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**ENVIRO**

**T**echnical

**I**nformation for

**P**roblem

**S**pills

**ACETIC ACID**

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A2313  
1985

February 1985

Canada

## **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.

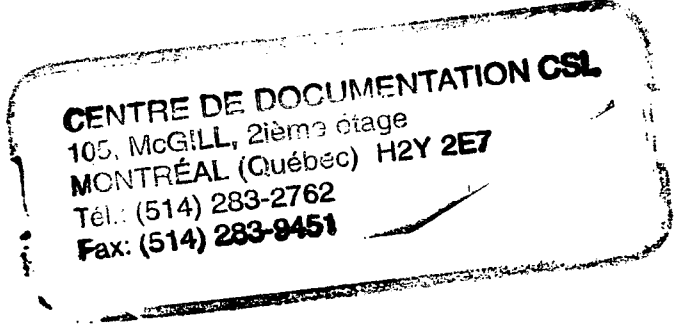
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ACETIC ACID

ENVIRONMENTAL AND TECHNICAL INFORMATION FOR PROBLEM SPILLS



Technical Services Branch  
Environmental Protection Programs Directorate  
Environmental Protection Service  
Ottawa, Ontario

February 1985

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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 that are 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 EnviroTIPS 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 they are recommended by the Government of Canada, nor by any other group.

## **ACKNOWLEDGEMENTS**

The final version of this manual was prepared by the staff of the Environmental Protection Service who wrote extensive revisions to the text, drafted illustrations and incorporated all comments and additions.

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. The draft of this manual was prepared under contract to Environment Canada by M.M. Dillon Consulting Engineers and Planners, Concord Scientific Corporation, and Waterloo Engineering Limited.



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## 1 SUMMARY

### ACETIC ACID (CH<sub>3</sub>COOH)

Colourless, watery liquid with a strong vinegar odour

### SYNONYMS

Glacial Acetic Acid, Aqueous Acetic Acid, Ethanoic Acid, Ethylic Acid, Vinegar Acid, Methane Carboxylic Acid, Acide Acétique (Fr.)

### IDENTIFICATION NUMBERS

UN No. 2789 (glacial and solutions, >80 percent), 2790 (solutions, 10-80 percent); CAS No. 064-19-7; OHM-TADS No. 7216566; STCC No. 4931401 (aqueous), 4931303 (glacial)

### GRADES & PURITIES

Glacial, 99.85 percent  
Technical solutions, 28, 56, 80, 92 percent

### IMMEDIATE CONCERNS

Fire: Combustible

Human Health: Moderately toxic by inhalation, ingestion, and contact

Environmental: Harmful to aquatic life in low concentration

### PHYSICAL PROPERTY DATA

State (15°C, 1 atm): liquid  
Boiling Point: 117.9°C  
Melting Point: 16.6°C  
Flammability: combustible  
Flash Point: 39°C (CC)  
Vapour Pressure: 1.6 kPa (20°C)  
Density: 1.0492 g/mL (20°C)

Solubility (in water): soluble in all proportions  
Behaviour (in water): sinks and mixes, evolving heat and fumes  
Behaviour (in air): vapours form explosive mixtures in air; vapours are heavier than air  
Odour Threshold Range: 1-10 ppm

### ENVIRONMENTAL CONCERNS

Acetic acid is harmful to aquatic life at concentrations as low as 50 ppm. Acetic acid shows no potential for biological accumulation or food chain contamination.

### HUMAN HEALTH

TLV: 10 ppm (25 mg/m<sup>3</sup>)

IDLH: 1000 ppm

Exposure Effects

**Inhalation:** Vapour concentrations over 50 ppm are intolerable, resulting in irritation of eyes, nose, throat and lungs. Causes coughing, nausea, vomiting, and difficult breathing.

**Contact:** Contact can produce deep burns, skin destruction, skin sensitization, inflammation of the mucous membrane and of the eyelids, and erosion of exposed teeth. Eye contact causes immediate burns and possible permanent damage.

**IMMEDIATE ACTION**

Spill Control

Restrict access to spill site. Issue warning: "CORROSIVE". 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 inhalation of vapour; stay upwind of release. Keep contaminated water from entering sewers or watercourses.

Fire Control

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

**COUNTERMEASURES**

Emergency Control Procedures in/on

**Soil:** Construct barriers to contain spill or divert to impermeable holding area. Remove material with pumps or vacuum equipment. Absorb residual liquid with natural or synthetic sorbents and shovel into containers with covers. Neutralize contaminated area with lime and shovel into containers for disposal.

**Water:** Contain by damming, water diversion or natural barriers. Neutralize with lime or sodium bicarbonate. Remove contaminated water for treatment.

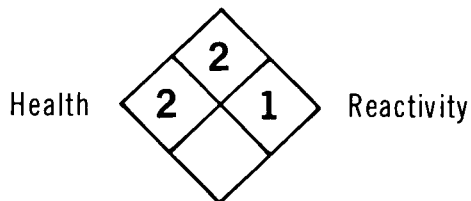
**Air:** Use water spray to knock down vapour. Control runoff for later treatment and/or disposal.

**NAS HAZARD RATING**

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

NFPA  
HAZARD  
CLASSIFICATION

Flammability



## 2 PHYSICAL AND CHEMICAL DATA

### Physical State Properties (Properties are for pure acetic acid unless stated otherwise)

|                               |   |
|-------------------------------|---|
| Appearance                    | Clear, colourless liquid (Celanese PB 1976)   |
| Usual shipping state(s)       | Liquid above 16.6°C (MCA 1951)                |
| Physical state at 15°C, 1 atm | Solid (Celanese MSDS 1979)                    |
| Melting point                 | 16.604°C (CRC 1980)<br>16.75°C (Ullmann 1975) |
| Boiling point                 | 117.87°C (Kirk-Othmer 1978)                   |
| Vapour Pressure               | 1.57 kPa (20°C) (Ullmann 1975)                |

### Densities

|                                      |                                       |
|--------------------------------------|---------------------------------------|
| Density                              | 1.0492 g/mL (20°C) (Kirk-Othmer 1978) |
| Specific gravity (liquid, water = 1) | 1.0492 (20°/4°C) (CRC 1980)           |
| (vapour, air = 1)                    | 2.07 (Verschuereen 1984)              |

### Fire Properties

|                          |   |
|--------------------------|---|
| Flammability             | Gives off flammable vapour at high temperatures (NFPA 1978)                 |
| Flash point CC           | 39°C (NFPA 1978)  |
| OC                       | 44°C (Celanese MSDS 1979)<br>57°C (Kirk-Othmer 1978)                        |
| Autoignition temperature | 464°C (NFPA 1978)   |
| Burning rate             | 1.6 mm/min (CHRIS 1978)   |
| Upper flammability limit | 19.9 percent (v/v) (200°C) (NFPA 1978)<br>17.0 percent (v/v) (Ullmann 1975) |
| Lower flammability limit | 4.0 percent (v/v) (NFPA 1978)<br>5.4 percent (v/v) (100°C) (Ullmann 1975)   |
| Heat of combustion       | -874.5 kJ/mole (25°C) (CRC 1980)  |
| Combustion products      | Carbon dioxide and water (CRC 1980)   |
| Explosiveness            | Vapour forms explosive mixtures with air (NFPA 1978)                        |

### Other Properties

|  |   |
|--|---|
| Molecular weight of pure substance                 | 60.05 (CRC 1980)  |
| Constituent components of typical commercial grade | Glacial: 99.85 percent acetic acid<br>0.15 percent (max.) water<br>0.5 percent (max.) acetaldehydes<br>(Celanese PB 1976) |



|  |  |
|--|--|
|  | Others: x percent acetic acid<br>100 - x percent water   |
| Refractive index                         | 1.36985 (25°C) (Kirk-Othmer 1978)  |
| Viscosity                                | 1.183 mPa·s (20°C), 0.018 mPa·s (40°C)<br>(Kirk-Othmer 1978)<br>1.2 mPa·s (20 percent at 25°C),<br>1.7 mPa·s (40 percent at 25°C),<br>2.1 mPa·s (60 percent at 25°C),<br>3.1 mPa·s (80 percent at 25°C) (PPH 1984) |
| Liquid interfacial tension<br>with air   | 27.57 mN/m (20°C) (Kirk-Othmer 1978)   |
| Liquid interfacial tension<br>with water | 38 mN/m (30°C) (CRC 1980)  |
| Latent heat of fusion                    | 11.74 kJ/mole (at melting point)<br>(Ullmann 1975)   |
| Latent heat of vaporization              | 23.69 kJ/mole (at boiling point)<br>(Kirk-Othmer 1978)   |
| Heat of formation                        | -484.3 kJ/mole (25°C) (Sussex 1977)  |
| Entropy                                  | 159.9 J/(mole·K) (Ullmann 1975)  |
| Ionization potential                     | 10.66 eV (Holmes 1980)   |
| Heat of solution                         | -1506 J/mole (25°C) (CRC 1980)   |
| Heat capacity                            |  |
| Constant pressure ( $C_p$ )              | Liquid: 122.68 J/(mole·°C) (14.4°C)<br>(Ullmann 1975)<br>Vapour: 301.99 J/(mole·°C) (124°C)<br>(Kirk-Othmer 1978)<br>Solid: 88.77 J/(mole·°C) (1.5°C)<br>(Ullmann 1975)  |
| Constant volume ( $C_v$ )                | 107 J/(mole·°C) (25°C) (CRC 1980;<br>CHRIS 1978)   |
| Critical pressure                        | 5786 kPa (CRC 1980)  |
| Critical temperature                     | 321.6°C (CRC 1980)   |
| Coefficient of thermal expansion         | $1.071 \times 10^{-3}/^{\circ}\text{C}$ (20°C) (Celanese PB 1976)  |
| Thermal conductivity                     | 0.158 W/(m·K) (20°C) (Kirk-Othmer 1978)  |
| Saturation concentration                 | 38 g/m <sup>3</sup> (20°C), 63 g/m <sup>3</sup> (30°C)<br>(Verschueren 1984)   |
| Dielectric constant                      | 2.665 (-10°C), 6.170 (20°C)<br>(Kirk-Othmer 1978)  |

|  |   |
|--|---|
| Dissociation constant                                    | $1.845 \times 10^{-5}$ (25°C) (Ullmann 1975)  |
| Specific conductance                                     | 0.060 cm <sup>2</sup> /ohm (100 percent, 25°C),<br>2.19 cm <sup>2</sup> /ohm (97.60 percent, 25°C),<br>111 cm <sup>2</sup> /ohm (90.75 percent, 25°C)<br>(Kirk-Othmer 1978) |
| Diffusivity  | 0.1064 cm <sup>2</sup> /s (in air, 0°C),<br>$1.24 \times 10^{-5}$ cm <sup>2</sup> /s (in water, 25°C)<br>(Perry 1973)   |
| pH of aqueous solution                                   | Highly corrosive at dilute concentrations,<br>somewhat less so at glacial strength<br>(MCA 1951).<br>2.4 (1 N at 25°C) (CRC 1980)   |
| Log <sub>10</sub> octanol/water partition<br>coefficient | -0.31 (Hansch and Leo 1979)   |
| Evaporation rate   | 0.45 g/(m <sup>2</sup> ·s) (glacial at 20°C, wind 4.5 m/s)<br>(this work)   |

### Solubility

|                           |  |
|---------------------------|--|
| In water                  | Completely soluble in all proportions<br>(Celanese PB 1976)  |
| In other common materials | Miscible in ethanol and diethyl ether, insoluble<br>in carbon disulphide (Celanese PB 1976).<br>Miscible in acetone and benzene (CRC 1980) |
| Azeotropes (Ullmann 1975) |  |

| <u>Substance</u>        | <u>Mass<br/>percent<br/>Acetic<br/>Acid</u> | <u>Boiling<br/>Point<br/>(°C)</u> |
|-------------------------|---|-----------------------------------|
| Bromoform               | 82  | 118.3                             |
| Carbon<br>tetrachloride | 1.44  | 76.6                              |
| Heptane                 | 33  | 91.9                              |
| Toluene                 | 34.4  | 104.8                             |
| Cyclohexane             | 6.5   | 81.8                              |
| Butanol                 | 43.0  | 120.3                             |
| Ethylbenzene            | 66.0  | 114.6                             |

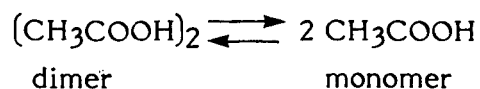
### Vapour Weight to Volume Conversion Factor

$$1 \text{ ppm} = 2.494 \text{ mg/m}^3 \text{ (20°C)}$$

$$1 \text{ mg/m}^3 = 0.401 \text{ ppm (Verschueren 1984)}$$

### Chemical and Physical Properties

In the vapour phase, acetic acid exists as a dimer in the temperature range of 25 to 120°C. The apparent molecular weight is shown in Figure 2. The equilibrium for this is as follows (Kirk-Othmer 1978):

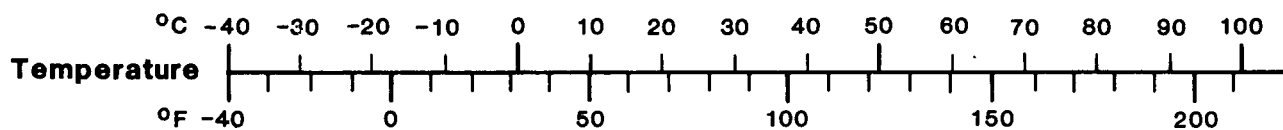
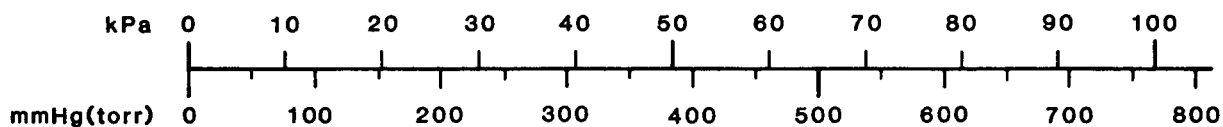
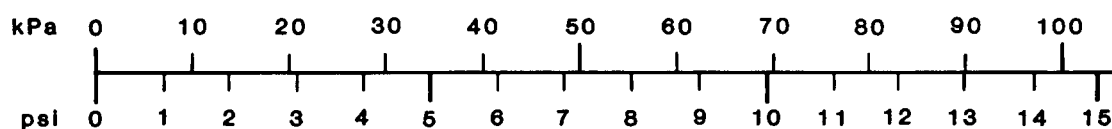
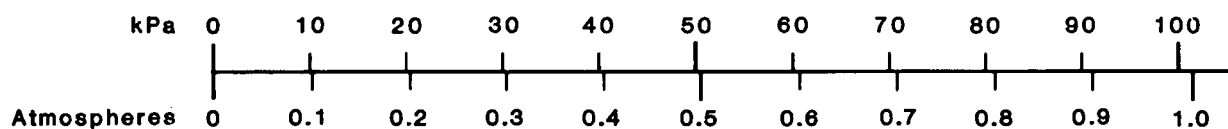


$$\text{Log K dimer} = \frac{3166}{T} - 10.4205$$

As a solid acetic acid also has two forms, the most stable (and common) is known as acetic acid I and consists of orthorhombic crystals. At high pressures (8000 kPa), acetic acid II is formed. Its crystals are monoclinic and are metastable, after formation, down to atmospheric pressures (Wilton 1974).

## ACETIC ACID

## CONVERSION NOMOGRAMS

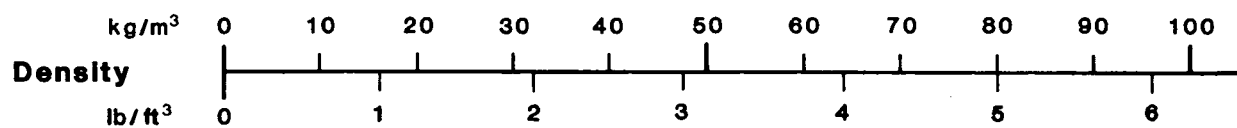
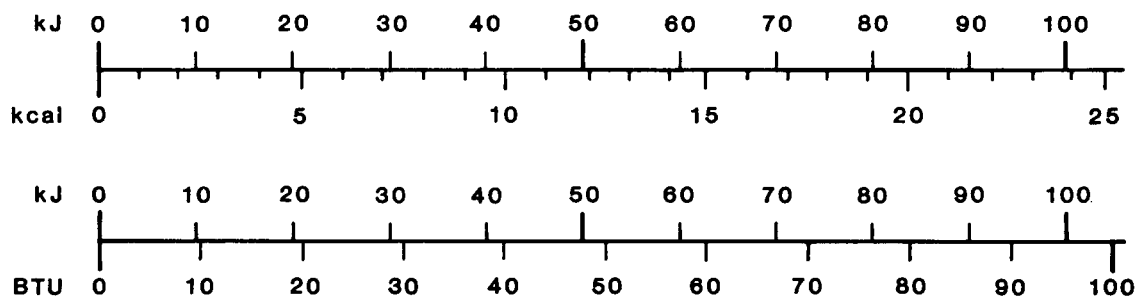
**Pressure** 1 kPa = 1 000 Pa**Viscosity**

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

**Kinematic** 1 m<sup>2</sup>/s = 1 000 000 centistokes (cSt)

**Concentration (in water)**

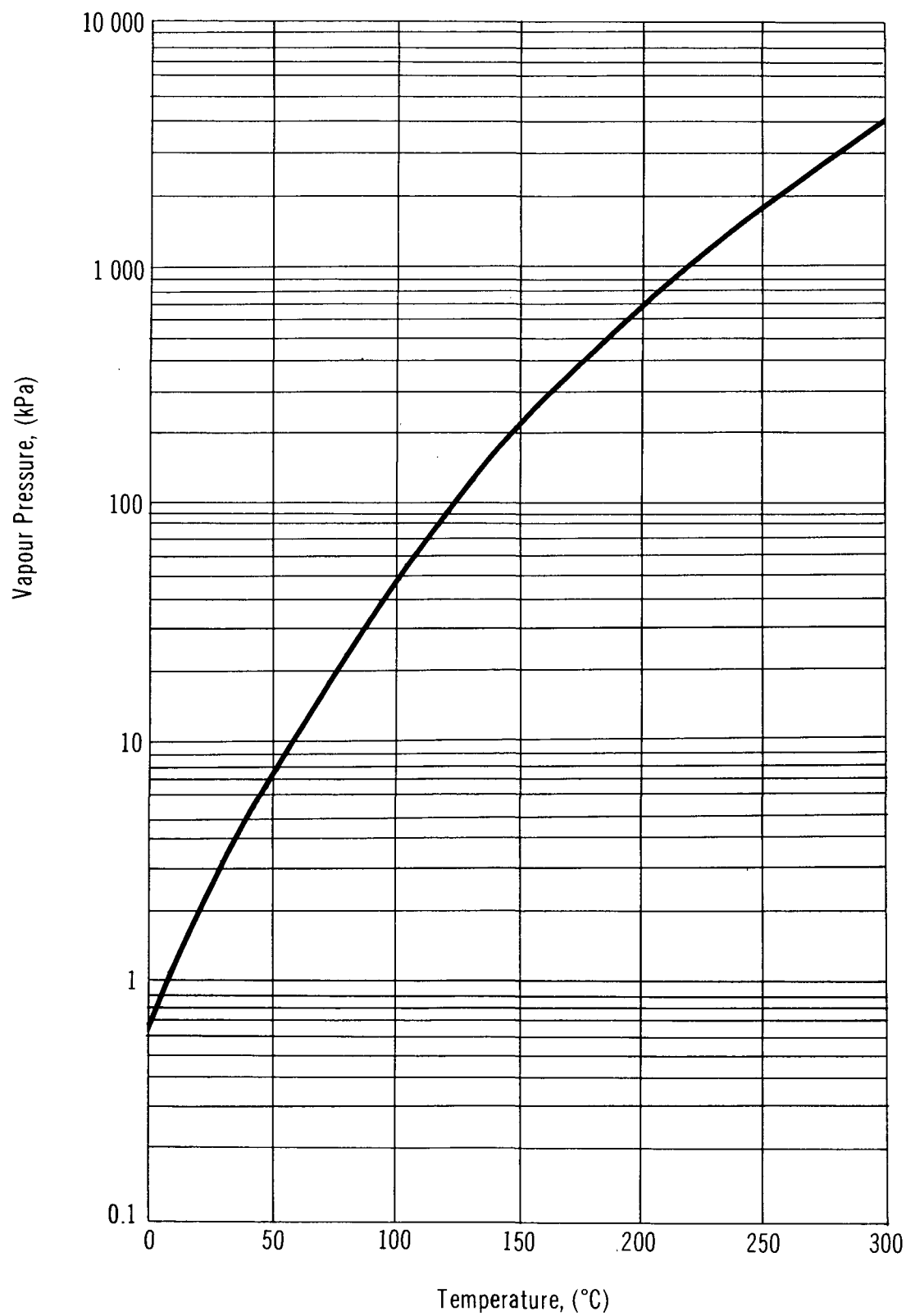
1 ppm  $\cong$  1 mg/L

**Energy (heat)** 1 kJ = 1 000 J

ACETIC ACID

## VAPOUR PRESSURE

Reference: ULLMANN 1975



ACETIC ACID (VAPOUR)

**APPARENT MOLECULAR WEIGHT**

Reference: KIRK-OTHMER 1978

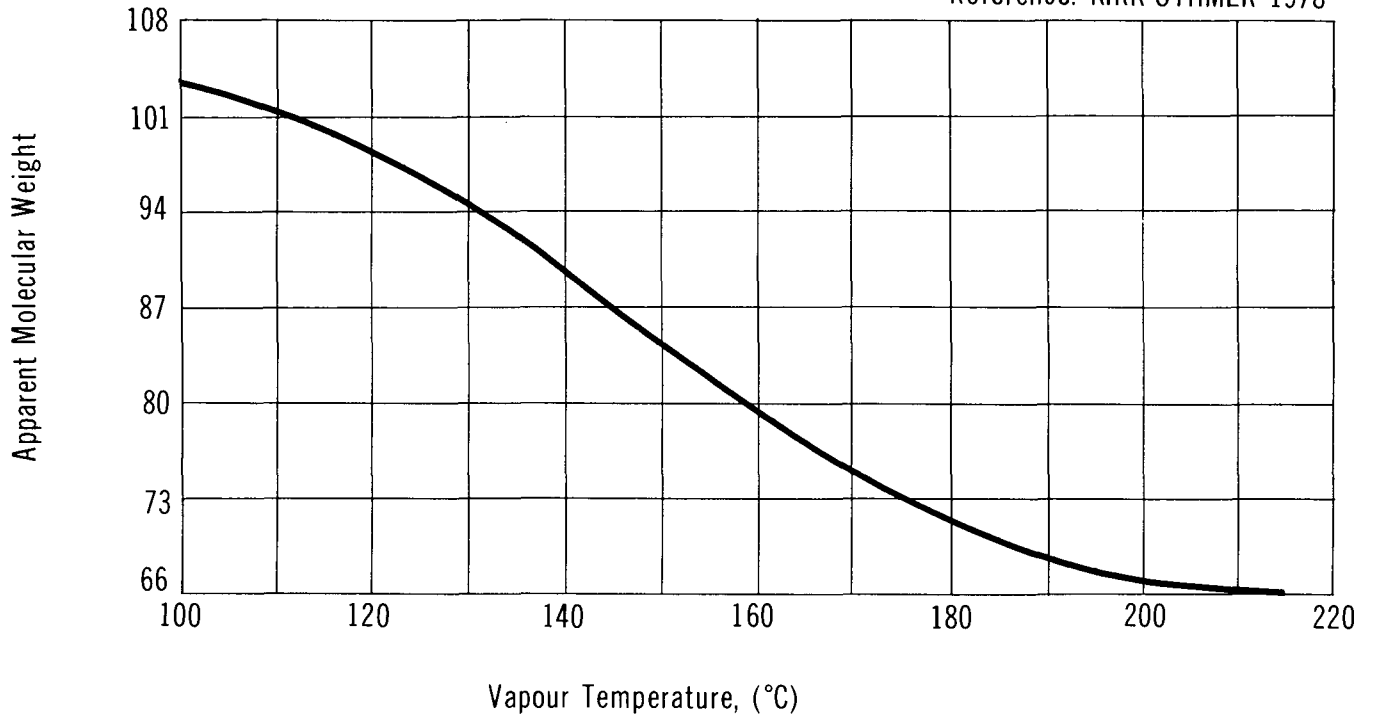
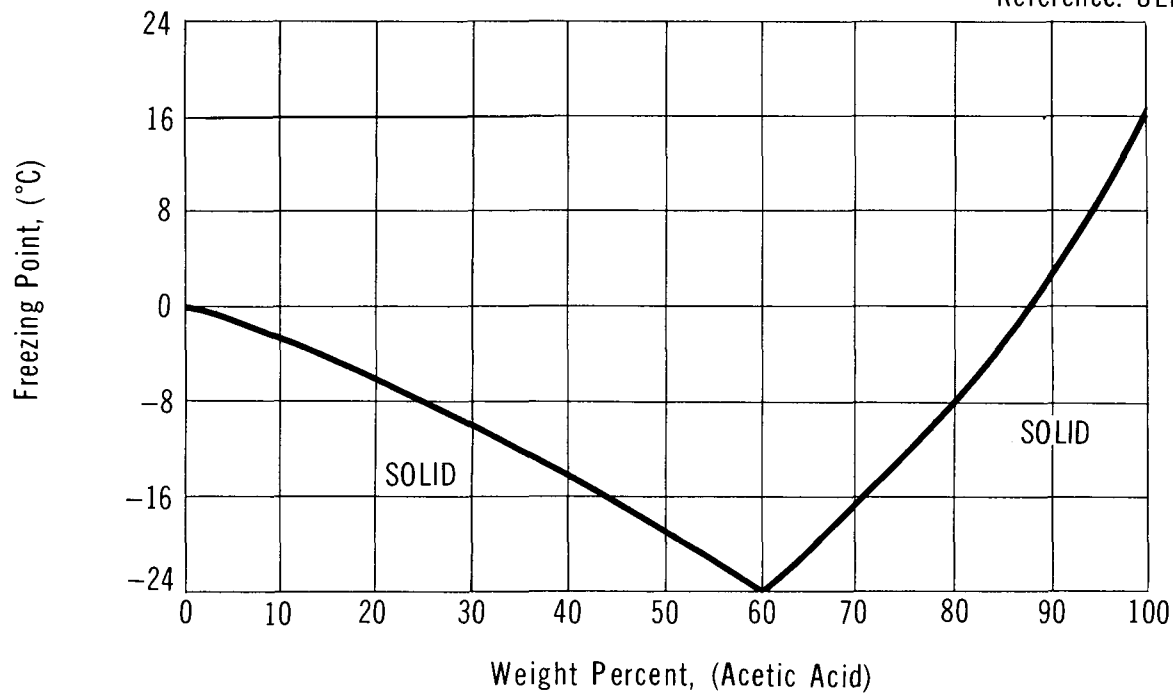


