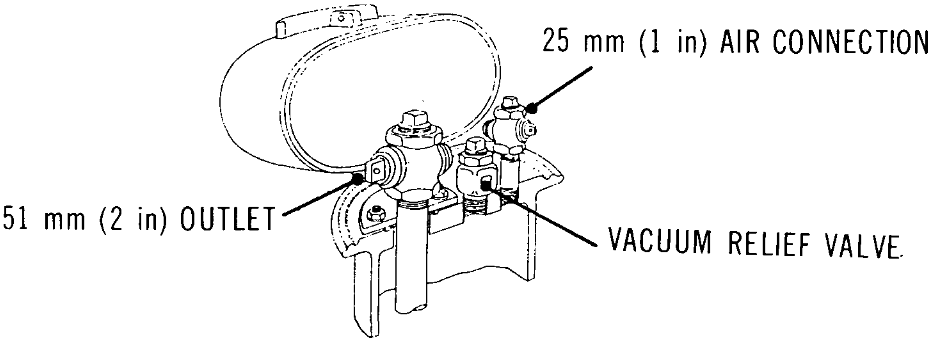
CTC/DOT* Specification Number	Description
111A60W1	Steel fusion-welded tank without dome. Uninsulated or insulated. 2% minimum outage. Gauging device. Test pressure 414 kPa (60 psi).
111A60F1	Steel forge-welded tank without dome. Uninsulated or insulated. 2% minimum outage. Gauging device. Test pressure 414 kPa (60 psi).
111A100W1	Steel fusion-welded tank without dome. Uninsulated or insulated. 2% minimum outage. Gauging device. Bottom outlet or washout optional. Test pressure 690 kPa (100 psi).

* Canadian Transport Commission and Department of Transportation (U.S.)

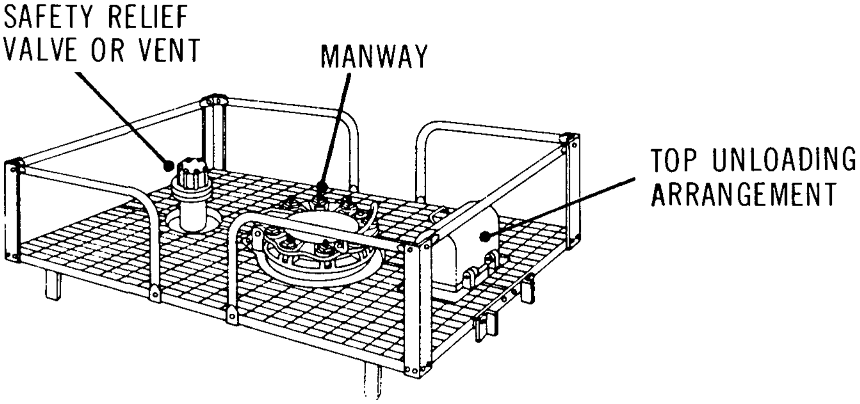
Toluene is usually shipped in railway tank cars with capacities of 75,700 L (16,700 Imp. gal.), 78,000 L (17,200 Imp. gal.), 90,900 L (20,000 Imp. gal.), and 98,400 L (21,650 Imp. gal.). Figure 7 shows a typical class 111A60W1 railway tank car used to transport toluene; Table 3 indicates railway tank car details associated with this drawing. Cars are equipped for unloading by pump or gravity through 102 mm (4 in.) or 152 mm (6 in.) diameter bottom outlets provided with inner plug valves (TDGC 1980). In addition to bottom unloading, the cars may be unloaded from the top by pump. In this case, the

RAILWAY TANK CAR - CLASS 111A60W1

(Reference - TCM 1979, RTDCR 1974)



Detail of top unloading arrangement



Detail of loading platform

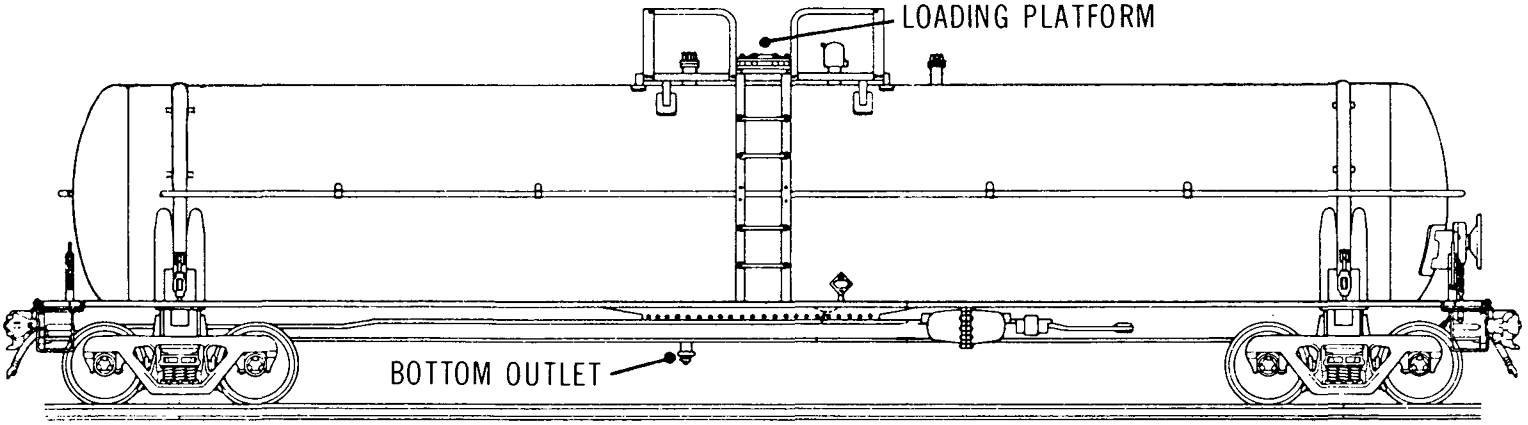


Illustration of tank car layout

TABLE 3 TYPICAL RAILWAY TANK CAR SPECIFICATIONS - CLASS 111A60W1 (TCM 1979; RTDCR 1974)

Description	Tank Car Size (Imp. Gal.)		
	16,700	17,200	20,000
Overall			
Nominal capacity	75,700 L (16,700 gal.)	78,000 L (17,200 gal.)	90,900 L (20,000 gal.)
Car weight - empty	33,900 kg (74,700 lb.)	33,900 kg (74,700 lb.)	38,900 kg (85,800 lb.)
Car weight - (max.)	119,000 kg (263,000 lb.)	83,500 kg (184,000 lb.)	119,000 kg (263,000 lb.)
Tank			
Material	Steel	Steel	Steel
Thickness	11.1 mm (7/16 in.)	11.1 mm (7/16 in.)	11.1 mm (7/16 in.)
Inside diameter	2.60 m (102 in.)	2.62 m (103 in.)	2.74 m (108 in.)
Test pressure	414 kPa (60 psi)	414 kPa (60 psi)	414 kPa (60 psi)
Burst pressure	1,640 kPa (240 psi)	1,640 kPa (240 psi)	1,640 kPa (240 psi)
Approximate Dimensions			
Coupled length	17 m (57 ft.)	17 m (57 ft.)	18 m (60 ft.)
Length over strikers	16 m (53 ft.)	16 m (53 ft.)	17 m (57 ft.)
Length of truck centers	13 m (42 ft.)	13 m (42 ft.)	14 m (45 ft.)
Height of top of grating	4 m (12 ft.)	4 m (12 ft.)	4 m (13 ft.)
Overall height	5 m (15 ft.)	5 m (15 ft.)	5 m (15 ft.)
Overall width (over grabs)	3.2 m (127 in.)	3.2 m (127 in.)	3.2 m (127 in.)
Length of grating	2-3 m (8-10 ft.)	2-3 m (8-10 ft.)	2-3 m (8-10 ft.)
Width of grating	1.5-2 m (5-6 ft.)	1.5-2 m (5-6 ft.)	1.5-2 m (5-6 ft.)
Loading/Unloading Fixtures			
Top Unloading			
Unloading connection	51 mm (2 in.)	51 mm (2 in.)	51 mm (2 in.)
Manway/fill hole	203-356 mm (8-14 in.)	203-356 mm (8-14 in.)	203-356 mm (8-14 in.)
Air connection	25-51 mm (1-2 in.)	25-51 mm (1-2 in.)	25-51 mm (1-2 in.)
Bottom Unloading			
Bottom outlet	102-152 mm (4-6 in.)	102-152 mm (4-6 in.)	102-152 mm (4-6 in.)
Safety Devices	Safety vent or valve	Safety vent or valve	Safety vent or valve
Dome	None	None	None
Insulation	Optional	Optional	Optional

toluene is withdrawn through an eduction pipe which extends from the bottom of the tank to the top operating platform where it terminates with an unloading connection valve. Air pressure is never used for unloading toluene tanks (MCA 1956).

A safety relief valve set at 241 kPa (35 psi) and a safety vent set at 414 kPa (60 psi) are required on top of the rail car (TCM 1979). A gauging device, either the rod type or the tape type, is optional. The top unloading connection must be protected by a housing. The maximum pressure allowable for the CTC/DOT 111A100W1 rail cars is 448 kPa (65 psi). When the 111A60W1 or 111A60F1 cars are used, this maximum pressure would be 276 kPa (40 psi) (TCM 1979). Toluene is never transported under pressure.

4.1.1.2 Tank motor vehicles. Toluene is transported by tank motor vehicles with tanks classed as non-pressure vessels (TDGC 1980). Design pressure for such tanks does not exceed 14 kPa (2 psi). Highway tanks carrying toluene are similar to the previously described railway tanks.

The off-loading equipment and procedures for tank motor vehicles are similar to those for railway tank cars, to be discussed later. Tanks are usually unloaded from the top by pump.

4.1.2 Packaging. Toluene, in addition to railway and highway bulk shipments, is also transported in drums (Figure 8). Drums fabricated from a variety of construction materials (Table 4) are permitted (TDGC 1980).

4.2 Off-loading

4.2.1 Off-loading Equipment and Procedures for Railway Tank Cars. Prior to off-loading, certain precautions must be taken (MCA 1956):

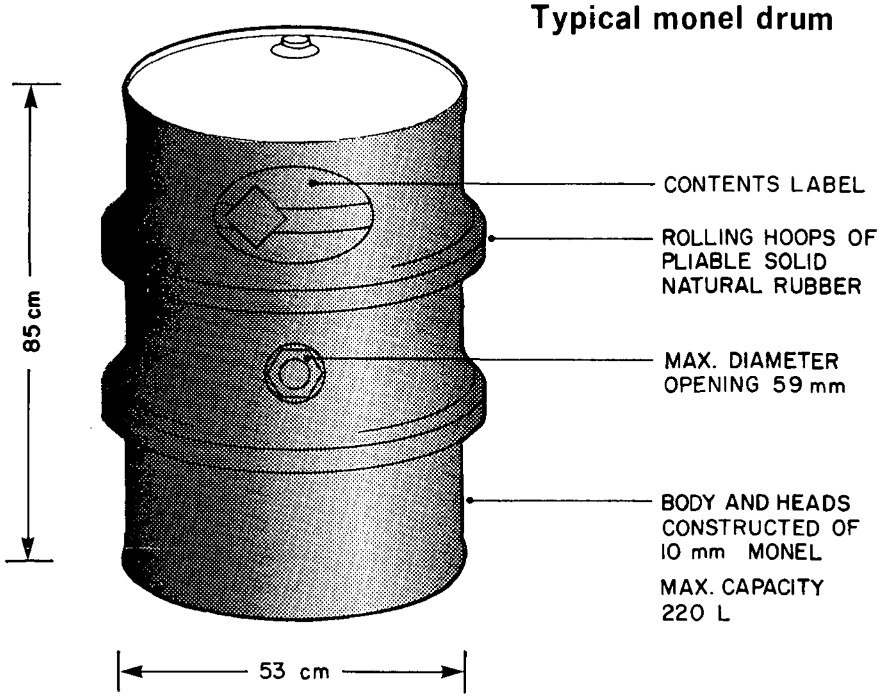
- The vented storage tank must be checked to make sure that it will hold the contents of the car.
- For night-time unloading, lights must have an explosion-proof rating.
- Personnel must not enter the car under any circumstances.
- Brakes must be set, wheels chocked, derails placed and caution signs displayed.
- A safe operating platform must be provided at the unloading point.
- Tools used during unloading must be spark-resistant.
- Tank car must be effectively grounded.

Two means of off-loading are used for toluene rail cars, top off-loading and bottom off-loading.

FIGURE 8

TYPICAL DRUM CONTAINERS

Typical monel drum



Typical steel drum

Typical aluminum drum

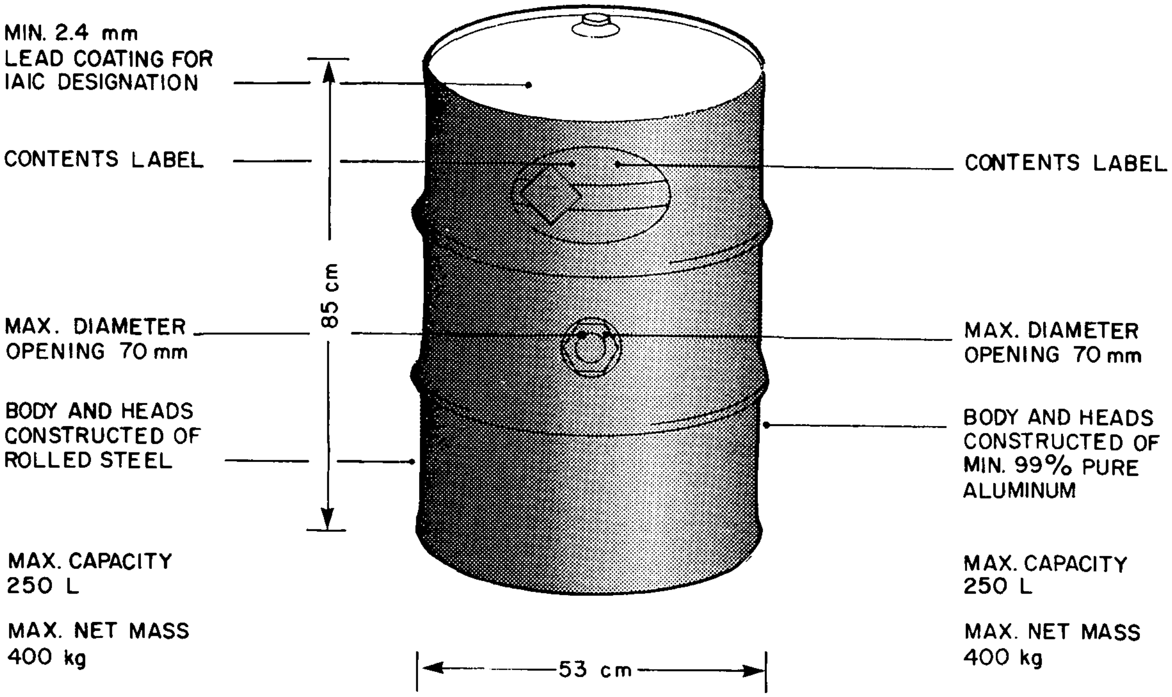


TABLE 4 DRUMS

Type of Drum	Designation	Description	Figure No. (if any)
Steel	1A1	Nonremovable head, reusable	8
	1A1A	1A1 with reinforced chime	8
	1A1B	1A1 with welded closure flange	8
	1A1D	1A1 with coating (other than lead)	8
	1A2	Removable head, reusable	8
	1A3	Nonremovable head, single use only	8
Monel*	TC5M		
Aluminum	1B1	Nonremovable head	8
	1B2	Removable head	8
Steel Drums with inner plastic receptacles	6HA1	Outer steel sheet in shape of drum. Inner plastic receptacle. Maximum capacity of 225 L (49 gal.)	
Fibreboard Drums with inner plastic receptacles	6HG1	Outer container of convolutely wound plies of fibreboard. Inner plastic in shape of drum. Maximum capacity of 225 L (49 gal.)	

* See Section 4.3 of this report.

Proceed with top off-loading as follows (MCA 1956):

- Relieve tank of internal vapour pressure by cooling tank with water or venting at short intervals.
- After removing the protective housing from the discharge line at the top of the car, connect the 51 mm (2 in.) unloading line.
- Off-load tanker by pumping.

Proceed with bottom off-loading in the following manner using gravity flow or pumping:

- Relieve internal pressure as previously mentioned.
- After connecting the unloading line to the 152 mm (6 in.) or 102 mm (4 in.) bottom outlet, open the inside bottom valve by turning the valve rod handle at the top of the car.
- Off-load the car by gravity or pump.

4.2.2 Specifications and Materials for Off-loading Equipment. The materials of construction for off-loading system components discussed in this section along with specifications refer to those generally used in toluene service. The components of a typical off-loading system that will be discussed include pipes and fittings, flexible connections, valves, gaskets and pumps.

Schedule 40 seamless ASTM A106 carbon steel pipes and fittings lined with polypropylene resin are recommended for toluene lines (DCRG 1978). Flanged joints should be used and these should be welded, because threaded pipes and fittings tend to leak after a very short time. Stress relief at the weld will also lengthen the serviceability of the pipe. The pipeline should be tested with air at pressures from 345 to 518 kPa (50 to 75 psi) and all leaks carefully stopped. If leaks develop in service, the only satisfactory way to repair them is to chip out the bad weld and reweld, or to replace the section of pipe.

The unloading line should be 51 mm (2 in.) pipe because this is the standard fitting on toluene tank cars. Process pipe may be almost any size; pipe under 25 mm (1 in.), however, is not recommended. Outdoor lines must be self-draining.

Flexible bellows-type expansion joints should be used for the flexible sections of the unloading line. They are manufactured with ASA ductile iron flanges with expansion members molded from tetrafluoroethylene resin (Dow PPS 1972). Some installations of flexible line are made with standard lined fittings using a number of flanged elbows. For valving, cast iron or cast steel diaphragm valves lined with chlorinated polyether or polyvinylidene chloride resin will serve adequately. Only Viton should be used as a gasket material at normal temperature ranges (Dow PPS 1972).

A single-suction, sealless magnetic drive centrifugal pump with "wet end" material of 316 stainless steel gives good results; an all iron pump is equally good (HIS 1969). There is virtually no leakage from this type of pump. Provision must be made for draining the pump so that repairs can be made safely. The pump should be equipped with flanges at both suction and discharge openings; screw connections are subject to leakage and should be avoided.

4.3 Compatibility with Materials of Construction

The compatibility of toluene with materials of construction is indicated in Table 5. The unbracketed abbreviations are described in Table 6. The rating system for this report is briefly described below:

Recommended:	This material will perform satisfactorily in the given application.
Conditional:	Material will show deterioration in the given application; however, it may be suitable for intermittent or short-term service.
Not Recommended:	Material will be severely affected in this application and should not be used.

TABLE 5 COMPATIBILITY WITH MATERIALS OF CONSTRUCTION

Application	Chemical Conc.	Chemical Temp. (°C)	Material of Construction: Recommended	Material of Construction: Conditional	Material of Construction: Not Recommended
1. Pipes and Fittings	98 to 100%	23	Carbon Steel Lined with Polypropylene Resin (DCRG 1978)		PE, ABS, PVC I, PVC II (DPPED 1967)
		24	Chlorinated Polyether, PP, PVDC (DCRG 1978)		
		93	PVDF (DCRG 1978)		
2. Valves	100%	21-100	SS 316 (JSSV 1979)		
3. Pumps	100%	38	GRP with FPM A "O" Ring, Bronze Fitted, All Iron (HIS 1969)		
4. Others	Technically Pure	20	PP POM (GF)	NBR* (GF)	uPVC, PE, NR, IIR, EPDM, CR, FPM, CSM (GF)
	98 to 100%	22			PVC, CPVC (TPS 1978)
		23		PP (TPS 1978)	
		49			PP (TPS 1978)
		66	PVDF (TPS 1978)		
					NR, SBR, CR, NBR, IIR, CSM, Si, EPDM (GPP)
	100%	24-100	Glass (CDS 1967)		

* Material was given a lower rating in a similar application by another reference.

TABLE 6 MATERIALS OF CONSTRUCTION

Abbreviation	Material of Construction
ABS	Acrylonitrile Butadiene Styrene
	Bronze
	Chlorinated Polyether
CPVC	Chlorinated Polyvinyl Chloride
CR	Polychloroprene (Neoprene)
CSM	Chlorosulphonated Polyethylene (Hypalon)
EPDM	Ethylene Propylene Rubber
FPM	Fluorine Rubber (Viton)
GRP	Glass Reinforced Vinyl Ester
	Glass
	Iron
IIR	Isobutylene/Isoprene (Butyl) Rubber
NBR	Acrylonitrile/Butadiene Rubber (Nitrile, Buna N)
NR	Natural Rubber
	Nickel-Copper Alloy (Monel)
PE	Polyethylene
POM	Polyoxymethylene
PP	Polypropylene
PVC (followed by grade, if any)	Polyvinyl Chloride
PVDC	Polyvinylidene Chloride
PVDF	Polyvinylidene Fluoride
SBR	Styrene/Butadiene (GR-5, Buna S)
Si	Silicone
SS (followed by grade)	Stainless Steel
uPVC	Unplasticized Polyvinyl Chloride

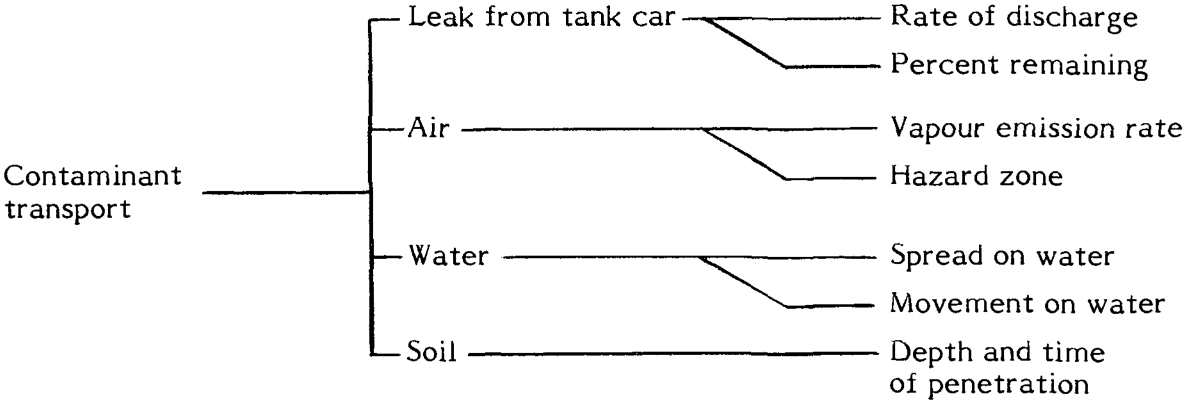
5 CONTAMINANT TRANSPORT

5.1 General Summary

When toluene is spilled on water, since it is only slightly soluble and is less dense than water, only a very small amount dissolves. The rest slowly evaporates.