FIGURE 3

ACETIC ACID

**FREEZING POINTS OF SOLUTIONS**

Reference: ULLMANN 1975



ACETIC ACID

**DENSITY OF SOLUTIONS**

Reference: ULLMANN 1975; PPH 1984

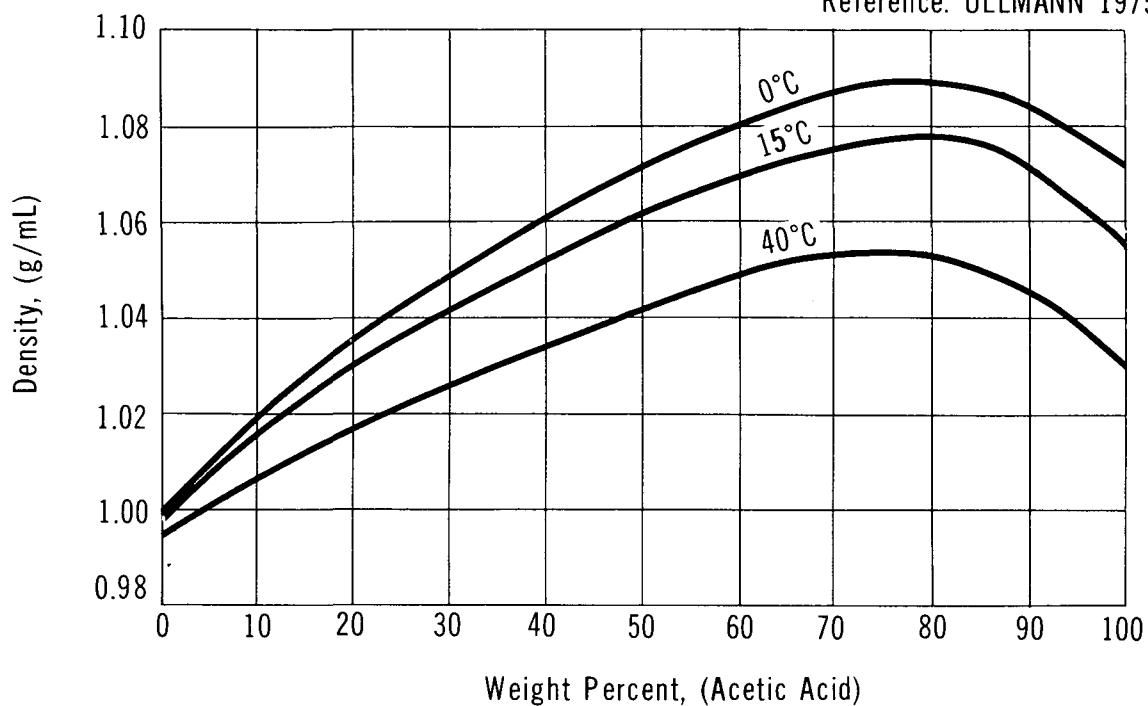
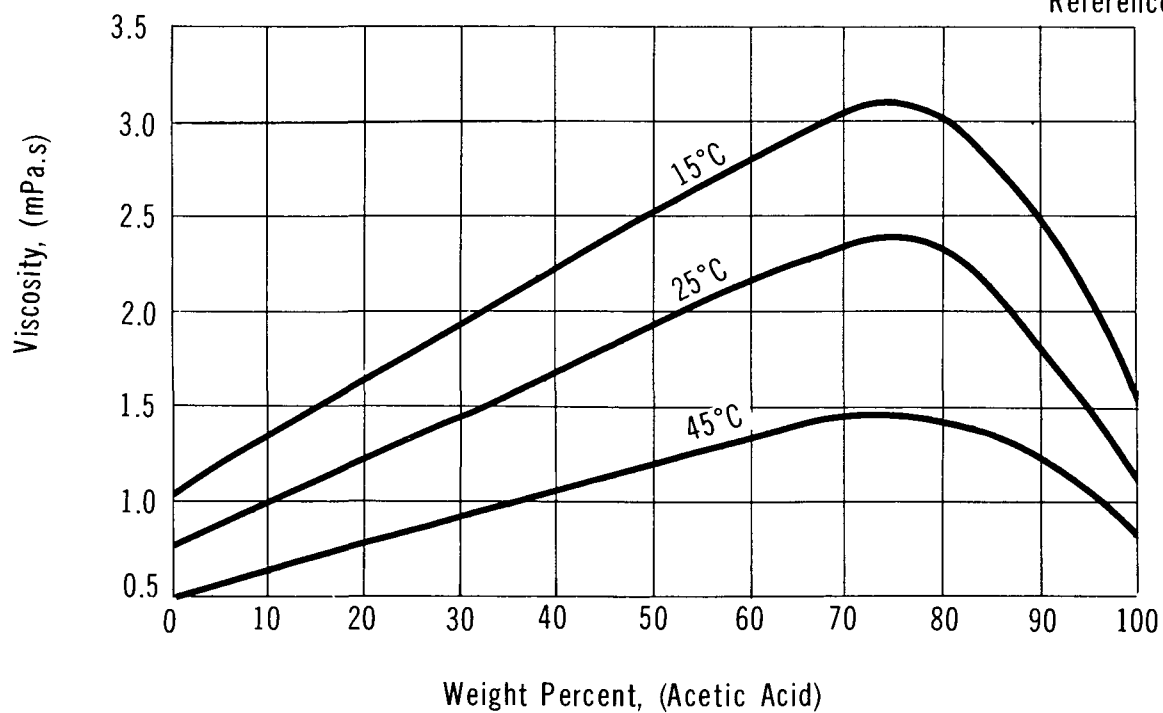


FIGURE 5

ACETIC ACID

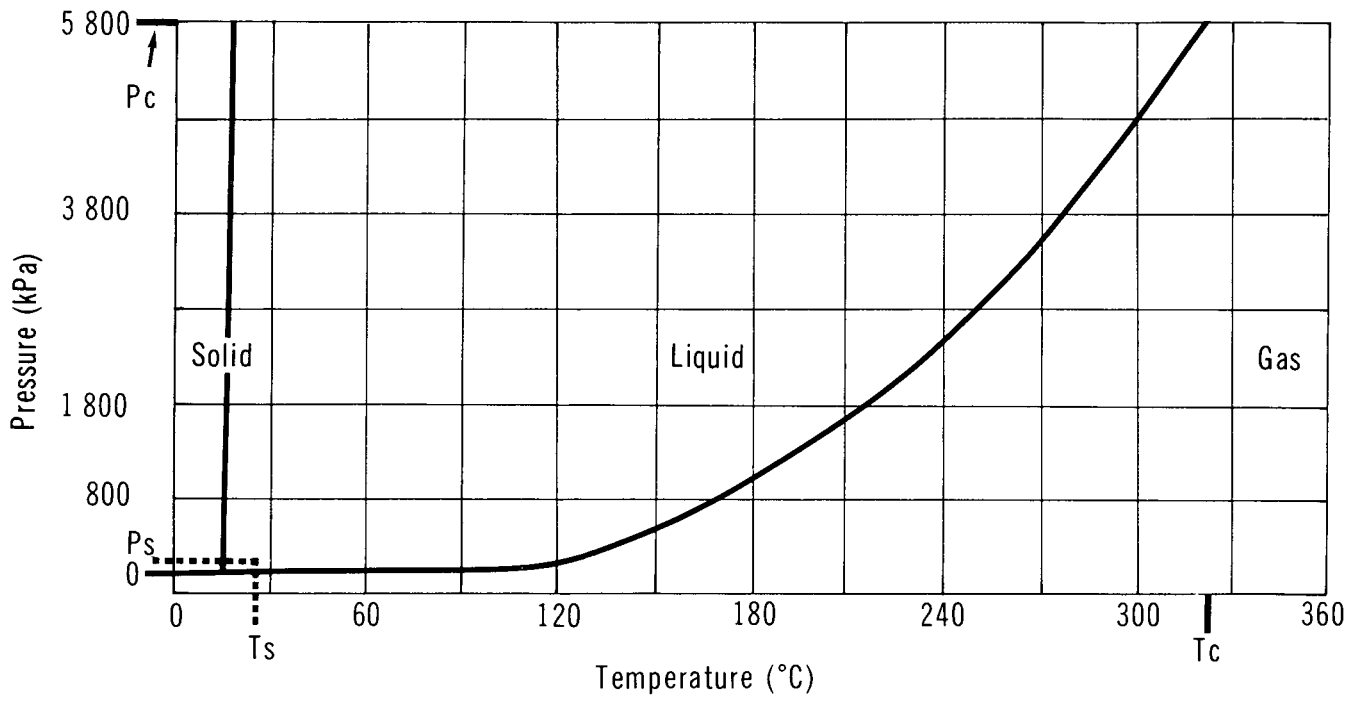
**VISCOSITY OF SOLUTIONS**

Reference: PPH 1984



ACETIC ACID

PHASE DIAGRAM





### 3 COMMERCE AND PRODUCTION

#### 3.1 Grades, Purities (Celanese PB 1976; DPIMR 1983)

Glacial acetic acid is available with a purity of 99.5 to 99.85 percent. The technical grade form is available in solutions of 28, 56, 70, 80 and 92 percent.

#### 3.2 Domestic Manufacturer (CBG 1980; Scott 1979)

Celanese Canada Inc.  
800 Dorchester Blvd. West  
Montreal, Quebec  
H3C 3K8  
(514) 878-1581

#### 3.3 Other Suppliers (Corpus 1983; CBG 1980)

Henkel Chemicals Canada Ltd.  
9550 rue Lawson  
Ville d'Anjou, Quebec  
H1J 1L3  
(514) 353-7550

Ternachem Inc.  
310 Victoria Avenue, Suite 101  
Montreal, Quebec  
H3Z 2M9  
(514) 487-2286

Kingsley and Keith (Canada) Ltd.  
Four Season's Court, P.O. Box 555  
Etobicoke, Ontario  
M9C 5B1  
(416) 626-8383

#### 3.4 Major Transportation Routes

Current Canadian production of acetic acid is located in Edmonton, Alberta. Small amounts of the product are shipped across Canada.

#### 3.5 Production Levels (Corpus 1983)

| Company, Plant Location          | Nameplate Capacity<br>kilotonnes/yr (1982) |
|----------------------------------|--|
| Celanese Canada, Edmonton, Alta. | <u>72.5</u>                                |
| TOTAL                            | <u>72.5</u>                                |
| Domestic Production (1982)       | 64.0                                       |
| Imports (1982)                   | <u>0.4</u>                                 |
| TOTAL SUPPLY                     | <u>64.4</u>                                |

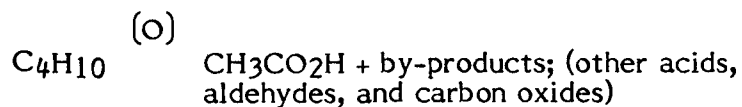
### 3.6 Future Developments (Corpus 1983; CCP 1981)

Celanese Canada is planning a 290 kt/yr acetic acid facility in Edmonton, Alberta, to be completed in the late 1980s.

### 3.7 Manufacture of Acetic Acid (FKC 1975; Kirk-Othmer 1978)

**3.7.1 General.** Acetic acid is currently manufactured by liquid-phase oxidation of butane. Future plans now exist to construct a large plant using a methanol carboxylation process.

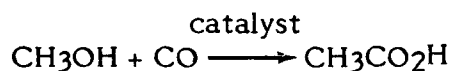
**3.7.2 Process.** Butane is charged to a reactor at high pressure (1000-5500 kPa, 50-250°C), with a solution of cobalt, manganese, or chromium acetate. Air at 5 kg per kg butane is bubbled through this solution:



Acetic acid yield is about 75 percent.

Nitrogen leaving the reactor carries oxidation products and butane; these are condensed and fractionated.

More capacity is planned; this expansion will use methanol and carbon monoxide as feedstock in a methanol carboxylation process. In this reaction, methanol and carbon monoxide are passed over an iodide-based catalyst (nickel iodide, copper or cobalt with iodine, etc.):



### 3.8 Major Uses in Canada (Corpus 1983)

Acetic acid is used in the manufacture of cellulose acetate, vinyl acetate, various other acetates, chloroacetic acid, textile processing, and photochemicals. In 1982, 33 percent of domestic production was used for the manufacture of vinyl acetate, 29 percent was exported, and 26 percent was used in the manufacture of cellulose acetate.

### 3.9 Major Buyers in Canada (Corpus 1983)

Allied Chemical, Montreal, Que.  
 Arliss Chemical, Montreal, Que.  
 C-I-L, Willowdale, Ont.

Canada Colors & Chemicals, Toronto, Ont.  
Christie Chemical, Montreal, Que.  
Harrison & Crosfield, Winnipeg, Man.  
Shefford Chemicals, Granby, Que.  
Signal Chemicals, Toronto, Ont.  
Stanchem, Montreal, Que.  
Uniroyal Chemical, Edmonton, Alta.  
Van Waters & Rogers, Vancouver, B.C.

## 4 MATERIAL HANDLING AND COMPATIBILITY

### 4.1 Containers and Transportation Vessels

**4.1.1 Bulk Shipment.** Acetic acid in glacial and solution form is shipped bulk in specially designed railway tank cars and tank motor vehicles.

**4.1.1.1 Railway tank cars.** Railway tank cars used in the transportation of acetic acid are listed in Table 2. Glacial acetic acid is usually shipped in IIIA60ALW1 railway tank cars as shown in Figure 7. Table 3 indicates railway tank car details associated with this drawing (TCM 1979; RTDCR 1974). The cars are unloaded from the top using compressed air or through the bottom using a pump. During top unloading, the acid is withdrawn through an eduction pipe which extends from the bottom of the tank to the top operating platform where it terminates with a 51 mm (2 in.) unloading connection valve. Air pressure of 103 kPa (15 psi) is applied through the 25 mm (1 in.) air connection valve (MCA 1951). Outside heating coils and fibreglass insulation may be required so that glacial acid will not freeze at common winter temperatures. It is important to note that aluminum cars are commonly used for glacial acetic acid and steel cars for solutions of 90 percent or less (Celanese MSDS 1978).

**4.1.1.2 Tank motor vehicles.** The capacities of tank trucks transporting acetic acid range from 14 900 L (3300 gal.) to 22 500 L (5000 gal.) (Celanese MSDS 1978). Similar to railway tank cars, these highway tankers are unloaded from the top, usually the standpipe being extended down over the back of the tank. Compressed air is used for unloading. The air inlet is usually a 25 mm (1 in.) diameter male threaded connection located at the top of the trailer through which air pressure not exceeding 103 kPa (15 psi) may be applied. Tanks are insulated and have outside heating coils (MCA 1951).

Tank motor vehicles are not specifically regulated under Transport Canada Specifications. Acetic acid solutions are not transported under pressure. Highway tankers must be pressure tested at 155 kPa (22 psi) minimum to allow for the compressed air pressure of 103 kPa (15 psi) used during top unloading. The maximum working pressure of the tanker is in effect 103 kPa (15 psi).

**4.1.2 Packaging.** In addition to bulk shipments, acetic acid is also transported in drums. Drums fabricated from a variety of construction materials are permitted. Table 4 lists drum types and descriptions for acetic acid (TDGC 1980). Glass carboys, boxed or in expanded polyethylene containers, are also used.

TABLE 2 RAILWAY TANK CAR SPECIFICATIONS

| CTC/DOT*<br>Specification<br>Number | Description  |
|-------------------------------------|--|
| 111A60ALW1                          | Aluminum fusion-welded tank without dome. Uninsulated or insulated. 2% minimum outage. Gauging device. Bottom outlet or washout optional. Safety valve (242 kPa) (35 psi) or safety vent (414 kPa) (60 psi). |
| 111A100W6                           | Alloy (stainless) steel fusion-welded tank without dome. Insulated or uninsulated. Gauging device. Top unloading arrangement required. Bottom outlet or washout prohibited. Test pressure 690 kPa (100 psi). |
| 103ALW                              | Aluminum fusion-welded tank with dome. Uninsulated or insulated. 2% dome. Safety valve (242 kPa) (35 psi) or safety vent (414 kPa) (60 psi). Bottom outlet or washout optional.                              |
| 103DW                               | Stainless steel fusion-welded tank with dome. Uninsulated or insulated. 2% dome. Safety valve (242 kPa) (35 psi) or safety vent (414 kPa) (60 psi).  |

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

## 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 1951):

- The vented storage tank must be checked to make sure that it will hold the contents of the car.
- Personnel must not enter the car under any circumstances.
- Brakes must be set, wheels chocked, derails placed and caution placards displayed.
- A safe operating platform must be provided at the unloading point.

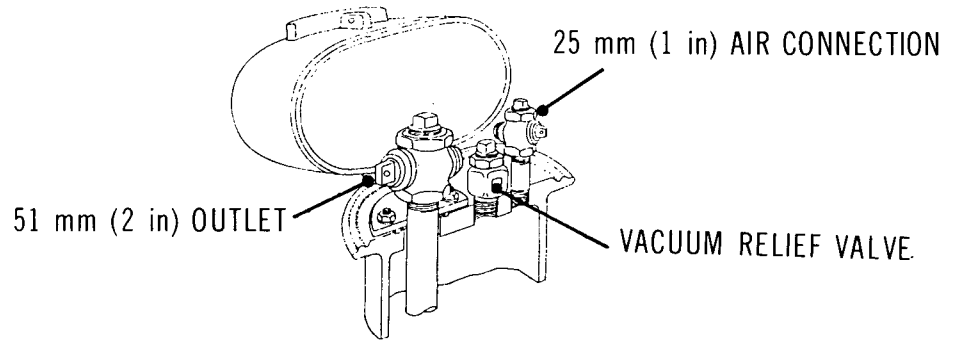
Proceed with off-loading by air pressure as follows (MCA 1951):

- In cold weather, connect the steam coil connection valves indicated in Figure 7 to live steam. Maximum pressure that may be applied is 1035 kPa (150 psi). Vents must be opened before heat is applied.

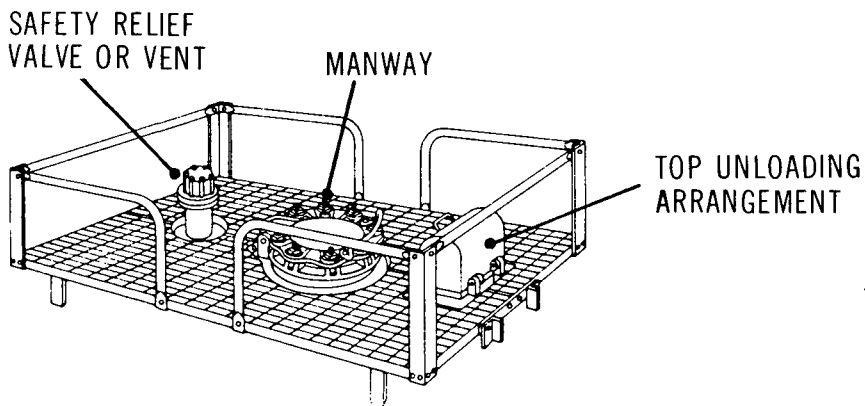
ACETIC ACID

**RAILWAY TANK CAR - CLASS 111A60ALW1**

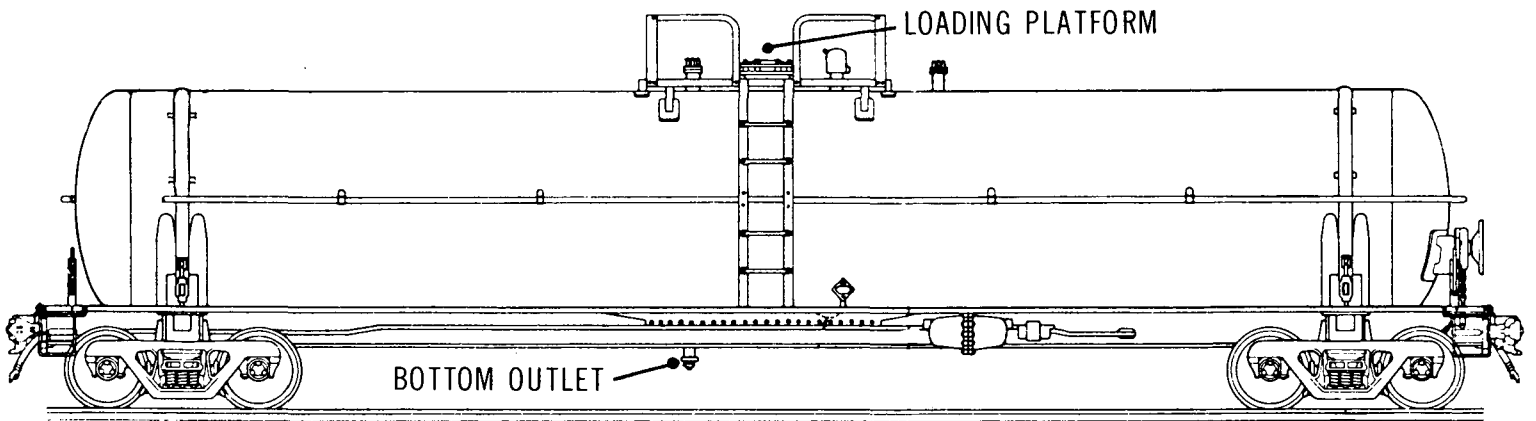
(Reference - TCM 1979; RTDCR 1974)



**Detail of top unloading arrangement**



**Detail of loading platform**



**Illustration of tank car layout**

TABLE 3 TYPICAL RAILWAY TANK CAR SPECIFICATIONS - CLASS 111A60ALW1 (TCM 1979; RTDCR 1974)

| Description                       | Tank Car Size (Imp. Gal.) |               |                      |               |                      |               |
|-----------------------------------|---------------------------|---------------|----------------------|---------------|----------------------|---------------|
|                                   | 16 700                    |               | 17 200               |               | 20 000               |               |
| <u>Overall</u>                    |                           |               |                      |               |                      |               |
| 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.) |
| <u>Tank</u>                       |                           |               |                      |               |                      |               |
| Material                          | Aluminum                  |               | Aluminum             |               | Aluminum             |               |
| 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                 | (108 in.)     |
| Test pressure                     | 414 kPa                   | (60 psi)      | 414 kPa              | (60 psi)      | 414 kPa              | (60 psi)      |
| Burst pressure                    | 1640 kPa                  | (240 psi)     | 1640 kPa             | (240 psi)     | 1640 kPa             | (240 psi)     |
| <u>Approximate Dimensions</u>     |                           |               |                      |               |                      |               |
| 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 centres           | 13 m                      | (42 ft.)      | 13 m                 | (42 ft.)      | 14 m                 | (45 ft.)      |
| Height to 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.)     |
| <u>Loading/Unloading Fixtures</u> |                           |               |                      |               |                      |               |
| <u>Top Unloading</u>              |                           |               |                      |               |                      |               |
| 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.)     |
| <u>Bottom Unloading</u>           |                           |               |                      |               |                      |               |
| Bottom outlet                     | 102-152 mm                | (4-6 in.)     | 102-152 mm           | (4-6 in.)     | 102-152 mm           | (4-6 in.)     |
| <u>Safety Devices</u>             |                           |               |                      |               |                      |               |
| Safety vent or valve              | Safety vent or valve      |               | Safety vent or valve |               | Safety vent or valve |               |
| <u>Dome</u>                       |                           |               |                      |               |                      |               |
| Dome                              | None                      |               | None                 |               | None                 |               |
| <u>Insulation</u>                 |                           |               |                      |               |                      |               |
| Insulation                        | Optional                  |               | Optional             |               | Optional             |               |

TABLE 4 DRUMS

| Type of Drum                               | Designation | Description   | Figure No.<br>(If Any) |
|--|-------------|---|------------------------|
| Steel                                      | 1A1         | Nonremovable head, reusable   | 8                      |
|  | 1A1A        | 1A1 with reinforced chime   | 8                      |
|  | 1A1B        | 1A1 with welded closure flange  | 8                      |
|  | 1A1C        | 1A1 with lead coating   | 8                      |
|  | 1A1D        | 1A1 with coating (other than lead)  | 8                      |
|  | 1A3         | Nonremovable head, single use only  |                        |
| Plastic                                    | 1H1         | Nonremovable head. Maximum capacity 250 L (55 gal.). Maximum net mass 400 kg (880 lb.)                |                        |
| Steel Drums with inner plastic receptacles | 6HA1        | Outer steel sheet in the shape of drum. Inner plastic receptacle. Maximum capacity of 225 L (50 gal.) |                        |
| Monel*                                     | TC5M        |   | 8                      |
| Nickel                                     | TC5K        | Similar to monel drum, only nickel  |                        |

\*See section 4.3 of this report.

- Connect the 51 mm (2 in.) unloading line to the discharge outlet and connect the 25 mm (1 in.) air line. Air pressure must be reduced to 103 kPa (15 psi) for unloading. A safety relief valve must be installed in the air line to release at 121 kPa (17.5 psi).
- After opening the air supply valve, the unloading connection valve can then be opened to unload the car.
- Once the car is empty, the air supply valve must be closed and the vent valve in the air line opened to allow the line pressure to equalize to atmospheric pressure.
- Reverse the above procedure to close up the car.

Proceed with bottom unloading as follows (MCA 1951):

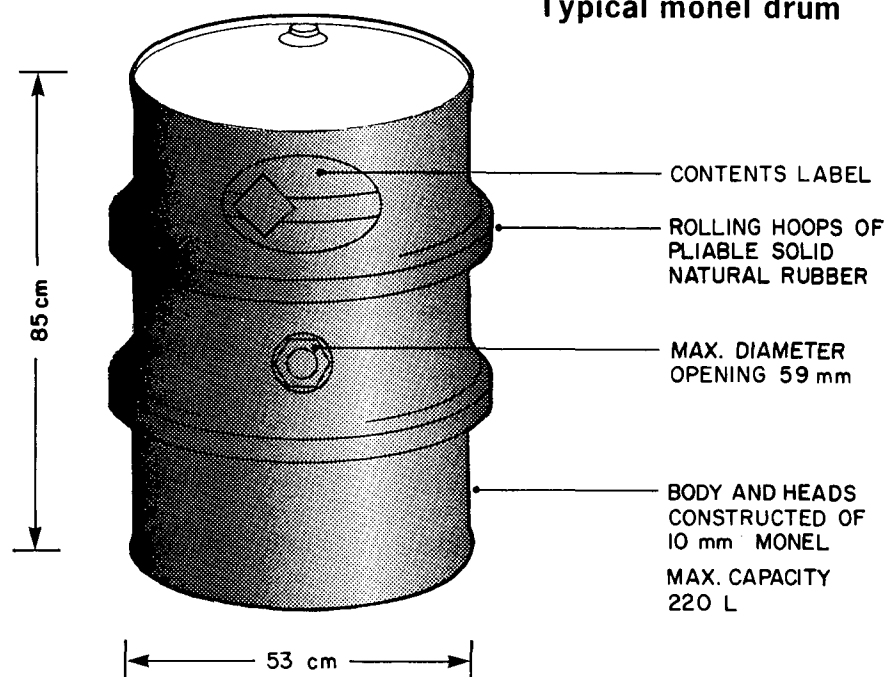
- Connect live steam to the bottom outlet connection as indicated in Figure 7.
- Make sure vents are functioning properly.
- Commence pumping to remove contents.



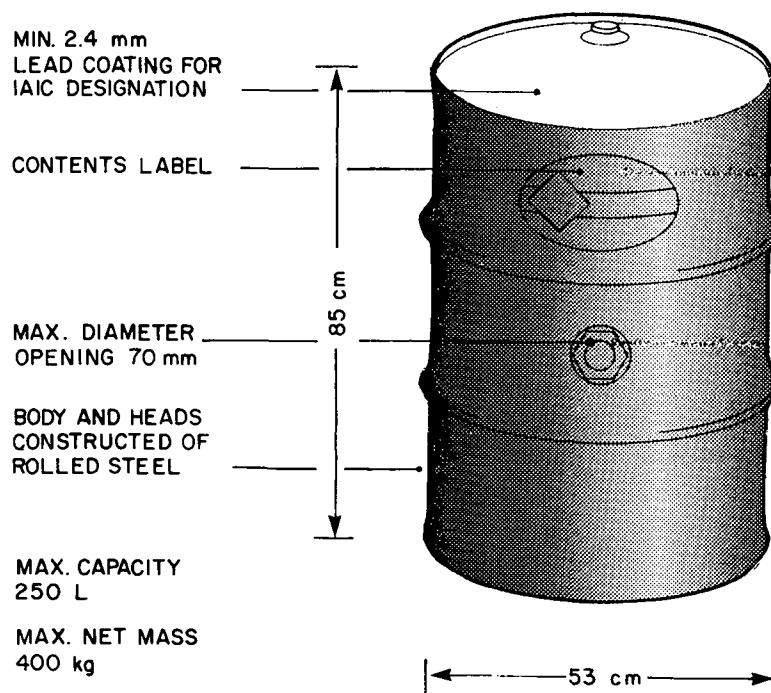
ACETIC ACID

## TYPICAL DRUM CONTAINERS

Typical monel drum



Typical steel drum



**4.2.2 Off-loading Equipment and Procedures for Tank Motor Vehicles.** The unloading of tank trailers is similar to that of railway tank cars. The general procedures for tank cars apply equally well to tank trailers.

**4.2.3 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. It is recognized that other materials may be used for particular applications as indicated in Table 5.

Schedule 40 aluminum or schedule 40 stainless steel 316 pipes and welding fittings are recommended for glacial acetic acid. Aluminum is not recommended for dilute solutions. Flanged joints should be used and these should be welded, because threaded pipes and fittings tend to leak (MCA 1951). The unloading line should be 51 mm (2 in.) pipe because this is the standard fitting on tank cars; however, process pipe may be almost any size. Pipe under 25 mm (1 in.), however, is not recommended. Outdoor lines must be self-draining and may be insulated depending upon acid strength. These can be steam traced with 9 or 13 mm (3/8 or 1/2 in.) copper tubing or steel pipe located inside the insulation (MCA 1951).

Stainless steel pipe and swivel joints may be used for flexible sections at rail car or tank truck unloading stations. Either the ball bearing type swivel joint or the simple stuffing box type will give adequate service with proper maintenance.

Cast iron or cast steel diaphragm valves lined with polyvinylidene chloride resin will serve adequately (DPLV 1972). Refer to Table 5 for other material possibilities.

A single-suction centrifugal pump with wet end material of SS 316 and high silicon cast iron casing is recommended for pumping (MCA 1951). Teflon is a good packing material.

Storage tanks, especially if located outside, should be insulated and equipped with steam coils to keep the acid from freezing (MCA 1951).

### **4.3 Compatibility with Materials of Construction**

The compatibility of acetic acid 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.

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

TABLE 5 COMPATIBILITY WITH MATERIALS OF CONSTRUCTION

| Application           | Chemical |                                | Material of Construction          |                              |                    |                     |
|-----------------------|----------|--------------------------------|-----------------------------------|------------------------------|--------------------|---------------------|
|                       | Conc.    | Temp. (°C)                     | Recommended                       | Conditional                  | Not Recommended    |                     |
| 1. Pipes and Fittings | 10%      | 66                             | PVDC (DCRG 1978)                  |                              |                    |                     |
|                       |          | 93                             | PP (DCRG 1978)                    |                              |                    |                     |
|                       |          | 107                            | PVDF (DCRG 1978)                  |                              |                    |                     |
|                       |          | 121                            | Chlorinated Polyether (DCRG 1978) |                              |                    |                     |
|                       | To 20%   | 23                             |                                   |                              |                    | ABS (DPPED 1967)    |
|                       |          | 24                             |                                   | ABS* (MWPP 1978)             |                    |                     |
|                       |          | 49                             |                                   | PE (DPPED 1967)              |                    |                     |
|                       |          | 60                             |                                   | PVC I<br>PVC II (DPPED 1967) |                    |                     |
|                       |          | To operating limit of material |                                   | PVC I<br>PE (MWPP 1978)      |                    |                     |
|                       | Glacial  |                                |                                   |                              |                    | PE (MWPP 1978)      |
|                       |          | 23                             |                                   |                              | PVC I (DPPED 1967) | PCV II (DPPED 1967) |
|                       |          | 24                             |                                   | PVC I* (MWPP 1978)           |                    |                     |
|                       |          | 49                             |                                   |                              |                    | PVC I (DPPED 1967)  |

TABLE 5 COMPATIBILITY WITH MATERIALS OF CONSTRUCTION  
(Cont'd)

| Application                       | Chemical       |            | Material of Construction  |             |                 |
|-----------------------------------|----------------|------------|---|-------------|-----------------|
|                                   | Conc.          | Temp. (°C) | Recommended   | Conditional | Not Recommended |
| 1. Pipes and Fittings<br>(Cont'd) | Glacial        | 52         | PVDC (DCRG 1978)  |             |                 |
|                                   |                | 66         | PVDF (DCRG 1978)  |             |                 |
|                                   |                | 93         | PP (DCRG 1978)  |             |                 |
|                                   |                | 121        | Chlorinated Polyether (DCRG 1978)                                       |             |                 |
| 2. Valves                         | All, Glacial   | 21         | SS J-20<br>SS 316<br>(JSSV 1979)  |             |                 |
|                                   | Glacial        | Boiling    | SS J-20<br>SS 316<br>(JSSV 1979)  |             |                 |
| 3. Pumps                          | 10%            | 82         | GRP with PTFE "O" Ring  |             |                 |
|                                   | Glacial Dilute | Cold       | All Iron<br>SS 304, SS 316,<br>High Silicon,<br>Cast Iron<br>(HIS 1969) |             |                 |
|                                   | Conc.          | Boiling    | SS 316<br>High Silicon<br>Cast Iron<br>(HIS 1969)                       |             |                 |
| 4. Storage                        | <90%           | Most       | Aluminum  |             |                 |
|                                   | All            | Most       | SS 316, SS 317<br>SS 318,<br>CS Glass-lined<br>(MCA 1951)               |             |                 |
| 5. Others                         | 5-10%          | 20         | SS 302, SS 304,<br>SS 316, SS 410,<br>SS 430 (ASS)                      |             |                 |
|                                   | 10%            | 22         | CPVC (TPS 1978)   |             |                 |

TABLE 5 COMPATIBILITY WITH MATERIALS OF CONSTRUCTION  
(Cont'd)

| Application           | Chemical  |            | Material of Construction                               |                     |   |
|-----------------------|-----------|------------|--|---------------------|---|
|                       | Conc.     | Temp. (°C) | Recommended  | Conditional         | Not Recommended                         |
| 5. Others<br>(Cont'd) | 10%       | 60         | PVC (TPS 1978)   |                     |   |
|                       |           | 82         | PP (TPS 1978)  |                     |   |
|                       |           | 85         |  | CPVC (TPS 1978)     |   |
|                       | Up to 25% | 40         | uPVC, PE, NR*, IIR*, EPDM, CSM* (GF)                   | POM, CR* (GF)       | NBR, FPM (GF)                           |
|                       | Dilute    |            | Si (GPP)   |                     | SBR, NR, CR, IIR, CSM (GPP)             |
|                       | Glacial   | 20         | SS 302, SS 304, SS 316 (ASS)<br>PE, PP, IIR, EPDM (GF) | uPVC, NR*, CR* (GF) | SS 410 (ASS)<br>POM, NBR, FPM, CSM (GF) |
|                       |           | 22         |  |                     | PVC, CPVC (TPS 1978)                    |
|                       |           | 49         | PP (TPS 1978)  |                     |   |
|                       |           | 66         | PVDF (TPS 1978)  | PP (TPS 1978)       |   |
|                       |           | 60         | IIR*, EPDM (GF)  | PE, PP, NR (GF)     | uPVC, POM, NBR, CR, FPM, CSM (GF)       |
|                       |           | Boiling    |  |                     | SS 302, SS 304, SS 316, SS 430 (ASS)    |
|                       |           | 121        |  |                     | PVDF (TPS 1978)                         |
|                       |           |            | EPDM (GPP)   |                     | NR, SBR, CR, NBR, IIR, CSM (GPP)        |

\* This material has been given a lower rating in a similar application by another reference.

TABLE 6 MATERIALS OF CONSTRUCTION

| Abbreviation                    | Material of Construction   |
|---------------------------------|--|
| ABS                             | Acrylonitrile Butadiene Styrene<br>Aluminum<br>Cast Iron, Austenitic<br>Cast Iron, High Silicon<br>Chlorinated Polyether |
| CPVC                            | Chlorinated Polyvinyl Chloride   |
| CR                              | Polychloroprene (Neoprene) Rubber  |
| CS                              | Carbon Steel   |
| CSM                             | Chlorosulphonated Polyethylene (Hypalon)   |
| EPDM                            | Ethylene Propylene Rubber  |
| FPM                             | Fluorine Rubber (Viton)<br>Glass<br>Glass Reinforced Vinyl Ester<br>Iron   |
| IIR                             | Isobutylene/Isoprene (Butyl) Rubber  |
| NBR                             | Acrylonitrile/Butadiene (Nitrile, Buna N) Rubber   |
| NR                              | Natural Rubber<br>Nickel<br>Nickel-Copper Alloy (Monel)  |
| PE                              | Polyethylene   |
| POM                             | Polyoxymethylene   |
| PP                              | Polypropylene  |
| PTFE                            | Polytetrafluoroethylene (Teflon)   |
| PVC (Followed by grade, if any) | Polyvinyl Chloride   |
| PVDC                            | Polyvinylidene Chloride (Saran)  |
| PVDF                            | Polyvinylidene Fluoride  |
| SBR                             | Styrene/Butadiene (GR-5, Buna S) Rubber  |
| Si                              | Silicon  |
| SS (Followed by grade)          | Stainless Steel<br>"20" Alloy (Durimet 20, Carpenter 20)   |
| uPVC                            | Unplasticized Polyvinyl Chloride   |

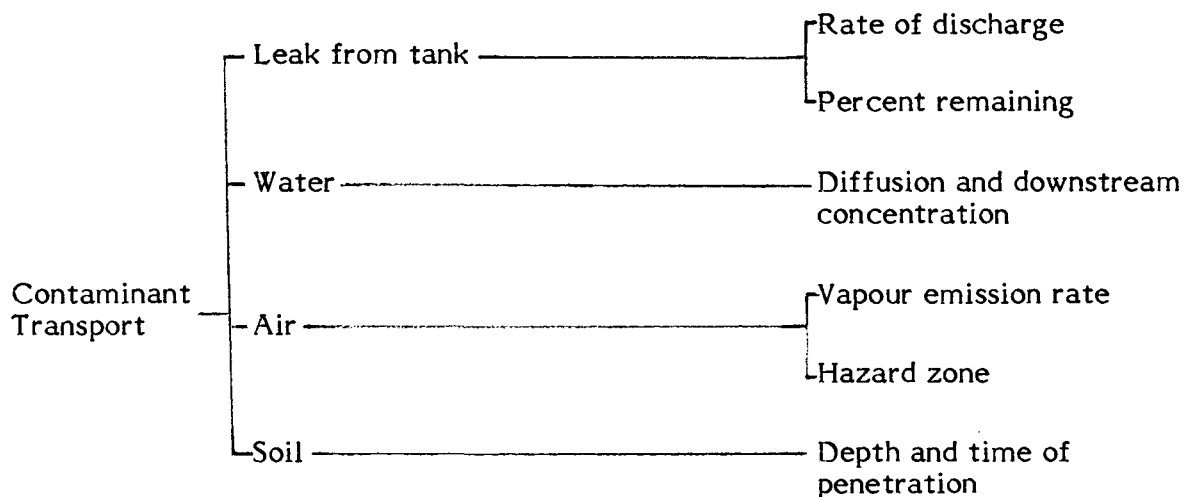
## 5 CONTAMINANT TRANSPORT

### 5.1 General Summary

Acetic acid is transported in glacial or solution forms. When spilled in water, all forms will mix rapidly; the heat of reaction may produce significant amounts of vapour. When spilled on soil, the liquid will spread on the surface and penetrate into the soil at a rate dependent on the soil type and its water content. Downward transport of the liquid toward the groundwater table may be an environmental problem.

Acetic acid is a liquid with a relatively low volatility; however, the vapour released from a liquid pool on the ground surface may be a potential environmental hazard.

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



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 and to some extent inconsistent. As well as producing worst case scenarios, this approach allows comparison of the behaviours of different chemicals under consistent assumptions.

### 5.2 Leak Nomograms

**5.2.1 Introduction.** Acetic acid is commonly transported in specially designed railway tank cars as a nonpressurized liquid. While the capacities of the tank cars vary

widely, one tank car size has been chosen throughout the EnviroTIPS series 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.

If a tank car loaded with acetic acid is punctured on 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 venting rate of the liquid. Because of the relatively low volatility of acetic acid and the fact that the tank cars are not pressurized, no leak nomograms have been prepared for vapour release from a puncture in the top of the tank.

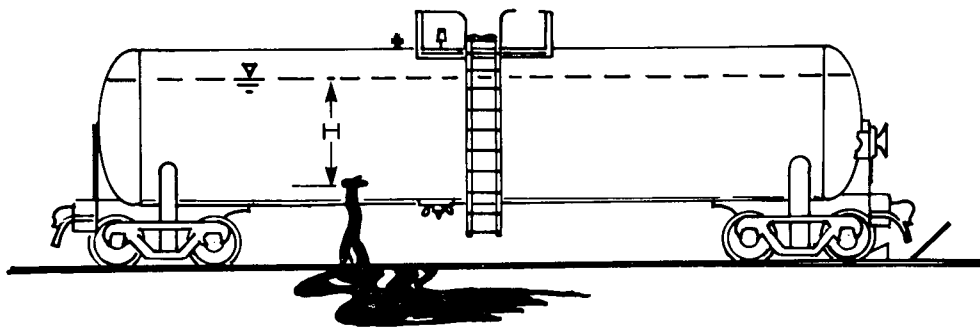


FIGURE 9 TANK CAR WITH PUNCTURE HOLE IN BOTTOM

## 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 (2.75 m  $\phi$  x 13.4 m long) is assumed to be initially full (at  $t=0$ ) with a volume of about 80 000 L of acetic acid. 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

ACETIC ACID

PERCENT REMAINING  
VS TIME

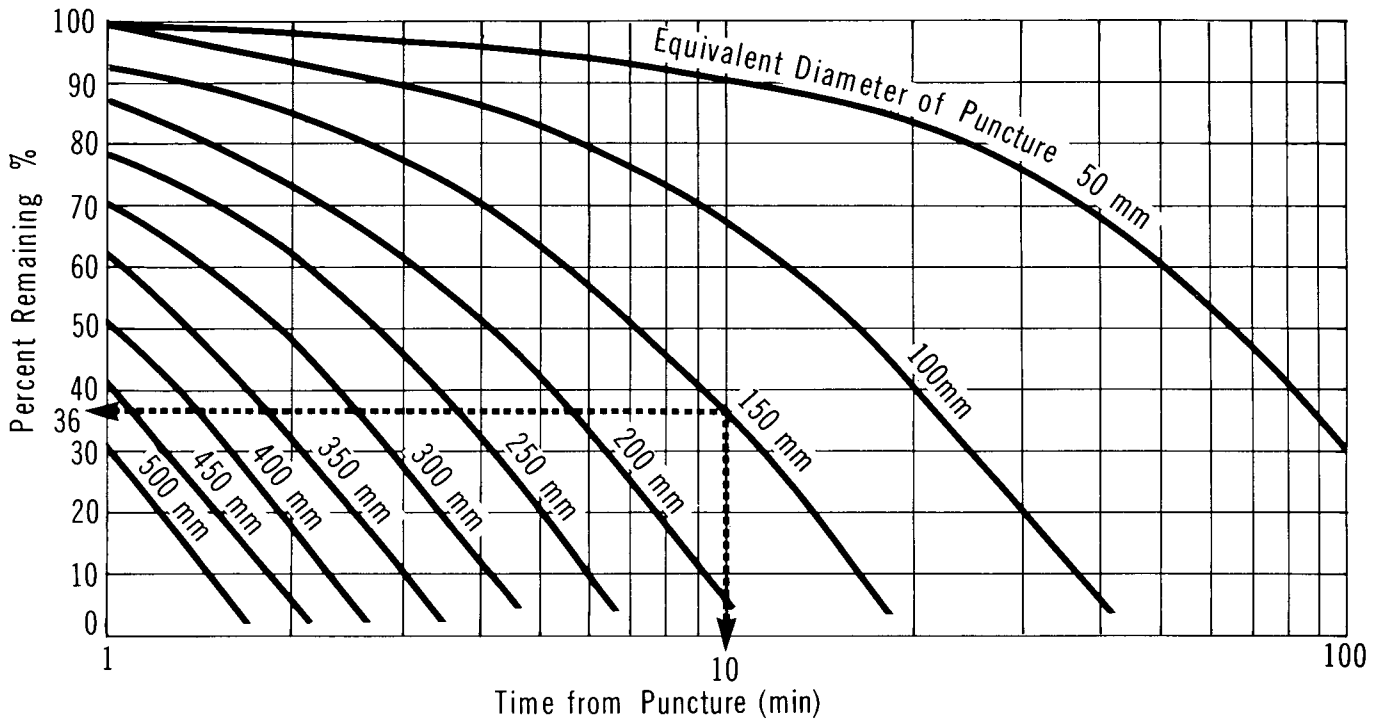
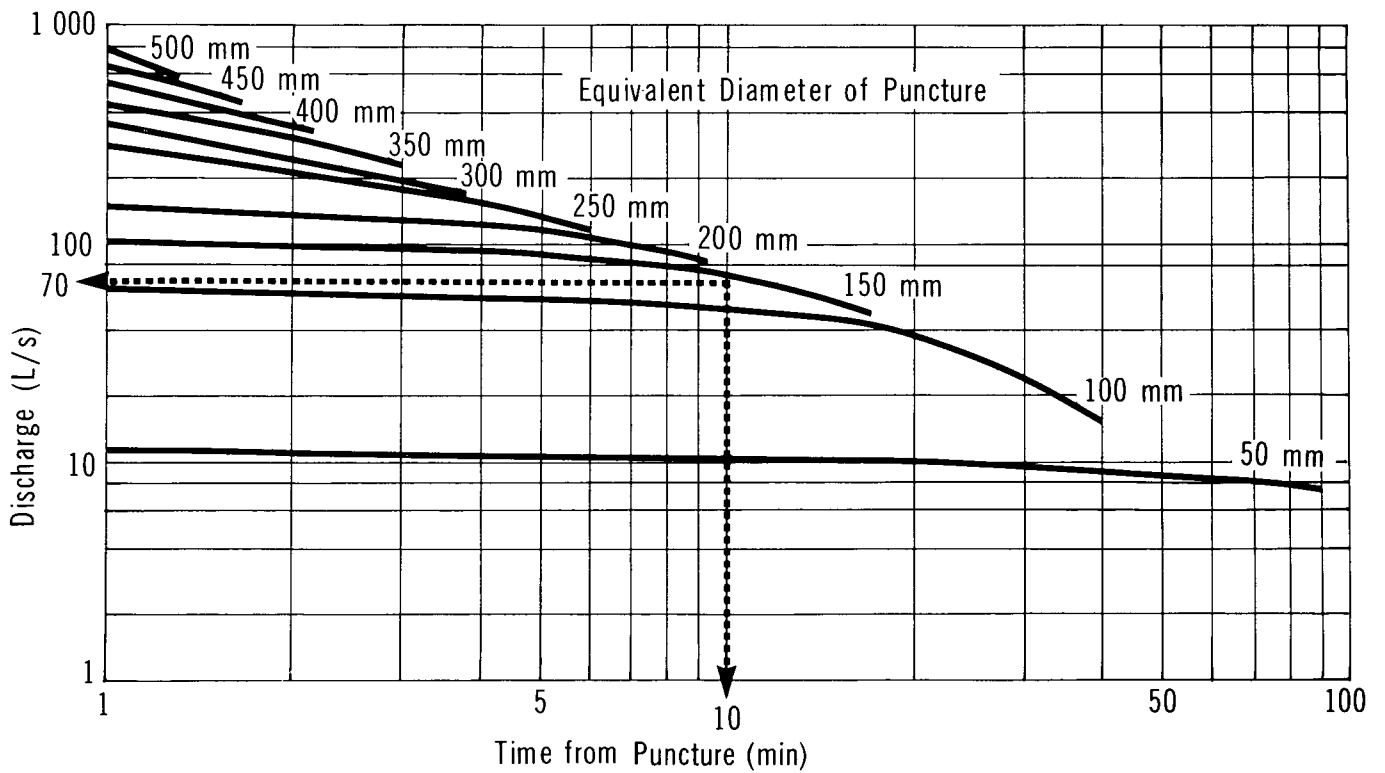


FIGURE 11

ACETIC ACID

DISCHARGE RATE  
VS TIME



### 5.2.3 Sample Calculations.

#### i) Problem A

The standard tank car filled with acetic acid has been punctured on the bottom. The equivalent diameter of the hole is 150 mm. What percent of the initial 80 000 L remains after 10 minutes?

#### Solution

- . Use Figure 10
- . With  $t=10$  min and  $d=150$  mm, the amount remaining is about 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 acetic acid is a relatively nonvolatile liquid, 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.

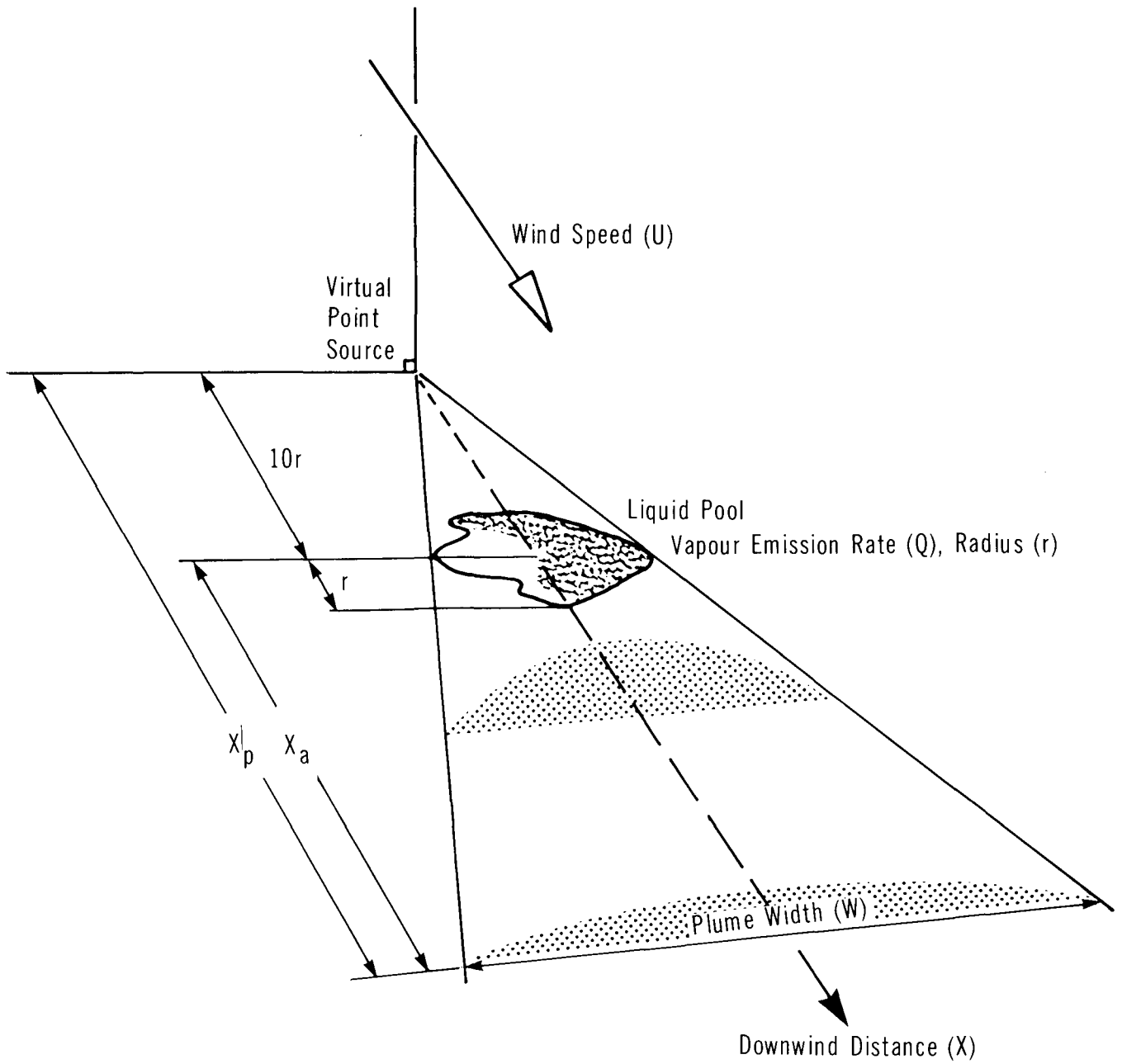
To estimate the vapour concentrations downwind of the accident site for the determination of the flammability or toxicity hazard zone, the atmospheric transport and dispersion of the contaminant vapour must be modelled. The models used here are based on Gaussian formulations and are the ones most widely 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 12 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.

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## SCHEMATIC OF CONTAMINANT PLUME



The following nomograms and data tables are contained in this section (to be used in the 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

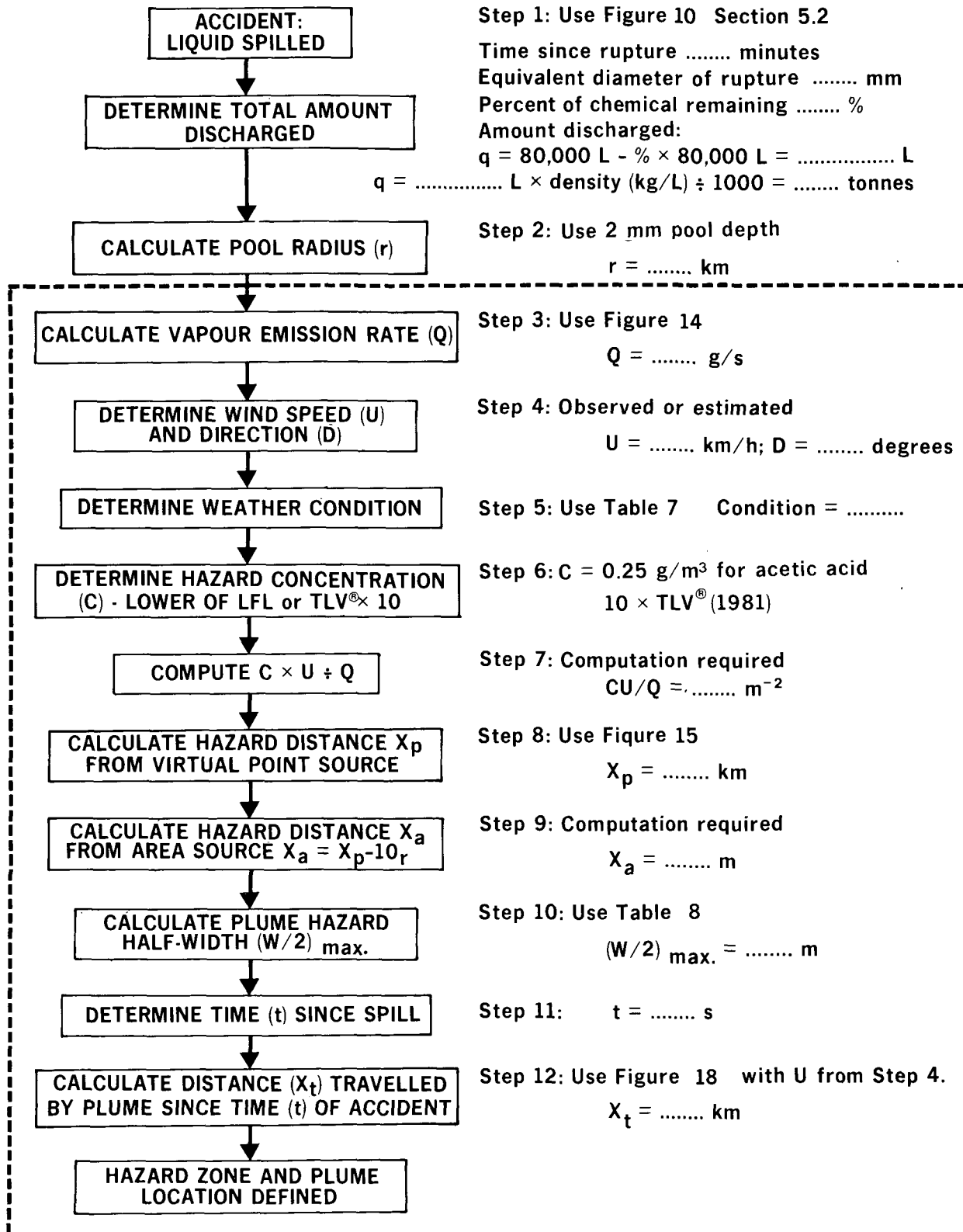
The flowchart given in Figure 13 outlines the steps necessary to make vapour dispersion calculations and identifies the nomograms or tables to be used. This section deals only with the portion contained within the dashed box. Data on "total liquid discharged" is contained in Section 5.2. A description of each vapour dispersion nomogram and its use follows.

**5.3.2.1 Figure 14: Vapour emission rate versus liquid pool radius for various temperatures.** An evaporation rate for acetic acid (as glacial) has been calculated employing the evaporation rate equations contained in the Introduction Manual. The computed evaporation rate for glacial acetic acid at 20°C and a wind speed of 4.5 m/s (16.1 km/h) is 0.24 g/(m<sup>2</sup>s). Evaporation rates at other temperatures have been calculated using the evaporation rate equation which, at given wind speed, is dependent on ambient temperature and the vapour pressure (Perry 1973) of acetic acid at that temperature. For example, evaporation rates of 0.077 g/(m<sup>2</sup>s) at 0°C and 0.42 g/(m<sup>2</sup>s) at 30°C were calculated for a wind speed of 4.5 m/s.

Use: For a pool of acetic acid of known radius, the rate (Q) at which acetic acid vapour is released to the atmosphere at a given temperature can then be estimated from Figure 14. The solid portions of the curves represent spills of 0.05 to 84 tonnes, the latter representing about one standard 80 000 L rail car load of acetic acid. 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 acetic acid vapour emission rates at other wind speeds. The Introduction Manual contains the appropriate equation to convert the evaporation rate at 4.5 m/s to an evaporation rate at another wind speed should it be desired.

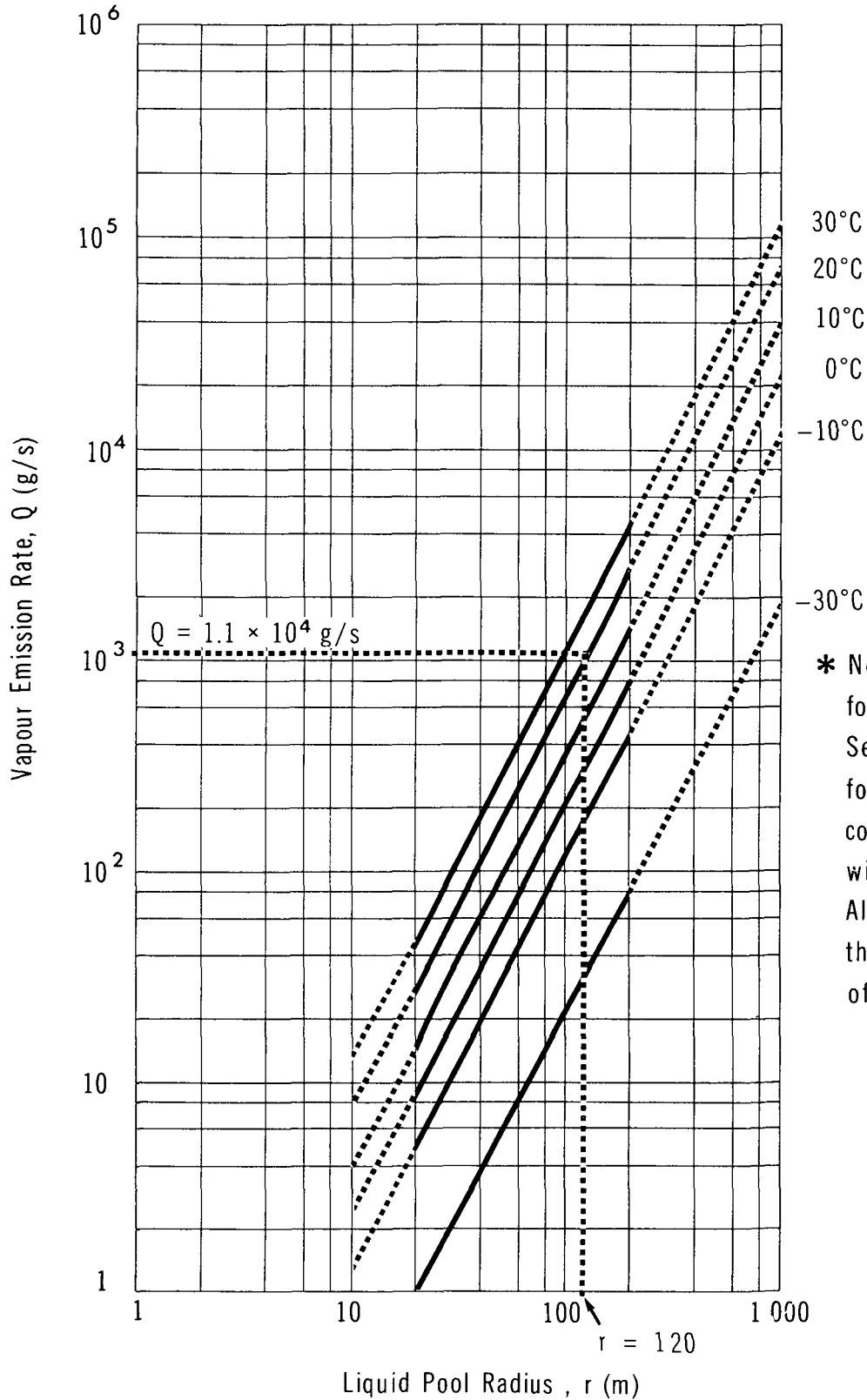
It should also be noted that the determination of the emission rate is based on the spill radius on calm water (Table T1, CHRIS 1974). The spill radius employed was

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**FLOW CHART TO DETERMINE  
VAPOUR HAZARD ZONE**


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VAPOUR EMISSION RATE VS LIQUID POOL 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 0.05 to 84 tonnes.

arbitrarily chosen as an intermediate value between that of benzene (a moderately volatile liquid) and that of iso-amyl nitrite (a nonvolatile liquid). This model situation was chosen to apply for water-soluble liquids with boiling points above ambient temperature, and to a limited number of water-soluble and water-insoluble organic liquids that are not treated by CHRIS (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 would be overestimated and worst case values are provided.