When spilled on the ground, toluene forms a pool that penetrates the soil at a rate dependent on the soil type and its degree of saturation with water. During downward transport, it adsorbs onto the soil. If it reaches the water table, it may cause environmental problems.

The following factors are considered for the transport of a toluene spill in the air, water and soil media:



It is important to note that, because of the approximate nature of the contaminant transport calculations, the approach adopted throughout has been to use conservative estimates of critical parameters so that predictions are approaching worst case scenarios for each medium. This may require that the assumptions made for each medium be quite different; however, the assumptions for each medium are consistent throughout the EnviroTIPS series, allowing comparison of the behaviours of different chemicals.

5.2 Leak Nomograms

5.2.1 Introduction. Toluene is commonly transported in railway tank cars as a non-pressurized liquid. While the capacities of the tank cars vary widely, one tank car size has been chosen for development of the leak nomograms. It is approximately 2.75 m in diameter and 13.4 m long, with a carrying capacity of about 80,000 L. This standard volume has been chosen for the EnviroTIPS to allow comparison of the behaviours of the different chemicals.

If a tank car loaded with toluene is punctured in the bottom, all of the contents will drain out by gravity. The aim of the nomograms is to provide a simple means to obtain the time history of the conditions in the tank car and the discharge rate of the liquid. Because of the relatively low volatility of toluene, no leak nomograms have been prepared for vapour release from a puncture in the top of the tank.

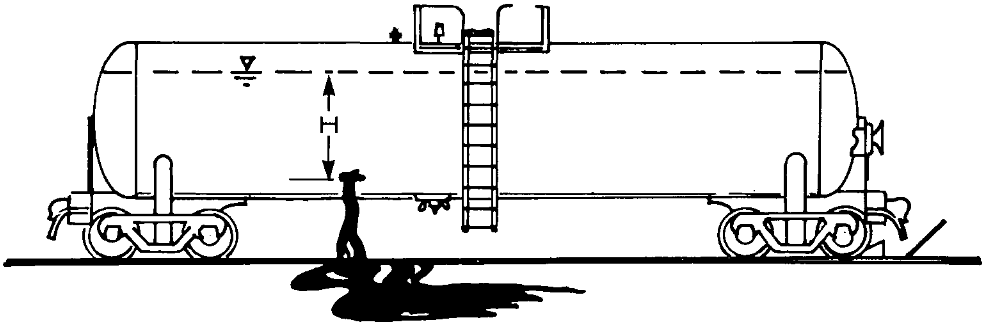


FIGURE 9 TANK CAR WITH PUNCTURE HOLE IN BOTTOM

5.2.2 Nomograms

5.2.2.1 Figure 10: Percent remaining versus time. Figure 10 provides a means of estimating the percent of liquid remaining in the standard tank car after the time of puncture, for a number of different hole diameters. The hole diameter is actually an equivalent diameter and can be applied to a noncircular puncture.

The standard tank car chosen for these nomograms is assumed to be initially full (at t=0) with a volume of about 80,000 L of toluene. The amount remaining at any time (t) is not only a function of the discharge rate over time, but also of the size and shape of the tank car.

5.2.2.2 Figure 11: Discharge rate versus time. Figure 11 provides a means of estimating the instantaneous discharge rate (L/s) at any time (t) after the time of puncture for a number of equivalent hole diameters. The nomogram is only applicable to the standard tank car size with an initial volume of 80,000 L.

FIGURE 10

TOLUENE

PERCENT REMAINING VS TIME

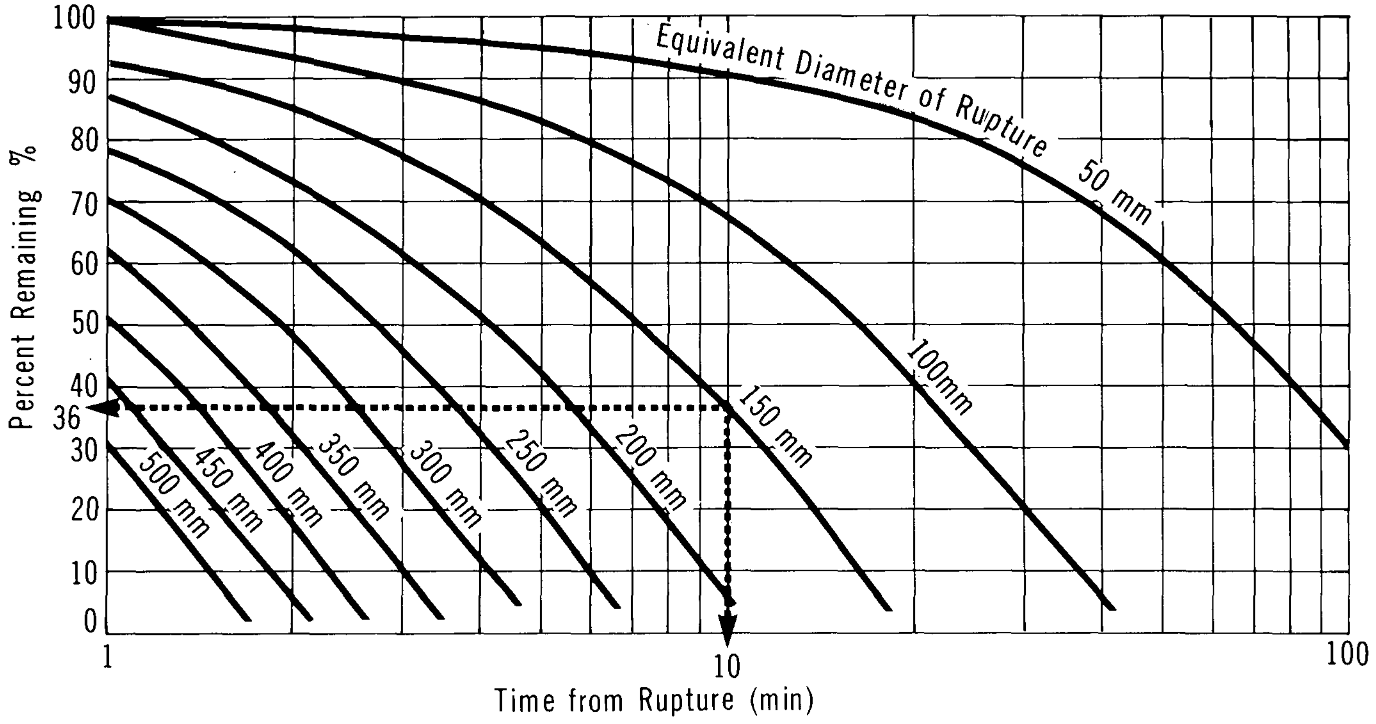
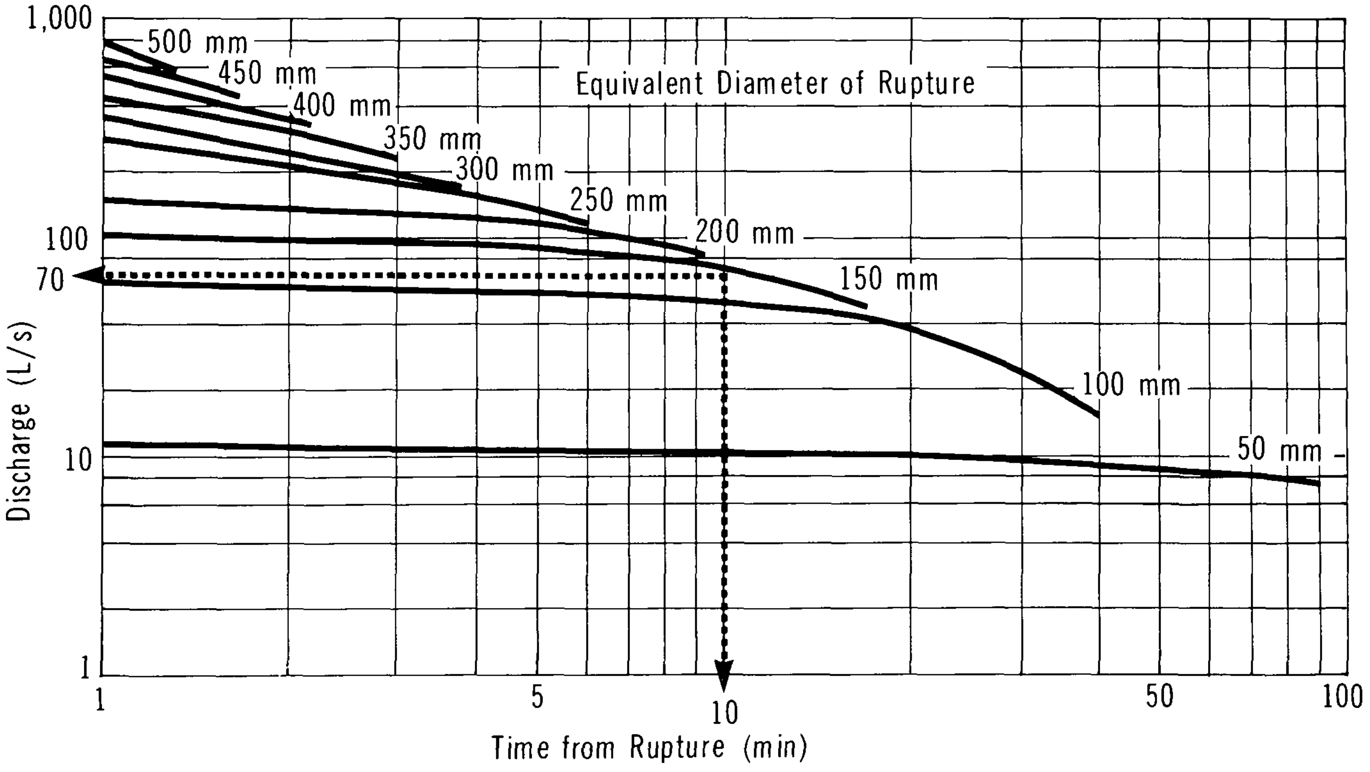


FIGURE 11

TOLUENE

DISCHARGE RATE VS TIME



5.2.3 Sample Calculations.

i) Problem A

The standard tank car (2.75 m Ø x 13.4 m long) filled with toluene has a bottom puncture. The equivalent diameter of the hole is 150 mm. What percent of the initial 80,000 L remains after 10 minutes?

Solution to Problem A

- Use Figure 10
- With t=10 min and d=150 mm, the amount remaining is approximately 36 percent or 28,800 L

ii) Problem B

With the same conditions as Problem A, what is the instantaneous discharge rate from the tank 10 minutes after the accident?

Solution to Problem B

- Use Figure 11
- With t=10 min and d=150 mm, the instantaneous discharge rate (q) = 70 L/s

5.3 Dispersion in the Air

5.3.1 Introduction. Since toluene has a low volatility, direct venting of the vapour to the atmosphere from a hole in a punctured vessel does not constitute a significant hazard downwind. Only vapour released from a liquid pool spilled on a ground or water surface is treated here.

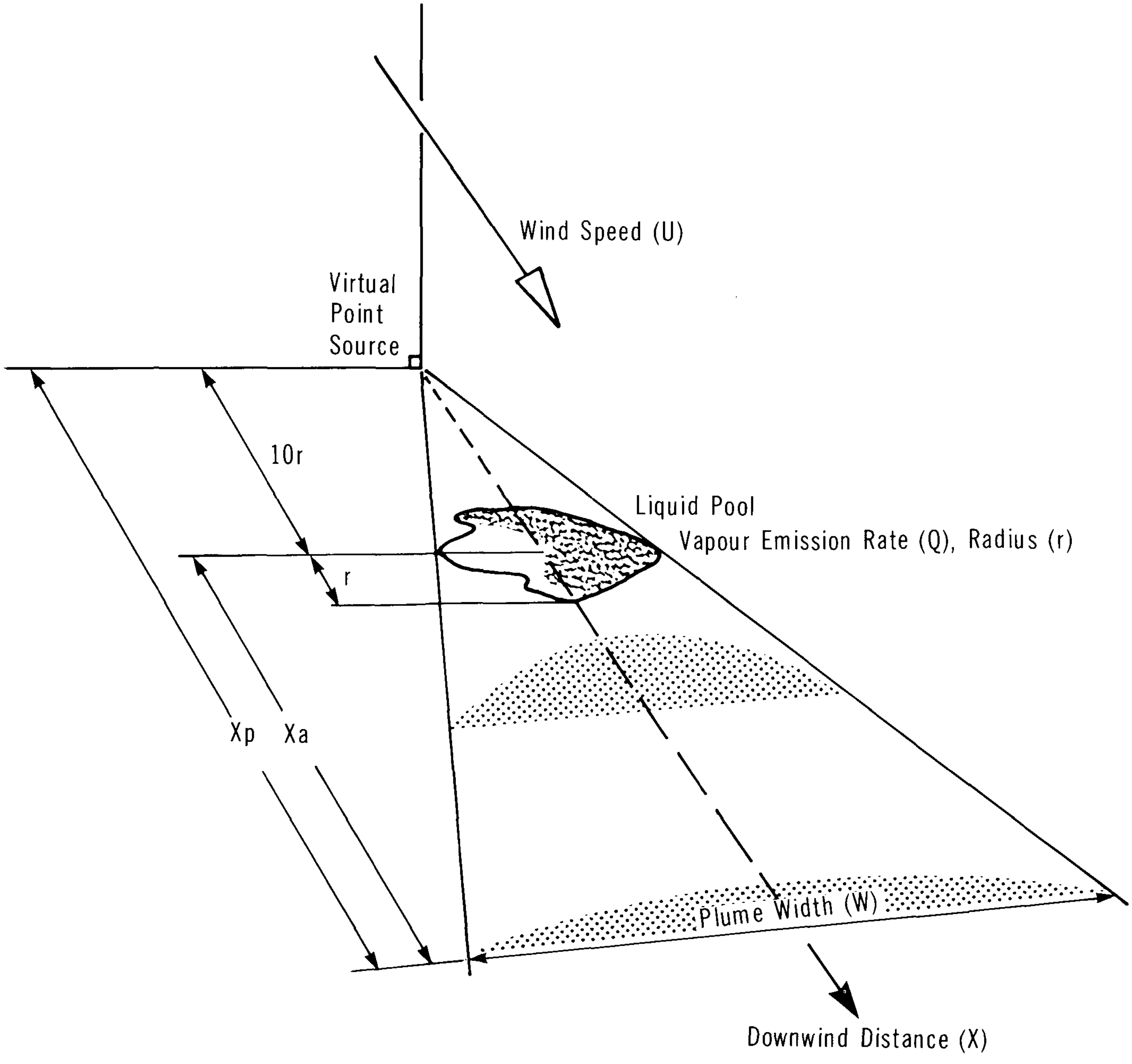
To estimate the vapour concentrations downwind of the accident site for the determination of the flammability or toxicity hazard zone, the atmospheric transport and dispersion of the contaminant vapour must be modelled. The models used here are based on Gaussian formulations and are the ones most widely used in practice for contaminant concentration predictions. The model details are contained in the Introduction Manual.

Figure 12 depicts schematically the contaminant plume configuration from a continuous surface release. The dispersion model represents the liquid pool area source as a virtual point source (with the same vapour emission rate, Q) located 10 equivalent pool radii upwind.

5.3.2 Vapour Dispersion Nomograms and Tables. The aim of the air dispersion nomograms is to define the hazard zone due to toxicity or flammability of a vapour cloud.

FIGURE 12

SCHEMATIC OF CONTAMINANT PLUME



The following nomograms and data tables are contained in this section (to be used in order given):

Figure 14:	vapour emission rate from a liquid pool as a function of maximum pool radius
Table 7:	weather conditions
Figure 15:	normalized vapour concentration as a function of downwind distance and weather conditions
Table 8:	maximum plume hazard half-widths
Figure 18:	vapour plume travel distance as a function of time elapsed since the spill and wind speed

The flow chart given in Figure 13 outlines the steps necessary to make vapour dispersion calculations and identifies the nomograms or tables to be used. This section deals only with the portion contained within the dashed box. Data on "total liquid discharged" and "equivalent pool radius" are contained in Sections 5.2 and 5.4, respectively. A description of the vapour dispersion nomogram and its use follows.

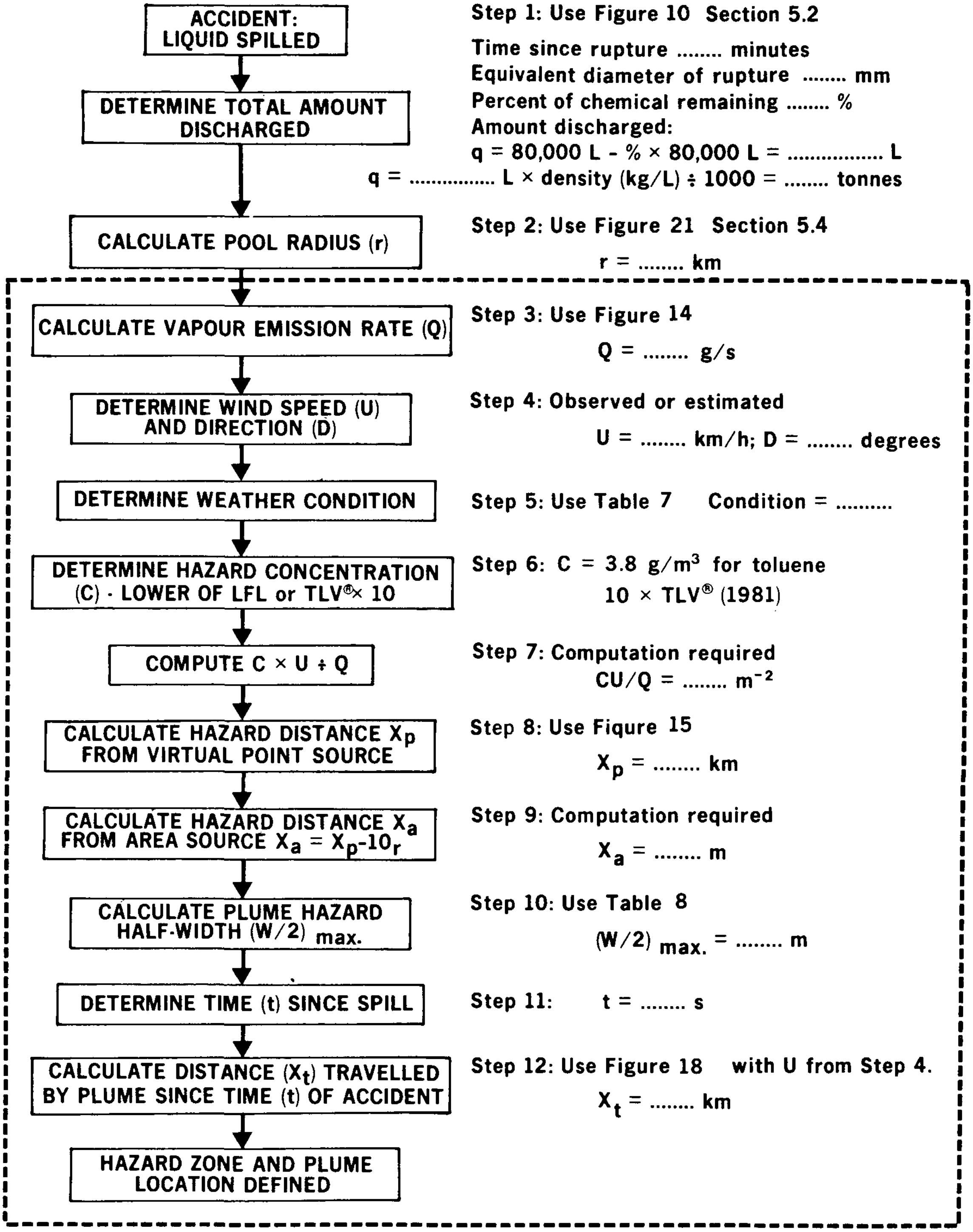
5.3.2.1 Figure 14: Vapour emission rate versus liquid spill radius for various temperatures. An evaporation rate for toluene has been calculated employing the evaporation rate equations contained in the Introduction Manual. The computed evaporation rate for toluene at 20°C and a wind speed of 4.5 m/s (16.1 km/h) is 0.54 g/(m^2·s). Evaporation rates at other temperatures have been calculated using the evaporation rate equation which, at a given wind speed, is dependent on ambient temperature and the vapour pressure (Chem. Eng. 1975) of toluene at that temperature. For example, evaporation rates of 0.217 g/(m^2·s) at 0°C and 1.08 g/(m^2·s) at 30°C were calculated for a wind speed of 4.5 m/s.

Using Figure 21, Section 5.4, the maximum spill radius corresponding to various spill amounts of toluene may be determined. The resultant spill areas and the toluene evaporation rates provide the basis for preparation of the vapour release rate versus spill radius nomogram in Figure 14.

Use: For a pool of toluene of known radius, the rate (Q) at which toluene vapour is released to the atmosphere at a given temperature can be estimated from Figure 14. The solid portion of the curves represents spills of 0.1 to 70 tonnes, the latter representing about one standard 80,000 L rail car load of toluene. It should be noted that Figure 14 is valid for a wind speed of 4.5 m/s (16.1 km/h) and therefore can only be used to provide an approximation of toluene vapour emission rates at other wind speeds. The

FIGURE 13

FLOW CHART TO DETERMINE VAPOUR HAZARD ZONE



Step 1: Use Figure 10 Section 5.2

Time since rupture .... minutes
Equivalent diameter of rupture .... mm
Percent of chemical remaining .... %
Amount discharged:
q = 80,000 L - % × 80,000 L = ... L
q = ... L × density (kg/L) ÷ 1000 = ... tonnes

Step 2: Use Figure 21 Section 5.4
r = ... km

Step 3: Use Figure 14
Q = ... g/s

Step 4: Observed or estimated
U = ... km/h; D = ... degrees

Step 5: Use Table 7 Condition = ...