**5.3.2.2 Figure 15: Normalized 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.

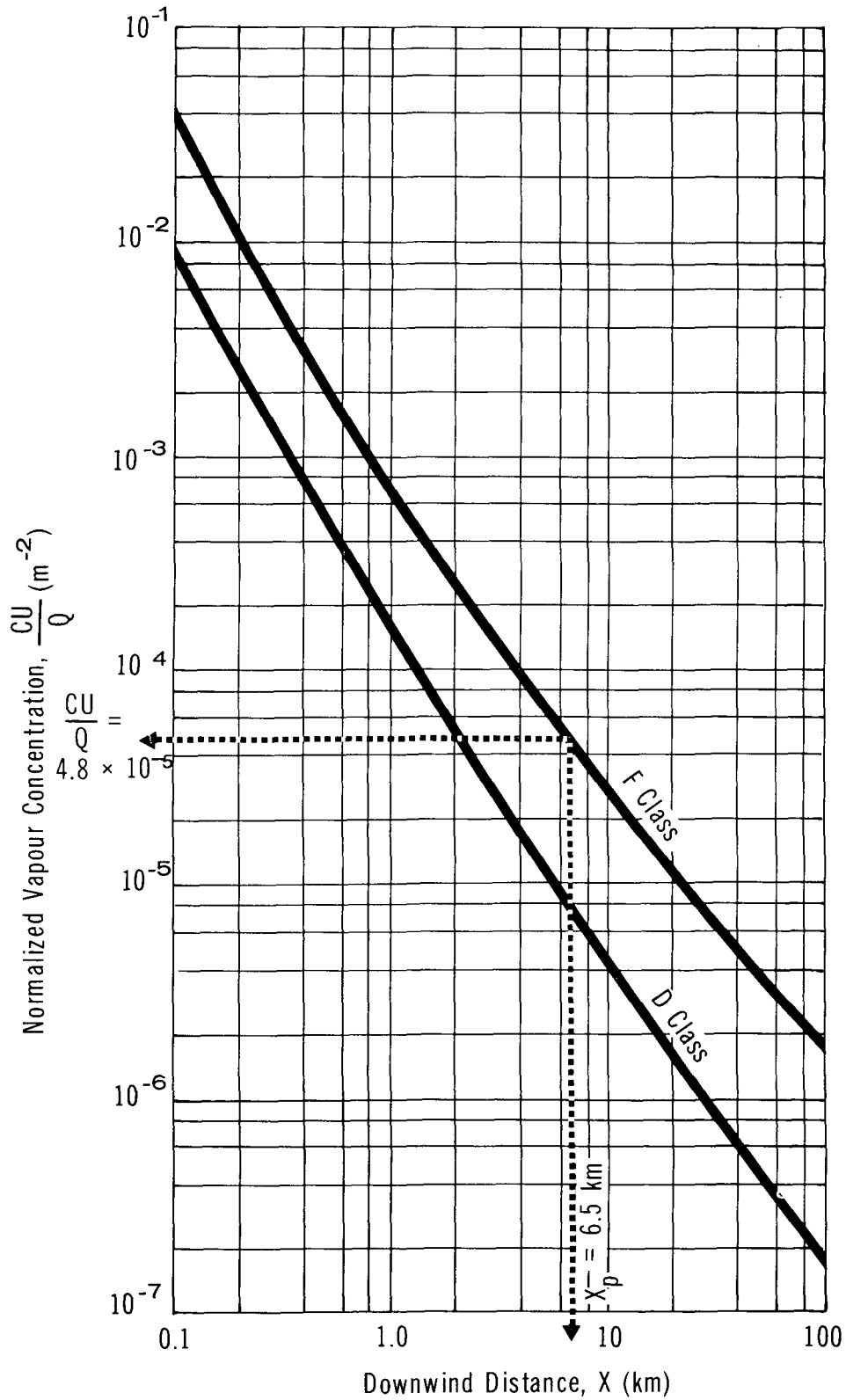
TABLE 7 WEATHER CONDITIONS

| Weather Condition F   | Weather Condition D          |
|---|------------------------------|
| Wind speed <11 km/h ( $\approx 3$ m/s)<br>and one of the following:<br>- overcast day<br>- night time<br>- severe temperature inversion | All other weather conditions |

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

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NORMALIZED VAPOUR CONCENTRATION  
VS DOWNWIND DISTANCE



- the hazard concentration limit,  $C$ , which is the lower value of 10 times the Threshold Limit Value (TLV<sup>®</sup>, in  $\text{g}/\text{m}^3$ ), or the Lower Flammability Limit (LFL, in  $\text{g}/\text{m}^3$ ). Note: To convert the TLV<sup>®</sup> (in ppm) and the LFL (in percent by volume) to concentrations in  $\text{g}/\text{m}^3$ , use Figures 16 and 17

A hazard concentration limit of 10 times the TLV<sup>®</sup> 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<sup>®</sup> is a workplace standard for long-term exposure and use of this value as the hazard limit would result in unrealistically large hazard zones.

**5.3.2.3 Table 8: Maximum plume hazard half-widths.** This table presents data on the maximum plume hazard half-width,  $(W/2)_{\text{max}}$ , 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 acetic acid Threshold Limit Value (TLV<sup>®</sup>) of  $0.025 \text{ g}/\text{m}^3$ , or  $0.25 \text{ g}/\text{m}^3$ . The maximum plume hazard half-width represents the maximum half-width of the acetic acid vapour cloud, downwind of the spill site, corresponding to a hazard concentration limit of  $10 \times \text{TLV}^{\circ}$ . Table 8 is therefore only applicable for an acetic acid hazard concentration limit of  $10 \times \text{TLV}^{\circ}$  or  $0.25 \text{ g}/\text{m}^3$ . 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 3000 to 1 600 000 g/s, corresponding to acetic acid spills in the range of about 3 to greater than 8000 tonnes, respectively. If the entire contents of an 80 000 L (17 600 Imp. gal.) tank car spill, the mass spilled would be 84 000 kg or approximately 84 tonnes. Therefore, under Class D of Table 8, data are provided for up to greater than 95 times this amount.

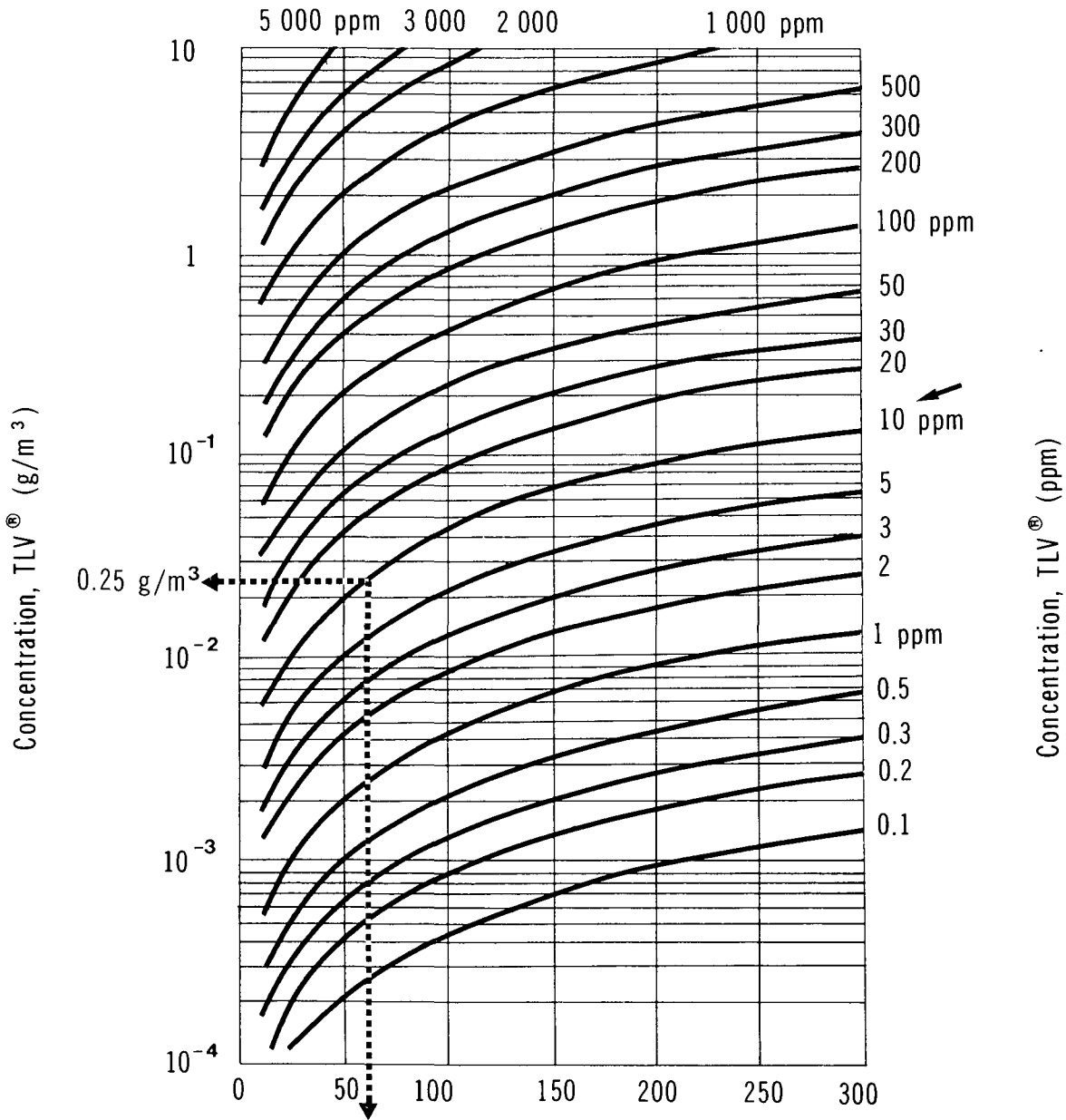
Under weather condition F, the wind speed ( $U$ ) range applicable is 1 to 3 m/s. The range of vapour emission rates ( $Q$ ) used was 300 to 165 000 g/s, corresponding to acetic acid spills in the range of about 0.05 to 1500 tonnes, respectively. Therefore, under class F of Table 8, data are provided for up to 17 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  $(W/2)_{\text{max}}$ , the maximum plume hazard half-width, in metres. (For an intermediate value, interpolate  $Q/U$  and  $(W/2)_{\text{max}}$  values.) Also refer to the example at the bottom of Table 8.

**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

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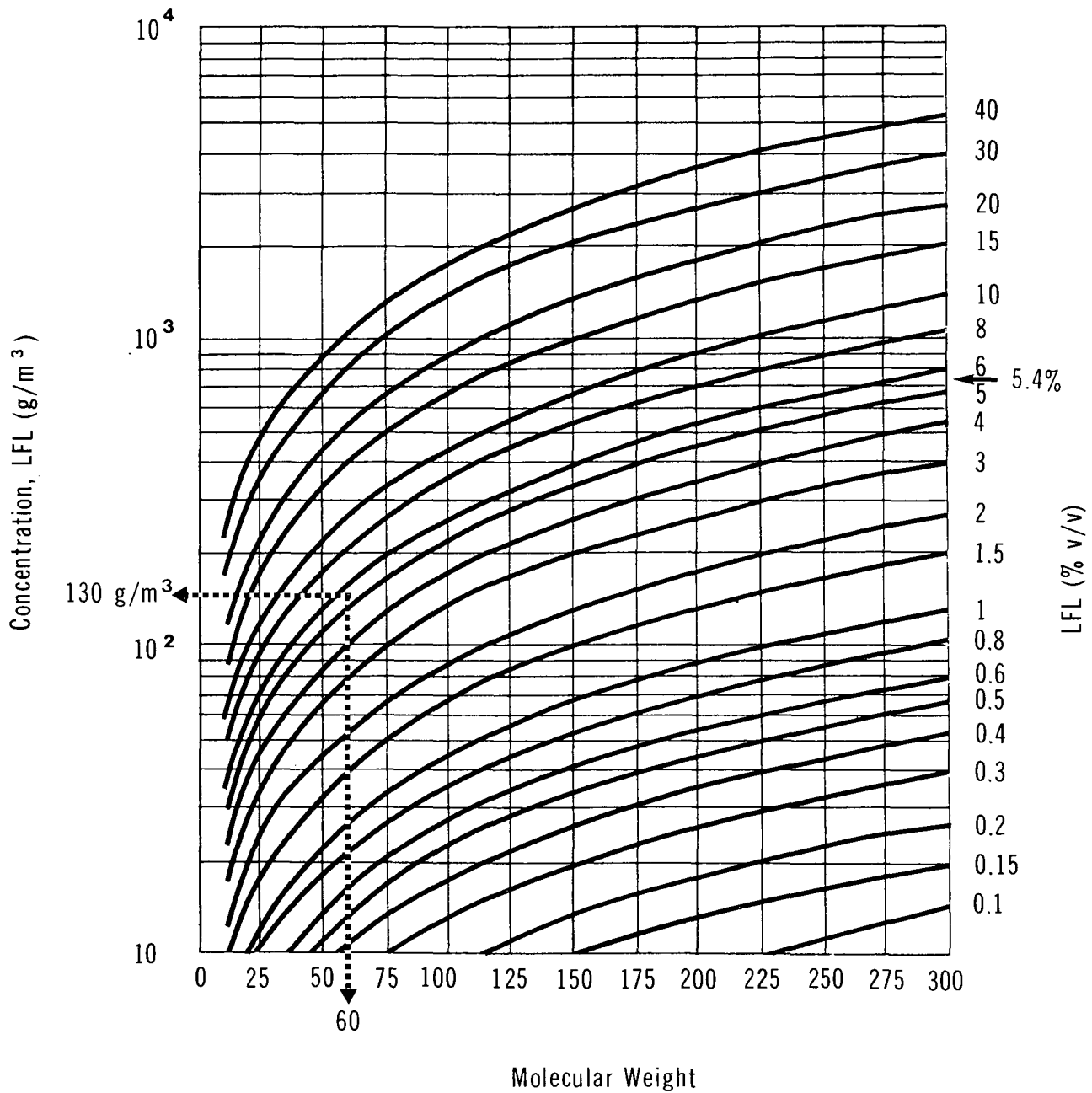
CONVERSION OF THRESHOLD LIMIT VALUE  
(TLV®) UNITS (ppm to g/m³)



Molecular Weight  
Example: Acetic acid MW = 60, TLV® = 10 ppm,  
then TLV® in g/m³ = 0.25

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

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**CONVERSION OF LOWER FLAMMABILITY  
LIMIT (LFL) UNITS (volume % to g/m<sup>3</sup>)**


Example: Acetic acid, MW = 60, LFL = 5.4%, then LFL in g/m<sup>3</sup> = 130

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

TABLE 8            MAXIMUM PLUME HAZARD HALF-WIDTHS (FOR ACETIC ACID AT 20°C)

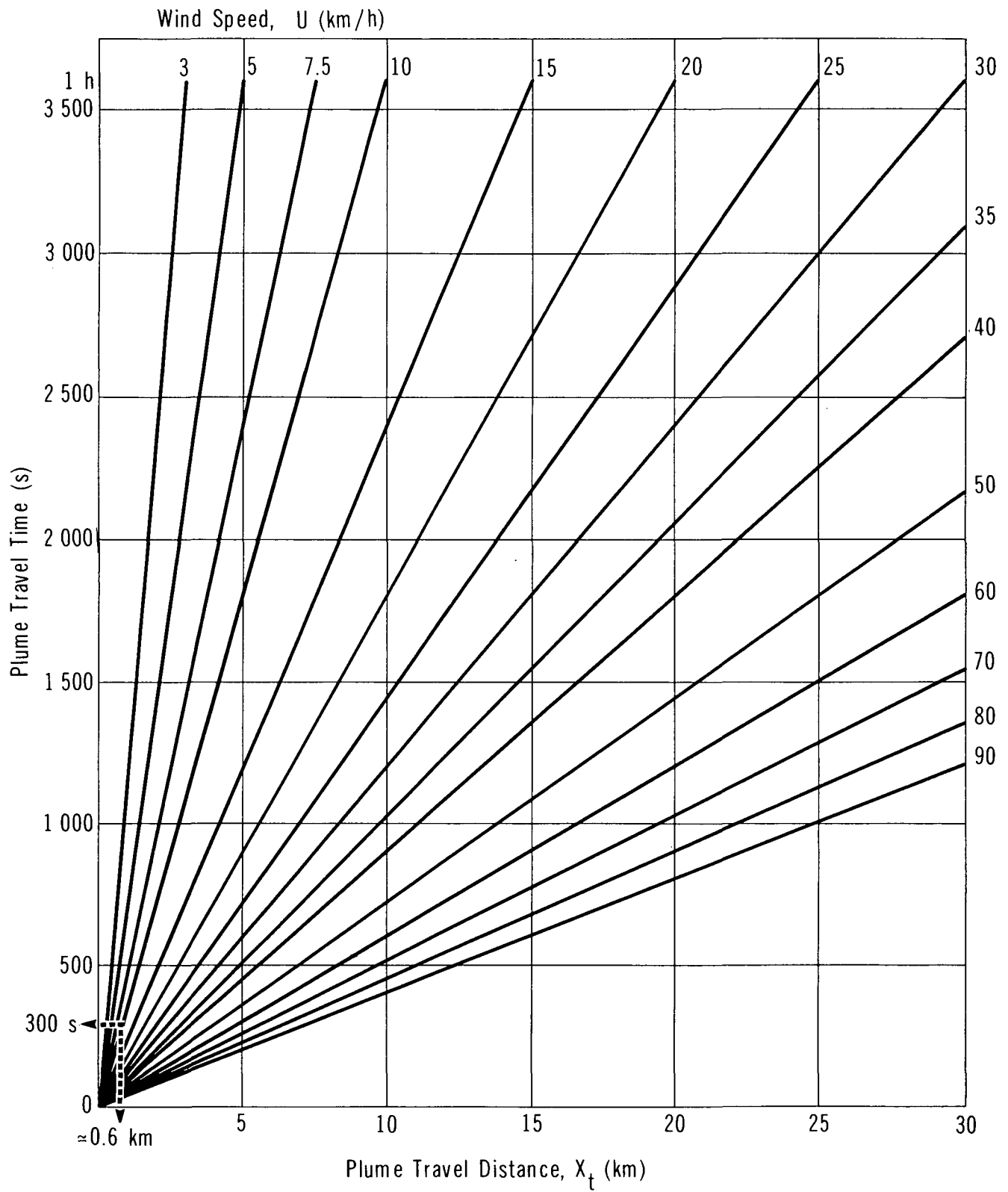
| Weather Condition D |                             |              | Weather Condition F |                             |                                |
|---------------------|-----------------------------|--------------|---------------------|-----------------------------|--------------------------------|
| Q/U<br>(g/m)        | (W/2) <sub>max</sub><br>(m) |              | Q/U<br>(g/m)        | (W/2) <sub>max</sub><br>(m) |                                |
| 1 600 000           | 3245                        | (99.5 km)*   | 165 000             | 1540                        | (99.5 km)*                     |
| 1 400 000           | 2985                        |              | 150 000             | 1430                        |                                |
| 1 200 000           | 2715                        |              | 125 000             | 1250                        |                                |
| 1 000 000           | 2425                        |              | 100 000             | 1060                        |                                |
| 800 000             | 2110                        |              | 75 000              | 855                         |                                |
| 600 000             | 1770                        |              | 50 000              | 630                         |                                |
| 500 000             | 1580                        |              | 40 000              | 535                         |                                |
| 400 000             | 1375                        |              | 30 000              | 430                         |                                |
| 300 000             | 1150                        |              | 25 000              | 375                         |                                |
| 200 000             | 895                         |              | 20 000              | 325                         |                                |
| 150 000             | 750                         |              | 15 000              | 270                         |                                |
| 125 000             | 670                         |              | 10 000              | 210                         |                                |
| 100 000             | 585                         | Q/U = 5240 → | 5 000               | 135                         | → (W/2) <sub>max</sub> = 140 m |
| 75 000              | 500                         |              | 2 000               | 75                          |                                |
| 50 000              | 395                         |              | 1 000               | 50                          |                                |
| 25 000              | 260                         |              | 500                 | 35                          |                                |
| 20 000              | 230                         |              | 200                 | 20                          |                                |
| 15 000              | 195                         |              | 100                 | 15                          |                                |
| 10 000              | 155                         |              |                     |                             |                                |
| 5 000               | 100                         |              |                     |                             |                                |
| 2 000               | 60                          |              |                     |                             |                                |
| 1 000               | 40                          |              |                     |                             |                                |
| 500                 | 30                          |              |                     |                             |                                |
| 200                 | 20                          |              |                     |                             |                                |
| 100                 | 15                          |              |                     |                             |                                |

\* Data are provided up to a maximum downwind hazard distance of 100 km

**Example:** A spill releasing acetic acid vapour at the rate of  $Q = 1.1 \times 10^4$  g/s under weather condition F and a wind speed  $U = 2.1$  m/s means  $Q/U = 5240$  g/m which results in a maximum plume hazard half-width  $(W/2)_{\max} = 140$  m.

**Note:** Above table is valid only for an acetic acid concentration of  $10 \times \text{TLV}^{\circ}$ , or  $0.25$  g/m<sup>3</sup>.

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**PLUME TRAVEL TIME  
VS TRAVEL DISTANCE**

speeds (U). This is simply the graphical presentation of the relationship  $X_t = Ut$  for a range of typical wind speeds.

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 acetic acid. 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 acetic acid 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 the pool radius (r) for a spill of 20 tonnes
- Use observed (measured) pool radius if possible. If not, use the maximum radius calculated assuming a 2 mm spill thickness
  - Radius (r) =  $120 \text{ m} \div 1000 = 0.12 \text{ km}$
- Step 3: Calculate the vapour emission rate (Q) at  $T = 20^\circ\text{C}$
- From Figure 14, for  $r = 120 \text{ m}$  and  $T = 20^\circ\text{C}$ ,  $Q = 1.1 \times 10^4 \text{ g/s}$
- Step 4: Determine the wind speed (U) and direction (D)
- Use available weather information, preferably on-site observations
  - Given:
    - $U = 7.5 \text{ km/h}$ , then  $U = 7.5 \div 3.6 = 2.1 \text{ m/s}$
    - $D = \text{NW or } 315^\circ$  (D = Direction from which wind is blowing)
- Step 5: Determine the weather condition
- From Table 7, weather condition = F since U is less than 11 km/h and it is night

- Step 6: Determine the hazard concentration limit (C)
- This is the lower of 10 times the TLV<sup>®</sup>, or the LFL, so for acetic acid  
 $C = 0.25 \text{ g/m}^3$  (TLV<sup>®</sup> =  $0.025 \text{ g/m}^3$ ; LFL =  $130 \text{ g/m}^3$ )
- Step 7: Compute CU/Q
- $CU/Q = \frac{0.25 \times 2.1}{1.1 \times 10^4} = 4.77 \times 10^{-5} \text{ m}^{-2}$
- Step 8: Calculate the downwind distance ( $X_p$ ) from the virtual point source
- From Figure 15, with  $CU/Q = 4.8 \times 10^{-5} \text{ m}^{-2}$  and weather condition F,  
 $X_p \approx 6.5 \text{ km}$
- Step 9: Calculate the hazard distance ( $X_a$ ) downwind of the area source
- With  $X_p = 6.5 \text{ km}$  and  $r = 0.12 \text{ km}$ , then  
 $X_a = X_p - 10 r = 6.5 \text{ km} - 10 (0.12 \text{ km}) = 5.3 \text{ km}$
- Step 10: Calculate the plume hazard half-width ( $(W/2)_{\max}$ )
- Use Table 8
  - With  $Q = 1.1 \times 10^4 \text{ g/s}$  and  $U = 2.1 \text{ m/s}$   
then  $Q/U = \frac{1.1 \times 10^4}{2.1} = 5240 \text{ g/m}$
  - Then for weather condition F, the closest  $Q/U$  value is between 5000 and 10 000 g/m, which gives  $(W/2)_{\max} \approx 140 \text{ m}$
- Step 11: Determine the time since the spill
- $t = 5 \text{ min} \times 60 = 300 \text{ s}$
- Step 12: Calculate the distance travelled ( $X_t$ ) by the vapour plume since the time of the accident
- Using Figure 18, with  $t = 300 \text{ s}$  and  $U = 7.5 \text{ km/h}$ , then  $X_t = 0.6 \text{ km}$  (more accurately from  $Ut = 2.1 \text{ m/s} \times 300 \text{ s} = 630 \text{ m} = 0.63 \text{ km}$ )
- Step 13: Map the hazard zone
- This is done by drawing a rectangular area with dimensions of twice the maximum plume hazard half-width (140 m) by the maximum hazard distance downwind of the area source (5.3 km) along the direction of the wind, as shown in Figure 19
  - If the wind is reported to be fluctuating by  $20^\circ$  about  $315^\circ$  (or from  $315^\circ \pm 10^\circ$ ), the hazard zone is defined as shown in Figure 20
  - 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 37 minutes before the plume reaches the maximum downwind hazard distance of 5.3 km

ACETIC ACID

**HAZARD AREA FOR STEADY WINDS, EXAMPLE PROBLEM**

Wind U = 7.5 km/h from 315° (NW)

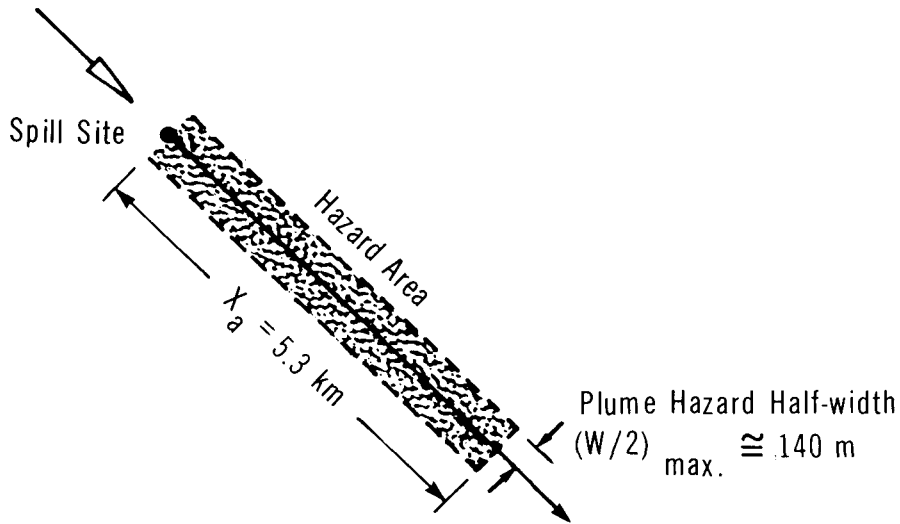
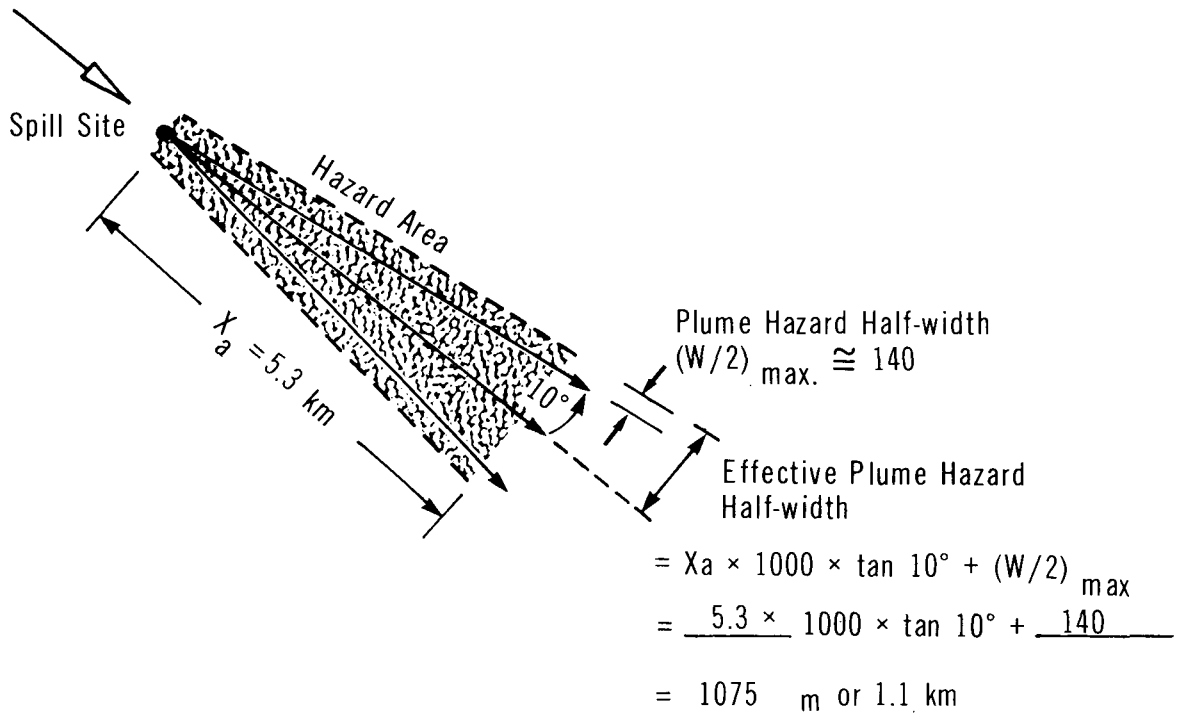


FIGURE 20

ACETIC ACID

**HAZARD AREA FOR UNSTEADY WINDS, EXAMPLE PROBLEM**

Wind U = 7.5 km/h from  $315^\circ \pm 10^\circ$





## 5.4 Behaviour in Water

**5.4.1 Introduction.** When spilled on a water surface, acetic acid mixes rapidly and the spill is diluted. This mixing can generally be described by classical diffusion equations with one or more diffusion coefficients. In rivers, the principal mixing agent is stream turbulence, while in calm water mixing takes place by molecular diffusion.