Step 6: $C = 3.8$ g/m^3 for toluene
10 × TLV® (1981)

Step 7: Computation required
CU/Q = ... m^{-2}

Step 8: Use Fiqure 15
X_p = ... km

Step 9: Computation required
X_a = ... m

Step 10: Use Table 8
$(W/2)_{max.}$ = ... m

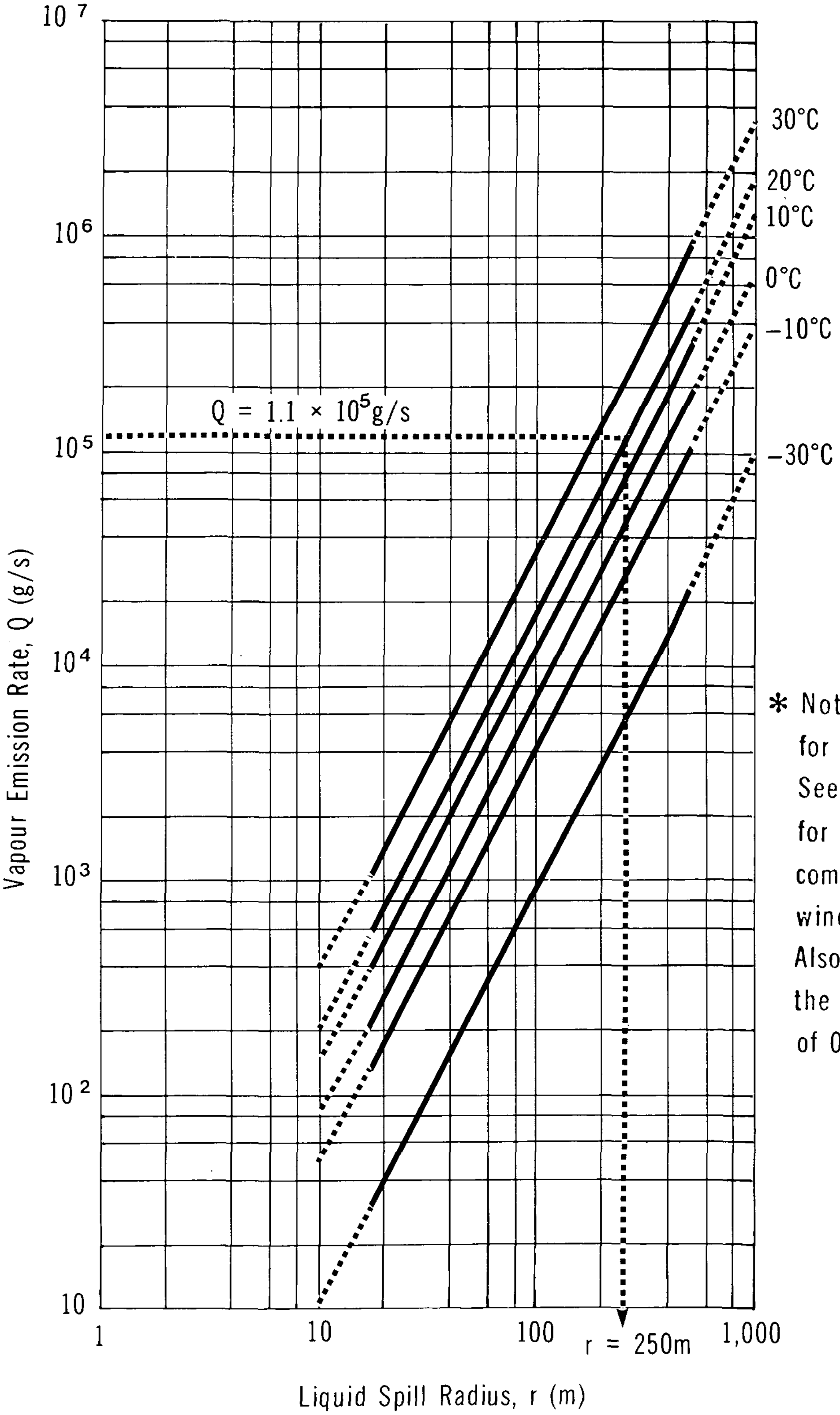
Step 11: t = ... s

Step 12: Use Figure 18 with U from Step 4.
X_t = ... km

FIGURE 14

TOLUENE

VAPOUR EMISSION RATE VS LIQUID SPILL RADIUS FOR VARIOUS TEMPERATURES *



* Note: Nomogram applies for wind speed of 4.5 m/s See Introduction Manual for relationships to compute values for other wind speeds, if necessary. Also, the solid portions of the curves represent spills of 0.2 to 70 tonnes

Introduction Manual contains the appropriate equation to convert the evaporation rate at a wind speed of 4.5 m/s to an evaporation rate at another wind speed should it be desired.

It should also be noted that the determination of the evaporation rate is based on the spill radius on calm water (Table VI, CHRIS 1974). Since calm water represents a flat, unbounded surface compared to the type of ground surface that would normally be encountered in a spill situation (namely, irregular and porous), the spill radius on calm water is considered to provide the maximum value. Therefore, when spills on land are assessed by using the water algorithm, the spill radius is overestimated and worst case values are provided.

5.3.2.2 Figure 15: Vapour concentration versus downwind distance. Figure 15 shows the relationship between the vapour concentration and the downwind distance for weather conditions D and F. The nomograms were developed using the dispersion models described in the Introduction Manual. The vapour concentration is represented by the normalized, ground-level concentration (CU/Q) at the centreline of the contaminant plume. Weather condition F is the poorest for dispersing a vapour cloud and condition D is the most common in most parts of Canada. Before using Figure 15, the weather condition must be determined from Table 7.

Use: The maximum hazard distance, X_p, downwind of the spill can be calculated from Figure 15 knowing:

- Q, the vapour emission rate (g/s)
- U, the wind speed (m/s)
- the weather condition
- the hazard concentration limit, C, which is the lower value of 10 times the Threshold Limit Value® (TLV® in g/m^3), or the Lower Flammability Limit (LFL in g/m^3). Note: To convert the TLV® (in ppm) and the LFL (in % by volume) to concentrations in g/m^3, use Figures 16 and 17.

A hazard concentration limit of 10 times the TLV® has been arbitrarily chosen as it represents a more realistic level at which there would be concern for human health on the short term (i.e., on the order of 30 minutes)*. The TLV® is a workplace standard for long-term exposure, use of this value as the hazard limit would result in unrealistically large hazard zones.

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* Note that this is an arbitrary figure and that health effects have been reported for exposure at lower concentrations (Chapter 7).

FIGURE 15

TOLUENE

NORMALIZED VAPOUR CONCENTRATION VS DOWNWIND DISTANCE

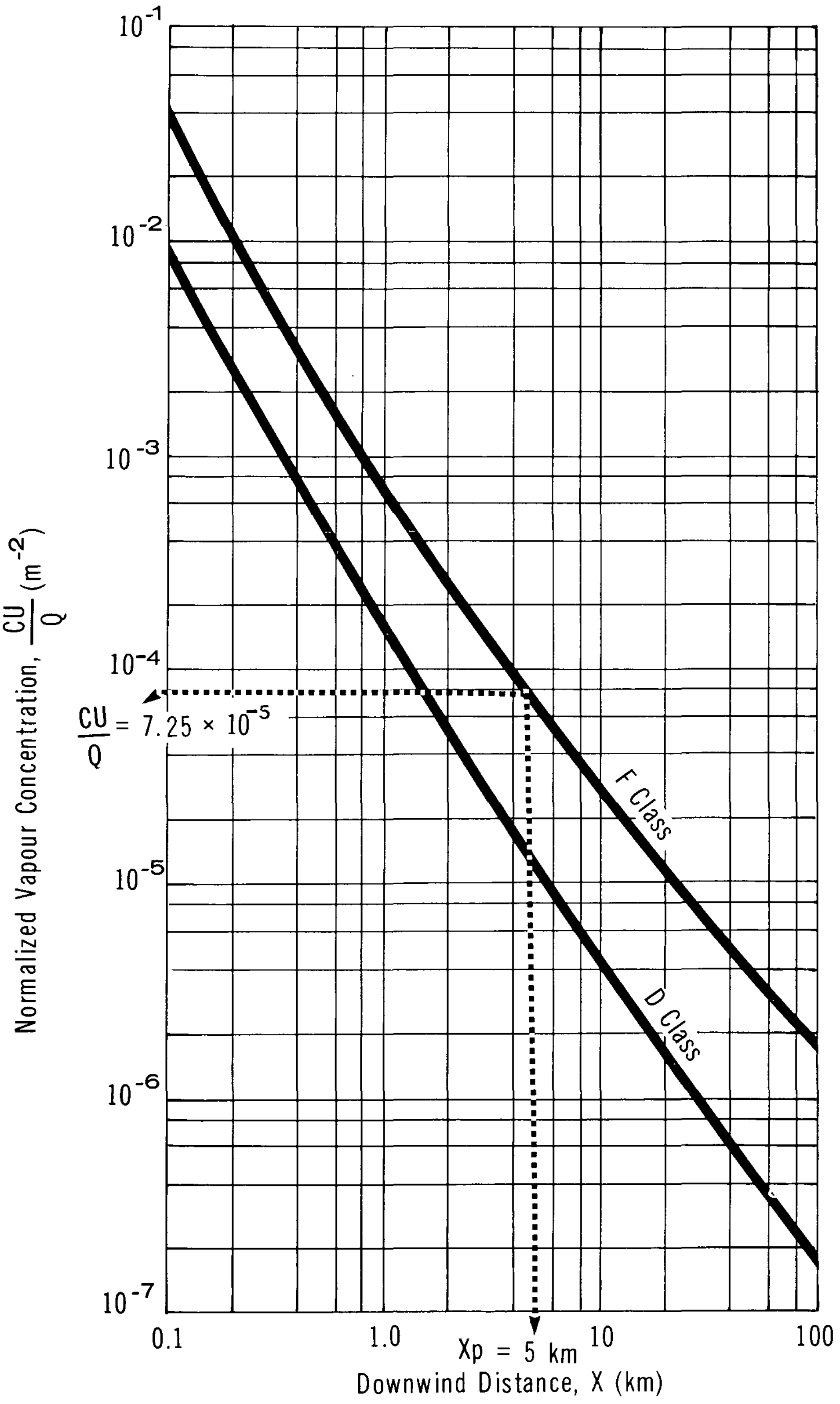


TABLE 7 WEATHER CONDITIONS

Weather Condition F	Weather Condition D
Wind speed <11 km/h (≈ 3 m/s) and one of the following: - overcast day - night time - severe temperature inversion	Most other weather conditions

5.3.2.3 **Table 8: Maximum plume hazard half-widths.** This table presents data on the maximum plume hazard half-width, $(W/2)_{max}$, for a range of Q/U values under weather conditions D and F. These data were computed using the dispersion modelling techniques given in the Introduction Manual for a value of 10 times the toluene Threshold Limit Value (TLV®) of 0.38 g/m^3, or 3.8 g/m^3. The maximum plume hazard half-width represents the maximum half-width of the toluene vapour cloud, downwind of the spill site, corresponding to a hazard concentration limit of 10 x TLV®. Table 8 is therefore only applicable for a toluene hazard concentration limit of 10 x TLV® or 3.8 g/m^3. Also, data are provided up to a maximum hazard distance downwind of 100 km.

Under weather condition D, the wind speed (U) range applicable is 1 to 30 m/s. The range of vapour emission rates (Q) used was 30,000 to 25,000,000 g/s, corresponding to toluene spills in the range of about 5 to 10,000 tonnes, respectively. If the entire contents of an 80,000 L (17,600 Imp. gal.) tank car spills, the mass spilled would be 69,400 kg or approximately 69 tonnes. Therefore, under Class D of Table 8, data are provided for up to about 58 times this amount.

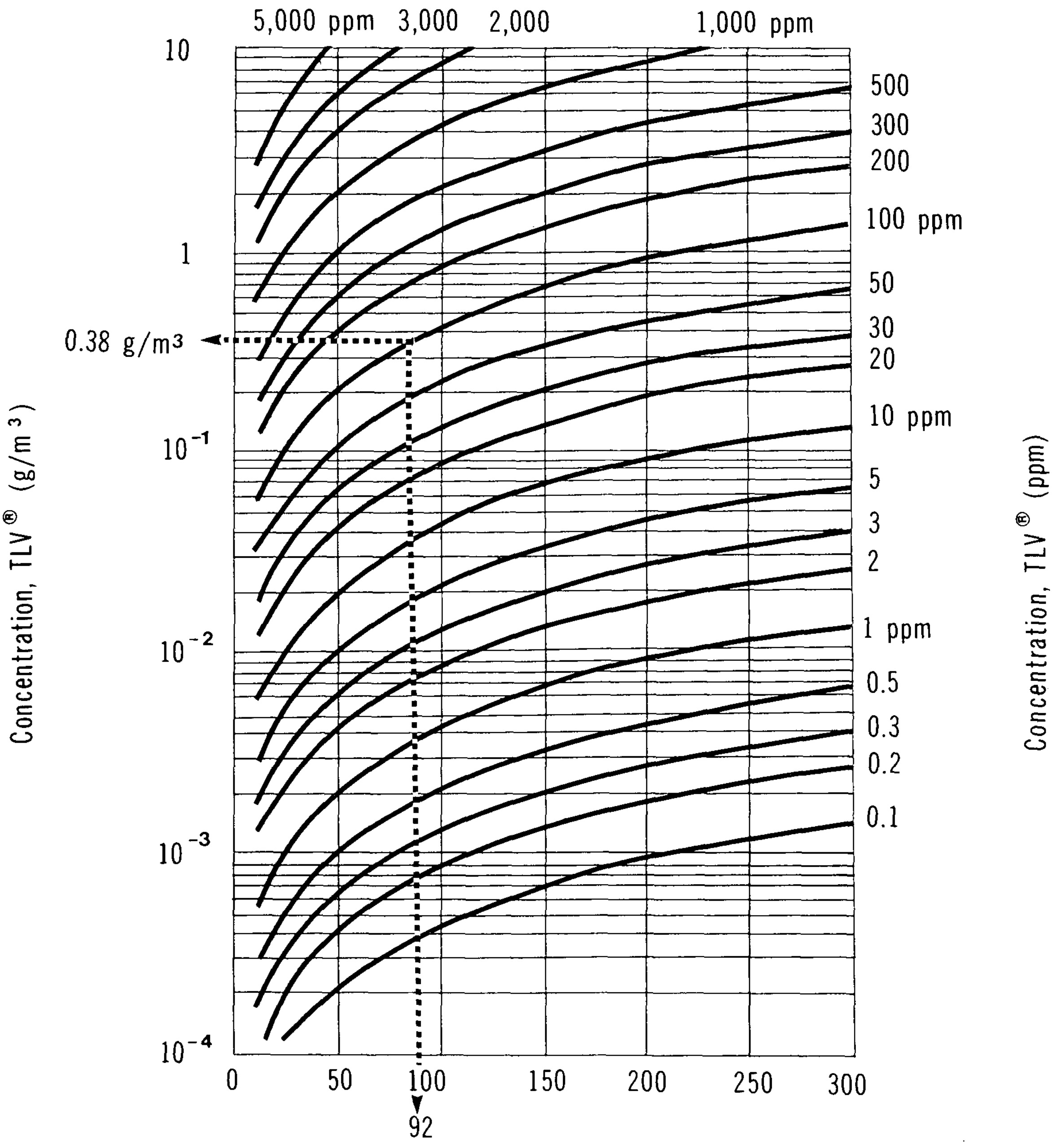
Under weather condition F, the wind speed (U) range applicable is 1 to 3 m/s. The range of vapour emission rates (Q) used was 3,000 to 2,225,000 g/s, corresponding to toluene spills in the range of about 0.5 to 400 tonnes, respectively. Therefore, under class F of Table 8, data are provided for up to about 6 times a standard rail car load.

Use: Knowing the weather condition, Q and U, compute Q/U. Choose the closest Q/U value in the table and the corresponding $(W/2)_{max}$, the maximum plume hazard half-width in metres. (For intermediate values, interpolate Q/U and $(W/2)_{max}$ values.) Also refer to the example at the bottom of Table 8.

FIGURE 16

TOLUENE

CONVERSION OF THRESHOLD LIMIT VALUE (TLV®) UNITS (ppm to g/m³)



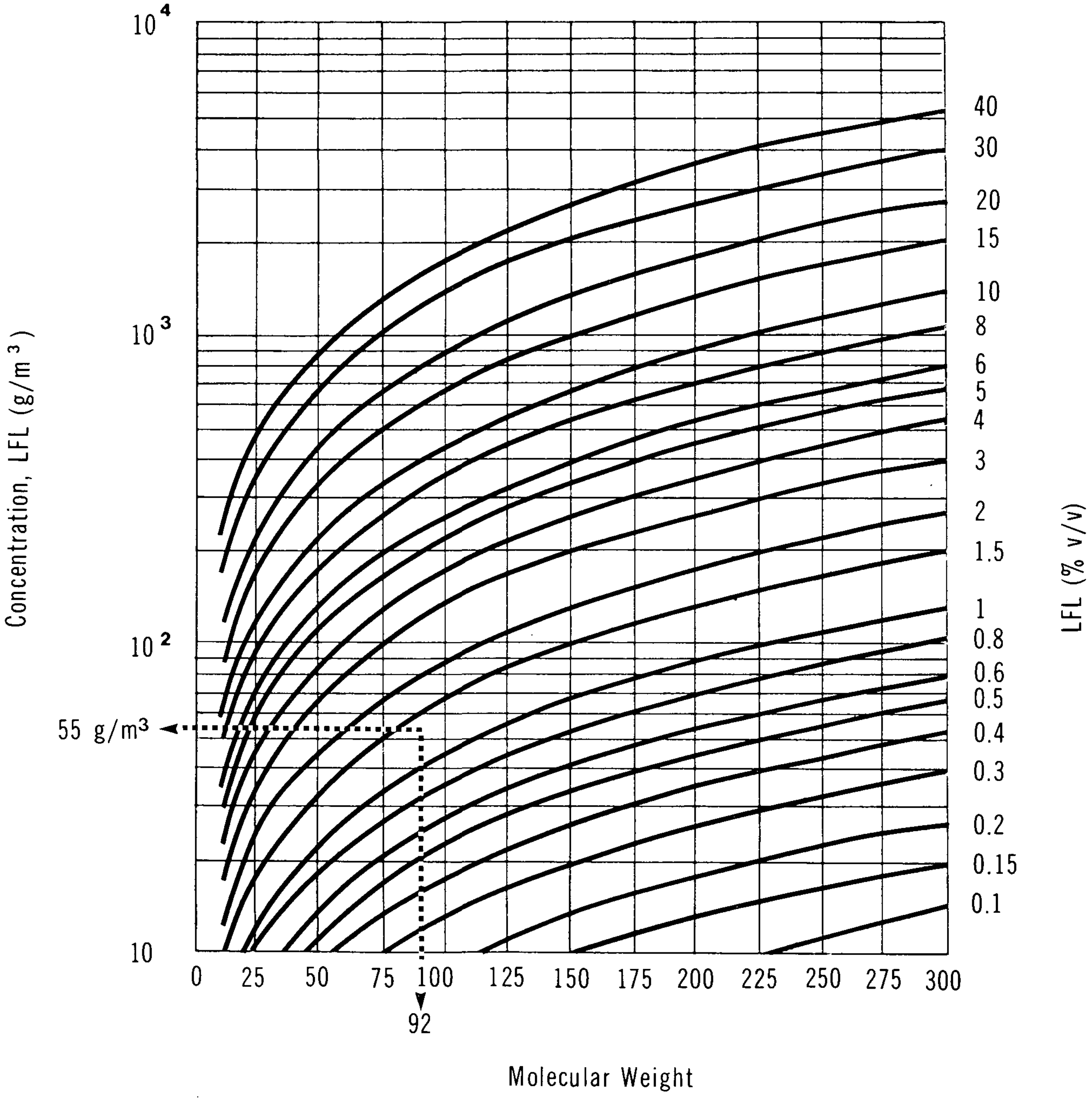
Example: Toluene, MW = 92, TLV® = 100 ppm then TLV® in g/m³ ≅ 0.38

Note: data applicable at 25° and 760 mm Hg pressure

FIGURE 17

TOLUENE

CONVERSION OF LOWER FLAMMABILITY LIMIT (LFL) UNITS (volume % to g/m³)



Example: Toluene, MW = 92, LFL = 1.27%,
then LFL in g/m³ = 55

Note: data applicable at 25°C and 760 mm Hg pressure

TABLE 8 MAXIMUM PLUME HAZARD HALF-WIDTHS (for toluene at 20°C)

Weather Condition D			Weather Condition F		
Q/U (g/m)	$(W/2)_{max}$ (m)		Q/U (g/m)	$(W/2)_{max}$ (m)	
25,000,000	3,300	($X_p \le 99.5$ km)*	2,250,000	1,420	($X_p \le 99.5$ km)*
22,500,000	3,090		2,000,000	1,300	
20,000,000	2,870		1,500,000	1,050	
15,000,000	2,405		1,000,000	775	
12,500,000	2,150		750,000	625	
10,000,000	1,870		500,000	460	
7,500,000	1,570		300,000	320	
5,000,000	1,220		250,000	285	
2,250,000	745		200,000	250	
2,000,000	690		150,000	205	
1,500,000	580		100,000	160	
1,000,000	465		75,000	135	
750,000	390	Q/U = 52,380 →	50,000	100	→ $(W/2)_{max}$= 110 m
500,000	310		25,000	65	
300,000	230		10,000	40	
250,000	205		5,000	25	
200,000	180		2,500	20	
150,000	150		1,000	10	
100,000	120				
75,000	100				
50,000	80				
25,000	55				
10,000	35				
5,000	20				
1,000	10				

* Data are provided up to a maximum downwind hazard distance (X_p) of 100 km

Example: A spill releasing toluene vapour at the rate of Q = 1.1 x 10^5 g/s under weather condition F and a wind speed U = 2.1 m/s means Q/U = 52,380 g/m which results in a maximum plume hazard half-width $(W/2)_{max}$ = 110 m.

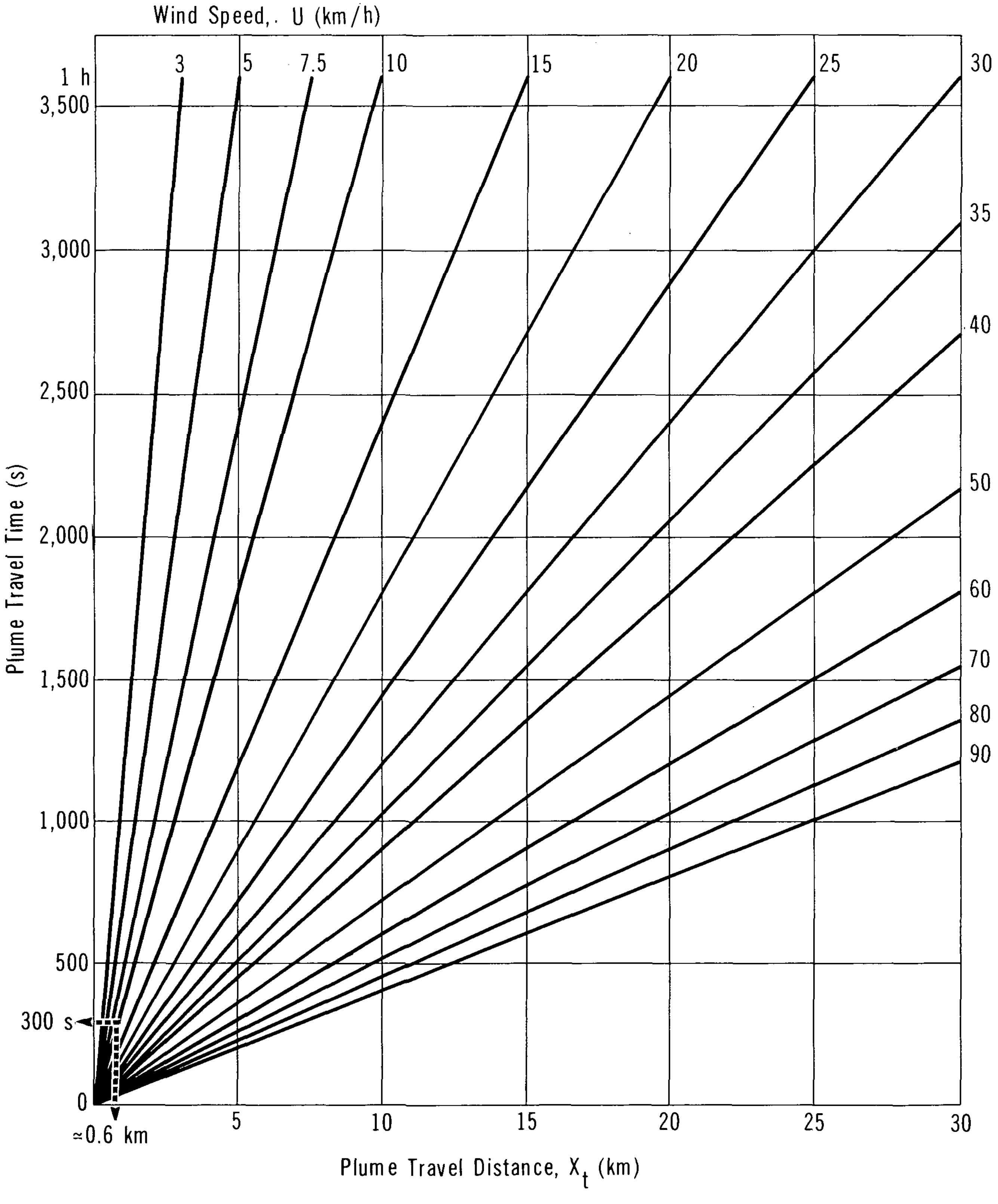
Note: Above table is valid only for a toluene concentration of 10 x TLV®, or 3.8 g/m^3.

5.3.2.4 **Figure 18: Plume travel time versus travel distance.** Figure 18 presents plots of plume travel time (t) versus plume travel distance (X_t) as a function of different wind speeds (U). This is simply the graphical presentation of the relationship X_t = Ut for a range of typical wind speeds.

FIGURE 18

TOLUENE

PLUME TRAVEL TIME VS TRAVEL DISTANCE



Use: Knowing the time (t) since the spill occurred and the wind speed (U), the distance (X_t) can be determined which indicates how far downwind the plume has travelled.

5.3.3 **Sample Calculation.** The sample calculation given below is intended to outline the steps required to estimate the downwind hazard zone which could result from a spill of liquid toluene. The user is cautioned to take note of the limitations in the calculation procedures described herein and in the Introduction Manual. The estimates provided here apply only for conditions given. It is recommended that the user employ known or observational estimates (i.e., of the spill radius) in a particular spill situation if possible.

Problem:

During the night, at about 2:00 a.m., 20 tonnes of toluene were spilled on a flat ground surface. It is now 2:05 a.m. The temperature is 20°C and the wind is from the NW at 7.5 km/h. Determine the extent of the vapour hazard zone.

Solution

Step 1: Quantity spilled is given, q = 20 tonnes

Step 2: Determine pool radius (r) for spill of 20 tonnes

- Use observed (measured) pool radius if possible. If not, use the maximum radius from Figure 21, Section 5.4. Note that use of these data, which apply specifically to spills on water, will result in an exaggerated pool radius on land
- Radius (r) = 250 m ÷ 1,000 = 0.25 km

Step 3: Calculate vapour emission rate (Q) at T = 20°C

- From Figure 14, for r = 250 m and T = 20°C, $Q = 1.1 \times 10^5$ g/s

Step 4: Determine wind speed (U) and direction (D)

- Use available weather information, preferably on-site observations
- Given:

  U = 7.5 km/h, then U = 7.5 ÷ 3.6 = 2.1 m/s

  D = NW or 315° (D = Direction from which wind is blowing)

Step 5: Determine weather condition

- From Table 7, weather condition = F since U is less than 11 km/h and it is night

Step 6: Determine hazard concentration limit (C)

- This is the lower of 10 times the TLV®, or the LFL, so for toluene $C = 3.8\ g/m^3$ (TLV® = $0.38\ g/m^3$; LFL = $55\ g/m^3$)

Step 7: Compute CU/Q

- $$CU/Q = \frac{3.8 \times 2.1}{1.1 \times 10^5} = 7.25 \times 10^{-5}\ m^{-2}$$

Step 8: Calculate downwind distance (X_p) from the virtual point source

- From Figure 15 with $CU/Q = 7.25 \times 10^{-5}\ m^{-2}$ and weather condition F, $X_p \simeq 5.0$ km

Step 9: Calculate hazard distance (X_a) downwind of the area source

- With $X_p = 5.0$ km and $r = 0.25$ km, then $X_a = X_p - 10\,r = 5.0\text{ km} - 10\,(0.25\text{ km}) = 2.5$ km

Step 10: Calculate plume hazard half-width $(W/2)_{max}$

- Use Table 8
- With $Q = 1.1 \times 10^5$ g/s and $U = 2.1$ m/s
  $$\text{then } Q/U = \frac{1.1 \times 10^5}{2.1} = 52{,}380\ g/m$$
- Then for weather condition F the closest Q/U value is between 50,000 and 75,000 g/m, which gives $(W/2)_{max} \simeq 110$ m

Step 11: Determine the time since spill

- $t = 5\text{ min} \times 60 = 300$ s

Step 12: Calculate distance travelled (X_t) by vapour plume since time of accident

- Using Figure 18 with $t = 300$ s and $U = 7.5$ km/h, then $X_t = 0.6$ km (more accurately from $Ut = 2.1\text{ m/s} \times 300\text{ s} = 630\text{ m} = 0.63$ km)

Step 13: Map the hazard zone

- This is done by drawing a rectangular area with dimensions of twice the maximum plume hazard half-width (110 m) by the maximum hazard distance downwind of the area source (2.5 km) along the direction of the wind, as shown in Figure 19
- If the wind is reported to be fluctuating by 20° about 315° (or from 315° ± 10°), the hazard zone is defined as shown in Figure 20

FIGURE 19

TOLUENE

HAZARD AREA FOR STEADY WINDS, EXAMPLE PROBLEM

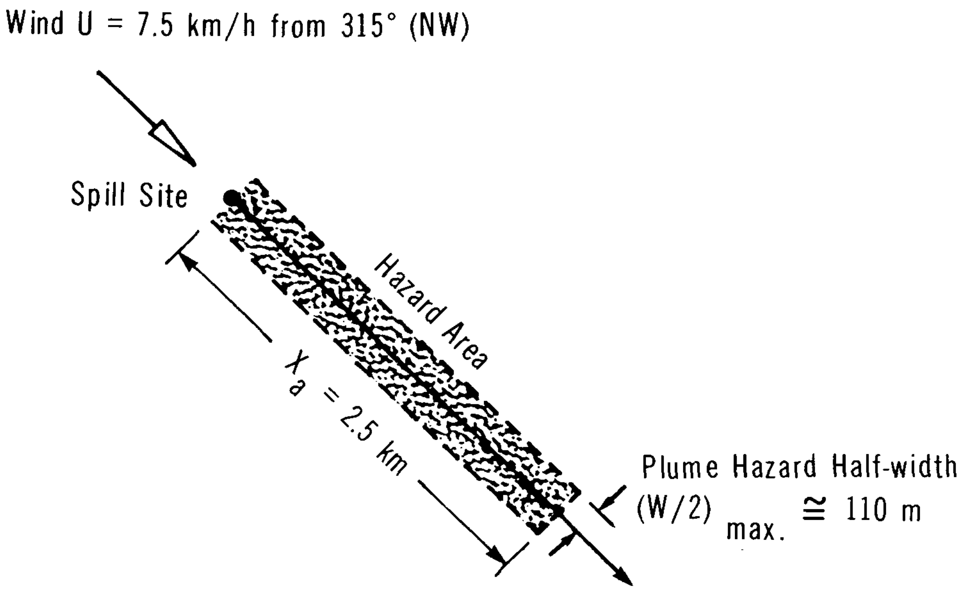
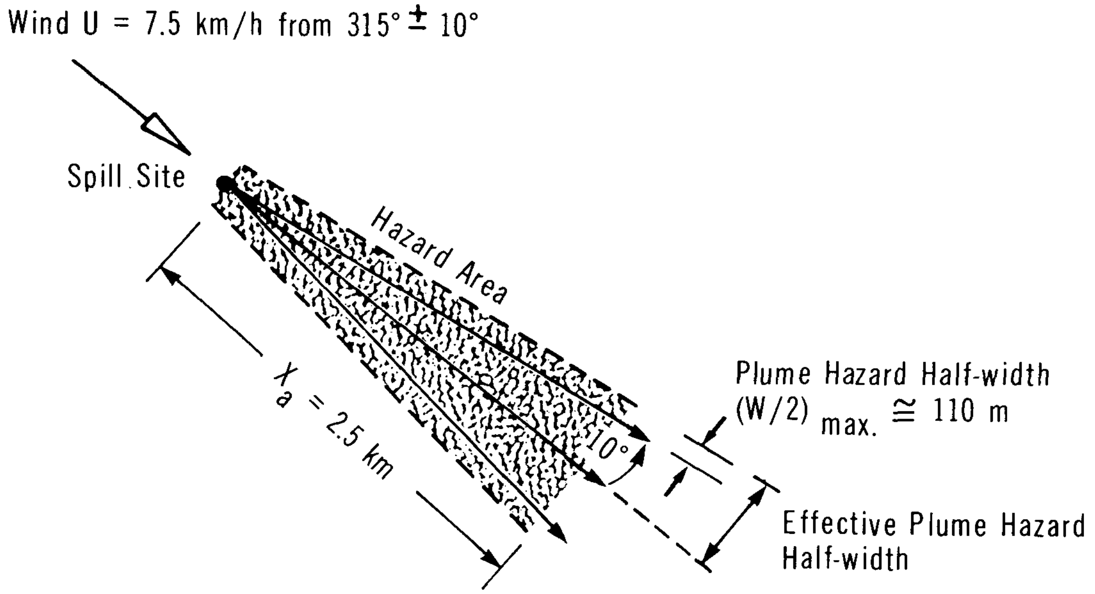


FIGURE 20

TOLUENE

HAZARD AREA FOR UNSTEADY WINDS, EXAMPLE PROBLEM



$= Xa \times 1000 \times \tan 10° + (W/2)_{max}$

$= 2.5 \times 1{,}000 \times \tan 10° + 110$ m

$= 460$ m

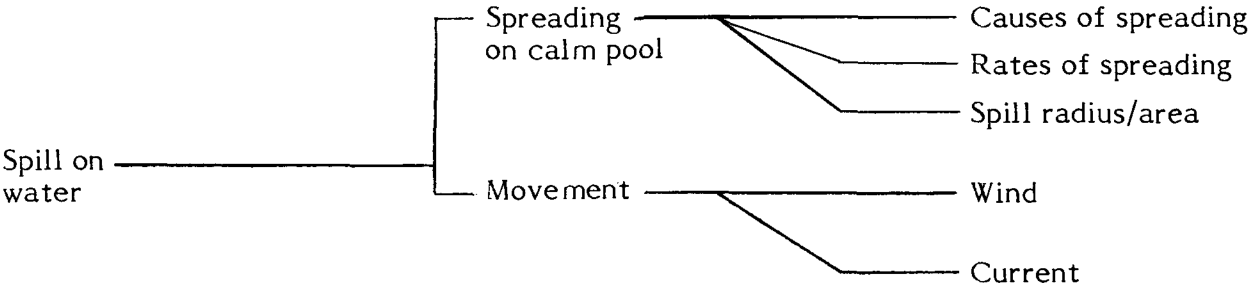
- Note that the plume has only travelled 0.63 km in the 5 minutes since the spill. At a wind speed of 7.5 km/h there remain 15 minutes before the plume reaches the maximum downwind hazard distance of 2.5 km

5.4 Behaviour with Water

5.4.1 **Introduction.** The rate of spreading on water is based on the balance between forces tending to spread the liquid (gravity and surface tension) and those tending to resist spreading (inertial and viscous forces).

In addition to the natural spreading tendency, the spill slick will move in the same direction and at the same speed as the surface water. Surface water direction and speed are influenced by currents and wind forces.

Factors considered in the spill nomograms are illustrated in the following chart:



5.4.2 **Nomograms.** The following nomograms are presented to simplify calculations:

Figure 21: spill radius versus time (still water - unconfined) for various sizes of spills; maximum spill radius indicated

Figure 22: length of channel affected versus equivalent spill radius (still water - confined) for a number of stream widths

Figure 23: translation distance versus time for a range of surface water velocities

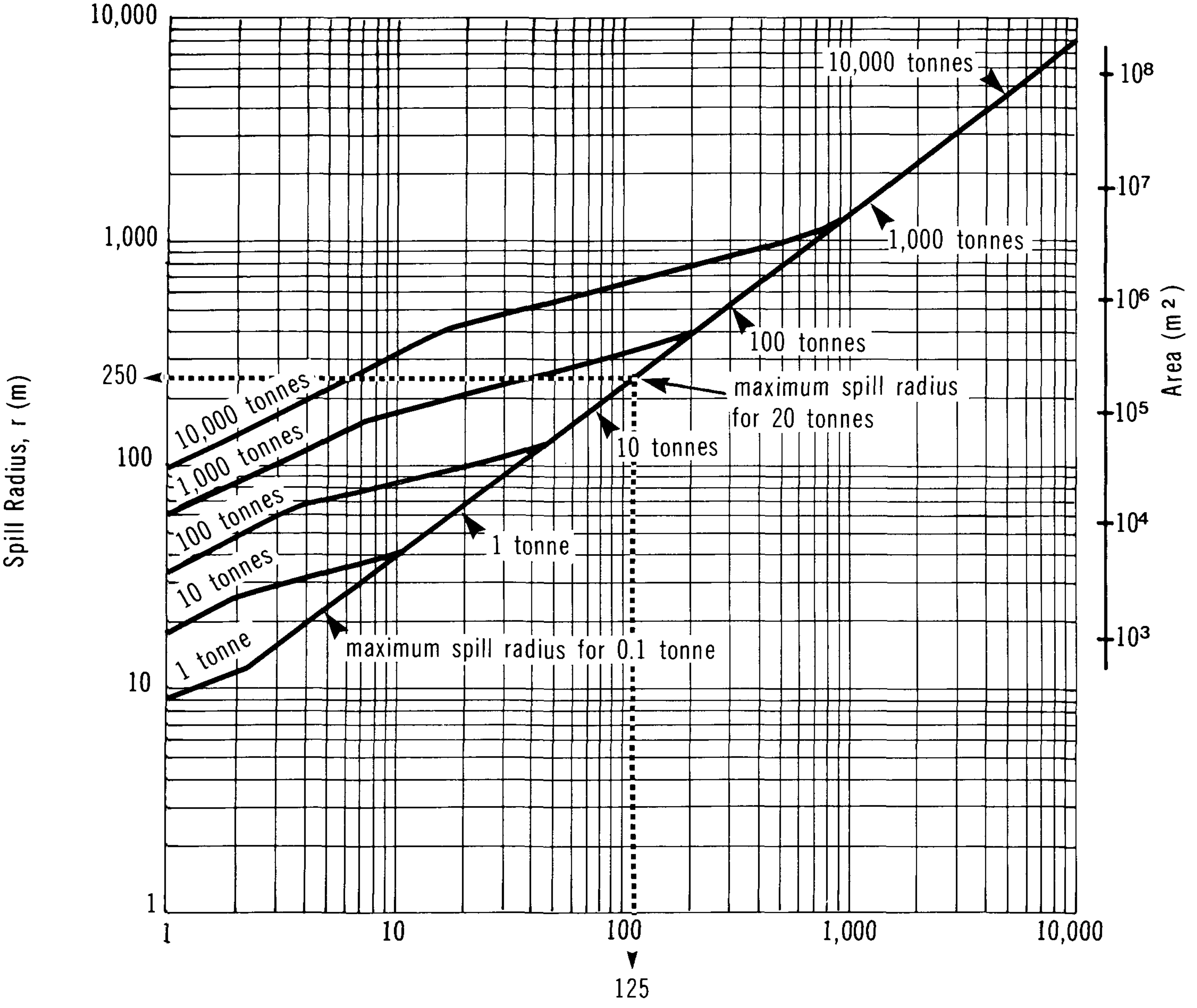
Figure 24: vectoral addition of surface current and wind

5.4.2.1 **Figure 21: Spill radius versus time (still water - unconfined).** Figure 21 provides a means of calculating the radius/area of an unconfined slick of toluene for a known mass of spill and at a defined time from the occurrence of the spill. The equations representing the spreading of the spill on water are presented in the Introduction Manual. A critique of a spreading model (Eisenberg 1975) suggests that the equations are valid for cases where the viscosity of the spilled liquid is greater than or equal to 0.2 times the viscosity of water ($U_L \geq 0.2\ U_W$).

FIGURE 21

TOLUENE

SPILL RADIUS VS TIME
(still water - unconfined)



For the purposes of the nomogram presented, the water/spill temperature has been taken at 20°C, representing a reasonable maximum for surface water bodies. This condition maximizes the spill size at any time of interest. If the indicated pool radius is larger than the theoretical maximum radius, use the theoretical maximum pool radius.

5.4.2.2 Figure 22: Length of channel affected versus equivalent spill radius (still water - confined). If the distance between the banks of the water body is less than the spill diameter, the slick will be confined. Using the effective radius of spill from Figure 21, the approximate length of channel affected by the spill can be computed from Figure 22, if the stream width is known.

5.4.2.3 Figure 23: Translation distance versus time (no wind). Figure 23 presents a simple relationship between velocity, time and distance. The distance a spill will be transported by a flowing stream is directly proportional to the surface current.

5.4.2.4 Figure 24: Vectoral addition of surface current and wind. To take into account the effect of both wind and surface current, the spill slick is assumed to move with a velocity given by the vectoral addition of current velocity and 3 percent of the wind velocity (Raj 1974; Fingas 1979, 1980). Figure 24 is designed to simplify vectoral addition of the current and velocity components. The horizontal velocity axis is scaled for wind velocity in kilometres per hour.

The surface current vector is added to the wind vector by determining its direction relative to the wind direction. The length of the surface current vector is defined by the vertical surface current velocity scale in m/s. The resultant vector represents the direction and velocity the spill slick will be moving due to wind and current effects. The length of the resultant vector represents the spill translation velocity (m/s) when measured against the vertical scale.

The nomogram does not account for deformation of the slick shape when influenced by wind and/or surface currents, or for any losses which occur by evaporation or any other means.

5.4.3 Sample Calculations

i) Problem A

A 20 tonne spill of toluene has occurred on a large lake. The wind is calm. Determine the size of the spill after 20 minutes, together with the maximum spill size and approximate time taken.