To estimate pollutant concentration in a river downstream from a spill, the turbulent diffusion has been modelled. The model employed is strictly applicable to neutrally buoyant liquids and solids that dissolve in water. Consequently, the model is applicable to acetic acid.

The one-dimensional model uses an idealized rectangular channel section and assumes a uniform concentration of the pollutant throughout the section. Obviously, this applies only to points sufficiently far downstream of the spill where mixing and dilution have distributed the pollutant across the entire river channel. The model is applicable to rivers where the ratio of width to depth is less than 100 ( $W/d < 100$ ) and assumes a Manning's roughness coefficient of 0.03. Details of the model are outlined in the Introduction Manual.

No modelling has been carried out for molecular diffusion in still water. Rather, nomograms have been prepared to define the hazard zone and the average concentration within the hazard zone as a function of spill size, but independent of time.

**5.4.2 Nomograms.** The following nomograms are presented to calculate pollutant concentrations in non-tidal rivers and in lakes (still water).

### Non-tidal Rivers

- Figure 22: distance versus time for a range of average stream velocities
- Figure 23: hydraulic radius versus channel width for a range of stream depths
- Figure 24: hydraulic radius versus diffusion coefficient for a range of average stream velocities
- Figure 25:  $\alpha^*$  versus diffusion coefficient for various time intervals
- Figure 26:  $\alpha$  versus  $\delta^*$  for a range of spill sizes
- Figure 27: maximum concentration versus  $\delta$  for a range of river cross-sectional areas

---

\*  $\alpha$  and  $\delta$  are conversion factors only and are of no significance other than to facilitate calculation of downstream concentration.

### Lakes or Still Water Bodies

Figure 28: volume versus radius for the hazard zone for a range of lake depths

Figure 29: average concentrations versus volume for the hazard zone for a range of spill sizes

The flow chart in Figure 21 outlines the steps required to estimate the downstream concentration after a spill and identifies the nomograms to be used. These nomograms (Figures 22 through 29) are described in the following subsections.

#### 5.4.2.1 Nomograms for non-tidal rivers.

**Figure 22: Time versus distance.** Figure 22 presents a simple relationship between average stream velocity, time, and distance. Using an estimate of average stream velocity ( $U$ ), the time ( $t$ ) to reach any point of interest, at some distance ( $X$ ) downstream of the spill, can be readily obtained from Figure 22.

**Figure 23: Hydraulic radius versus channel width.** The model used to estimate downstream pollutant concentration is based on an idealized rectangular channel of width ( $W$ ) and depth ( $d$ ).

The hydraulic radius ( $r$ ) for the channel is required in order to estimate the turbulent diffusion coefficient ( $E$ ). The hydraulic radius ( $r$ ) is defined as the stream cross-sectional area ( $A$ ) divided by the wetted perimeter ( $P$ ). Figure 23 is a nomogram for computation of the hydraulic radius ( $r$ ) using the width and depth of the idealized river cross-section.

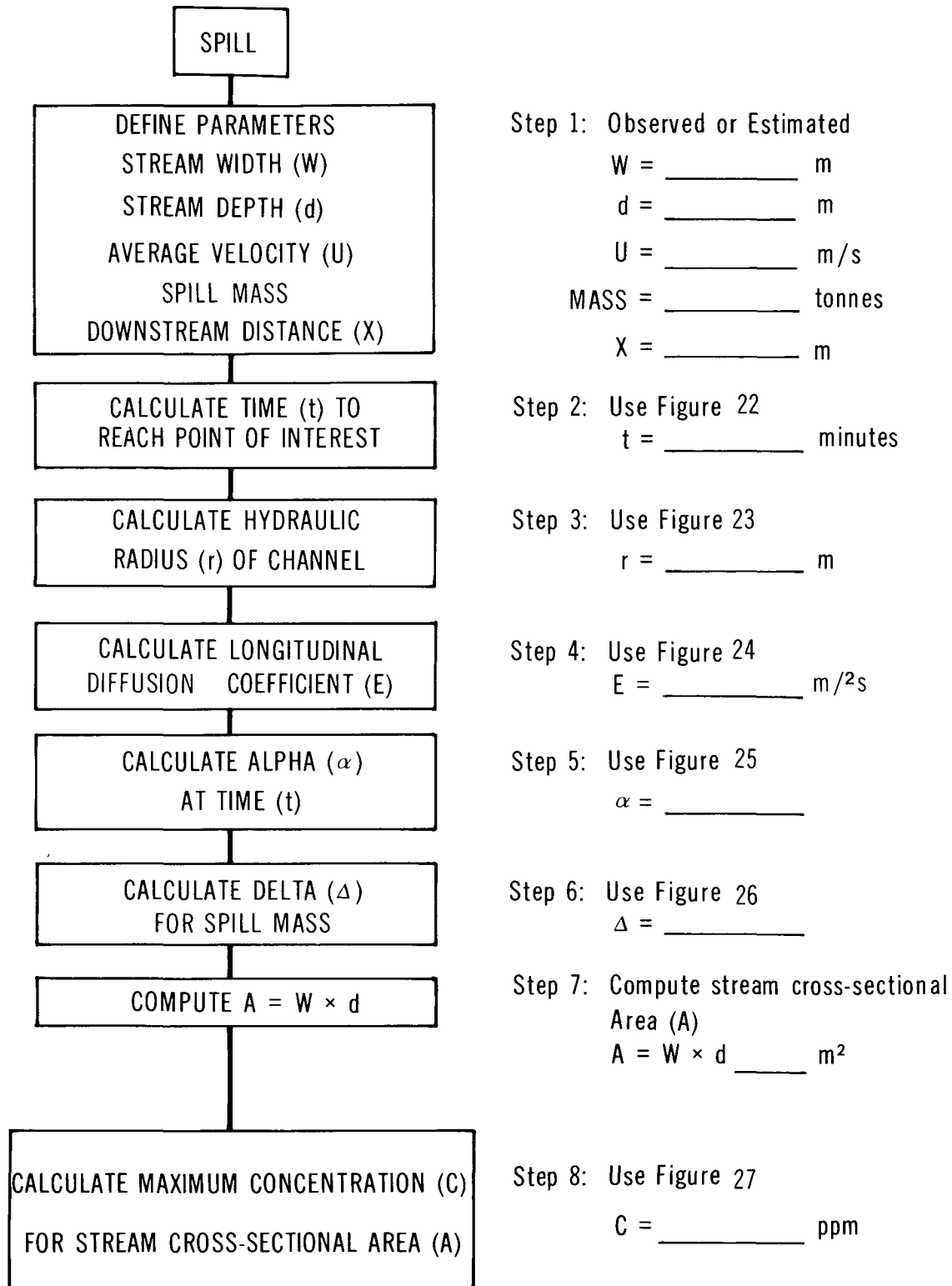
**Figure 24: Diffusion coefficient versus hydraulic radius.** Figure 24 permits calculation of the longitudinal diffusion coefficient ( $E$ ), knowing the hydraulic radius ( $r$ ) from Figure 23 and the average stream velocity ( $U$ ).

**Figure 25: Alpha versus diffusion coefficient.** Figure 25 is used to estimate a conversion factor, alpha, ( $\alpha$ ), which is a function of the diffusion coefficient ( $E$ ) and the time ( $t$ ) to reach the point of interest downstream of the spill.

**Figure 26: Alpha versus delta.** A second conversion factor, delta ( $\Delta$ ), must be estimated from Figure 26 to allow determination of the pollutant concentration at the point of interest. Delta ( $\Delta$ ) is a function of alpha ( $\alpha$ ) and the spill size.

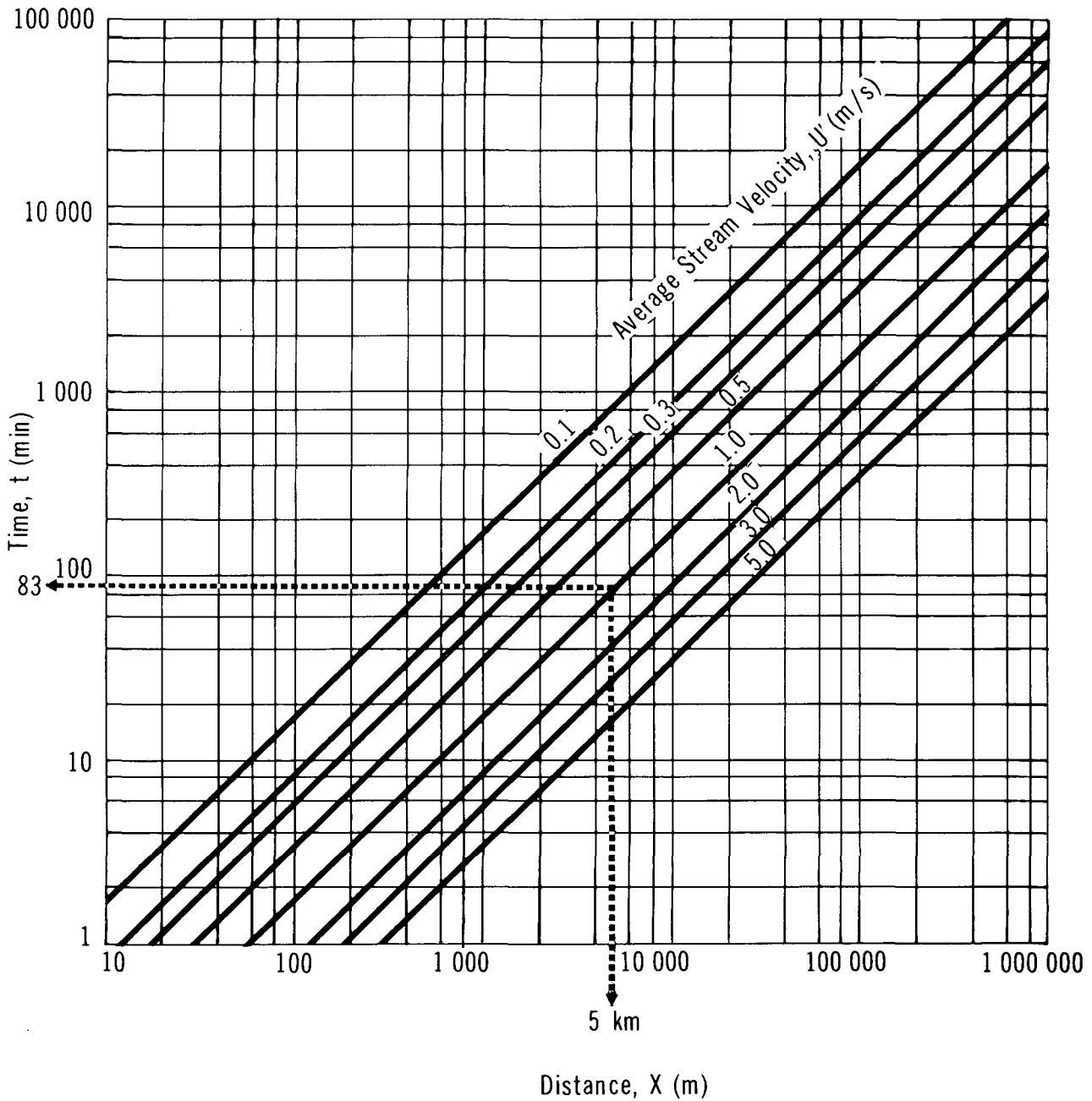
**Figure 27: Maximum concentration versus delta.** Figure 27 represents the final step for calculation of the maximum downstream pollutant concentration ( $C$ ) at the point of interest. Using the factor delta ( $\Delta$ ) and knowing the stream-cross sectional area

ACETIC ACID

**FLOW CHART TO DETERMINE POLLUTANT CONCENTRATION IN NON-TIDAL RIVERS**

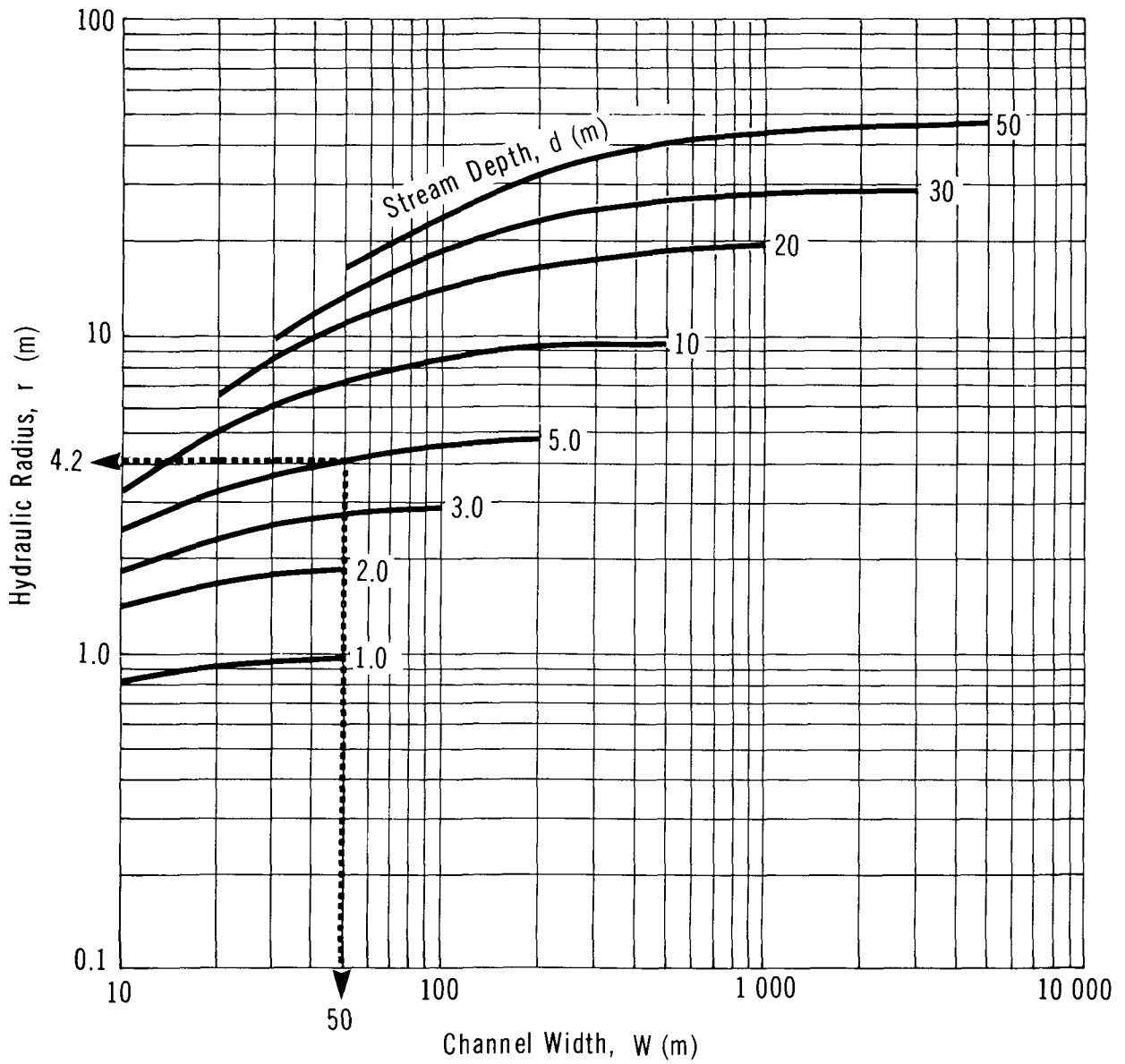
ACETIC ACID

TIME vs DISTANCE

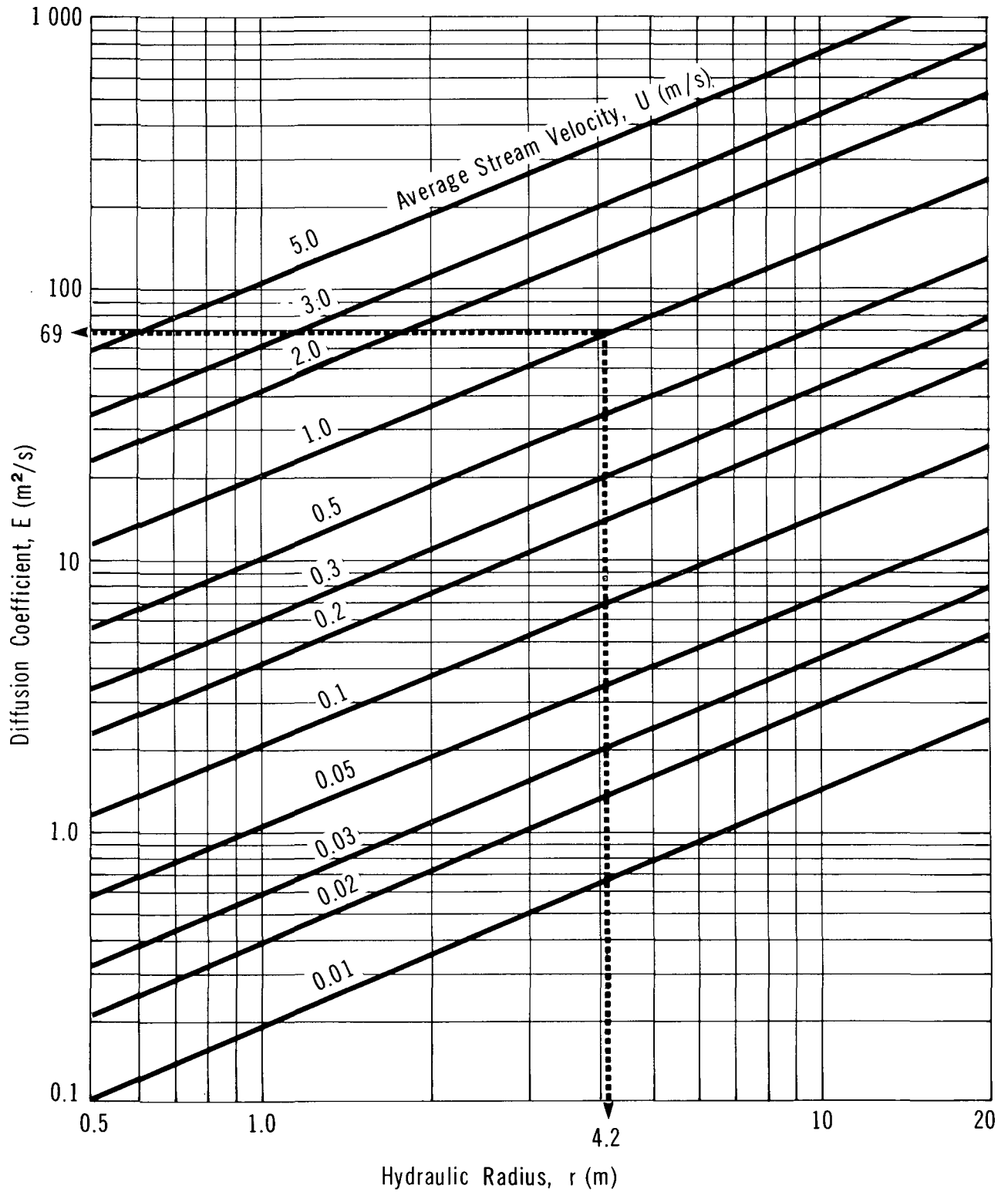


ACETIC ACID

HYDRAULIC RADIUS VS CHANNEL WIDTH

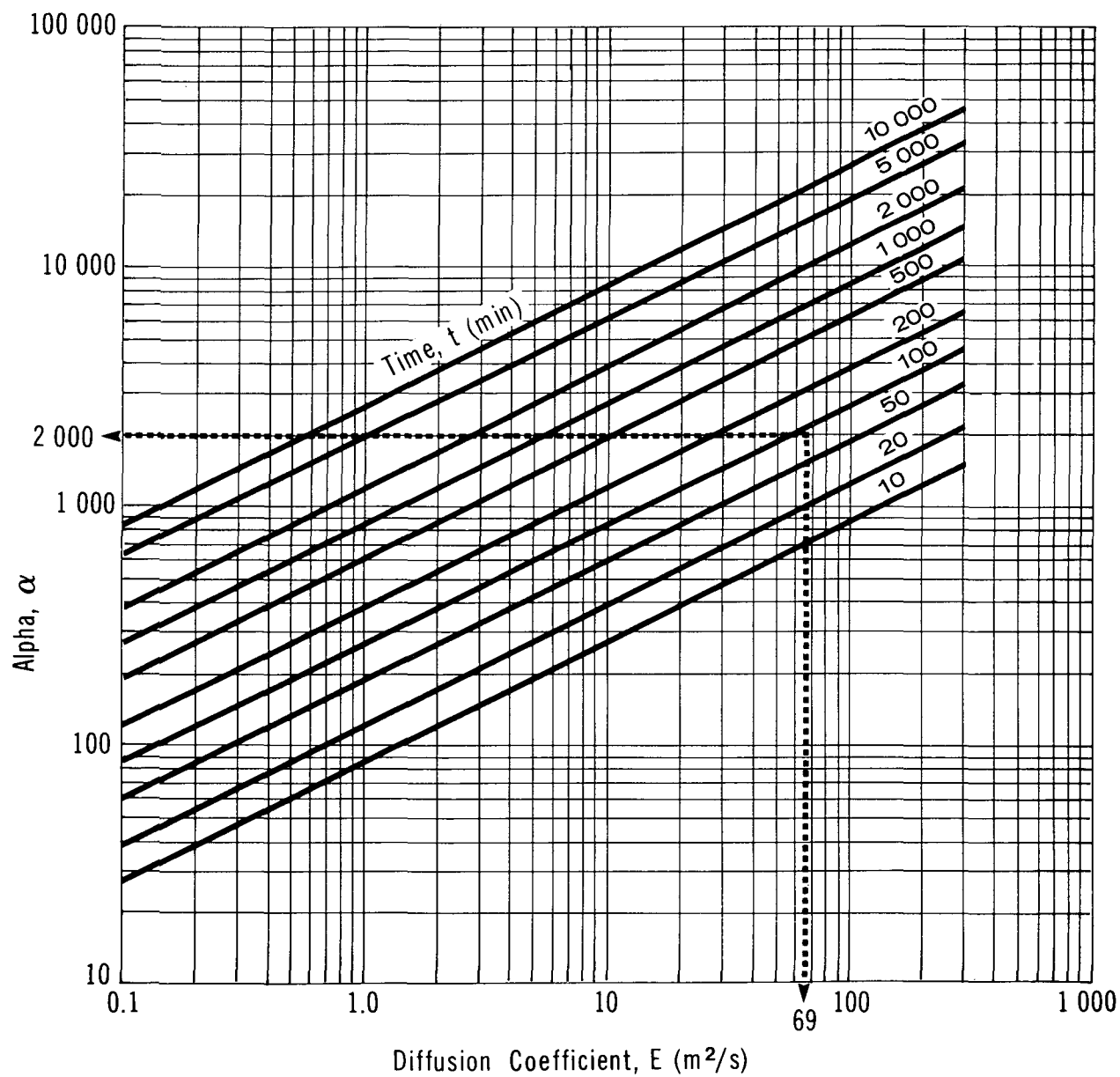


ACETIC ACID

DIFFUSION COEFFICIENT  
VS HYDRAULIC RADIUS

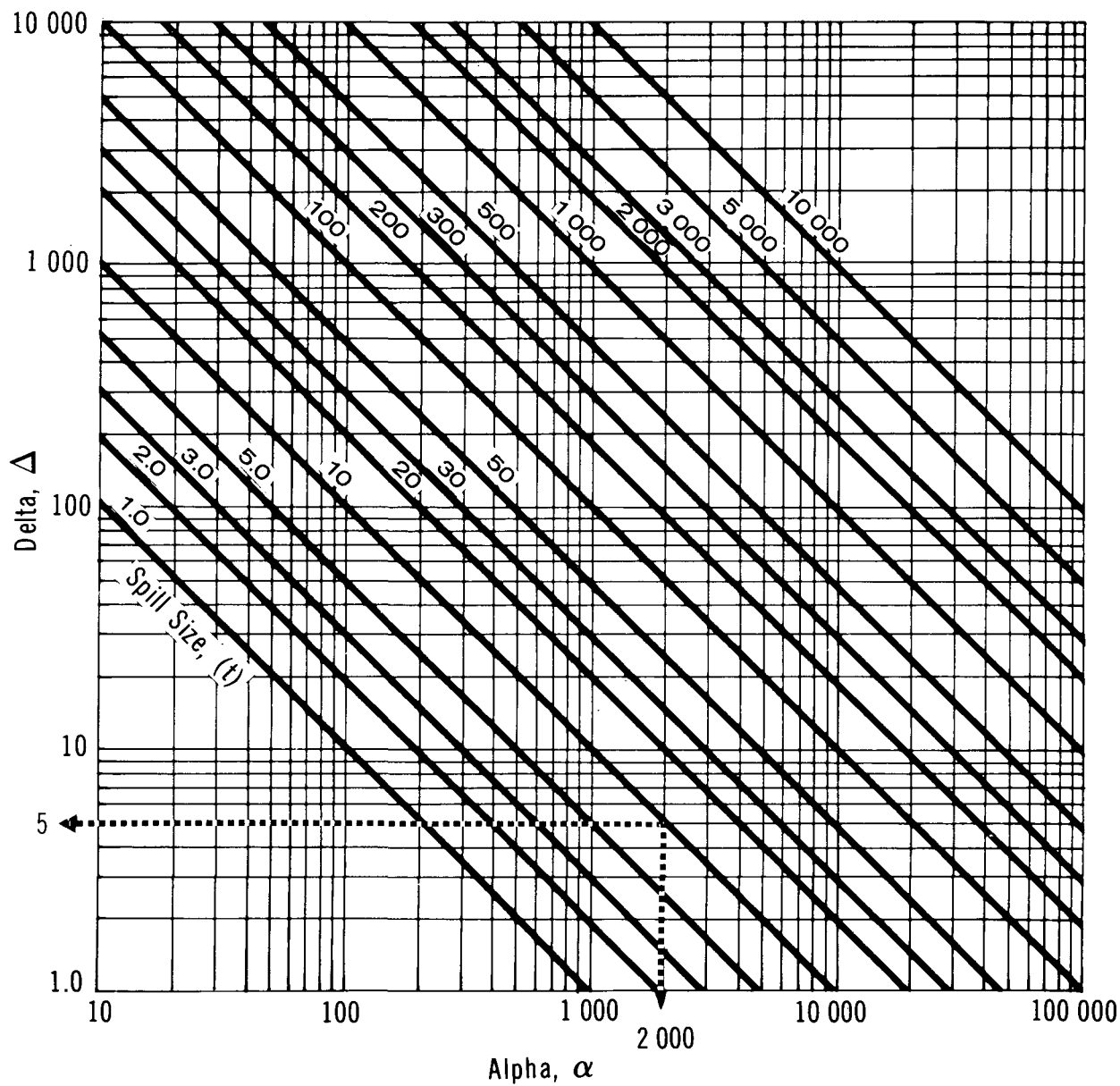
ACETIC ACID

## ALPHA vs DIFFUSION COEFFICIENT



ACETIC ACID

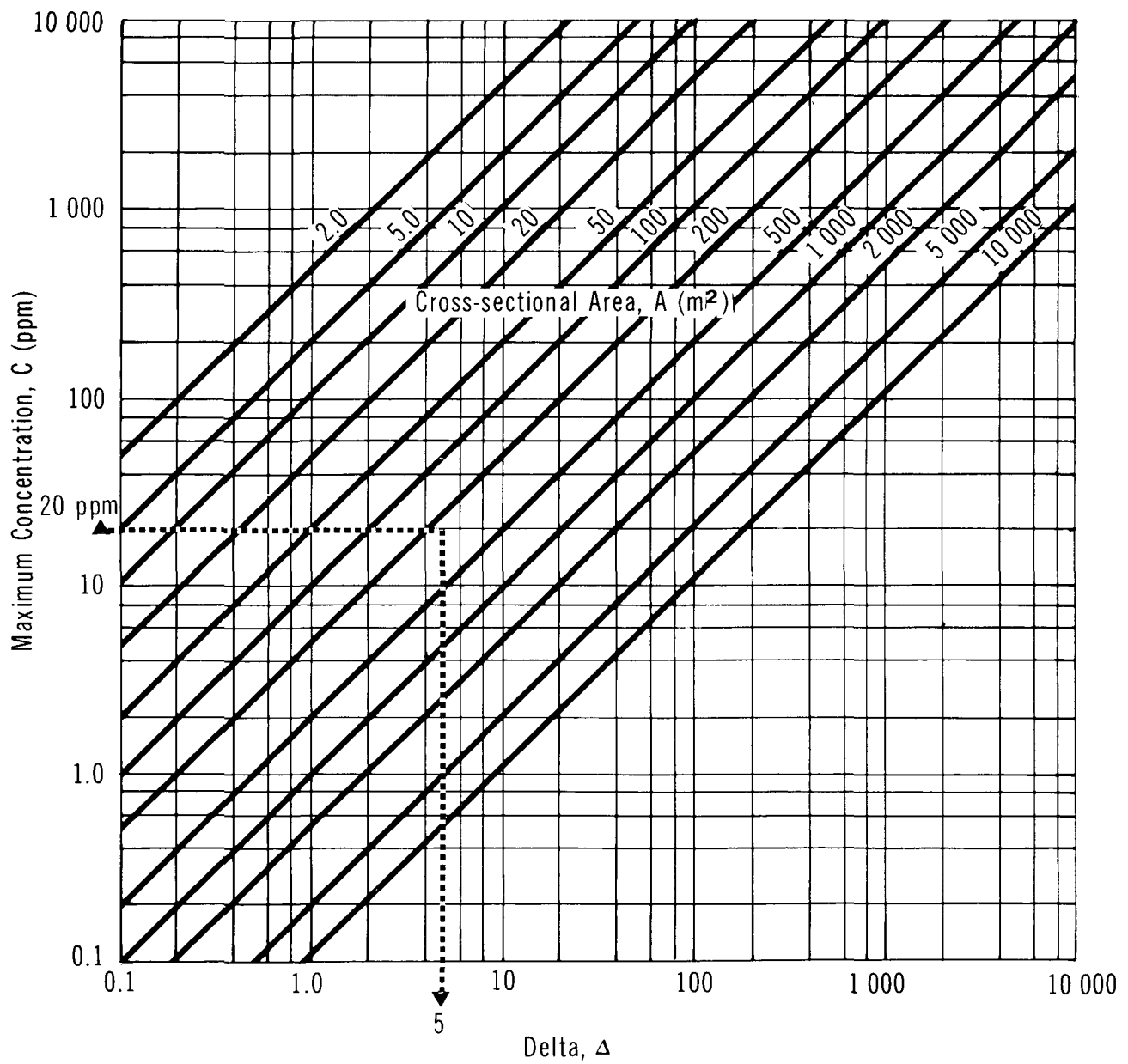
ALPHA vs DELTA





ACETIC ACID

MAXIMUM CONCENTRATION vs DELTA



(A), the concentration (C) is readily obtained from the nomogram. The value obtained from Figure 27 applies to neutrally buoyant liquids or solids and will vary somewhat for other pollutants which are heavier or lighter than water.

#### 5.4.2.2 Nomograms for lakes or still water bodies.

**Figure 28: Volume versus radius.** The spill of a neutrally buoyant liquid in a lake in the absence of wind and current has been idealized as a cylinder of radius ( $r$ ) and length ( $d$ ), equivalent to the depth of the lake at the point of the spill. The volume of water in the cylinder can be obtained from Figure 28. The radius ( $r$ ) represents the distance from the spill to the point of interest.

**Figure 29: Average concentration versus volume.** For a known volume of water (within the idealized cylinder of radius ( $r$ ) and length ( $d$ )), the average concentration of pollutant (C) can be obtained from Figure 29 for a known mass of spill. This assumes the pollutant is spread evenly throughout the cylinder. For pollutants that are more or less dense than water, the actual concentration at the bottom would be higher or lower, respectively.

#### 5.4.3 Sample Calculations.

**5.4.3.1 Pollutant concentration in non-tidal rivers.** A 20 tonne spill of 50 percent acetic acid solution has occurred in a river. The stream width is 50 m and the stream depth is 5 m. The average stream velocity is estimated at 1 m/s. What is the maximum concentration expected at a water intake located 5 km downstream?

##### Solution

Step 1: Define parameters

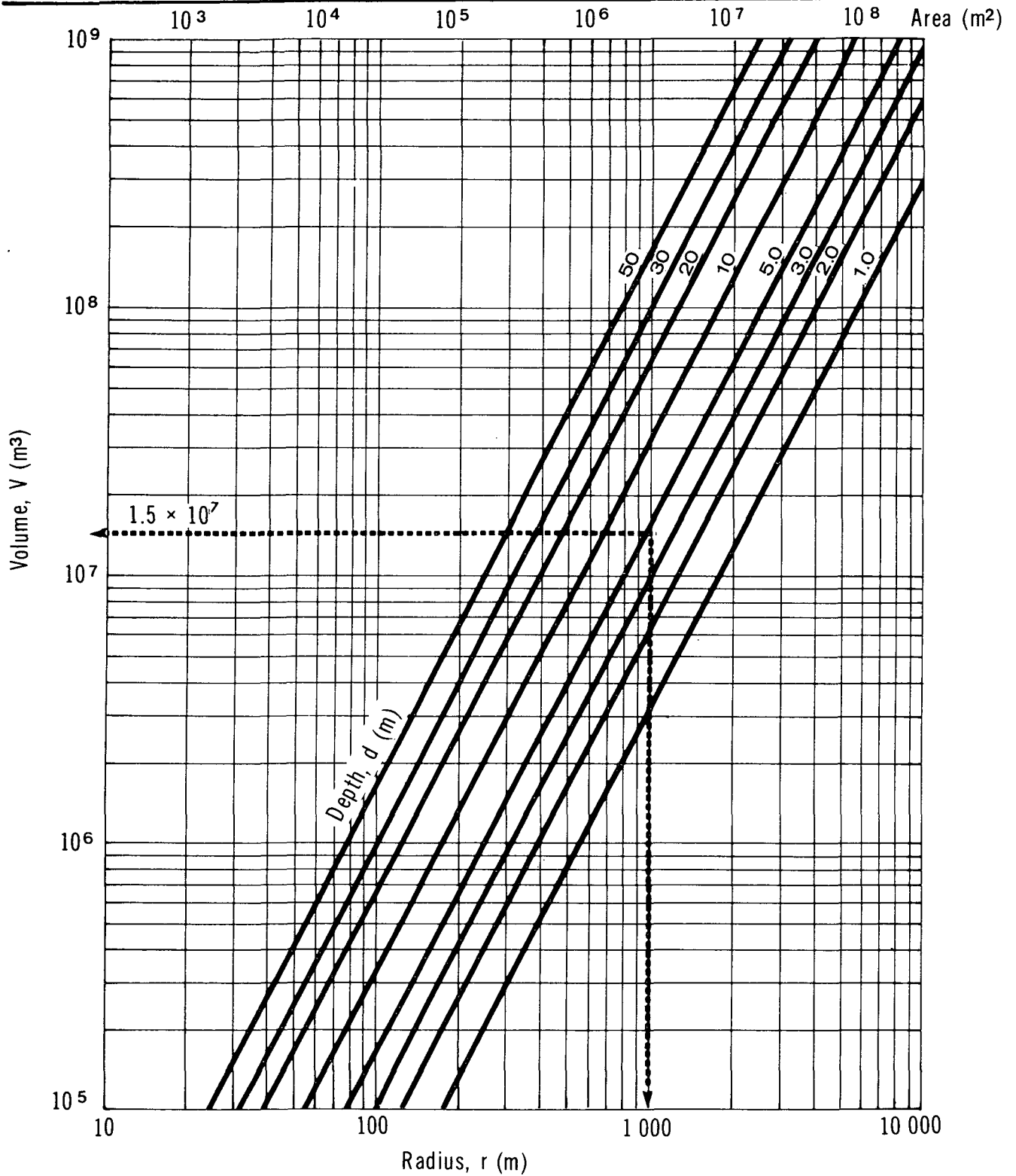
- .  $W = 50$  m
- .  $d = 5$  m
- .  $U = 1$  m/s
- . spill mass = 20 tonnes of 50 percent solution, contains the equivalent of 10 tonnes of acetic acid
- .  $X = 5000$  m

Step 2: Calculate the time to reach the point of interest

- . Use Figure 22
- . With  $X = 5000$  m and  $U = 1$  m/s,  $t = 83$  min

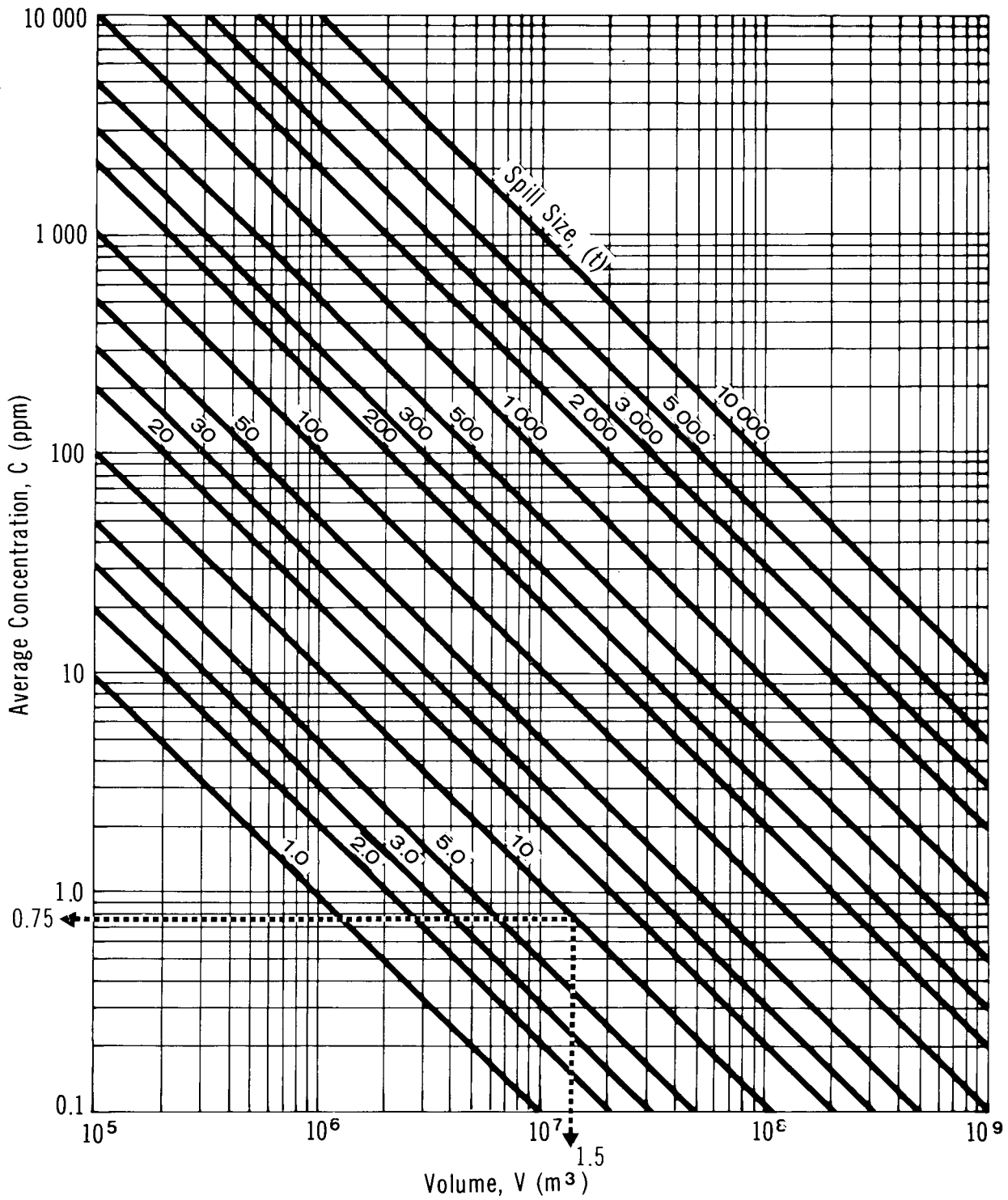
ACETIC ACID

VOLUME vs RADIUS



ACETIC ACID

## AVERAGE CONCENTRATION vs VOLUME



- Step 3: Calculate the hydraulic radius ( $r$ )
- Use Figure 23
  - With  $W = 50$  m and  $d = 5$  m,  $r = 4.2$  m
- Step 4: Calculate the longitudinal diffusion coefficient ( $E$ )
- Use Figure 24
  - With  $r = 4.2$  m and  $U = 1$  m/s,  $E = 69$  m<sup>2</sup>/s
- Step 5: Calculate alpha ( $\alpha$ )
- Use Figure 25
  - With  $E = 69$  m<sup>2</sup>/s and  $t = 83$  min,  $(\alpha) = 2000$
- Step 6: Calculate delta ( $\Delta$ )
- Use Figure 25
  - With alpha ( $\alpha$ ) = 2000 and spill mass = 10 tonnes, delta ( $\Delta$ ) = 5
- Step 7: Compute the stream cross-sectional area ( $A$ )
- $A = W \times d = 50 \times 5 = 250$  m<sup>2</sup>
- Step 8: Calculate the maximum concentration ( $C$ ) at the point of interest
- Use Figure 27
  - With  $\Delta = 5$  and  $A = 250$  m<sup>2</sup>,  $C = 20$  ppm

**5.4.3.2 Average pollutant concentration in lakes or still water bodies.** A 20 tonne spill of 50 percent acetic acid solution has occurred in a lake. The point of interest is located on the shore approximately 1000 m from the spill. The average depth between the spill site and the point of interest is 5 m. What is the average concentration which could be expected?

#### Solution

- Step 1: Define parameters
- $d = 5$  m
  - $r = 1000$  m
  - spill mass = 10 tonnes (equivalent weight of acetic acid)
- Step 2: Determine the volume of water available for dilution
- Use Figure 28
  - With  $r = 1000$  m,  $d = 5$  m, the volume is approximately  $1.5 \times 10^7$  m<sup>3</sup>
- Step 3: Determine the average concentration
- Use Figure 29
  - With  $V = 1.5 \times 10^7$  m<sup>3</sup> and spill mass = 10 tonnes, the average concentration is 0.75 ppm

## 5.5 Subsurface Behaviour: Penetration into Soil

**5.5.1 Mechanisms.** The principles of contaminant transport in soil and their application to this work are presented in the Introduction Manual. Special considerations related to the spill of acetic acid onto soil and its transport downward through the soil are presented here.

Acetic acid is shipped as a liquid, either pure or diluted with water. When spilled at temperatures above its freezing point, it will readily infiltrate the soil and will be diluted by precipitation or by water used to flush the spill site. The fluid will move downward through the soil and toward the groundwater table.

If the soil surface is saturated with moisture at the time of the spill, as might be the case after a rainfall, the spilled chemical will run off or remain ponded.

For this work, the soils have been assumed to be at field capacity. This situation provides very little interstitial water to dilute the chemical during transport or to impede its downward movement and thus represents "worst case" analysis.

During transport through the soil, acetic acid will dissolve some of the carbonate soil materials. The acid will be neutralized to some degree, with adsorption of protons and acetate ions occurring on clay minerals to some degree. However, the analysis used here neglects these retarding factors. Significant amounts of acid are expected to remain for transport down toward the groundwater table.

Upon reaching the groundwater table, the acid will continue to move, now in the direction of groundwater flow. A contaminated plume will be produced, with dilution and diffusion serving to reduce the acid concentrations. This is shown schematically in Figure 30.

**5.5.2 Equations Describing Acetic Acid Movement into Soil.** The equations and assumptions used to describe contaminant movement downward through the unsaturated soil zone toward the groundwater table have been 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 Acetic Acid in Soil.** The saturated hydraulic conductivity ( $K_0$ ), in m/s, is given by:

$$K_0 = \frac{(\rho g)k}{\mu}$$

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

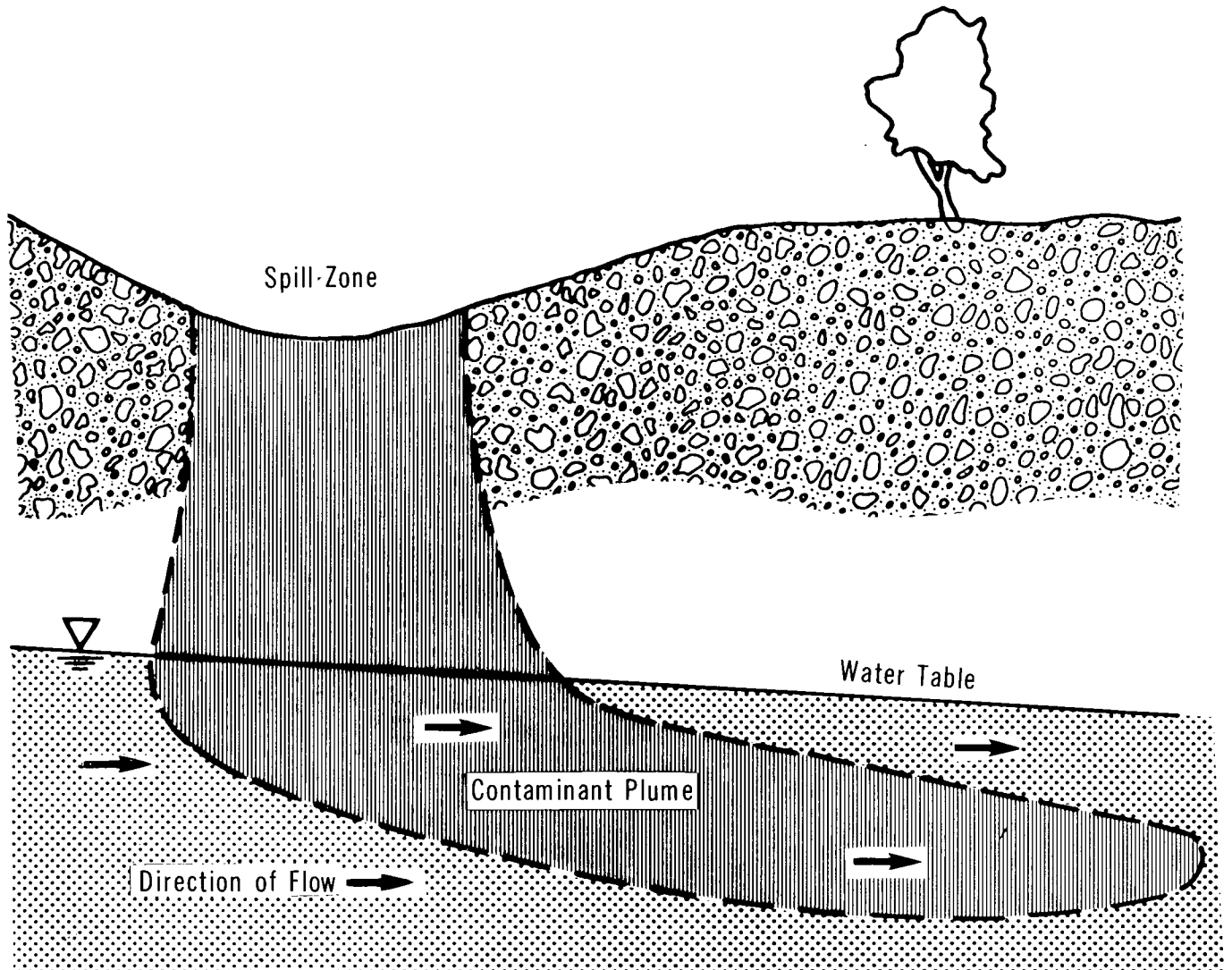
$\rho$  = mass density of the fluid ( $kg/m^3$ )

$\mu$  = absolute viscosity of the fluid ( $Pa \cdot s$ )

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

ACETIC ACID

## SCHEMATIC SOIL TRANSPORT



Soil: Coarse Sand

–Porosity ( $n$ ) = 0.35

–Intrinsic Permeability ( $k$ ) =  $10^{-9} \text{ m}^2$

–Field Capacity ( $\theta_{fc}$ ) = 0.075

The fluids involved are pure acetic acid, 10 percent by weight acetic acid, and water. The water calculations represent the extreme as acetic acid is diluted. The appropriate properties of acetic acid are given in the chart below.

| Property  | Acetic Acid           |                       |                       |
|---|-----------------------|-----------------------|-----------------------|
|   | Pure (20°C)           | 10 percent (20°C)     | Water (20°C)          |
| Mass density ( $\rho$ ), kg/m <sup>3</sup>      | 1049                  | 1012                  | 998                   |
| Absolute viscosity ( $\mu$ ), Pa·s              | $1.28 \times 10^{-3}$ | $1.23 \times 10^{-3}$ | $1.0 \times 10^{-3}$  |
| Saturated hydraulic conductivity ( $K_0$ ), m/s | $(0.8 \times 10^7)k$  | $(0.8 \times 10^7)k$  | $(0.98 \times 10^7)k$ |

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

| Property   | Soil Type   |            |            |
|--|-------------|------------|------------|
|  | Coarse Sand | Silty Sand | Clay Till  |
| Porosity ( $n$ ), m <sup>3</sup> /m <sup>3</sup>                 | 0.35        | 0.45       | 0.55       |
| Intrinsic permeability ( $k$ ), m <sup>2</sup>                   | $10^{-9}$   | $10^{-12}$ | $10^{-15}$ |
| Field capacity ( $\theta_{fc}$ ), m <sup>3</sup> /m <sup>3</sup> | 0.075       | 0.3        | 0.45       |

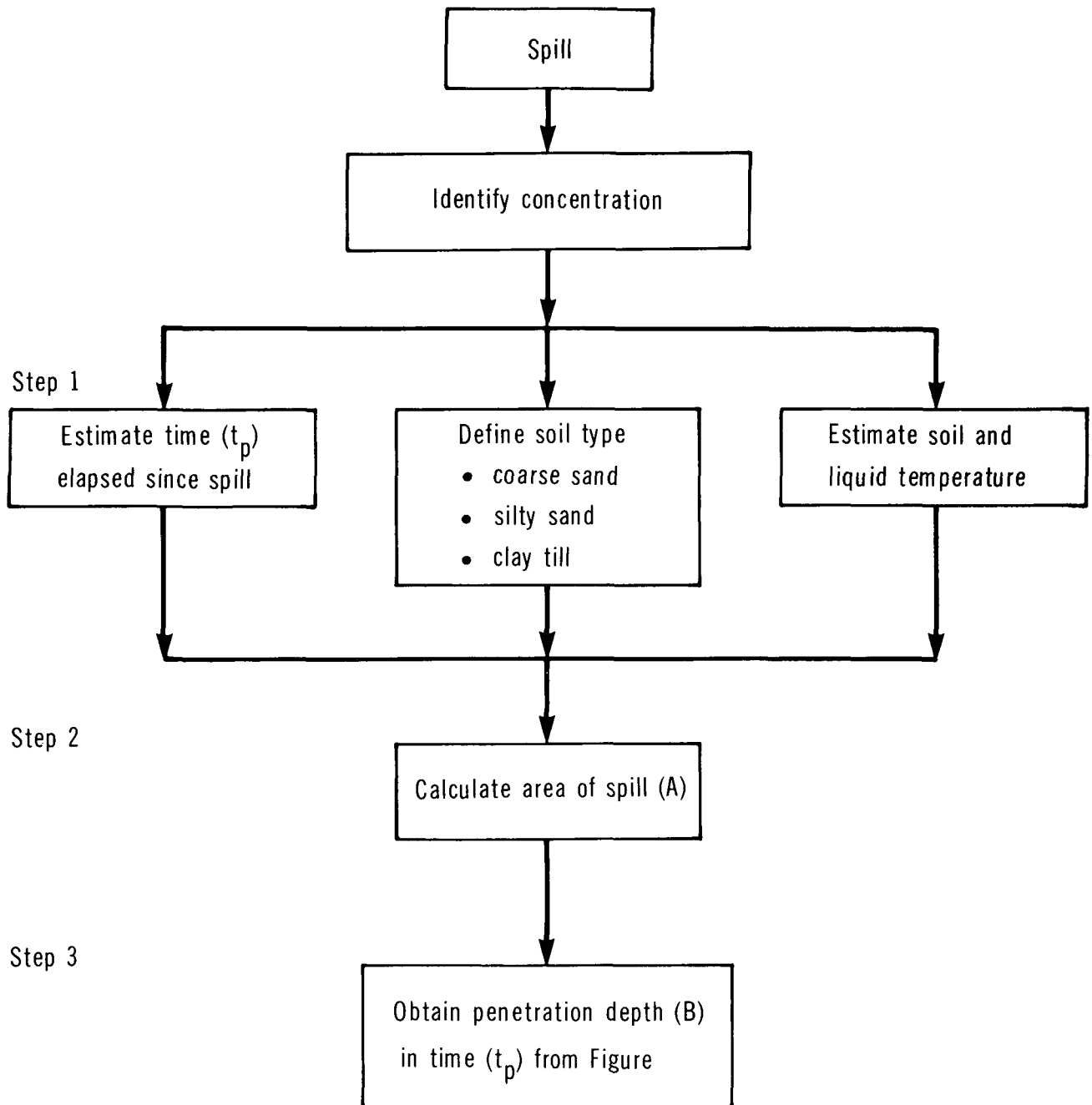
**5.5.5 Penetration Nomograms.** Nomograms for the penetration of acetic acid into the unsaturated zone above the groundwater table were prepared for each soil. They present penetration time ( $t_p$ ) plotted against depth of penetration ( $B$ ). Because of the methods and assumptions used, the penetration depth should be considered as a maximum depth in time  $t_p$ .

A flowchart for the use of the nomograms is presented in Figure 31. The nomograms are presented as Figures 32, 33, and 34. The water line on the nomograms represents the maximum penetration of water at 20°C in time  $t_p$ . It is a limiting condition as acetic acid becomes diluted with water.