FIGURE 22

TOLUENE

LENGTH OF CHANNEL AFFECTED VS SPILL RADIUS (still water - confined)

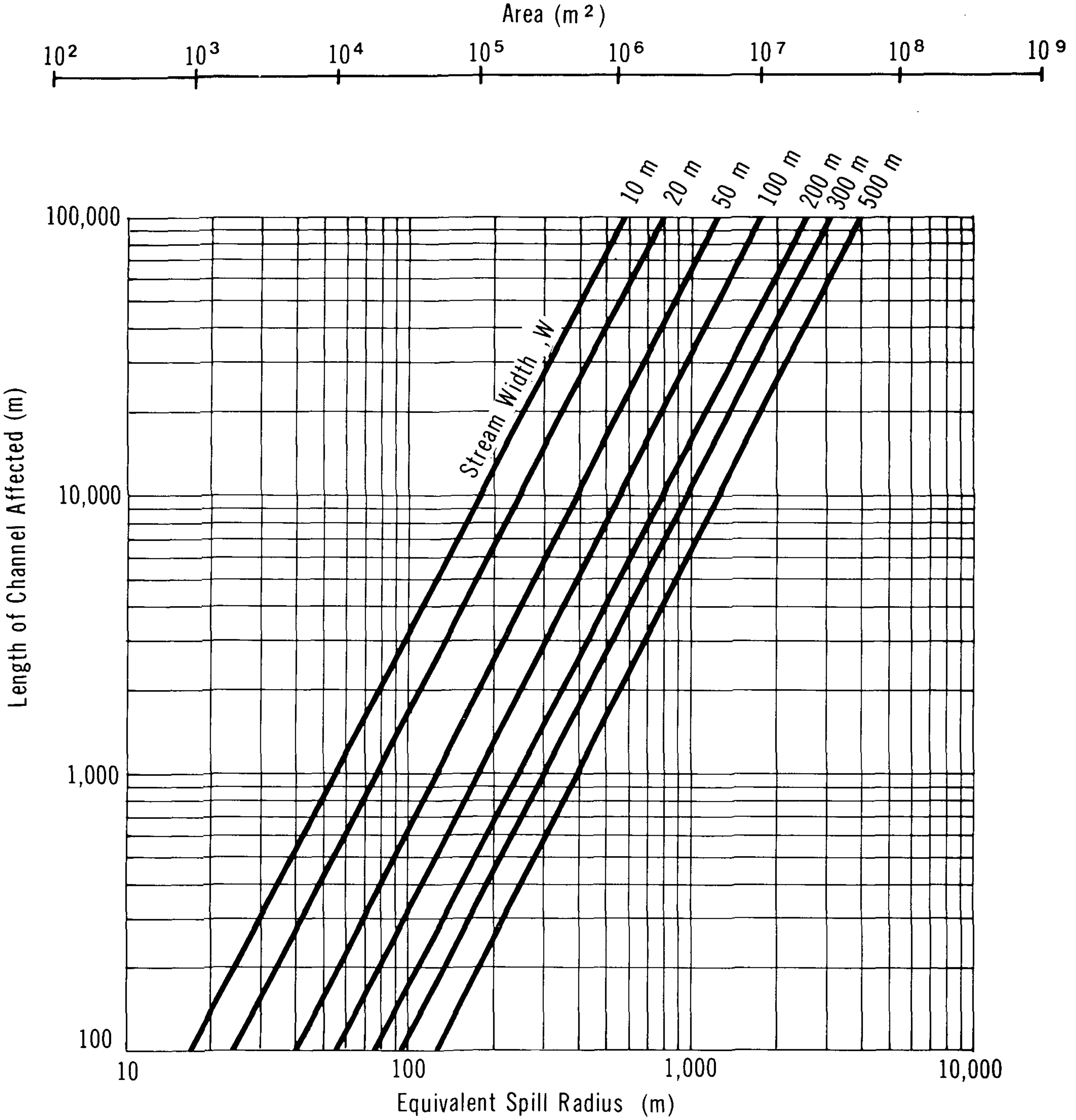


FIGURE 23

TOLUENE

TRANSLATION DISTANCE vs TIME (No wind)

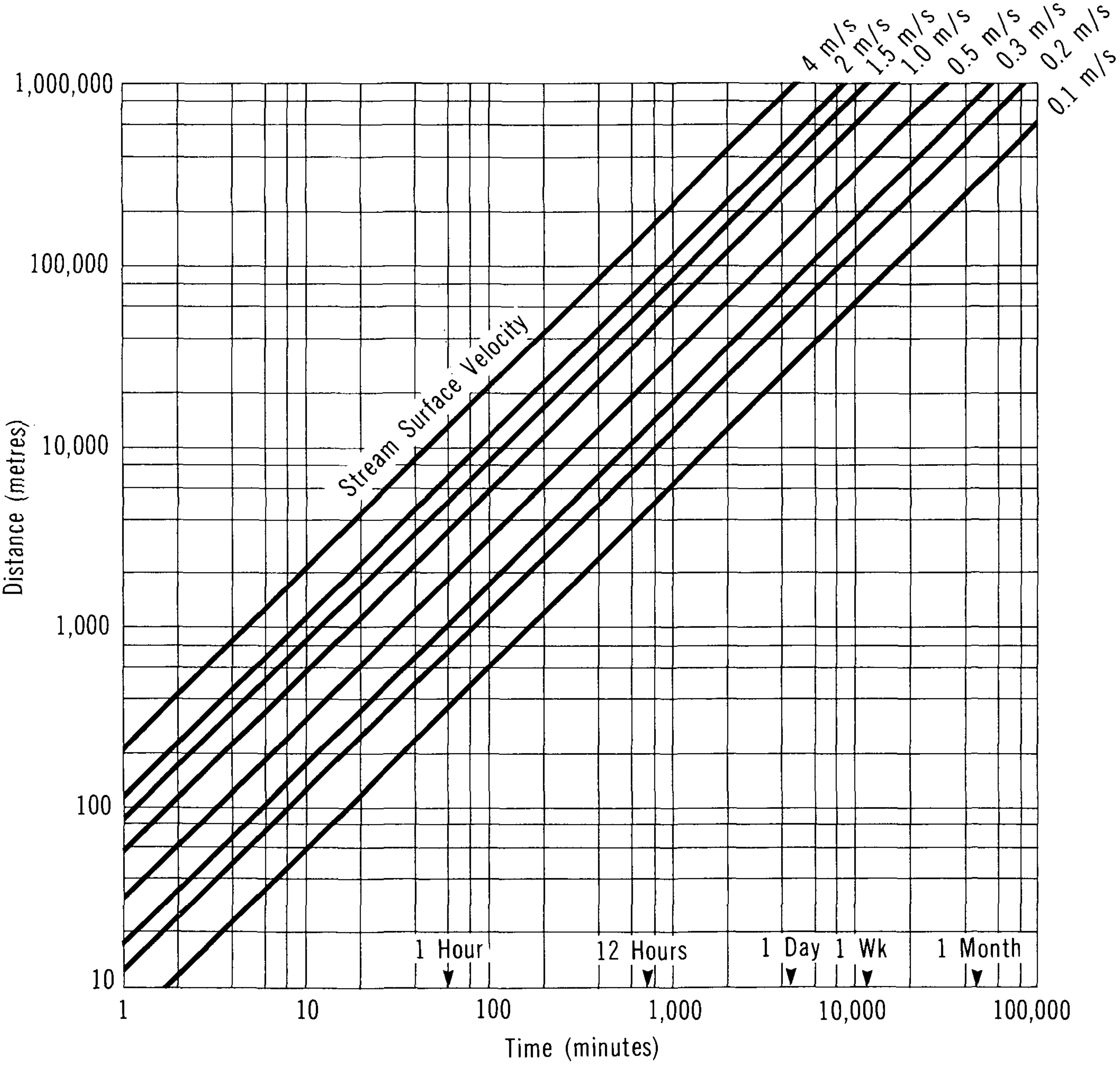
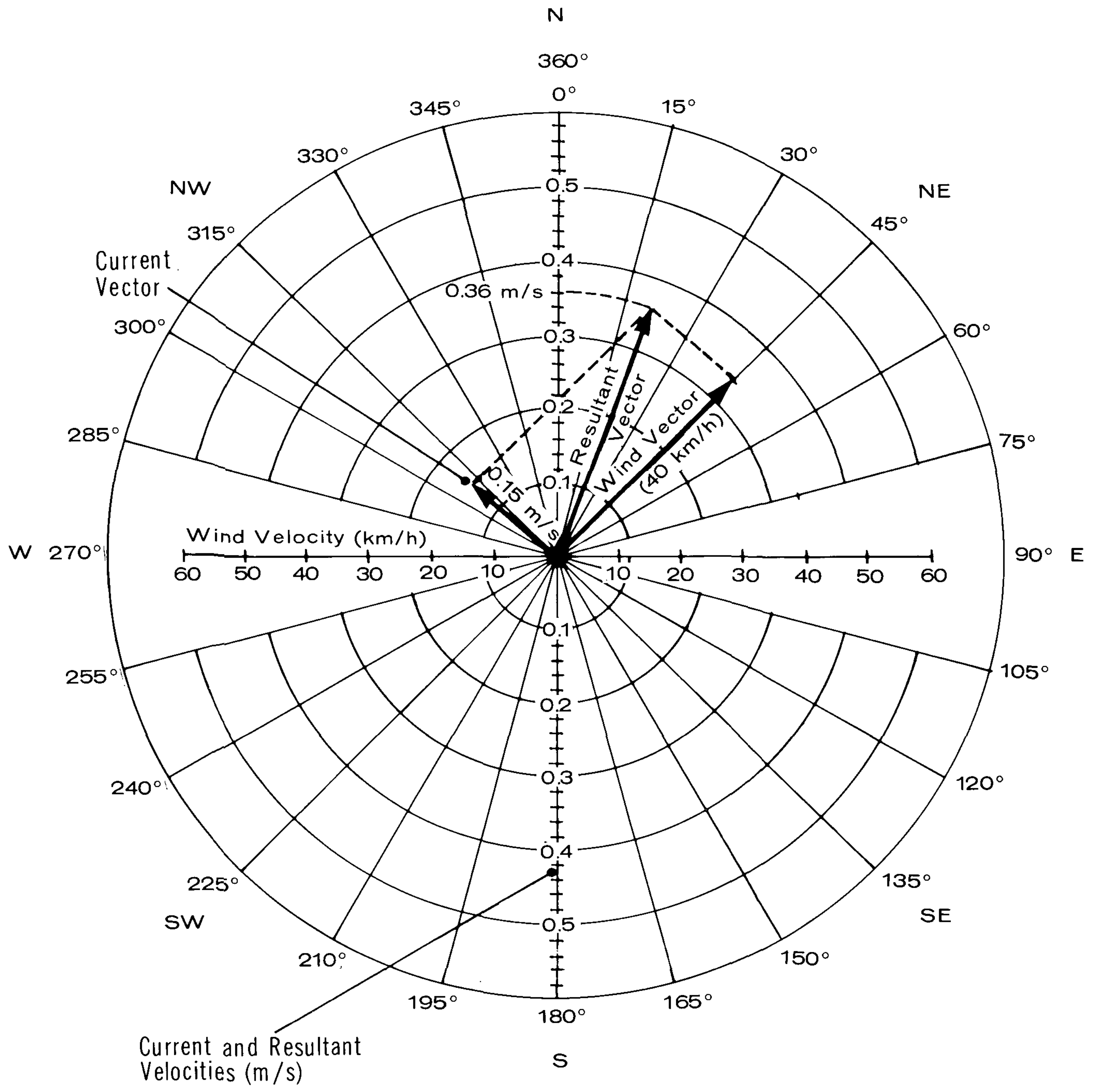


FIGURE 24

TOLUENE

VECTORAL ADDITION OF SURFACE CURRENT AND WIND



Solution to Problem A

- Use Figure 21
- With t = 20 min and for a spill mass of 20 tonnes, the spill radius (r) is estimated at about 60 m (by interpolation)
- Similarly, the maximum spill radius (r_{max}) of about 250 m will occur in approximately 125 min (2 h)

ii) Problem B

The slick in Problem A is confined to a calm channel, approximately 50 m in width. What is the *maximum* length of channel affected by this spill?

Solution to Problem B

- Figure 21 (or Solution to Problem A) gives r_{max} = 250 m for a 20 tonne spill
- Use Figure 22: with r_{max} = 250 m and a stream width of 50 m, the maximum length of channel affected under still conditions is about 4,000 m (4 km)

iii) Problem C

The 20 tonne spill in Problem A is being affected by a wind velocity of 40 km/h from the southwest and a surface current of 0.15 m/s at 90° from the wind direction (i.e., flow is northwest). What is the resultant direction and speed of the slick and the distance the slick has moved when it reaches its maximum size?

Solution to Problem C

Step 1: Define wind vector

- Use Figure 24
- Determine length of wind vector for 40 km/h against horizontal wind velocity scale
- Draw wind vector at appropriate length and in northeasterly direction starting at origin

Step 2: Define surface current vector

- Determine length of surface current vector of 0.15 m/s against vertical axis on Figure 24
- Draw surface current vector at appropriate length and in northwesterly direction, starting from head of wind vector

Step 3: Define resultant vector

- Draw resultant vector from origin to head of current vector
- Direction of translation as given by resultant vector is about 20° east of North
- Define translation velocity by measuring length of the resultant vector against vertical scale. Spill translation velocity is estimated at 0.36 m/s

Step 4: Determine distance travelled when spill reaches maximum radius

- From Figure 21 (or Problem A), r_{max} = 250 m at t = 125 min (7,500 s)
- Distance travelled = 7,500 s x 0.36 m/s = 2,700 m, by time spill reaches maximum radius

5.5 Subsurface Behaviour: Penetration into Soil

5.5.1 Introduction. The general principles of contaminant transport in soil and their application to this work are described in the Introduction Manual. Specific items related to toluene are presented here.

When toluene is spilled onto soil, its transport becomes a multi-phase phenomenon. The phases include the liquids and vapours of toluene and water, toluene adsorbed onto soil, and toluene in the aqueous phase. However, the central concern with immiscible liquids is downward transport of the liquid toluene toward the groundwater table.

Unfortunately, sufficient data do not exist to permit a detailed assessment of contaminant transport in a specific circumstance. A few extensive field investigations have been carried out, especially involving spills of oil, gasoline and PCBs. But, for toluene, very limited information exists to enable predictions to be made under a broad range of spill conditions. Consequently, it is necessary to simplify the soil and groundwater conditions and to express contaminant behaviour through analogy to other more extensively studied materials.

A pattern for the downward movement of immiscible fluids such as toluene in soil has been prepared by using models designed for oils and petroleum products (Blokker 1971; Freeze and Cherry 1979). As these behave similarly in soil, the model is felt to be applicable to toluene. It is assumed that when the spill occurs, the soil contains water only up to its field capacity (the maximum amount of water that the soil holds after excess water is drained) and that this condition prevails down to the groundwater table. The spilled toluene fills the pores at the soil surface and begins to penetrate downward. The infiltration rate is governed by the saturated hydraulic conductivity (K_0) of toluene in the soil as described in the Introduction Manual. Surface ponding occurs when the spilling rate exceeds the infiltration rate. It is assumed that the toluene moves downward through the soil as a saturated slug, leaving behind a constant residual amount (S_o) of toluene within the soil pores.

Downward transport will continue until the volume of toluene spilled per unit area (B_o) equals the amount retained in the soil as S_o. Some lateral spreading may occur due to capillary action. If B_o is greater than the volume that can be retained as S_o above the groundwater table, the excess toluene will spread as a pancake within the saturated groundwater capillary fringe. The resultant contaminated zone containing the residual amount of toluene, S_o, consists of a "vertical" column and a "horizontal" pancake of soil. This is shown schematically in Figure 25.

5.5.2 Equations Describing Toluene Movement into Soil. The equations and assumptions used to describe contaminant movement downward through the unsaturated soil zone toward the groundwater table are described in the Introduction Manual. Transport velocities have been based on Darcy's Law assuming saturated piston flow.

5.5.3 Saturated Hydraulic Conductivity of Toluene in Soil. The saturated hydraulic conductivity (K_o) in m/s is given by:

$$K_o = \frac{(\rho g)k}{\mu}$$

where: k = intrinsic permeability of the soil (m^2)

ρ = mass density of the fluid (kg/m^3)

μ = absolute viscosity of the fluid (Pa•s)

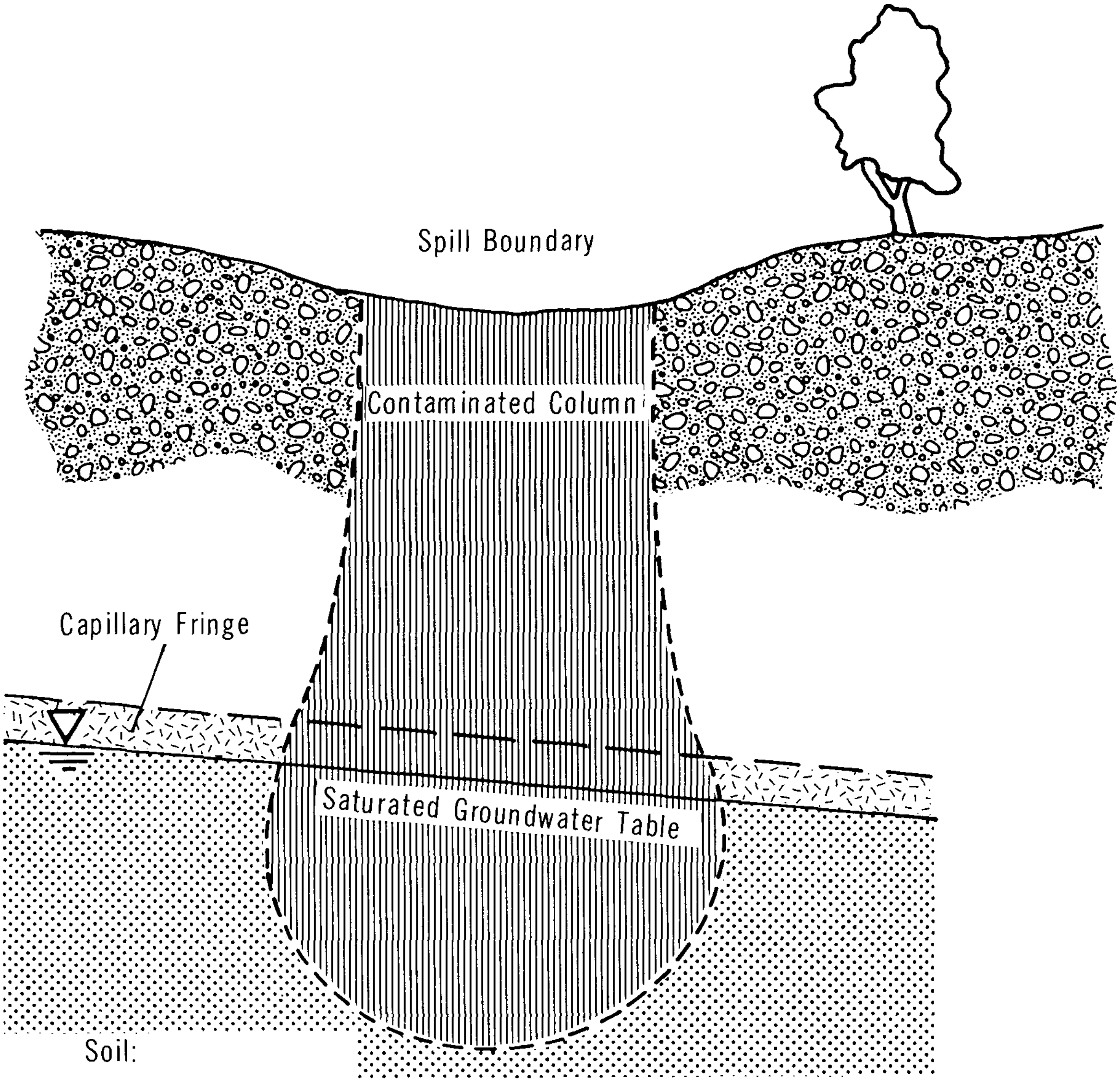
g = acceleration due to gravity = 9.81 m/s^2

	Toluene	
Property	20°C	4°C
Mass density (ρ), kg/m^3	866	881
Absolute viscosity (μ), Pa•s	0.59×10^{-3}	0.75×10^{-3}
Saturated hydraulic conductivity (K_o), m/s	$(1.44 \times 10^7)k$	$(1.15 \times 10^7)k$

5.5.4 Soils. The Introduction Manual describes the three soils selected for this work. Their relevant properties are:

FIGURE 25

SCHEMATIC SOIL TRANSPORT



Soil:

- Coarse Sand
- Porosity (n) = 0.35
- Intrinsic Permeability (k) = $10^{-9} m^2$
- Field Capacity (θ_{fc}) = 0.075

Property	Soil Type Coarse Sand	 Silty Sand	 Clay Till
Porosity (n), m^3/m^3	0.35	0.45	0.55
Intrinsic permeability (k), m^2	10^{-9}	10^{-12}	10^{-15}
Field capacity (θ_{fc}), m^3/m^3	0.075	0.3	0.45
Residual fraction (S_o), m^3/m^3	0.05	0.1	0.2

5.5.5 Penetration Nomograms. Nomograms for the penetration of toluene into the unsaturated zone above the groundwater table were prepared for each soil. They show the total depth of toluene penetration (B) versus penetration time (t_p) for various volumes spilled per unit area of soil (B_o). Temperatures of 4°C and 20°C were used. Calculations were based on the equations developed in the Introduction Manual.

A flowchart for use of the nomograms is shown in Figure 26. The nomograms are presented in Figures 27, 28 and 29.

5.5.6 Sample Calculation. A 20 tonne spill of toluene has occurred on coarse sandy soil. The temperature is 20°C; the spill radius is approximately 8.6 m. Calculate the depth and time of penetration.

Solution

Step 1: Define parameters

- Mass spilled = 20,000 kg (20 tonnes)
- T = 20°C
- Mass density $\rho = 866\ kg/m^3$
- $r = 8.6\ m$

Step 2: Calculate volume and area of spill

- $V = \frac{M}{\rho} = \frac{2 \times 10^4\ kg}{866\ kg/m^3} = 23.1\ m^3$
- $A = \pi r^2 = 232\ m^2$

FLOWCHART FOR NOMOGRAM USE

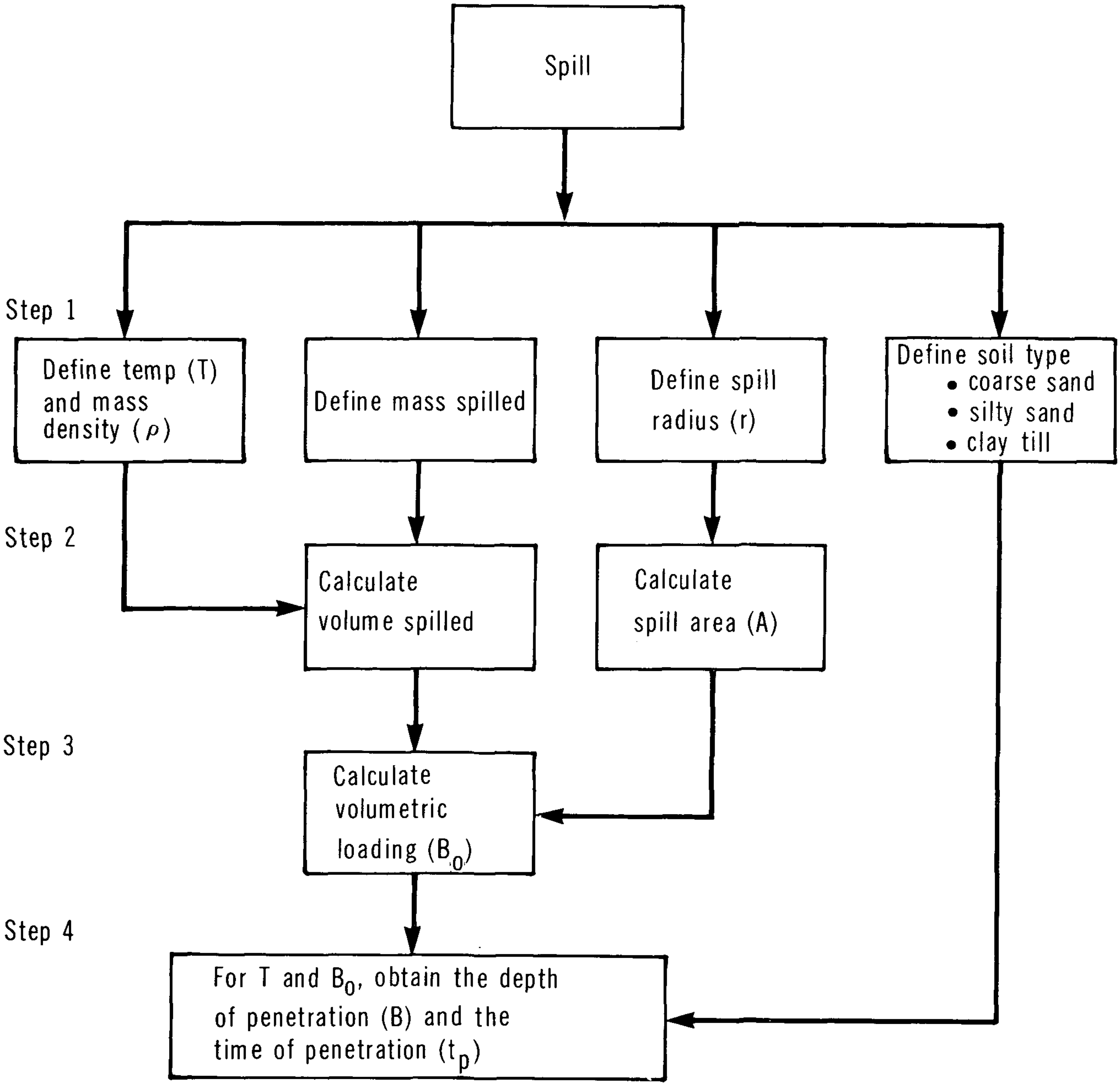
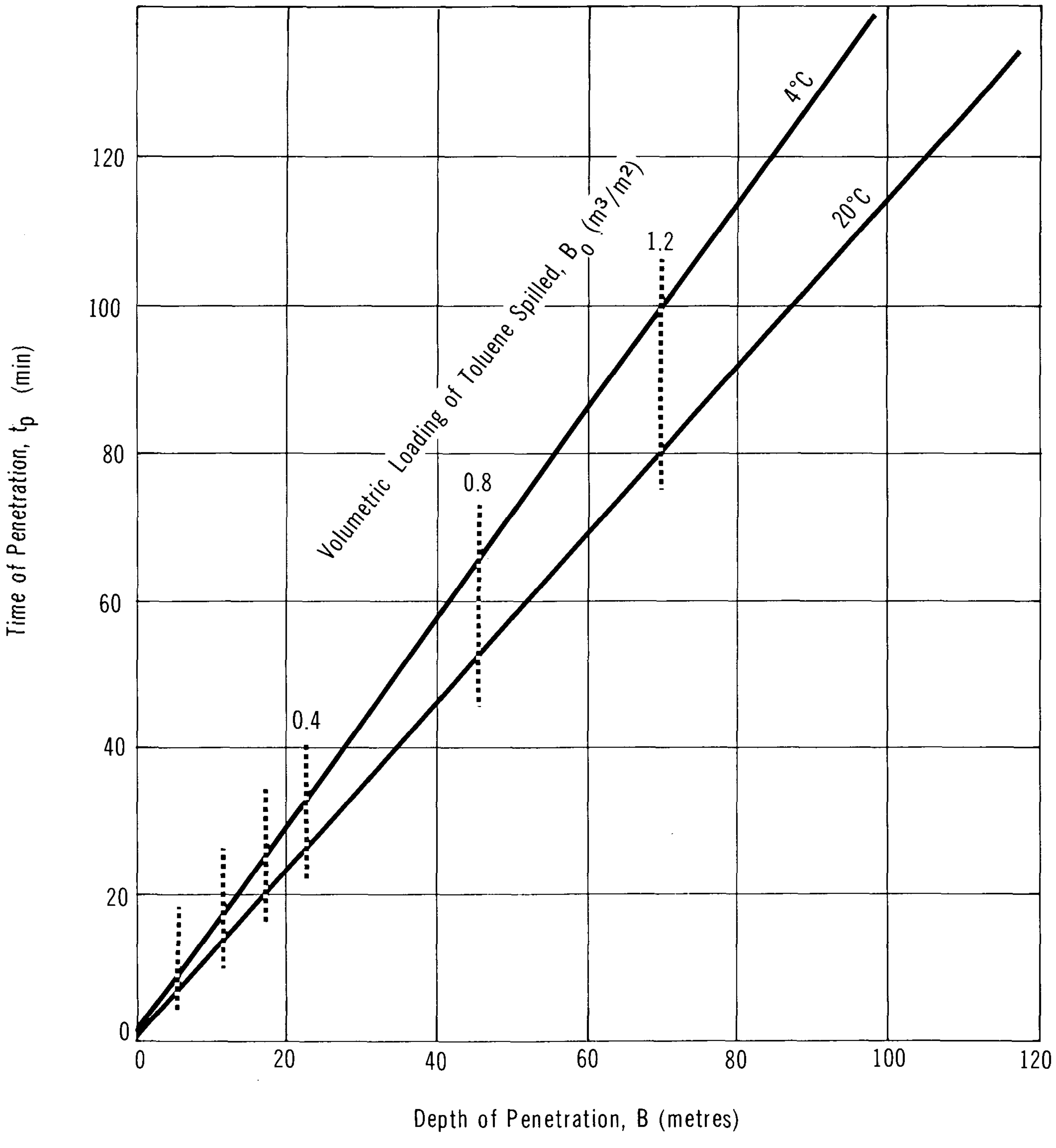


FIGURE 27

TOLUENE

PENETRATION IN COARSE SAND



TOLUENE

PENETRATION IN SILTY SAND

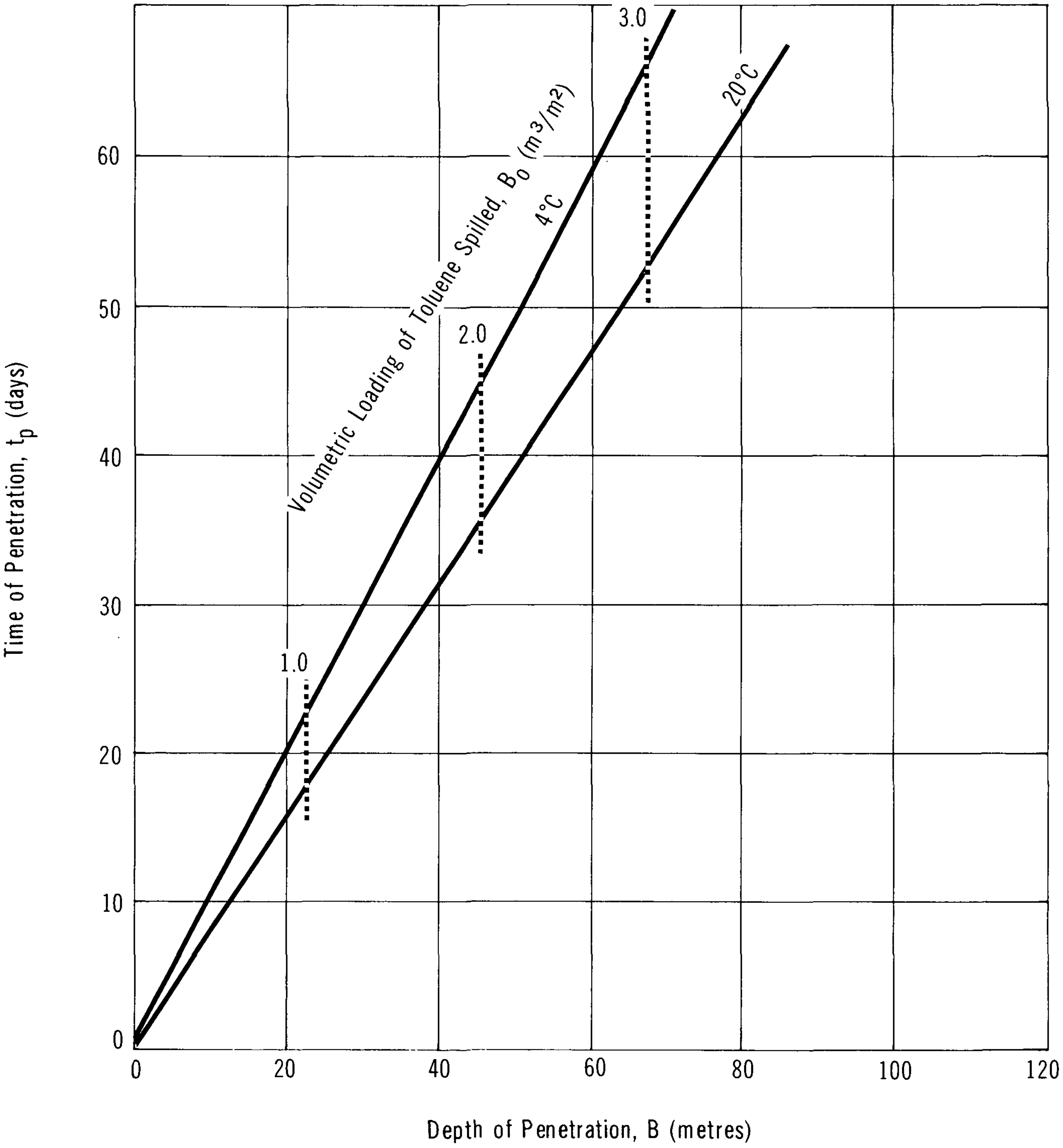
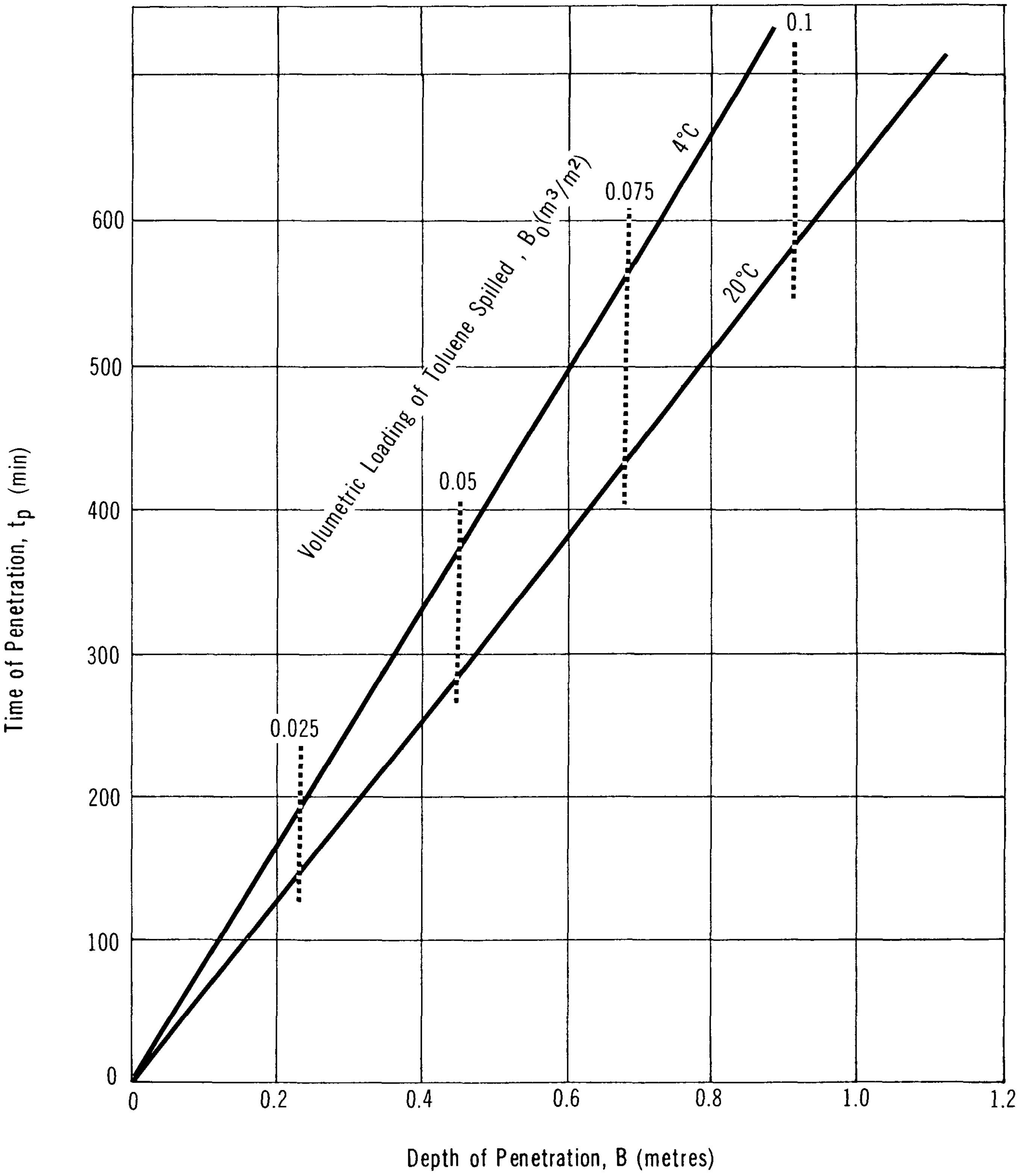


FIGURE 29

TOLUENE

PENETRATION IN CLAY TILL



Step 3: Calculate volumetric loading B_o

- $B_o = \frac{V}{A} = \frac{23.1}{232} = 0.1\ m^3/m^2$

Step 4: Estimate depth of penetration (B) and time of penetration (t_p) using Figure 27

- For coarse sand, $B_o = 0.1\ m^3/m^2$
- $B = 6$ m, $t_p = 7$ min

6 ENVIRONMENTAL DATA

6.1 Suggested or Regulated Limits

6.1.1 Water. There are no federal or provincial guidelines for toluene concentrations in water (PTP 1980). Less than 0.25 mg/kg of toluene is sufficient to taint the flavour of fish flesh (EPA 440/9-75-009).

6.1.2 Air. In Ontario, the environmental limit for toluene emissions (half-hour average) is 2,000 $\mu g/m^3$ (Ontario E.P. Act 1971). There are no specific standards in the U.S. for general atmospheric pollution by toluene (PTP 1980).

6.2 Aquatic Toxicity

6.2.1 Canada. Toxicity range for short-term exposure for fish is 10 to 65 mg/L; for lower water organisms, the limit is 60 mg/L (MHSSW 1976). A concentration of 0.25 mg toluene in a litre of water can cause tainting of fish and other aquatic organisms (WQC 1972). The 96-h LC_{50} (concentration for 50 percent mortality) for fish is less than 10 mg/L (Water Management Goals 1978).

6.2.2 Other Countries. The maximum allowable concentration (MAC) of toluene in surface waters of Classes I to III is 0.1 mg/L in Romania (1974) (Verschueren 1977).

6.2.2.1 United States. Toluene has been assigned a TLm 96 (4-day median lethal toxicity rating) of 10 to 100 mg/L (RTECS 1979). The criterion to protect freshwater aquatic life is 2.3 mg/L as a 24-hour average and the concentration should not exceed 5.2 mg/L at any time (PTP 1980). The criterion to protect saltwater aquatic life is 0.1 mg/L at a 24-hour average, and the concentration should not exceed 2.3 mg/L at any time (PTP 1980).

6.2.3 Measured Toxicities.

6.2.3.1 Freshwater toxicity.

Conc. (mg/L)	Time (hours)	Species	Result	Water Conditions	Reference
Fish Kill Data					
10	not stated	Rainbow trout	lethal dose		MHSSW 1976

Conc. (mg/L)	Time (hours)	Species	Result	Water Conditions	Reference
Fish Toxicity Tests					
9.36 µL/L	96	Coho salmon fry	LC_{50}; slow growth rate		Spehar 1981
240	96	Channel catfish	LC_{50}	22°C	Johnson 1980
170	96	Bluegill	LC_{50}; metabolize toluene	17°C	Johnson 1980; Berry 1980
70	not stated	Dace	LC_{50}		Juhnke 1978
58	24	Goldfish	LD_{50}		Verschueren 1977
56 to 34	24 to 96	Fathead minnow	TLm		Verschueren 1977
10	not stated	Rainbow trout	lethal dose		MHSSW 1976
1,340 to 1,280	24 to 96	Mosquito fish	TLm	turbid, farm pond	WQCDB-3 1971
61 to 65	1	Sunfish	TLm, lethal	tar and gas waste	WQCDB-1 1970
24	96	Bluegill	TLm	temp. constant; soft	Pickering 1966
63 to 59	24 to 96	Guppies	TLm	soft	Pickering 1966

Conc. (mg/L)	Time (hours)	Species	Result	Reference
Microorganisms				
313	48	*Daphnia magna*	LC_{50}	NRC 1981
105	not stated	Algae (*Microcystis aeruginosa*)	inhibition of cell multiplication	Verschueren 1977
120	not stated	Algae (*Scenedesmus*)	danger thresholds	MHSSW 1976

Conc. (mg/L)	Time (hours)	Species	Result	Water Conditions	Reference
Invertebrates					
24.2 to 72.4	24	Copepod	LC_{50}		NRC 1981
not stated	48	Crayfish	lack of ability to metabolize toluene		Berry 1980
33	24	Brine shrimp	TLm	static bioassay	Haque 1974

6.2.3.2 Saltwater toxicity.

Conc. (mg/L)	Time (hours)	Species	Result	Water Conditions	Reference
7.3	96	Striped bass	LC_{50}		NRC 1981
277 to 485	96	Sheepshead minnow	LC_{50}		NRC 1981
0.1	24	Pacific herring	absorbed rapidly; tissues contained conc. 340 times greater than measured		NRC 1981
50 (in crude oil suspension)	10 days	Eels	accumulated in flesh; conc. ratios of 13.2		NRC 1981
54	96	Japanese medaka (eggs)	TL_{50}; 41 mg/L produced teratogenic effects	static bioassays	Stoss 1979
10	24 to 96	Young coho salmon	no significant mortality	artificial seawater, 8°C	Verschueren 1977
50	24	Young coho salmon	90% mortality	artificial seawater, 8°C	Verschueren 1977

Conc. (mg/L)	Time (hours)	Species	Result	Water Conditions	Reference
Invertebrates					
12.5	69	Marine isopod	ET_{50}; narcoticization is reversible		Bakke 1979
1.0	not stated	Mussel	no lethal effect		APOP 1975
23	not stated	Brine shrimp	TLm		EPA 440/9-75-009

Conc. (mg/L)	Species	Result	Reference
Plants			
>100	Phytoplankton	toxic; growth inhibited	NRC 1981
10	Giant kelp	reduced photosynthetis	WQC 1963
Microorganisms			
1,000	Pseudomonads (marine bacteria)	sublethal; negative chemotactic response	NRC 1981
6,000	Pseudomonads (marine bacteria)	all chemotactic response inhibited	NRC 1981

6.2.4 Aquatic Studies. Toluene can be toxic to fish and fish food organisms (EPA 440/9-75-009). Concentrations of toluene which cause acute poisoning in fish are dependent on temperature and fish species. The range is between 10 and 90 mg/L (MHSSW 1976). Freshwater algae are more resistant to toluene than are fish (PTP 1980). Marine studies indicate that toluene is toxic to marine bacteria, phytoplankton and marine fish (PTP 1980).

6.3 Toxicity to Other Biota

6.3.1 Livestock.

Conc.	Time	Species	Result	Reference
>0.0078 g/egg	2, 3 & 6 days	Chick embryos	LD_{50}; death after 14-day incubation	Elovaara 1979

Conc.	Time	Species	Result	Reference
5,000 mg/kg (b.w.)	not stated	Mammals	ave. LD_{50} (oral)	MHSSW 1976

The reported maximum concentration of toluene found in freshwater that produces no effect in mammals when administered on a chronic basis is 0.5 to 1.0 mg/L (WQCDB-3 1971).

6.3.2 **Avian.** A toluene slick on water is harmful to waterfowl as it destroys the insulation offered by the feathers by removing the waxes and other substances which waterproof and trap air in feathers (OHM-TADS 1981).

6.3.3 Insects and Vertebrates.

Conc. (mg/L)	Species	Result	Reference
10 to 15	Houseflies	lethal	NRC 1981
22	Mosquito larvae (4th. instar)	LD_{50}	NRC 1981
96	Grain weevils	LD_{50}	NRC 1981
in pure toluene (30 min)	Grasshopper egg	prevent or terminate diapause	NRC 1981
920 mg/kg	Frogs	LC_{LO} (subcutaneous)	RTECS 1979

6.3.4 Plants.

Conc. (mg/m^3)	Species	Result	Reference
45.5	Barley plants	injury to plant	NRC 1981
not stated	Avocado fruit	vapour absorbed and metabolized	NRC 1981
not stated	Corn and bean seedlings; tea and grape plants	vapour absorbed and metabolized in roots, leaves and stems	NRC 1981

All cotton varieties tested were sensitive to toluene during germination, but differed with regard to their degree of sensitivity. Growth inhibition of seedlings increased with increasing toluene rate (2.5 to 10 kg/ha) (Kamilova 1979). Tomato plants have been found to be particularly sensitive to toluene vapours. Most observed plant injuries in response to toluene are acute rather than chronic. It enters the plant readily, through the stomata and cuticle, and quickly kills the tissues with which it comes into contact. Toluene is neither accumulated nor translocated in the plant (NRC 1981).

6.4 Degradation

6.4.1 Biological Degradation. Toluene is degraded by various bacteria (Brown 1978). Low levels of toluene (20 mg/L) appear to increase the growth rate of bacteria in sewage sludge deposits (measured by rate of methane evolution); a toxic effect is observed at higher concentrations (200 mg/L) (NRC 1981).

Conc. (mg/L)	Species	Result	Reference
200	Bacteria (*E. coli*)	lethal dose; inhibition of degradation	Verschueren 1977
30	Bacteria (*P. fluorescens*)	inhibition of degradation of glucose	Verschueren 1977

6.4.2 B.O.D.

B.O.D. (kg/kg)	% Theo.	Days	Seed	Reference
1.23		5	dilute sewage; acclimated	Jones 1971
1.47		35	not specified	Verschueren 1977
>1	53	5	sewage	Price 1974
>1	86	20	acclimated sewage	Price 1974
<1	3	15	sewage; saltwater	Price 1974

The half-life of a saturated solution is expected to be less than 30.6 minutes as a result of evaporation (MacKay and Walkoff 1973).