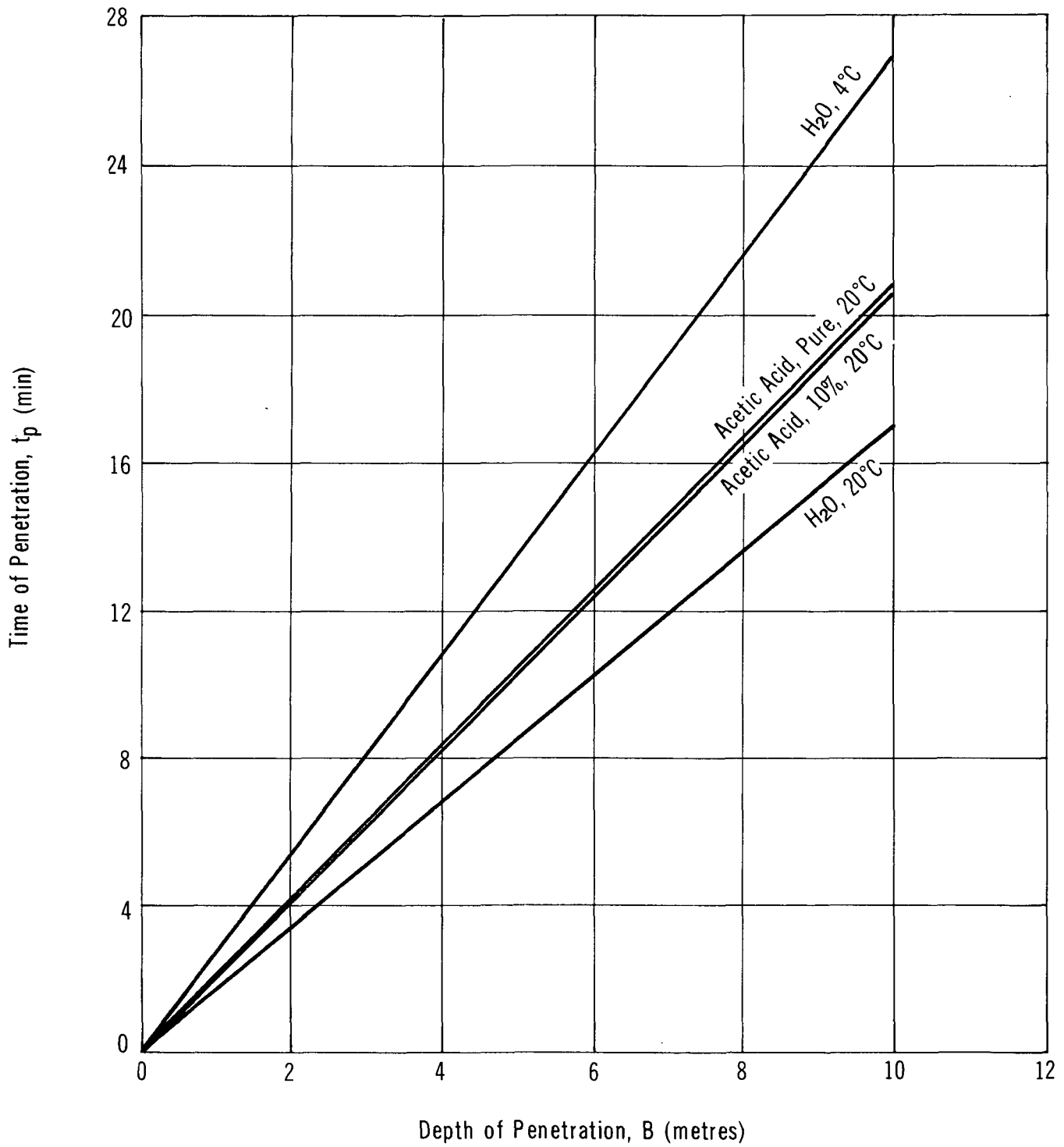
ACETIC ACID

## FLOWCHART FOR NOMOGRAM USE



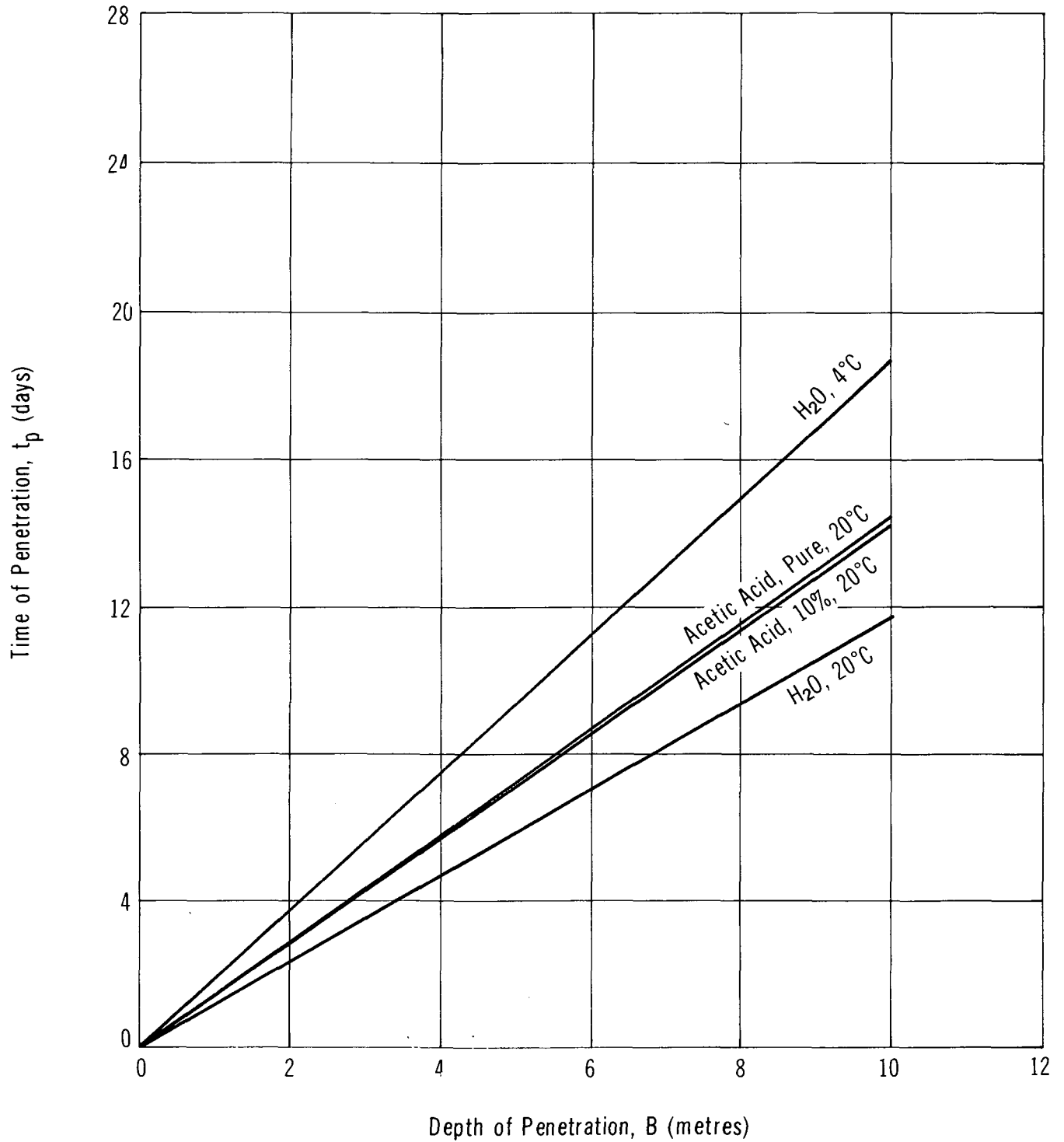
ACETIC ACID

PENETRATION IN COARSE SAND



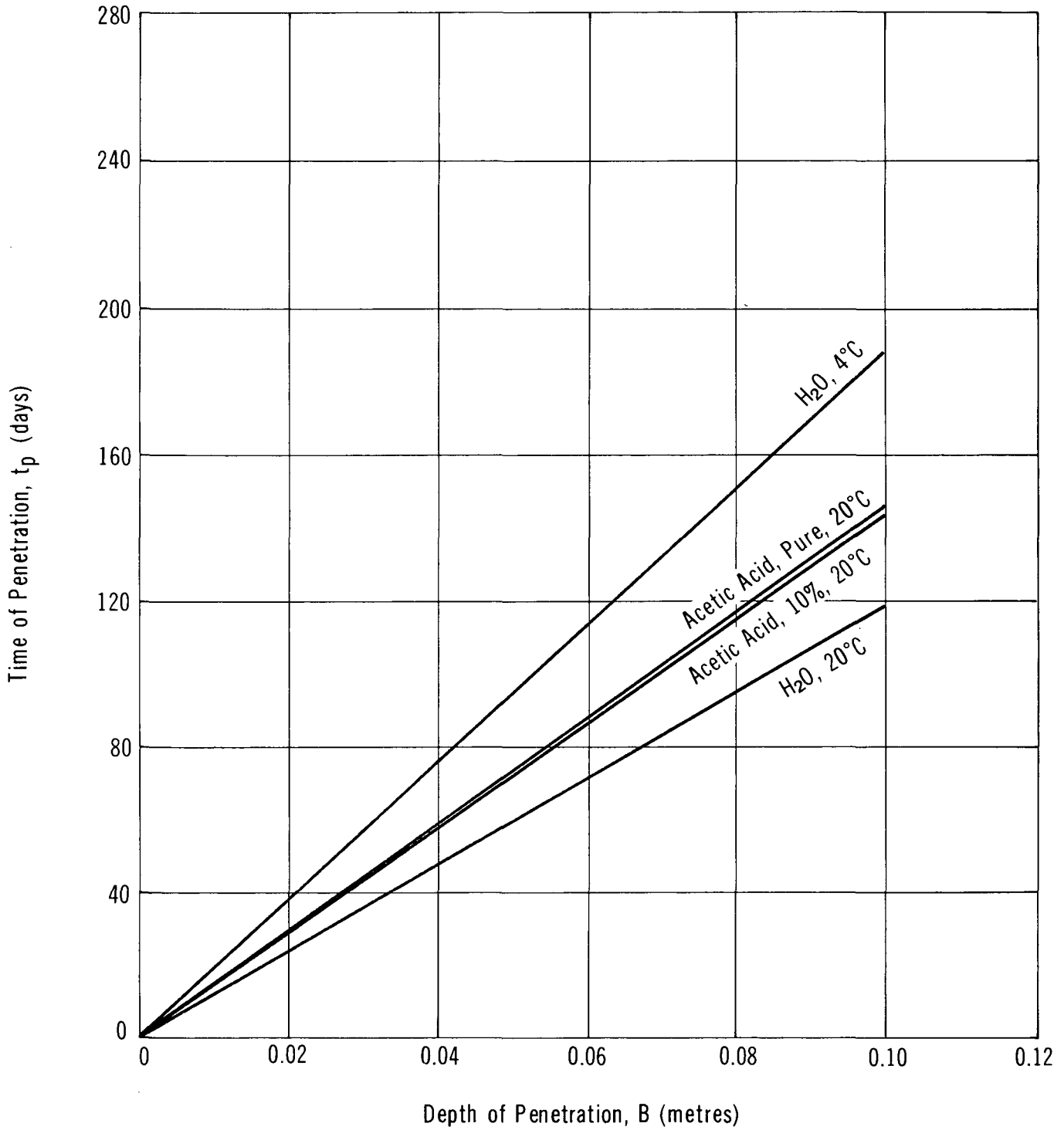
ACETIC ACID

PENETRATION IN SILTY SAND



ACETIC ACID

PENETRATION IN CLAY TILL



**5.5.6 Sample Calculation.** A 20 tonne spill of acetic acid has occurred on coarse sand. The temperature is 20°C; the spill radius is 8.6 m. Calculate the depth of penetration 20 minutes after the spill.

Solution

Step 1: Define parameters

- Mass spilled = 20 000 kg (20 tonnes)
- $T = 20^{\circ}\text{C}$
- $r = 8.6 \text{ m}$
- Soil = coarse sand
- Groundwater table depth ( $d$ ) = 13 m
- Time since spill ( $t_p$ ) = 20 m

Step 2: Calculate the area of spill

- $A = \pi r^2 = 232 \text{ m}^2$

Step 3: Estimate the depth of penetration (B) at time ( $t_p$ )

- For coarse sand,  $B = 9.7 \text{ m}$  at  $t_p = 20 \text{ min}$
- Groundwater table has not been reached in this time

## 6 ENVIRONMENTAL DATA

### 6.1 Suggested or Regulated Limits

**6.1.1 Water.** A drinking water limit of 128 ppm has been recommended in the U.S. (OHM-TADS 1981).

**6.1.2 Air.** The Ontario environmental air limit is 2.5 mg/m<sup>3</sup> (Ontario E.P. Act 1971).

### 6.2 Aquatic Toxicity

**6.2.1 U.S. Toxicity Rating.** Acetic acid has been assigned a TL<sub>m</sub>96 of 10 to 100 ppm (RTECS 1979).

### 6.2.2 Measured Toxicities.

#### 6.2.2.1 Freshwater toxicity.

| Conc. (mg/L)               | Time (hours) | Species         | Result            | Water Conditions                      | Reference        |
|----------------------------|--------------|-----------------|-------------------|---------------------------------------|------------------|
| <u>Fish Kill Data</u>      |              |                 |                   |                                       |                  |
| 50                         | 24           | Brook trout     | lethal            |                                       | WQC 1963         |
| 114                        | 24           | Minnow          | lethal            |                                       | WQC 1963         |
| 423                        | 20           | Goldfish        | lethal            |                                       | Verschueren 1984 |
| <u>Fish Toxicity Tests</u> |              |                 |                   |                                       |                  |
| >100                       | 72           | Fathead minnow  | no toxic effect   | 50°F                                  | EPA 440/9-75-009 |
| 100                        | 96           | Goldfish        | TL <sub>m</sub>   |                                       | Little 1970      |
| 100-200                    | 96           | Creek chub      | TL <sub>m</sub>   | Detroit river water                   | Little 1970      |
| 75                         | 96           | Bluegill        | TL <sub>m</sub>   |                                       | Cairns 1968      |
| 75                         | 96           | Sunfish         | TL <sub>m</sub>   | 18-20°C, soft water                   | WQC 1963         |
| 286                        | 24           | Goldfish        | LC <sub>50</sub>  | -                                     | DPIMR 1983       |
| 270                        | 72           | Channel catfish | TL <sub>m</sub>   | 25°C                                  | DPIMR 1983       |
| 251                        | 24-96        | Mosquito fish   | TL <sub>m</sub>   | turbid                                | DPIMR 1983       |
| 624                        | 72           | Channel catfish | LC <sub>100</sub> | 25°C                                  | DPIMR 1983       |
| 175                        | 1            | Fathead minnow  | LC <sub>50</sub>  | 18-22°C, reconstituted water, pH <5.9 | Mattson 1976     |

| Conc. (mg/L)          | Time (hours) | Species                                | Result                            | Water Conditions                      | Reference         |
|-----------------------|--------------|--|-----------------------------------|---------------------------------------|-------------------|
| 106                   | 24-48        | Fathead minnow                         | LC <sub>50</sub>                  | 18-22°C, reconstituted water, pH <5.9 | Mattson 1976      |
| 79                    | 72-96        | Fathead minnow                         | LC <sub>50</sub>                  | 18-22°C, pH <5.9, reconstituted water | Mattson 1976      |
| >315                  | 1            | Fathead minnow                         | LC <sub>50</sub>                  | pH <5.9, 18-22°C, Lake Superior water | Mattson 1976      |
| 122                   | 24           | Fathead minnow                         | LC <sub>50</sub>                  | pH <5.9, 18-22°C, Lake Superior water | Mattson 1976      |
| 92                    | 48           | Fathead minnow                         | LC <sub>50</sub>                  | pH <5.9, 18-22°C, Lake Superior water | Mattson 1976      |
| 88                    | 72-96        | Fathead minnow                         | LC <sub>50</sub>                  | pH <5.9, 18-22°C, Lake Superior water | Mattson 1976      |
| <u>Invertebrates</u>  |              |  |                                   |                                       |                   |
| 80-150                | 120          | Daphnia                                | immobilized                       | Lake Erie                             | WQCDB-5 1973      |
| 47                    | 24           | <i>Daphnia magna</i>                   | TL <sub>m</sub>                   | -                                     | Verschuereen 1984 |
| <u>Microorganisms</u> |              |  |                                   |                                       |                   |
| 74                    | -            | Diatom ( <i>Navicula seminulum</i> )   | 50% reduction in growth           | soft water, 20°C                      | DPIMR 1983        |
| >4                    | 12           | Algae ( <i>Nitzschia linearis</i> )    | LC <sub>50</sub>                  | -                                     | DPIMR 1983        |
| 74                    | -            | Algae ( <i>Nitzschia linearis</i> )    | LC <sub>50</sub>                  | synthetic water                       | WQCDB-5 1973      |
| 2850                  | -            | Bacteria ( <i>Pseudomonas putida</i> ) | inhibition of cell multiplication | -                                     | Verschuereen 1984 |

| Conc. (mg/L) | Time (hours) | Species  | Result                            | Water Conditions | Reference         |
|--------------|--------------|--|-----------------------------------|------------------|-------------------|
| 90           | -            | Algae ( <i>Microcystis aeruginosa</i> )        | inhibition of cell multiplication | -                | Verschuereen 1984 |
| 4000         | -            | Green algae ( <i>Scenedesmus quadricauda</i> ) | inhibition of cell multiplication | -                | Verschuereen 1984 |
| 1350         | -            | Protozoa ( <i>Uronema parduczi</i> )           | inhibition of cell multiplication | -                | Verschuereen 1984 |
| 78           | -            | Protozoa ( <i>Entosiphon sulcatum</i> )        | inhibition of cell multiplication | -                | Verschuereen 1984 |
| 350          | -            | <i>Chlorella pyranoidosa</i>                   | toxic                             | -                | Jones 1971        |

#### 6.2.2.2 Saltwater toxicity.

| Conc. (mg/L) | Time (hours) | Species                               | Result             | Water Conditions | Reference         |
|--------------|--------------|---------------------------------------|--------------------|------------------|-------------------|
| 32           | 48           | Brine shrimp                          | TL <sub>m</sub>    | static           | Price 1974        |
| 100-300      | 48           | Shrimp                                | LC <sub>50</sub>   | aerated          | Portman 1970      |
| 42           | 24           | Brine shrimp                          | TL <sub>m</sub>    | static           | DPIMR 1983        |
| >100         | 96           | Shore crab ( <i>Carcinus maenus</i> ) | LC <sub>50</sub>   | continuous flow  | WQCDB-5 1973      |
| >100         | 96           | Crab ( <i>Crangon crangon</i> )       | LC <sub>50</sub>   | continuous flow  | WQCDB-5 1973      |
| 6            | -            | Amphipod ( <i>Limnea ovata</i> )      | perturbation level | -                | Verschuereen 1984 |
| 14           | -            | Amphipod ( <i>Gammarus pulex</i> )    | perturbation level | -                | Verschuereen 1984 |



### 6.3 Effect Studies

Hardness in water is antagonistic to freshwater toxicity, raising the concentration required for given  $TL_m$  values (WQC 1963).

The toxicity of acetic acid on an insect (mosquito larvae, *Culex* sp.) in water has been determined to be 1500 mg/L in 24 hours (Verschueren 1984).

The effect of the vapour on a number of plant species has been determined. The 2-hour  $EC_{50}$  (for visible leaf damage) is as follows (Verschueren 1984):

| <u>Plant</u> | <u><math>EC_{50}</math> (ppm)</u> |
|--------------|-----------------------------------|
| Wheat        | 9.3                               |
| Alfalfa      | 3.1                               |
| Tobacco      | 16.5                              |
| Soybean      | 8.1                               |
| Corn         | 20.1                              |

### 6.4 Degradation

#### 6.4.1 Biochemical Oxygen Demand.

| B.O.D. Oxygen/ Acetic Acid (w/w) | % of Theoretical B.O.D. | Time Days | Seed                               | Method       | Reference  |
|----------------------------------|-------------------------|-----------|------------------------------------|--------------|------------|
| >1                               | 66                      | 5         | sewage seed                        | saltwater    | Price 1974 |
| >1                               | 88                      | 10        | sewage seed                        | saltwater    | Price 1974 |
| >1                               | 100                     | 20        | sewage seed                        | saltwater    | Price 1974 |
| >1                               | 76                      | 5         | sewage seed                        | freshwater   | Price 1974 |
| >1                               | 82                      | 10        | sewage seed                        | freshwater   | Price 1974 |
| >1                               | 85                      | 15        | sewage seed                        | freshwater   | Price 1974 |
| >1                               | 96                      | 20        | sewage seed                        | freshwater   | Price 1974 |
| >1                               | 50                      | 0.5       | phenol-acclimated activated sludge | -            | DPIMR 1983 |
| >1                               | 53                      | 1-5       | activated sludge                   | respirometer | DPIMR 1983 |
| 0.7                              | -                       | 5         | -                                  | -            | DPIMR 1983 |
| 0.9                              | -                       | 20        | -                                  | -            | DPIMR 1983 |
| 0.34-0.88                        | -                       | 5         | sewage seed                        | -            | DPIMR 1983 |
| 1                                | -                       | -         | chemical                           | C.O.D.       | DPIMR 1983 |

Oxygen deficiencies may result from rapid biochemical and chemical oxygen demand. High concentrations may cause extremely low pH, killing biota and interfering with coagulation (OHM-TADS 1981).

### **6.5 Long-term Fate and Effects**

Natural waters will neutralize dilute solutions to acetate salts. Acetic acid shows no potential for biological accumulation or food chain contamination (OHM-TADS 1981).

## 7 HUMAN HEALTH

Acetic acid is a clear, colourless liquid with a pungent, vinegar-like odour. It is a very common and widely used industrial chemical found in industries as diverse as cellulose production and food processing.

Acetic acid is extremely corrosive on contact with living tissue by any route of exposure. Its health effects are primarily local in nature, although cases of bronchitis have been reported to develop at some time following acute exposures (Doc. TLV 1981).

It is likely that the well-known local effects of acetic acid account for the paucity of research and review publications concerning the toxic effects of this chemical. No data were found in the literature on acetic acid's mutagenicity or teratogenicity nor its carcinogenic potential. Acetic acid has been reported in the EPA TSCA Inventory.

The toxicological data summarized here have been extracted from reliable standard reference sources. 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. Only acute (short-term) exposure data are given for non-human mammalian species, to support interpretation of the human data where appropriate.

### 7.1 Recommended Exposure Limits

The exposure standards for acetic acid are based upon its irritant properties. Canadian provincial guidelines generally are similar to those of the USA-ACGIH, unless indicated otherwise.

| Guideline (Time)                         | Origin    | Recommended Level              | Reference        |
|--|-----------|--------------------------------|------------------|
| <u>Time-weighted Averages (TWA)</u>      |           |                                |                  |
| TLV*                                     | USA-ACGIH | 10 ppm (25 mg/m <sup>3</sup> ) | TLV 1983         |
| TWA                                      | USA-OSHA  | 10 ppm                         | NIOSH/OSHA 1981  |
| <u>Short-term Exposure Limits (STEL)</u> |           |                                |                  |
| STEL (15 min)                            | USA-ACGIH | 15 ppm (37 mg/m <sup>3</sup> ) | TLV 1983         |
| <u>Other Human Toxicities</u>            |           |                                |                  |
| IDLH (inhalation)                        | USA-NIOSH | 1000 ppm                       | NIOSH Guide 1978 |
| TD <sub>LO</sub> (ingestion)             |           | 1.47 mg/kg                     | RTECS 1979       |

## 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:

$$\text{ITI} = 1315.12 (\text{Vapour Pressure, in mm Hg} / \text{TLV}^{\circ}, \text{ in ppm})$$

$$\begin{aligned} \text{At } 36^{\circ}\text{C, } \text{ITI} &= 1315.12 (9.7 \text{ mm Hg} / 10 \text{ ppm}) \\ &= 1.3 \times 10^3 \end{aligned}$$

## 7.2 Irritation Data

### 7.2.1 Skin Contact.

| Exposure Level<br>(and Duration) | Effects                       | Reference       |
|----------------------------------|-------------------------------|-----------------|
| SPECIES: Human                   |                               |                 |
| 50 mg (24 h)                     | Mild irritation               | RTECS 1979      |
| Concentrated<br>acetic acid      | Severe damage                 | NIOSH/OSHA 1981 |
| SPECIES: Rabbit                  |                               |                 |
| 1060 mg/kg                       | LD <sub>50</sub>              | Patty 1982      |
| 525 mg                           | Severe irritation - open skin | DPIMR 1983      |
| 50 mg (24 h)                     | Mild irritation               | RTECS 1979      |
| SPECIES: Guinea Pig              |                               |                 |
| 80 percent                       | Severe burns                  | NIOSH/OSHA 1981 |
| 80 to 50 percent                 | Moderate to severe burns      | NIOSH/OSHA 1981 |
| <50 percent                      | Relatively mild injury        | NIOSH/OSHA 1981 |
| 5 to 10 percent                  | No injury                     | NIOSH/OSHA 1981 |

### 7.2.2 Eye Contact.

| Exposure Level<br>(and Duration)     | Effects                         | Reference       |
|--------------------------------------|---------------------------------|-----------------|
| SPECIES: Human                       |                                 |                 |
| Glacial (100 percent)<br>acetic acid | Permanent corneal opacification | NIOSH/OSHA 1981 |

| Exposure Level<br>(and Duration)     | Effects  | Reference       |
|--------------------------------------|--|-----------------|
| 4 to 10 percent acetic acid solution | Immediate pain and conjunctival hyperemia, sometimes with injury of corneal epithelium | NIOSH/OSHA 1981 |
| 10 to 15 ppm (vapour)                | Irritation   | NIOSH/OSHA 1981 |
| SPECIES: Rabbit                      |  |                 |
| Glacial (100 percent) acetic acid    | Severe injury  | NIOSH/OSHA 1981 |
| 50 µg                                | Severe irritation  | DPIMR 1983      |

### 7.3 Threshold Perception Properties

**7.3.1 Odour.** Odour Characteristics: Sharp, vinegar-like (Kirk-Othmer 1978).  
Odour Index: 15 000 (AAR 1981).

| Parameter              | Media  | Concentration | Reference       |
|------------------------|--------|---------------|-----------------|
| Odour Threshold        | in air | 24 ppm        | NIOSH/OSHA 1981 |
| Odour Threshold        | in air | 10 ppm        | NIOSH/OSHA 1981 |
| Odour Threshold        | in air | 0.2 to 1 ppm  | NIOSH/OSHA 1981 |
| Lower Odour Threshold  | in air | 5 ppm         | DPIMR 1983      |
| Median Odour Threshold | in air | 24.3 ppm      | DPIMR 1983      |
| Upper Odour Threshold  | in air | 80 ppm        | DPIMR 1983      |

**7.3.2 Taste.** Taste Characteristics: Vinegar-like, burning, sour (Kirk-Othmer 1978).

| Parameter             | Media    | Concentration | Reference  |
|-----------------------|----------|---------------|------------|
| Upper Taste Threshold | in water | 1000 ppm      | DPIMR 1983 |
| Lower Taste Threshold | in water | 300 ppm       | DPIMR 1983 |

## 7.4 Toxicity Studies

### 7.4.1 Inhalation.

| Exposure Level<br>(and Duration)                        | Effects   | Reference        |
|---|---|------------------|
| <u>Acute Exposure</u>                                   |   |                  |
| SPECIES: Human  |   |                  |
| 800 to 1200 ppm   | Cannot be tolerated for longer than 3 minutes   | Doc. TLV 1981    |
| 816 ppm (3 min)   | TC <sub>LO</sub>  | RTECS 1979       |
| 200 ppm   | Severe effects  | Verschueren 1984 |
| >50 ppm   | Intolerable to most persons. Results in intense lacrimation and irritation of eyes, nose and throat, with pharyngeal edema and chronic bronchitis | NIOSH/OSHA 1981  |
| 50 ppm  | Intolerable   | NIOSH/OSHA 1981  |
| 40 ppm  | Symptoms of illness   | Verschueren 1984 |
| >25 ppm   | Unacclimatized humans experience extreme eye and nasal irritation   | NIOSH/OSHA 1981  |
| SPECIES: Guinea Pig                                     |   |                  |
| >100 ppm (1 h)  | Irritation of respiratory tract   | NIOSH/OSHA 1981  |
| SPECIES: Rat  |   |                  |
| 16 000 ppm (4 h)  | Killed one out of six test rats, LC <sub>LO</sub>   | Doc. TLV 1981    |
| SPECIES: Mouse  |   |                  |
| 5620 ppm (1 h)  | LC <sub>50</sub>  | Patty 1982       |
| >100 ppm (1 h)  | Irritation of respiratory tract   | NIOSH/OSHA 1981  |
| <u>Chronic Exposure</u>                                 |   |                  |
| SPECIES: Human  |   |                  |
| 80 to 200 ppm<br>(7 to 12 yr)                           | Congestion of the pharynx   | NIOSH/OSHA 1981  |
| 60 ppm, plus 1 h/d at<br>100 to 260 ppm<br>(7 to 12 yr) | No injury except slight irritation of respiratory tract, stomach and skin   | Doc. TLV 1981    |

| Exposure Level<br>(and Duration)                        | Effects  | Reference     |
|---|--|---------------|
| 60 ppm, plus 1 h/d at<br>100 to 260 ppm<br>(7 to 12 yr) | Conjunctivitis, bronchitis,<br>pharyngitis and erosion of<br>exposed teeth | Doc. TLV 1981 |

#### 7.4.2 Ingestion.

| Exposure Level<br>(and Duration) | Effects  | Reference       |
|----------------------------------|--|-----------------|
| SPECIES: Human                   |  |                 |
| 1.47 mg/kg                       | TD <sub>LO</sub> , gastrointestinal tract<br>effects | DPIMR 1983      |
| 1.0 mL glacial<br>acetic acid    | Perforation of esophagus                             | NIOSH/OSHA 1981 |
| SPECIES: Rabbit                  |  |                 |
| 1200 mg/kg                       | LD <sub>LO</sub>                                     | Patty 1982      |
| SPECIES: Rat                     |  |                 |
| 3310 mg/kg                       | LD <sub>50</sub>                                     | Patty 1982      |
| SPECIES: Mouse                   |  |                 |
| 4960 mg/kg                       | LD <sub>50</sub>                                     | Patty 1982      |

#### 7.4.3 Mutagenicity, Teratogenicity and Carcinogenicity.

| Exposure Level<br>(and Duration)         | Effects   | Reference        |
|--|---|------------------|
| SPECIES: Salmonella                      |   |                  |
| Not specified                            | Low mutagenic potential;<br><0.004 revertant colonies/n mole;<br><70 revertant colonies at<br>1000 µg/plate | Verschueren 1984 |
| SPECIES: <i>Saccharomyces cerevisiae</i> |   |                  |
|  | No mutagenic response   | Patty 1982       |

| Exposure Level<br>(and Duration) | Effects  | Reference  |
|----------------------------------|--|------------|
| SPECIES: Rabbit                  |  |            |
| 1.6 g/kg/d                       | No fetal abnormalities after treatment of pregnant rabbits             | Patty 1982 |
| SPECIES: Chicken                 |  |            |
| 100 mg/kg                        | Chicken embryos treated; no teratogenic effects noted after incubation | Patty 1982 |

## 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.

Note: Acclimation may occur gradually to increasing concentrations.

1. Coughing (AAR 1981).
2. Irritation of nose and throat (AAR 1981).
3. Erosion of exposed teeth (GE 1980).
4. Nausea (AAR 1981).
5. Vomiting (AAR 1981).
6. Bronchial constriction (TDB (on-line) 1981).
7. Chest pain (AAR 1981).
8. Bronchopneumonia (NIOSH/OSHA 1981).
9. Pulmonary edema.

### 7.5.2 Ingestion.

1. Pain in the mouth, pharynx, esophagus and stomach.
2. Laryngitis.
3. Diarrhea (USDHEW 1977).
4. Bloody vomiting (USDHEW 1977).
5. Hemolysis (USDHEW 1977).