6.4.3 C.O.D. The Chemical Oxygen Demand (C.O.D.) for toluene has been found to be 1.88 kg/kg (Jones 1971). Theoretical Oxygen Demand (Th.O.D.) is 3.13 kg/kg (Verschueren 1977). Toluene's ability to inhibit sewage cultures and its low solubility result in very little development of oxygen deficiency in a spill situation (EPA 440/9-75-009).

6.5 Long-term Fate and Effects

Toluene has been shown to be readily transferred from water surfaces to the atmosphere under ideal conditions. In the atmosphere, it is subject to photochemical degradation to various organics. Toluene is also known to re-enter the hydrosphere in rain (PTP 1980). Toluene can reside in the atmosphere for hours or days (NRC 1981).

The biological effects of toluene are likely to be short-lived in living organisms in the environment. Because toluene is not stored in animal tissues and is rapidly metabolized and excreted, chronic toxic effects are unlikely to occur (NRC 1981).

6.6 Soil

6.6.1 Soil Degradation of Material. Toluene in low concentrations may be degraded by soil microbes within a short period of time depending on soil types and other environmental factors. In high concentrations, it is toxic to microorganisms and thus is not degraded significantly (NRC 1981).

6.7 Other Effects

6.7.1 Possible Effects on Water Treatment Processes. Sewage sludge digestion is inhibited by a concentration greater than 0.05 percent (EPA 440/9-75-009).

7 HUMAN HEALTH

There is a considerable amount of information in the literature concerning the toxicological effects of toluene to test animals and humans. Current occupational standards for toluene are based chiefly on subjective and objective signs of mucous membrane irritation and deficits in central nervous system function upon acute inhalation exposure. There is a limited amount of literature available to date on the effects of toluene exposure on reproduction, mutagenicity and carcinogenicity.

Numerous research reports on the toxicology of toluene have been recently reported in TOX TIPS (a summary of current research activity), including several long-term mortality studies of occupational exposures, a neurotoxicity study and a carcinogenesis bioassay at the U.S. National Cancer Institute. Toluene has been reported in the EPA TSCA Inventory. The data summarized here are representative of information in the literature.

The toxicological data summarized here have been extracted from reliable standard reference sources and are representative of information in the literature. It should be noted that some of the data are for chronic (long-term), low-level exposures and may not be directly applicable to spill situations.

7.1 Recommended Exposure Limits

The exposure standards for toluene are based upon a potential contribution to overall exposure via skin absorption and its central nervous system effects. Canadian provincial standards are generally similar to those of the USA-ACGIH unless indicated otherwise.

Guideline (Time)	Origin	Recomended Level	Reference
Time-weighted Averages (TWA)			
TLV® (8 h)	USA-ACGIH	100 ppm (375 mg/m^3)	TLV 1983
PEL (8 h)	USA-NIOSH	100 ppm (375 mg/m^3)	NIOSH/OSHA 1981
TWA (8 h)	USA-OSHA	200 ppm (750 mg/m^3)	NIOSH/OSHA 1981
Action Level**	USA-NIOSH/OSHA	50 ppm (163 mg/m^3)	GE 1979
	Sweden	375 mg/m^3	Verschueren 1977

Guideline (Time)	Origin	Recomended Level	Reference
	Poland	30 ppm (100 mg/m^3)	ILO 1980
	USSR	15 ppm (50 mg/m^3)	ILO 1980
	East Germany	60 ppm (200 mg/m^3)	ILO 1980
	Finland	200 ppm (750 mg/m^3)	ILO 1980
Short-term Exposure Limits (STEL)			
STEL (15 min)	USA-ACGIH	150 ppm (560 mg/m^3)	TLV 1983
Ceiling (10 min)	USA-NIOSH	200 ppm (750 mg/m^3)	NIOSH/OSHA 1981
Ceiling, Maximum (10 min)	USA-OSHA	500 ppm (1,875 mg/m^3)	NIOSH/OSHA 1981
STIL* (30 min)		600 ppm	CHRIS 1978
Ceiling, Acceptable (15 min)	USA-OSHA	300 ppm (1,125 mg/m^3)	NIOSH/OSHA 1981
Other Human Toxicities			
IDLH	USA-NIOSH	2,000 ppm (7,500 mg/m^3)	NIOSH Guide 1978
TC_{LO}		500 ppm	AAR 1981
TC_{LO}		200 ppm	RTECS 1979
TC_{LO}		100 ppm	RTECS 1979

* STIL - Short-term Inhalation Limit
** Recommended only

Inhalation Toxicity Index

The Inhalation Toxicity Index (ITI) is a measure of the potential of a substance to cause injury by inhalation. It is calculated as follows:

ITI = 1,315.12 (Vapour pressure in mm Hg)/(TLV® in ppm)

ITI = 1,315.12 x 27.8 mm Hg (25°C)/100 ppm = 365.6

At 25°C, ITI = 3.65×10^2

7.2 Irritation Data

7.2.1 Skin Contact.

Exposure Level (and Duration)	Effects	Reference
SPECIES: Human		
200 to 100 ppm	Itching skin	GE 1979
SPECIES: Rabbit		
14 g/kg	LD_{50}	RTECS 1979
435 mg (72 h patch test)	Erythema, slight edema	RTECS 1979

7.2.2 Eye Contact.

Exposure Level (and Duration)	Effects	Reference
SPECIES: Human		
300 ppm	Irritation	RTECS 1979
200 ppm	Irritation	GE 1979
SPECIES: Rabbit		
2 mg (24 h)	Severe irritation	RTECS 1979
870 µg (72 h)	Mild irritation	RTECS 1979

7.3 Threshold Perception Properties

7.3.1 Odour.

Odour Characteristics: Pungent, aromatic; benzene-like; like model glue (AAR 1981).

Odour Index: 16,609 (AAR 1981)

Parameter	Media	Concentration	Reference
Absolute Odour Threshold	-	0.17 ppm	AAR 1981
Odour Threshold	-	10 to 15 ppm	NIOSH/OSHA 1981
50% Recognition	-	1.74 ppm	Verschueren 1977
100% Recognition		1.75 ppm	Verschueren 1977

Parameter	Media	Concentration	Reference
Odour Threshold	In air	4.68 ppm	ASTM 1980
Odour Threshold	In air	2.14 ppm	ASTM 1980
Odour Threshold	In air	4.78 ppm	ASTM 1980
Threshold Odour Concentration	In air	0.17 to 40 ppm	ASTM 1980

7.3.2 Taste.

Parameter	Media	Concentration	Reference
Lower Taste Threshold	-	<0.25 ppm	AAR 1981

7.4 Long-term Studies

7.4.1 Inhalation.

Exposure Level (and Duration)	Effects	Reference
SPECIES: Human		
30,000 ppm to 10,000 ppm (time not specified)	Dizziness, collapse, loss of consciousness. Rapid recovery, no residual after-effects	Wilson 1943. IN NRC 1981
2,050 ppm (estimated)	Four adolescents found dead in automobile. Death appears to have been due to fatal anesthetic effect	NRC 1981
1,000 ppm	Severe toxic effects	AAR 1981
800 ppm	Metallic taste, headache, lassitude, slight nausea	Carpenter et al. IN NIOSH 1977
600 ppm	Lassitude, hilarity, slight nausea	Carpenter et al. IN NIOSH 1977
400 ppm	Mild eye irritation, lacrimation, hilarity	Carpenter et al. IN NIOSH 1977
200 ppm	TC_{LO}, central nervous system effects	GE 1979
200 ppm (3 to 7 h)	Increased reaction time, decreased systolic blood pressure and heart rate	Ogata et al. 1970. IN NRC 1981
100 ppm	Psychological effects, transient irritation	Patty 1981

Exposure Level (and Duration)	Effects	Reference
SPECIES: Monkey		
100 ppm	TC_{LO}. Psychotropic effects	ITII 1981
SPECIES: Dog		
760 ppm (6 h)	No signs of discomfort	Patty 1981
SPECIES: Cat		
7,800 ppm (6 h)	CNS effect, mydriasis, mild tremors. Prostration in 80 minutes. Light anesthesia in 2 hours	Patty 1981
SPECIES: Rat		
70,000 to 45,000 ppm (16.1 min)	Excitation, tremors, running movements	Patty 1981
70,000 to 45,000 ppm (14.8 min)	Loss of blinking reflex	Patty 1981
70,000 to 45,000 ppm (9.5 min)	Pupillary contraction	Patty 1981
70,000 to 45,000 ppm (2.9 min)	Light anesthesia, relaxed	Patty 1981
25,000 to 15,000 ppm (80 to 130 min)	Lethal to 7 of 10 rats with O_2 supplied	Patty 1981
20,000 ppm (30 to 50 min)	Lethal	NRC 1981
25,000 to 15,000 ppm (15 to 35 min)	Lethal to 4 of 5 rats	Patty 1981
8,000 ppm (4 h)	LC_{50}	Patty 1981
4,000 ppm (4 h)	LC_{LO}	ITII 1981
4,000 ppm (4 h)	Narcosis or depression, inability to walk, myoclonic seizures	Takeuchi 1977. IN NRC 1981
2,000 ppm (4 h)	Occasional myoclonic seizures	Takeuchi 1977. IN NRC 1981
1,700 ppm (4 h)	Dose was tolerated	Patty 1981
SPECIES: Mouse		
9,300 to 8,000 ppm	Lethal to all test animals	Patty 1981

Exposure Level (and Duration)	Effects	Reference
8,520 ppm	Lethal to 87.5% of test animals	Patty 1981
5,320 ppm (8 h)	LC_{50}	RTECS 1979
5,300 ppm (8 h)	Minimum lethal concentration	Svirbely et al. IN NIOSH 1977
5,300 ppm	LC_{50}	NRC 1981
3,200 to 2,650 ppm	Loss of reflexes	Patty 1981
Concentration not specified	Pulmonary irritation, renal irritation, evidence of cellular damage to the spleen	Svirbely et al. IN NIOSH 1977
Concentration not specified	Cardiotoxicity	Taylor and Harris 1970. IN NIOSH 1977
Chronic Exposures		
SPECIES: Human		
1,500 to 500 ppm (6 h to 8 h/d for 1 to 3 wk)	Headache, nausea, dizziness, anorexia, palpitation and extreme weakness. Definite impairment of reaction time and pronounced loss of coordination	Wilson 1943. IN NIOSH 1977
1,100 to 100 ppm (2 wk to 5 yr)	Hepatomegaly, mild intoxication, enlarged livers, macrocytosis, mild depression of erythrocyte level, absolute lymphocytosis	Greenberg et al. 1942. IN NRC 1981
1,100 to 100 ppm (2 wk to 5 yr)	Elevation of hemoglobin level and mean corpuscular hemoglobin concentration	Greenberg et al. 1942. IN NIOSH 1977
800 ppm (8 h/d, 2 d/wk for 3 mo)	Severe fatigue, nausea, mental confusion, staggering gait, lack of self control. Insomnia lasting several days after exposure	Von Oettingen et al. 1942. IN NRC 1981
600 ppm (8 h/d, 2 d/wk for 3 mo)	Extreme fatigue, mental confusion, exhilaration, nausea, severe headache, and dizziness after 3 h exposure. After-effects included nervousness and some confusion	Von Oettingen et al. 1942. IN NIOSH 1977
400 ppm (8 h/d, 2 d/wk, for 3 mo)	Fatigue, mental confusion, headache, skin paresthesia, weakness,	Von Oettingen et al. 1942. IN NIOSH 1977

Exposure Level (and Duration)	Effects	Reference
	dilated pupils. After-effects: fatigue, headache, skin paresthesia, insomnia	
300 ppm (8 h/d, 2 d/wk for 3 mo)	Severe fatigue, headache, muscular weakness, incoordination, slight pallor. After-effects: fatigue, headache, skin paresthesia, insomnia	Von Oettingen et al. 1942. IN NIOSH 1977
300 to 200 ppm (>10 yr)	No signs of health impairment including toxic effects on the liver, deviations in neurological examinations, and physical disturbances	Toxline (on-line) 1981
200 ppm (8 h/d, 2 d/wk for 3 mo)	Paresthesia of the skin, confusion, muscular weakness, impaired coordination, headache, nausea and dilation of pupils	Von Oettingen et al. 1942. IN NRC 1981
200 ppm (15 yr)	No significant increase in the number of chromosome aberrations	Forni et al. 1971. IN NRC 1981
125 ppm (several yr)	No changes in liver function	Capellini 1971. IN NRC 1981
100 ppm (8 h/d, 2 d/wk, for 3 mo)	No definite effects	Von Oettingen et al. 1942. IN NRC 1981
1.5 mg/m^3 (chronic exposure)	No clinical symptoms of intoxication. Structural and functional disturbances in erythrocyte membranes including changes in the phospholipid component of membranes, decreased binding strength of membrane components, macrocytosis, increased osmotic resistance, and shortening of erythrocyte life	Toxline (on-line) 1981
SPECIES: Dog		
2,000 ppm (8 h/d) 6 d/wk for 4 mo) Followed by 2,660 ppm (8 h/d, 6 d/wk for 2 mo)	During the last 2 months of exposure: CNS intoxication, incoordination and paralysis of the hind legs. No hematological abnormalities were found	Fabre et al. 1955. IN NIOSH 1977

Exposure Level (and Duration)	Effects	Reference
SPECIES: Guinea Pig		
1,250 ppm (4 h/d for 18 d)	Narcosis	Smyth 1928. IN NRC 1981
1,000 ppm (4 h/d for more than 18 d)	No apparent harmful effects	Smyth 1928. IN NRC 1981
SPECIES: Rat		
2,000 ppm (8 h/d for 32 wk)	No significant changes were found in body weight, leukocyte count, erythrocyte count, eosinophil count, or hemoglobin levels	Takeuchi 1969. IN NIOSH 1977
1,000 ppm (6 h/d, 5 d/wk for 13 wk)	No deleterious effects	Rhudy 1978. IN NRC 1981
610 mg/m^3 (4 h/d for 4 mo)	Chromosome aberrations persisting for at least 1 month after termination of exposure. Leukosis	Dobrokhotov 1977. IN NRC 1981
SPECIES: Mouse		
1,000, 100, 10 and 1 ppm (6 h/d for 20 d)	Depression of spontaneous locomotor activity	Horiguch et al. 1977. IN NRC 1981
500 mg/m^3 (24 h/d for 7 d, day 6 to day 13 of pregnancy)	Increased skeletal abnormalities. "Teratogenicity not proven"	Hudak and Unguary 1978. IN NRC 1981

7.4.2 Ingestion.

Exposure Level (and Duration)	Effects	Reference
Acute Exposures		
SPECIES: Human	No data	

Exposure Level (and Duration)	Effects	Reference
SPECIES: Rat		
7,000 mg/kg	LD_{50}	Patty 1981
5,000 mg/kg	LD_{50}	GE 1979
3,000 mg/kg	LD_{50}	ITII 1981
2,500 mg/kg	LD (30% of test animals)	Patty 1981
6.4 mL/kg	LD_{50} (young adult)	Patty 1981
3.0 mL/kg	LD_{50} (14-day-old animals)	Patty 1981
7 g/kg	LD_{50} (young adults)	Wolfe et al. 1956. IN NRC 1981
6.4 mL/kg	LD_{50} (young adults)	Kimura et al. 1971. IN NRC 1981
3 mL/kg	LD_{50}	Kimura et al. 1971. IN NRC 1981
1 mL/kg	LD_{50}	Kimura et al. 1971. IN NRC 1981
Chronic exposures		
SPECIES: Rat		
590 mg/kg (5 x/wk for 6 mo)	No adverse effects on cell counts of bone marrow or circulating blood	Wolfe et al. 1956. IN NRC 1981
354 mg/kg (5 x/wk for 6 mo)	No adverse effects on cell counts of bone marrow or circulating blood	Wolfe et al. 1956. IN NRC 1981
118 mg/kg (5 x/wk for 6 mo)	No adverse effects on cell counts of bone marrow or circulating blood	Wolfe et al. 1956. IN NRC 1981
SPECIES: Rabbit		
700 mg/kg/d for 6 wk	Lack of myelotoxicity	Speck and Moeschlin 1968. IN NIOSH 1977
300 mg/kg/d for up to 9 wk	Lack of myelotoxicity	Speck and Moeschlin 1968. IN NIOSH 1977

Exposure Level (and Duration)	Effects	Reference
SPECIES: Mouse		
1.0 to 0.8 g/kg (12 d)	Increased frequency of chromosome damage in bone marrow cells	Lyapkalo 1973. IN NRC 1981
1 mg/kg	Effects on blood, thymus, spleen and bone marrow	Gerarde 1956. IN NIOSH 1977

7.4.3 Carcinogenicity.

Exposure Level (and Duration)	Effects	Reference
SPECIES: Rat		
Up to 300 ppm for as long as 18 mo	Has not been demonstrated to be carcinogenic	PTP 1981

7.4.4 Teratogenicity and Mutagenicity.

Exposure Level (and Duration)	Effects	Reference
SPECIES: Human		
200 ppm (15 yr)	No significant increase in the number of chromosome aberrations	Forni et al. 1971. IN NRC 1981
SPECIES: Rat		
610 mg/m^3 (4 h/d for 4 mo)	Chromosome aberration persisting for at least 1 month after termination of exposure. Leukosis	Dobrokhotov 1977. IN NRC 1981
1.0 to 0.8 g/kg 12 d (subcutaneous)	Increased frequency (13.7%) of chromosome damage in the bone marrow cells of rats, compared with 4.2% in a control group	Lyapkalo 1973. IN NRC 1981
SPECIES: Mouse		
500 mg/m^3 (24 h/d for 7 d, day 6 to day 13 of pregnancy)	Increased skeletal abnormalities, teratogenicity not proven. Retardation of fetal development	Hudak and Unguary 1978. IN NRC 1981

Exposure Level (and Duration)	Effects	Reference
SPECIES: Bacteria, yeast and mouse lymphoma	All microbial tests were negative; however, bacterial tests were somewhat varied because of the extreme toxicity of toluene to these organisms	Litton Bionetics, Inc., 1978. IN NRC 1981

7.5 Symptoms of Exposure

General symptoms of exposure found in most information sources have not been specifically referenced. Only those of a more specific or unusual nature have their sources indicated.

7.5.1 Inhalation.

1. Lassitude, hilarity (NIOSH 1977).
2. Headache.
3. Impairment of coordination and reaction time (Sax 1979).
4. Irritation of eyes and upper respiratory tract.
5. Dizziness, collapse, loss of consciousness (Wilson 1943. IN NRC 1981).
6. Nausea, vomiting, difficulty breathing (CHRIS 1978).
7. Anesthesia, respiratory arrest (CHRIS 1978).
8. Decreased systolic blood pressure and heart rate (Oguta 1970. IN NRC 1981).
9. Psychological effects (Patty 1981).
10. High concentrations cause pulmonary edema (AAR 1981).
11. Death.

7.5.2 Ingestion.

1. Nausea.
2. Depressed respiration (AAR 1981).
3. Vomiting.
4. Griping and diarrhea (AAR 1981).
5. Loss of consciousness (CHRIS 1978).

7.5.3 Skin Contact.

1. Irritation.
2. Defatting of skin (GE 1979).

3. Dermatitis, fissuring (NIOSH/OSHA 1981).

7.5.4 Eye Contact.

1. Conjunctival irritation.
2. Transient corneal damage (NIOSH/OSHA 1981).

7.6 Human Toxicity to Decay or Combustion Products

Incomplete combustion can yield carbon monoxide (AAR 1981).

7.6.1 Carbon Monoxide. Carbon monoxide is a colourless, practically odourless gas which is a chemical asphyxiant. It causes hypoxia by complexing with hemoglobin and reducing the oxygen-carrying capacity of the blood. Excessive exposures will result in death from asphyxia. More moderate exposures may cause headaches and affect mental functions. The effects of moderate exposures are reversible although considerable time is required to reverse the carbon monoxide-hemoglobin complexing reaction. The TLV® for carbon monoxide is 50 ppm (8-h TWA) and 400 ppm (STEL) (TLV 1983).

8 CHEMICAL COMPATIBILITY

8.1 Compatibility of Toluene with Other Chemicals and Chemical Groups

SPECIFIC CHEMICAL OR CHEMICAL GROUP	HEAT GENERATION	FIRE	EXPLOSION	FORMATION OF FLAMMABLE GASES	VIOLENT POLYMERIZATION	DECOMPOSITION	FORMATION OF TOXIC FUMES	FORMATION OF SUBSTANCES OF GREATER TOXICITY	PRESSURIZATION IN CLOSED VESSELS	SOLUBILIZATION	VIOLENT REACTION	NON-HAZARDOUS REACTION	SPECIFICS	REFERENCE
GENERAL														
Heat							X							Sax 1979
Fire		X											Extremely flammable	Bretherick 1979
SPECIFIC CHEMICALS														
Bromine Trifluoride		X									X		Reacts with solvents generally	Bretherick 1979
1,3-Dichloro-5, 5-dimethyl-2, 4-imidazolidindione			X											Bretherick 1979
Dinitrogen Tetraoxide			X										at 50°C	Bretherick 1979
Nitric Acid		X	X										Reacts with hydrocarbons generally	Bretherick 1979
Silver Perchlorate			X										May form explosive complex	NFPA 1978
Tetranitromethane			X										Hydrocarbons generally	Bretherick 1979

8.1 Compatibility of Toluene with Other Chemicals and Chemical Groups (Cont'd)

SPECIFIC CHEMICAL OR CHEMICAL GROUP	HEAT GENERATION	FIRE	EXPLOSION	FORMATION OF FLAMMABLE GASES	VIOLENT POLYMERIZATION	DECOMPOSITION	FORMATION OF TOXIC FUMES	FORMATION OF SUBSTANCES OF GREATER TOXICITY	PRESSURIZATION IN CLOSED VESSELS	SOLUBILIZATION	VIOLENT REACTION	NON-HAZARDOUS REACTION	SPECIFICS	REFERENCE
Uranium Hexafluoride											X		Reacts with aromatics generally	Bretherick 1979
<u>CHEMICAL GROUPS</u>														
Strong Oxidizing Agents		X									X			EPA 600/2-80-076

9 COUNTERMEASURES

9.1 Recommended Handling Procedures

The following procedures have been derived from a literature review. To avoid any deviation from the intended meaning, the wording of the original source has been presented essentially unchanged - in so doing, it is recognized that there may be some discrepancies between different sources of information. Countermeasures are dependent on the situation; thus, what may appear to be conflicting information may in fact be correct for different situations. The following procedures should not be considered as Environment Canada's recommendations.

9.1.1 **Fire Concerns.** Toluene emits vapours that can form flammable mixtures with air (NFPA 1978; GE 1979). Vapours may move along the ground and be ignited by open flames or sparks at locations remote from the site at which it is handled and flash back (MCA 1956). Nitric acid and toluene, especially in combination with sulphuric acid, will produce nitrated compounds which are dangerously explosive (GE 1979).

9.1.2 **Fire Extinguishing Agents.** Use water spray to cool containers involved in a fire to help prevent rupture. Water may be ineffective for putting out fires involving toluene (NFPA 1978; GE 1979).

Small Fires: Dry chemical, CO_2, foam or water spray.
Large Fires: Water spray, fog or foam.

Move containers from fire area if this can be done without risk. Stay away from tank ends. For massive fires, use unmanned hose holder or monitor nozzles (ERG 1980).

9.1.3 Spill Actions.

9.1.3.1 **General.** Stop or reduce discharge of material if this can be done without risk. Eliminate all sources of ignition. Avoid skin contact or inhalation (GE 1979). Use water spray to reduce vapours (ERG 1980). Application of fluorocarbon water foam to diminish vapours should be considered (EPA 670/2-75-042).

The following absorbent materials have shown possible applicability for vapour suppression and/or containment of toluene: cellosive and hycar (ICI 1982).

Leaking containers should be removed to the outdoors or to an isolated, well-ventilated area and the contents transferred to other suitable containers (MCA 1956).

9.1.3.2 **Spills on land.** Contain if possible; remove free liquid with explosion-proof equipment, soak residue up with sand, earth or vermiculite and shovel into covered metal containers for disposal (GE 1979; ERG 1980). Application of fly ash or cement powder to absorb the liquid may be considered. Application of a gelling agent may also be used to immobilize the spill (EPA 670/2-75-042).

9.1.3.3 **Spills on water.** Contain if possible with booms or natural barriers to limit spreading. Use of surface acting agents to compress and thicken spilled material will require approval of environmental authorities. Remove trapped material with suction hoses (EPA 670/2-75-042).

9.1.4 Cleanup and Treatment.

9.1.4.1 **Spills on land.** After containment of toluene into a holding area, pumping and/or sorbents can be applied to remove the slick. Activated carbon can be applied to remove the remaining liquid and vapours. Remove recovered material for disposal (OHM-TADS 1981).

9.1.4.2 **Spills on water.** After containment of spilled material with booms, (oil) skimming equipment can be used to remove the slick (OHM-TADS 1981). Most oil spill equipment techniques can be used (EPA 670/2-75-042). Activated carbon can be applied at 10% of the spill amount over region occupied by 10 mg/L or greater concentrations (EPA 670/2-75/042). Peat moss can also be applied (OHM-TADS 1981).

9.1.4.3 **General.** For treatment of contaminated water, gravity separation of solids, followed by skimming of surface to remove spilled material is recommended. The contaminated water is then passed through dual media filtration and carbon adsorption units. Recommended carbon ratio: 1.0 kg to 10.0 kg soluble material. The wastewater from backwash of the filtration and adsorption units is returned to the gravity separator (EPA 600/2-77-227).

The following treatment processes have shown possible applicability for spill countermeasures.

Process	% Removal (TSA 1980)	Process	Maximum % Removal (EPA 600-8-80-042)
Biological	48-100	Clarification/Sedimentation	69
		Clarification/Sedimentation with Chemical Addition (Alum)	93

Process	% Removal (TSA 1980)	Process	Maximum % Removal (EPA-600-8-80-042)
Stripping	73-92	Clarification/Sedimentation with Chemical Addition (Alum, Polymer)	73
Solvent Extraction	94-96	Clarification/Sedimentation with Chemical Addition (Alum, Lime)	96
		Gas Floatation (Dissolved Air Floatation)	92
		Gas Floatation with Chemical Addition (Calcium Chloride, Polymer)	65
		Gas Floatation with Chemical Addition (Polymer)	59
		Granular Media Filtration	>99
		Activated Sludge	>99
		Lagoon (Aerated)	>95
		Solvent Extraction	96
		Granular Activated Carbon Adsorption	>99
Carbon Adsorption	79-98	Powdered Carbon Addition (with Activated Sludge)	79

9.1.5 **Disposal.** Waste toluene must never be discharged directly into sewers or surface waters. Reclaiming by distillation or disposal via a licensed waste disposal company should be considered. It may be incinerated under properly controlled conditions (GE 1979). Additional flammable solvent may be added to increase burning of the material (OHM-TADS 1981).

9.1.6 **Charcoal Filtration Data** (EPA 600/8-80-023). The following recommended values for the removal of toluene in water by either the single stage powdered carbon contactor or the granular carbon column adsorption system were obtained using the Freundlich Adsorption equation. The derivation of the equation is discussed in the Introduction Manual.

SINGLE STAGE POWDERED CARBON CONTACTOR SYSTEM

Initial Concentration (mg/L)	Carbon Doses (mg/L)	Final Concentration (mg/L)
1.0	96	0.1
1.0	290	0.01
1.0	820	0.001
0.1	27	0.01
0.1	81	0.001
0.01	7.4	0.001

GRANULAR CARBON COLUMN SYSTEM: (ESTIMATED)

Initial Concentration (mg/L)	Carbon Doses or Requirements (to achieve breakthrough) (mg/L)
1.0	38
0.1	11
0.01	2.9

9.1.7 Protective Measures. For entry into a situation where the spilled material and its characteristics are unknown, self-contained breathing apparatus and a totally encapsulated chemical suit should be worn.

If the spilled material is known to be toluene:

- Response personnel should be provided with and required to use impervious clothing, gloves, face shields (20 cm minimum), and other appropriate protective clothing necessary to prevent repeated or prolonged skin contact with liquid toluene. PVC and rubber are not recommended for gloves or outer wear (OHM-TADS 1981). Neoprene has been recommended as a chemical protection suit material (GE 1979).
- Any clothing which becomes wet with liquid toluene should be removed immediately and not reworn until the toluene is removed from the clothing.
- Splash-proof safety goggles can also be used where liquid toluene may contact the eyes (NIOSH/OSHA 1981).

- Eye wash fountains and safety showers should be readily available in areas of use or in spill situations (GE 1979).

The following is a list of the minimum respiratory protection recommended for personnel working in areas where toluene is present (NIOSH/OSHA 1981).

Condition	Minimum Respiratory Protection* Required Above 200 ppm
Vapour Concentration 500 ppm or less	Any chemical cartridge respirator with organic vapour cartridge(s). Any supplied-air respirator. Any self-contained breathing apparatus.
1,000 ppm or less	A chemical cartridge respirator with a full facepiece and an organic vapour cartridge(s).
2,000 ppm or less	A gas mask with a chin-style or a front- or back-mounted organic vapour canister. Any supplied-air respirator with a full facepiece, helmet or hood. Any self-contained breathing apparatus with a full facepiece.
Greater than 2,000 ppm or entry and escape from unknown concentrations	Self-contained breathing apparatus with a full facepiece operated in pressure-demand or other positive pressure mode. A combination respirator which includes a Type C supplied-air respirator with a full facepiece operated in pressure-demand or other positive pressure or continuous-flow mode and an auxiliary self-contained breathing apparatus operated in pressure-demand or other positive pressure mode.
Fire Fighting	Self-contained breathing apparatus with a full facepiece operated in pressure-demand or other positive pressure mode.
Escape	Any gas mask providing protection against organic vapours. Any escape self-contained breathing apparatus.

* Only NIOSH-approved or MSHA-approved equipment should be used.

9.1.8 Special Precautions. Store toluene in a cool, clean, well-ventilated area away from sources of heat and ignition and away from oxidizing agents. No smoking in areas of storage or use. Only nonsparking tools should be used near toluene. Use safety cans for handling small amounts. Ground and bond metal containers for liquid transfers to prevent sparks from static electricity. Protect containers from physical damage (GE 1979).

9.2 Specialized Countermeasures Equipment, Materials or Systems

The following items are devices or materials specially tested or claimed to be effective for controlling toluene spills. This information is taken from a previous study (Dillon 1982) and should not be considered to be the only suitable specialized countermeasures equipment, materials or systems available. More details on the specifications, performance and availability of these items can be found in the referenced study.

Leak Plugging	Rockwell External Leak Plugging System
Vapour Suppression	National, Lorcon, Rockwood, 3M, MSA Foams
Recovery from Water - Floating Materials	Amine Carbamate Gelling Agent and Application System
Pumps for Liquids	U.S. Coast Guard ADAPTS
Removal from Water	EPA Mobile Physical-Chemical Treatment Trailers
Treating Agents	Hazorb (sorbent)

10 PREVIOUS SPILL EXPERIENCE

This section contains information on previous spill experience which will be useful to readers in understanding spill response and countermeasures. Only those which meet these criteria are included; the number of experiences is not an indication of the problems or frequency of spillage. As technology in spill control advances, this section will be updated in future manual revisions to include the most useful information.

10.1 Train Derailment (HMIR 1981)

A train derailment occurred in an urban area. Two tank cars containing toluene tipped over and struck the asphalt pavement at a highway crossing. One of the cars spilled its entire load of approximately 98,000 L through a gash in the tank while the other spilled about half of its contents through its dome. A third tank car carrying toluene, along with four other cars filled with anhydrous ammonia, had also derailed, but did not rupture. Firefighters arrived at the site and applied water spray to cool the ammonia cars in order to prevent an explosion. One hundred persons were evacuated in the vicinity of the spill area. Cleanup crews arrived at the spill site a few hours later and noticed that most of the spilled toluene had flowed into a ditch adjacent to the railroad and down into a swamp area, about 400 m away. Approximately 152,000 L of contaminated water, containing about 50 percent toluene, were pumped from the ditch and swamp area, using vacuum trucks. The contaminated water was then taken to a solvent recovery facility. Approximately 2,300 m^3 of contaminated soil and asphalt were removed from the spill area and disposed of in a hazardous waste landfill. In some areas, up to 3 m of soil had to be removed in order to mitigate the contamination. No serious environmental damage resulted from the accident.

This incident illustrates the extensive cleanup required if toluene is allowed to flow away from the site. Immediate containment of the spilled liquid and contaminated water from firefighting may have eliminated some of the cleanup required. The use of vacuum trucks for recovery and a solvent recovery facility for disposal (actually re-use) are illustrated.

11 ANALYTICAL METHODS

The general approach adopted for each of the Priority Chemicals was as follows.

Methods have been documented here for analyses of samples from air, water and soil in a normally equipped chemical laboratory remote from the spill site. Customary sources of standard or recommended analytical methods were consulted, and outlines are presented for each chemical. These sources included publications of the U.S. National Institute for Occupational Safety and Health (NIOSH), the U.S. Environmental Protection Agency (EPA), the American Water Works Association (AWWA), the American Society for Testing and Materials (ASTM), and the American National Standards Institute (ANSI).

If the standard or recommended methods were judged to be reliable and specific enough for the analysis of environmental and materials samples from spill sites and if they do not require highly specialized laboratory equipment, no additional methods were sought.

If especially simple, reliable tests (e.g., commonly used industrial methods) were found, they have been presented as well.

11.1 Quantitative Method for the Detection of Toluene in Air

11.1.1 **Gas Chromatography** (NIOSH 1977). A range of 145.5 to 582 ppm toluene in air may be analyzed by gas chromatography (GC). This is currently the most practical method for identifying and measuring many volatile organic compounds. Retention time or Kovats index is used to identify the compound but positive identification requires the use of more than one column, special detectors, spiking the sample with the suspected component or combining GC with mass spectrometry (MS).

A known volume of air is drawn through a glass sampling tube. The front section is packed with 100 mg of activated charcoal which is separated from 50 mg of charcoal in the back section by a 2 mm section of urethane foam. The desorption efficiency of the charcoal must be known or measured to produce a reliable result. A 2 L air sample is recommended but this should be reduced if there is a large amount of toluene present. The sample is desorbed with 1.0 mL carbon disulphide. (Alternatively, one source recommends 0.5 mL carbon disulphide.) Analysis is by GC with a flame ionization detector (FID) using a column packed with 50/80 mesh Porapak Q. In high humidity, the condensation of water vapour reduces the collection efficiency of the charcoal and the concentration of toluene may appear to be lower than it actually is. The loss of sample through overloading the charcoal tube may also produce lower results. This can be determined by desorbing the back and front portions separately. If the back section is greater than 25 percent of the front portion, overloading has occurred. An advantage of this method is that in the event of a mixed spill, two or more substances may be analyzed simultaneously.

Other sample collection methods may be useful in certain circumstances. A 1 L air sample may be collected and a 50 mL aliquot injected into a freeze-out trap at -80°C, packed with 20 percent Dow-Corning SF200 on 60/80 mesh Columnpak. Toluene is released by heating the trap to 100°C (Pilar 1973). Where a GC is used at a spill site, an automated gas sampling valve may be used. Outside air is injected directly through a 1 cm^3 sampling loop by means of a diaphragm pump (Hester 1979). This is useful for ongoing monitoring. Alternately, the sample may be drawn through an adsorption tube packed with 80/100 mesh Porapak. The sample is thermally desorbed at 250°C directly into the GC (Baxter 1980). Advantages of these methods include the simplification of sample preparation and the elimination of solvent interference on the chromatograph.

Alternate columns are 10 percent Carbowax on 80/100 mesh chromosorb W (ASTM 1981), 10 percent 1,2,3-tris(2-cyanoethoxy) propane on 100/200 mesh chromosorb PAW (Hester 1979), 1 percent OV-101 (or SE-30) on 100/120 mesh chromosorb W (Jones 1976; IERL 1976), and 30 percent N,N-Bis-2-cyanoethylformamide on 80/100 mesh pink support (Baxter 1980).

The use of photoionization detector (PID) rather than FID, allows analysis at the sub-ppm level without pre-concentration or trapping. Sample dilution may be necessary if GC-PID is used as a vehicle portable method and transported to the spill site where the concentration may exceed the range of the detector (Hester 1979). Detectors using infrared absorption, with carbon monoxide or carbon dioxide lasers as sources, have a detection limit of 3 ppb for toluene (Kreuzer 1972).

11.2 Qualitative Method for the Detection of Toluene in Air

Air is drawn through a glass sampling tube as in Section 11.1.1. The sample is desorbed with chloroform and identified using the Friedel-Crafts alkylation reaction. Anhydrous aluminum chloride (about 100 mg) is placed in a test tube and heated until it sublimes. When it has cooled, a drop of the extract and two drops of chloroform are added with shaking. The appearance of an orange-red colour indicates the presence of an aromatic ring (Owen 1969).

11.3 Quantitative Methods for the Detection of Toluene in Water

11.3.1 Gas Chromatography (ASTM 1981). Concentrations of toluene greater than 1 ppm can be measured by direct injection of the water sample into the gas chromatograph (GC). This is the method of choice when the identification of a spill is necessary or when low levels of toluene are present (see Section 11.1.1).

A representative sample is collected in a glass bottle. Analysis is by GC using various columns and detectors as described in Section 11.1.1. If the sample concentration is less than 1 ppm, the sample may be concentrated by evaporation, freeze-out, solvent extraction, or adsorption on activated charcoal. Highly concentrated samples may be diluted. Particulate or suspended matter must be removed by centrifugation or membrane filtration. Acidification of the sample will help to dissolve particulate matter. An advantage of the GC method is that in the event of a mixed spill, two or more substances may be separated and analyzed. This method can be combined with mass spectrometry for positive identification of the sample.

11.3.2 Infrared Spectroscopy (AWWA 1976). Concentrations of 4 to 40 ppm toluene in water can be measured using 1 cm path length cells with a precision of ±10 percent.

Approximately 1 L of water is collected, the volume determined accurately and the sample acidified with hydrochloric acid. The toluene is extracted using Freon 113® (1,1,2-trichloro-1,2,2-trifluoroethane). Recovery is 99 percent. Using matched quartz cells with Freon 113® in the reference beam of a double-beam IR recording spectrophotometer, the sample is scanned from 3,200 cm^{-1} to 2,700 cm^{-1}. The advantage of this method over methods that involve heating the sample is that sample loss through volatilization is minimized. This method lacks high sensitivity but is adequate for spills. It is not specific and assumes that the identity of the spill is known.

11.3.3 Gravimetric (AWWA 1976). This method is suitable for concentrations of toluene greater than 10 ppm. The precision is ± 6 percent.

Approximately 1 L of sample is collected, the volume accurately determined and the sample acidified with hydrochloric acid. The toluene is extracted using Freon 113® (1,1,2-trichloro-1,2,2-trifluoroethane). Recovery is 99 percent. The Freon 113® is distilled from the extraction flask on a water bath at 70°C. Sample loss may be a problem if the temperature is not carefully controlled. Air is drawn through the flask for the final minute to remove all traces of the Freon 113®. The flask is cooled and weighed.

This is a simple and inexpensive method which does not require complex instrumentation. It is not highly sensitive or specific but is adequate for spills of a known composition.

11.4 Qualitative Method for the Detection of Toluene in Water

The water sample is extracted with chloroform and the Friedel-Crafts alkylation reaction is used to identify aromatic hydrocarbons. Anhydrous aluminum chloride (about 100 mg) is placed in a test tube and heated until it sublimes. When it has cooled, a drop of the extract and two drops of chloroform are added with shaking. The appearance of an orange-red colour indicates the presence of an aromatic ring (Owen 1969).

The infrared spectroscopy method discussed in Section 11.3.2 may be used for qualitative identification by observing the presence of absorption bands between 3,200 cm^{-1} and 2,700 cm^{-1} (AWWA 1976).

11.5 Quantitative Methods for the Detection of Toluene in Soil

11.5.1 Gas Chromatography (NIOSH 1977; ASTM 1981). Concentrations of toluene at the ppm level may be detected using a flame ionization detector. The detection limit may be extended to the ppb level through the use of a photoionization detector.

Approximately 20 g of soil, accurately weighed, are collected in a glass jar and dried by the addition of magnesium sulphate. Freon 113® (1,1,2-trichloro-1,2,2-trifluoroethane) is used to extract toluene from the soil. The Freon 113® is distilled from the extraction flask on a water bath at 70°C. Sample loss may be a problem if the temperature is not carefully controlled. Air is drawn through the flask for the final minute to remove all traces of the Freon 113®. The toluene-containing residue is dissolved in carbon disulphide. This is injected into a gas chromatograph equipped with a column and detector as described in Section 11.1.1. This is the method of choice when the identification of a spill is necessary or when low levels of toluene are present.

11.5.2 Infrared Spectroscopy (AWWA 1976). Concentrations of 4 to 40 ppm toluene in soil may be measured using 1 cm path length cells.

Approximately 20 g of soil, accurately weighed, are collected in a glass jar and dried by the addition of magnesium sulphate. Freon 113® (1,1,2-trichloro-1,2,2-trifluoroethane) is used to extract the toluene from the soil. Using quartz cells with Freon 113® in the reference beam of a double-beam IR recording spectrophotometer, the sample is scanned from 3,200 cm^{-1} to 2,700 cm^{-1}. This is a simple, inexpensive method. It lacks sensitivity but is adequate for spills of a known composition.

11.5.3 Gravimetric (AWWA 1976). This method is used for the detection of concentrations greater than 10 ppm toluene in soil.

Approximately 20 g of soil, accurately weighed, are collected in a glass jar and dried by the addition of magnesium sulphate. Freon 113® (1,1,2-trichloro-1,2,2-trifluoroethane) is used to extract the toluene then distilled from the extraction flask on a water bath. A temperature of 70°C must be carefully controlled or sample loss will be a problem. Air is drawn through the flask for the final minute. The flask is cooled and weighed. This is a simple, inexpensive method. It lacks sensitivity and specificity, but is adequate for spills of a known composition.

11.6 Qualitative Method for the Detection of Toluene in Soil

The Friedel-Crafts alkylation reaction is used to identify aromatic hydrocarbons. A sample of soil is extracted with Freon 113® (1,1,2-trichloro-1,2,2-trifluoroethane) and the Freon 113® is evaporated as in Section 11.5.3 above. The residue is taken up in chloroform. Anhydrous aluminum chloride (about 100 mg) is placed in a test tube and heated until it sublimes. When it has cooled, several drops of the chloroform containing the residue are added with shaking. The appearance of an orange-red colour indicates the presence of a compound containing an aromatic ring (Gilreath 1954).

The infrared spectroscopy method discussed in Section 11.5.2 may be used for qualitative identification of toluene by observing the presence of absorption bands between 3,200 cm^{-1} and 2,700 cm^{-1} (AWWA 1976).

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EnviroTIPS

Common Abbreviations

BOD	biological oxygen demand
b.p.	boiling point
CC	closed cup
cm	centimetre
CMD	count median diameter
COD	chemical oxygen demand
conc.	concentration
c.t.	critical temperature
eV	electron volt
g	gram
ha	hectare
Hg	mercury
IDLH	immediately dangerous to life and health
Imp. gal.	imperial gallon
in.	inch
J	joule
kg	kilogram
kJ	kilojoule
km	kilometre
kPa	kilopascal
kt	kilotonne
L	litre
lb.	pound
LC_{50}	lethal concentration fifty
LC_{LO}	lethal concentration low
LD_{50}	lethal dose fifty
LD_{LO}	lethal dose low
LEL	lower explosive limit
LFL	lower flammability limit
m	metre
m	meta
M	molar
MAC	maximum acceptable concentration
max	maximum
mg	milligram
MIC	maximum immision concentration
min	minute or minimum
mm	millimetre
µg	microgram
µm	micrometre
°Be	degrees Baumé (density)
MMAD	mass median aerodynamic diameter
MMD	mass median diameter
m.p.	melting point
MW	molecular weight
N	newton
NAS	National Academy of Sciences
NFPA	National Fire Protection Association
NIOSH	National Institute for Occupational Safety and Health
nm	nanometre
o	ortho
OC	open cup
p	para
P_c	critical pressure
PEL	permissible exposure level
pH	measure of acidity/alkalinity
ppb	parts per billion
ppm	parts per million
P_s	standard pressure
psi	pounds per square inch
s	second
STEL	short-term exposure limit
STIL	short-term inhalation limit
T_c	critical temperature
TC_{LO}	toxic concentration low
T_d	decomposition temperature
TD_{LO}	toxic dose low
TL_m	median tolerance limit
TLV	Threshold Limit Value
T_s	standard temperature
TWA	time weighted average
UEL	upper explosive limit
UFL	upper flammability limit
VMD	volume mean diameter
v/v	volume per volume
w/w	weight per weight