6. Hemoglobinuria (USDHEW 1977).
7. Anuria (USDHEW 1977).
8. Shock (USDHEW 1977).
9. Penetration of the esophagus.
10. Death (NIOSH/OSHA 1981).

#### **7.5.3 Skin Contact.**

1. Dermatitis (DPIMR 1981).
2. Ulcers (DPIMR 1981).
3. Skin may become blackened, hyperkeratotic (TDB (on-line) 1981).

#### **7.5.4 Eye Contact.**

1. Lacrimation.
2. Hyperemia.
3. Conjunctivitis.
4. Iritis.
5. Corneal erosion.
6. Loss of sight (NIOSH/OSHA 1981).

## 8 CHEMICAL COMPATIBILITY

## 8.1 Compatibility of Acetic Acid with Other Chemicals and Chemical Groups

| SPECIFIC CHEMICAL<br>OR CHEMICAL GROUP | HEAT GENERATION | FIRE | EXPLOSION | FORMATION OF<br>VIOLENT POLYMERIZATION | FORMATION OF FLAMMABLE GASES | DECOMPOSITION<br>OF GREATER TOXICITY | FORMATION OF TOXIC FUMES<br>IN CLOSED VESSELS | PRESSURIZATION IN CLOSED<br>VESSELS | SOLUBILIZATION | VIOLENT REACTION | NON-HAZARDOUS REACTION | SPECIFICS                             | REFERENCE                 |           |
|--|-----------------|------|-----------|--|------------------------------|--------------------------------------|---|-------------------------------------|----------------|------------------|------------------------|---------------------------------------|---------------------------|-----------|
| <u>GENERAL</u>                         |                 |      |           |  |                              |                                      |   |                                     |                |                  |                        |                                       |                           |           |
| Fire                                   |                 | •    | •         |  |                              |                                      |   |                                     |                |                  |                        | Moderate explosion hazard             | Sax 1979                  |           |
| Heat                                   |                 | •    |           |  |                              |                                      |   |                                     |                |                  |                        |                                       | Sax 1979                  |           |
| <u>SPECIFIC CHEMICALS</u>              |                 |      |           |  |                              |                                      |   |                                     |                |                  |                        |                                       |                           |           |
| Acetaldehyde                           | •               |      |           | •                                      |                              |                                      |   |                                     |                |                  |                        | Causes polymerization of acetaldehyde | Bretherick 1979           |           |
| 2-Aminoethanol                         | •               |      |           |  |                              |                                      |   | •                                   |                |                  |                        | In a closed container                 | NFPA 1978                 |           |
| Ammonium Nitrate                       |                 | •    |           |  |                              |                                      |   |                                     |                |                  |                        | Ignites on warming                    | NFPA 1978                 |           |
| 5-Azidotetrazole                       |                 |      | •         |  |                              |                                      |   |                                     |                |                  |                        |                                       | Bretherick 1979           |           |
| Bromine Pentafluoride                  |                 | •    | •         |  |                              |                                      |   |                                     |                |                  |                        |                                       | NFPA 1978                 |           |
| Chlorine Trifluoride                   |                 |      | •         |  |                              |                                      |   |                                     |                | •                |                        | Violent, sometimes explosive reaction | NFPA 1978                 |           |
| Chlorosulphonic Acid                   | •               |      |           |  |                              |                                      |   | •                                   |                |                  |                        | In a closed container                 | NFPA 1978                 |           |
| Chromic Acid                           |                 |      | •         |  |                              |                                      |   |                                     |                |                  |                        |                                       | Explodes if not kept cold | NFPA 1978 |

### 8.1 Compatibility of Acetic Acid with Other Chemicals and Chemical Groups (Cont'd)

| SPECIFIC CHEMICAL<br>OR CHEMICAL GROUP | HEAT GENERATION | FIRE | EXPLOSION | FORMATION OF<br>VIOLENT REACTIONS | FORMATION OF FLAMMABLE GASES | DECOMPOSITION | FORMATION OF TOXIC FUMES | PRESSURIZATION OF<br>VESSELS | SOLUBILIZATION | VIOLENT REACTION | NON-HAZARDOUS REACTION | SPECIFICS   | REFERENCE       |
|--|-----------------|------|-----------|-----------------------------------|------------------------------|---------------|--------------------------|------------------------------|----------------|------------------|------------------------|---|-----------------|
| Ethylene Diamine                       | •               |      |           |                                   |                              |               |                          |                              |                |                  |                        | In a closed container                                       | NFPA 1978       |
| Ethyleneimine                          | •               |      |           |                                   |                              |               |                          |                              |                |                  |                        | In a closed container                                       | NFPA 1978       |
| Hydrogen Peroxide                      |                 | •    | •         |                                   |                              |               |                          |                              |                |                  |                        | On heating, produces peracetic acid which explodes at 110°C | NFPA 1978       |
| Nitric Acid                            |                 | •    |           |                                   |                              |               |                          |                              |                |                  |                        | Explodes if not kept cold                                   | NFPA 1978       |
| Oleum                                  | •               |      |           |                                   |                              |               |                          |                              |                |                  |                        | In a closed container                                       | NFPA 1978       |
| Perchloric Acid                        |                 |      |           | •                                 | •                            |               |                          |                              |                |                  |                        |   | Leleu 1972      |
| Phosphorus Iso-cyanate                 |                 |      |           |                                   |                              |               |                          |                              |                |                  |                        | Upon contact  | NFPA 1978       |
| Phosphorus Trichloride                 |                 | •    |           |                                   |                              |               |                          |                              |                |                  |                        | Explosion with heat and formation of phosphine              | NFPA 1978       |
| Potassium Hydroxide                    |                 |      |           |                                   |                              |               |                          |                              |                |                  |                        | With a production residue of potassium hydroxide            | Leleu 1976      |
| Potassium Tert-Butoxide                | •               |      |           |                                   |                              |               |                          |                              |                |                  |                        | Ignition 3 min after contact with acetic acid vapour        | Bretherick 1979 |

### 8.1 Compatibility of Acetic Acid with Other Chemicals and Chemical Groups (Cont'd)

| SPECIFIC CHEMICAL<br>OR CHEMICAL GROUP | HEAT GENERATION |           |                         |                                 |                                 |                             |  |                |                  |                           |  | SPECIFICS | REFERENCE   |                      |
|--|-----------------|-----------|-------------------------|---------------------------------|---------------------------------|-----------------------------|--|----------------|------------------|---------------------------|--|-----------|---|----------------------|
|  | FIRE            | EXPLOSION | FORMATION OF<br>VIOLENT | DECOMPOSITION<br>POLYMERIZATION | FORMATION OF<br>FLAMMABLE GASES | FORMATION OF<br>TOXIC FUMES | PRESSURIZATION<br>OF SUBSTANCES<br>VESSELS | SOLUBILIZATION | VIOLENT REACTION | NON-HAZARDOUS<br>REACTION |  |           |   |                      |
| Sodium Hydroxide                       | •               |           |                         |                                 |                                 |                             |  |                |                  |                           |  |           | NFPA 1978   |                      |
| Sodium Peroxide                        |                 |           | •                       |                                 |                                 |                             |  |                |                  |                           |  |           | Explodes if not<br>kept cold  | NFPA 1978            |
| p-Xylene                               |                 |           | •                       |                                 |                                 |                             |  |                |                  |                           |  |           | Detonating mix-<br>tures may be<br>produced                                       | NFPA 1978            |
| <u>CHEMICAL<br/>GROUPS</u>             |                 |           |                         |                                 |                                 |                             |  |                |                  |                           |  |           |   |                      |
| Cyanides                               |                 |           | •                       |                                 |                                 | •                           |  |                |                  |                           |  |           | Produces hydro-<br>gen cyanide  | EPA 600/2-<br>80-076 |
| Epoxides                               | •               |           |                         |                                 | •                               |                             |  |                |                  |                           |  |           |   | EPA 600/2-<br>80-076 |
| Explosives                             |                 |           | •                       |                                 | •                               |                             |  |                |                  |                           |  |           | Can decompose<br>explosives<br>resulting in<br>enough heat to<br>cause detonation | EPA 600/2-<br>80-076 |
| Metal Fluorides                        |                 |           |                         |                                 |                                 |                             |  | •              |                  |                           |  |           | Forms hydrogen<br>fluoride  | EPA 600/2-<br>80-076 |
| Metals                                 |                 | •         |                         | •                               |                                 |                             |  |                |                  |                           |  |           | Generates<br>hydrogen   | EPA 600/2-<br>80-076 |
| Oxidizing Agents                       |                 | •         | •                       |                                 |                                 |                             |  |                |                  |                           |  |           |   | Bretherick<br>1979   |

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

| SPECIFIC CHEMICAL OR CHEMICAL GROUP | HEAT GENERATION | FIRE | EXPLOSION | FORMATION OF POLYMERIZATION | VIOLENT POLYMERIZATION | DECOMPOSITION OF TOXIC FUMES | FORMATION OF FLAMMABLE GASES | PRESSURIZATION OF VESSELS | PRESSURIZATION IN CLOSED | NON-HAZARDOUS REACTION | SPECIFICS                   | REFERENCE        |
|-------------------------------------|-----------------|------|-----------|-----------------------------|------------------------|------------------------------|------------------------------|---------------------------|--------------------------|------------------------|-----------------------------|------------------|
| Permanganates                       |                 | •    |           |                             |                        |                              |                              |                           |                          |                        | Explosion if not kept cold  | NFPA 1978        |
| Sulphides                           | •               |      | •         |                             | •                      |                              |                              |                           |                          |                        | Generates hydrogen sulphide | 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 essentially unchanged - in so doing, it is recognized that there may be some discrepancies between different sources of information. It is recognized that countermeasures are dependent on the situation, and 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.** Acetic acid is combustible but is not a flammable liquid (MCA 1951). It gives off flammable vapours which may form explosive mixtures with air (NFPA 1978).

**9.1.2 Fire Extinguishing Agents.** Use water spray to cool containers involved in a fire (GE 1980).

Small fires: Dry chemical, CO<sub>2</sub>, water spray or foam (alcohol).

Large fires: Water spray, fog or foam.

Move containers from fire area if this can be done without risk. Avoid adding water inside containers; stay away from tank ends (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 and inhalation (Celanese MSDS 1979). If the leak or spill has not ignited, use water spray to disperse the vapours and to protect men attempting to stop the leak (GE 1980). Cellosize, an absorbent material, has shown possible applicability for vapour suppression and/or containment of acetic acid spills (ICI 1982).

**9.1.3.2 Spills on land.** Contain, if possible, by forming mechanical and/or chemical barriers to prevent spreading. Remove as much material as possible by pump or vacuum equipment. Cover the area with lime or sodium bicarbonate to neutralize the residual acid and shovel into containers for disposal (EPA 670/2-75-042; GE 1980).

**9.1.3.3 Spills in water.** Contain, if possible. Neutralize with sodium bicarbonate or lime (EPA 670/2-75-042; OHM-TADS 1981). Dowex 5WX4 might also be considered as

sorbent materials in spill situations (CG-D-38-76). Remove contaminated water for treatment as indicated below.

#### 9.1.4 Cleanup and Treatment.

**9.1.4.1 General.** For treatment of contaminated water, gravity separation of solids followed by neutralization with sodium hydroxide is recommended. Further treatment is accomplished by passing the above treated water through dual media filtration (EPA 600/2-77-227).

The following treatment process has shown possible applicability for spill countermeasures (TSA 1980):

| <u>Process</u>  | <u>Percent Removal</u> |
|-----------------|------------------------|
| Reverse Osmosis | <20 to 80              |

Acetic acid can also be removed by treating the contaminated water with activated sludge (Metry 1980).

Narkis (1980) used a number of treatment methods on acetic acid-contaminated water. Ferric chloride removed an average of 9.5 percent and lime 14.9 percent. Carbon absorption did not show any appreciable removal. Kvo (1977) used ozonation combined with UV light to remove up to 92 percent of acetic acid in 2 hours. Successive oxidation of acetic acid produces glyoxylic acid, oxalic acid and ultimately carbon dioxide. Fang (1976) used reverse osmosis to remove acetic acid and achieved the following removal efficiencies with various membranes:

| <u>Membrane</u>            | <u>Removal (%)</u> |
|----------------------------|--------------------|
| Polyamide                  | 10-70              |
| Polyethylenimine           | 50-70              |
| Cellulose acetate          | 5-12               |
| Cellulose triacetate       | 20                 |
| Cellulose acetate butyrate | 4                  |
| Chlorinated polyphenylene  | 22                 |

**9.1.5 Disposal.** Waste acetic acid must never be discharged directly into sewers or surface waters. Following treatment, either at the spill site or at a waste management facility, the resultant sludge can be disposed of to a secure landfill.

**9.1.6 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 acetic acid:

- 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 any possibility of skin contact with solid or liquid acetic acid or solutions containing acetic acid (NIOSH/OSHA 1981).
- Dust- and splash-proof safety goggles are recommended where there is any possibility of solid or liquid acetic acid or solutions containing acetic acid contacting the eyes (NIOSH/OSHA 1981). Gas-tight and chemical safety goggles should also be considered (Celanese MSDS 1979).
- The following clothing materials are penetrated by acetic acid in time periods greater than 1 hour: butyl rubber, neoprene, nitrile, polyethylene, polyurethane, and PVC. The following materials showed penetration times of about 1 hour: natural rubber, neoprene with styrene-butadiene coating, nitrile with PVC coating, and styrene-butadiene rubber (Little 1983).
- Rubber high top safety shoes or boots, outer clothing fitted snugly at the neck and wrist, rubber aprons, and gloves should also be considered as protective clothing to be worn when handling acetic acid (GE 1980).
- The following chemical suit materials are recommended for protection against acetic acid (EE-20): cloropel, neoprene, PVC (excellent resistance) and butyl (good resistance).
- Nonimpervious clothing which becomes contaminated with solid or liquid acetic acid or solutions containing acetic acid should be removed immediately and not reworn until the acetic acid is removed from the clothing (NIOSH/OSHA 1981).
- Eye wash stations and chemical safety showers should be readily available in areas of use or spill situations (GE 1980).

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

| Condition                               | Minimum Respiratory Protection*<br>Required Above 10 ppm  |
|---|---|
| Vapour Concentration<br>500 ppm or less | Any chemical cartridge respirator with a full face-piece and an organic vapour cartridge(s).<br>A gas mask with a chin-style or a front- or back-mounted organic vapour canister. |



| Condition   | Minimum Respiratory Protection*<br>Required Above 10 ppm   |
|---|--|
| 1000 ppm or less  | <p>Any supplied-air respirator with a full facepiece, helmet, or hood.</p> <p>Any self-contained breathing apparatus with a full facepiece.</p> <p>A Type C supplied-air respirator with a full facepiece operated in pressure-demand or other positive pressure mode or with a full facepiece, helmet, or hood operated in continuous-flow mode.</p>  |
| Greater than 1000 ppm or entry and escape from unknown concentrations | <p>Self-contained breathing apparatus with a full facepiece operated in pressure-demand or other positive pressure mode.</p> <p>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.</p> |
| Fire fighting   | <p>Self-contained breathing apparatus with a full facepiece operated in pressure-demand or other positive pressure mode.</p>   |
| Escape  | <p>Any gas mask providing protection against organic vapours.</p> <p>Any escape self-contained breathing apparatus.</p>  |

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

## 9.2 Specialized Countermeasures Equipment, Materials or Systems

The following items are 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     | Plug N' Dike®           |
| Pumps for Liquids | U.S. Coast Guard ADAPTS |
| 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 the criteria are included, and thus, 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.

## 11 ANALYTICAL METHODS

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

Methods have been documented here for the analysis 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 Acetic Acid in Air

**11.1.1 Gas Chromatography** (NIOSH 1977). A range of 12.5 to 50 mg/m<sup>3</sup> (5.1-20.4 ppm) of acetic acid in air may be determined by gas chromatography using flame ionization detection.

A known volume in air is drawn through a 7 cm x 6 mm O.D. charcoal tube containing 2 sections of 20/40 mesh activated charcoal separated by a 2 mm portion of urethane foam. The first section contains 100 mg whereas the second section contains 50 mg. A silylated glass wool plug is placed before the front absorbing section. A sample size of 168 L of air sampled at 1.0 L/min is recommended.

The charcoal tube sample is scored before the first section of charcoal and broken. The larger, or front, section of charcoal is transferred to a 2 mL stoppered sample container containing 1.0 mL of formic acid. The same operation is performed with the back-up section. The sample should be allowed to desorb for 60 min. A 5 µL aliquot of sample is injected into a gas chromatograph equipped with a flame ionization detector.

The acetic acid is determined using an electronic integrator which measures peak area in conjunction with a calibration curve.

Typical gas chromatograph conditions are: a 1 m x 4 mm I.D. glass column packed with 60/80 mesh Carbopack B/3 percent carbowax 20 M/0.5 percent H<sub>3</sub>PO<sub>4</sub>, 60 mL/min nitrogen carrier gas, hydrogen gas flow at 50 mL/min, air flow at 500 mL/min, injector temperature at 230°C, detector temperature at 230°C, and the column temperature from 130 to 180°C at 10°C/min.

## **11.2 Qualitative Method for the Detection of Acetic Acid in Air**

A range of 5 to 50 ppm of acetic acid in air may be determined using a Drager detector tube for acetic acid.

A known volume of air is drawn through a Drager detector tube for acetic acid using a Drager gas detector pump. A colour change of the bluish-violet indicating layer to yellow indicates acetic acid. The colour change is based on the reaction between acetic acid and an acid indicator in the reaction ampoule (Drager 1979).

## **11.3 Quantitative Method for the Detection of Acetic Acid in Water**

**11.3.1 Steam Distillation** (AWWA 1981). A range of up to 5000 ppm of organic acids as acetic acid may be determined using steam distillation.

A minimum 1 L volume of representative sample is collected in an appropriate container and acidified to pH 3 with 50 percent sulphuric acid. A 6 mL volume of ferric chloride solution, prepared by dissolving 82.5 g ferric chloride solution, prepared by dissolving 82.5 g ferric chloride-hexahydrate in 1 L of distilled water, is added to the sample. A 50 g mass of diatomaceous-silica filter aide is added and the mixture is shaken. The sample is suction-filtered using a Buchner funnel containing a filter paper freshly coated with a thin layer of diatomacous-silica. The residue is washed four times with water and the filtrate adjusted to pH 11 with sodium hydroxide solution. The sample is concentrated to 150 mL on a steam bath and refrigerated. The cooled filtrate is adjusted to pH 4 with 50 percent sulphuric acid and transferred to a suitable distilling flask. Magnesium sulphate is added to slight excess and heat is applied to a steam generating flask connected to the distilling flask. A distillate volume of 200 mL is collected in approximately 25 min. The distillation rate is increased and a total of 500 mL of distillate is collected.

The acetic acid is determined by titration with 0.1 N sodium hydroxide using phenolphthalein indicator.

#### **11.4 Qualitative Method for the Detection of Acetic Acid in Water**

The sample is collected as in Section 11.3.1. A one drop volume of sample is combined with 50 mg of solid sodium bicarbonate dissolved in 1 mL of water. The mixture is shaken gently. Vigorous effervescence or steady evolution of gas indicates a carboxylic acid (Owen 1969).

#### **11.5 Quantitative Method for the Detection of Acetic Acid in Soil**

**11.5.1 Gas Chromatography** (NIOSH 1977; ASTM 1979). Concentrations of acetic acid at the ppm level may be detected using a flame ionization detector.

Approximately 20 g of soil, accurately weighed, are collected in a glass jar. Freon 113<sup>®</sup> (1,1,2-trichloro-1,2,2-trifluoroethane) is used to extract acetic acid from the soil. The Freon<sup>®</sup> is distilled from the reaction 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<sup>®</sup>. The residue is dissolved in carbon disulphide.

A suitable aliquot of the dissolved residue is injected into a gas chromatograph equipped with a flame ionization detector. The acetic acid is determined using an electronic integrator which measures the area under the peak in conjunction with a calibration curve.

#### **11.6 Qualitative Method for the Detection of Acetic Acid in Soil**

The sample is collected as in Section 11.5.1 and extracted using Freon 113<sup>®</sup> (1,1,2-trichloro-1,2,2-trifluoroethane). The Freon<sup>®</sup> is distilled from the reaction flask on a water bath at 70°C. Air is drawn through the flask for the final minute to remove all traces of the Freon<sup>®</sup>. The residue is dissolved in water. A one drop volume of sample is combined with 50 mg of solid sodium bicarbonate dissolved in 1 mL of water. The mixture is shaken gently. Vigorous effervescence or steady evolution of gas indicates a carboxylic acid (AWWA 1981; Owen 1969).

## 12 REFERENCES AND BIBLIOGRAPHY

### 12.1 References

AAR 1981: BDM Corporation, The AAR Hazardous Materials Data Base, Prepared for the Association of American Railroads, Parts I and II, McLean, VA. (May, 1981).

ASS: Atlas Steel, Atlas Stainless Steels, Toronto, Ontario. Not dated.

ASTM 1979: American Society for Testing and Materials, Annual Book of ASTM Standards, Part 31: Water, Philadelphia, PA, D2908-74, D1192-70, D3370. (1979).

AWWA 1981: American Water Works Association, Standard Methods for the Examination of Water and Wastewater, 15th Edition, American Public Health Association, Washington, DC, Method 504B. (1981).

Bretherick 1979: Bretherick, L., Handbook of Reactive Chemical Hazards, Second Edition, Butterworths, London, England. (1979).

Cairns 1968: Cairns, J., Scheier, A., "A Comparison of the Toxicity of Some Common Industrial Waste Components Tested Individually and Combined", Progr. Fish. Cult., Vol. 30, No. 1, pp. 3-8. (1968).

CBG 1980: Southam Business Publications Ltd., "1981 Chemical Buyers' Guide", Canadian Chemical Processing, Vol. 64, No. 9, Don Mills, Ontario. (December, 1980).

CCP 1981: "Celanese Plans Giant VAM Plant", Canadian Chemical Processing, Vol. 65, No. 7, p. 10. (October, 1981).

Celanese MSDS 1978: Celanese Canada Inc., Material Safety Data Sheet, Montreal, Quebec. (1978).

Celanese MSDS 1979: Celanese Chemical Company, Inc., Material Safety Data Sheet, Dallas, TX. (November, 1979).

Celanese PB 1976: Celanese Chemical Company, Inc., Product Bulletin - Glacial Acetic Acid, New York, NY. (1976).

CG-D-38-76: Bauer, W.H., Borton, D.N., et al., Agents, Methods and Devices for Amelioration of Discharge of Hazardous Chemicals on Water, Rensselaer Polytechnic Institute for the U.S. Coast Guard, Washington, DC, CG-D-38-76. (August, 1975).

CHRIS 1974: U.S. Department of Transportation, CHRIS Hazard Assessment Handbook, U.S. Coast Guard, Washington, DC, CG-446-3. (April, 1974).

CHRIS 1978: U.S. Department of Transportation, Coast Guard, Chemical Hazards Response Information System (CHRIS), Washington, DC. (1978).

Corpus 1983: Corpus Information Services Ltd., "Acetic Acid", Chemical Product Profiles, Don Mills, Ontario. (September, 1983).

CRC 1980: Weast, R.C. (ed.), CRC Handbook of Chemistry and Physics, 60th Edition, Chemical Rubber Publishing Company, Cleveland, OH. (1980).

DCRG 1978: Dow Chemical Company, Dow Chemical Resistance Guide for Dow Plastic Lined Piping Products, Midland, MI. (1978).

Dillon 1982: M.M. Dillon, Survey of Countermeasures Systems for Hazardous Material Spills, Environment Canada, Ottawa, Canada. (1982).

Doc. TLV 1981: American Conference of Governmental Industrial Hygienists (ACGIH), Documentation of Threshold Limit Values, Fourth Edition, Cincinnati, OH. (1981).

DPIMR 1983: Sax, N.I. (ed.), Dangerous Properties of Industrial Materials Report, Vol. 1, No. 3, pp. 23-25. (March/April, 1983).

DPLV 1972: Dow Chemical Company, Dow Plastic Lined Valves, Midland, MI. (1972).

DPPED 1967: DOM-X, DOM-X Plastic Pipe Engineering Data, Toronto, Ontario. (1967).

Drager 1979: Leichnetz, K. (ed.), "Air Investigations and Technical Gas Analysis with Drager Tubes", Detector Tube Handbook, Fourth Edition, Lubeck, Germany, p. 30. (1979).

EE-20: Buchan, Lawton, Parent Ltd., A Survey of Self-Contained Breathing Apparatus and Totally-Encapsulated Chemical Protection Suits, Unedited Version. Not dated.

EPA 440/9-75-009: Supplement to Development Document: Hazardous Substances Regulations, Section 311 Federal Water Pollution Control Act, U.S. Environmental Protection Agency, Office of Water and Standards, Washington, DC, EPA 440/9-75-009. (November, 1975).

EPA 600/2-77-227: Huibregtse, K.R., et al., Manual for the Control of Hazardous Material Spills - Volume One - Spill Assessment and Water Treatment Techniques, U.S. Environmental Protection Agency, National Environmental Research Center, Cincinnati, OH, EPA 600/2-77-227. (November, 1977).

EPA 600/2-80-076: Hatayama, H.K., Chen, J.J., deVera, E.R., Stephens, R.D., Storm, D.L., A Method for Determining the Compatibility of Hazardous Wastes, Municipal Environmental Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, OH. (April, 1980).

EPA 670/2-75-042: Pilie, R.J., et al., Methods to Treat, Control and Monitor Spilled Hazardous Materials, U.S. Environmental Protection Agency, National Environmental Research Center, Cincinnati, OH, EPA 670/2-75-042. (June, 1975).

ERG 1980: U.S. Department of Transportation, Hazardous Materials, 1980 Emergency Response Guidebook, Research and Special Programs Administration, Materials Transportation Bureau, Washington, DC. (1980).

Fang 1976: Fang, H.H.P., Chian, E.S.K., "Reverse Osmosis Separation of Polar Organic Compounds in Aqueous Solution", Environ. Sci. Technol., Vol. 10, No. 4, pp. 364-369. (1976).

FKC 1975: Lowenheim, F.A., Moran, M.K., Faith, Keyes and Clark's Industrial Chemicals, Wiley-Interscience, New York, NY. (1975).

GE 1980: General Electric Company, Material Safety Data Sheets, Material Safety Information Services, Schenectady, NY. (October/December, 1980).

GF: GF Plastic Systems Inc., GF Plastic Systems, Santa Ana, CA. Not dated.

GPP: Uniroyal, Guide to Polymer Properties, Uniroyal Inc., Mishawaka, IN. Not dated.

Hansch and Leo 1979: Hansch, C., Leo, A., Substitute Constants for Correlation Analysis in Chemistry and Biology, John Wiley & Sons Inc., New York, NY. (1979).

HIS 1969: Hydraulic Institute, Hydraulic Institute Standards, 12th Edition, New York, NY. (1969).

Holmes 1980: Holmes, J.L., Lossing, F.P., "Gas-phase Heats of Formation of Keto and Enol Ions of Carbonyl Compounds", J. Amer. Chem. Soc., Vol. 102, p. 1591. (1980).

ICI 1982: Imperial Chemical Industries (ICI), Treatment of Organic Compounds, Appendix 7, Cheshire, England. (April, 1982).

Jones 1971: Jones, H.R., "Environmental Control in the Organic and Petrochemical Industries", Noyes Data Corp., NJ. (1971).

JSSV 1979: Jenkins Brothers, Jenkins Corrosion Resistant Stainless Steel Valves, New York, NY. (1979).

Kirk-Othmer 1978: Grayson, M., Eckroth, D. (ed.), Kirk-Othmer Encyclopedia of Chemical Technology, Third Edition, Vol. 1, John Wiley & Sons Inc., New York, NY. (1978).

Kvo 1977: Kvo, P.P.K., Chian, E.S.K., Chang, B.J., "Identification of End Products Resulting from Ozonation and Chlorination of Organic Compounds Commonly Found in Water", Environ. Sci. Technol., Vol. 11, No. 13, pp. 1177-1181. (1977).

Lange's Handbook 1979: Dean, J.A. (ed.), Lange's Handbook of Chemistry, 12th Edition, McGraw-Hill Book Company, New York, NY. (1979).

Lefèvre 1980: Lefèvre, M.J., Becker, E.O., First Aid Manual for Chemical Accidents -For Use with Nonpharmaceutical Chemicals, Dowden, Hutchinson and Ross Inc., Stroudsburg, PA. (1980).

Leleu 1972: Leleu, M.J., "Les réactions chimiques dangereuses - acide perchlorique", Cahiers de Notes Documentaires, Note 815-64-72, Paris, France. (1972).

Leleu 1976: Leleu, M.J., "Les réactions chimiques dangereuses - hydroxides inorganiques", Cahiers de Notes Documentaires, Note 1023-84-76, Paris, France. (1976).

Little 1970: Little, A.D. (ed.), Relationship between Organic Chemical Pollution of Fresh Water and Health, A.D. Little Inc., Cambridge, MA. (December, 1970).



Little 1983: Schwope, A.D., Costas, P.P., Jackson, J.D., Weitzman, P.J., Guidelines for the Selection of Chemical Protective Clothing, Arthur D. Little, Inc., for U.S. Environmental Protection Agency, Washington, DC. (1983).

Mattson 1976: Mattson, V.R., Arthur, J.W., Walbridge, W.R., Acute Toxicity of Selected Organic Compounds to Fathead Minnows, U.S. Environmental Protection Agency, Duluth, MN, EPA 600/2-76-097. (1976).

MCA 1951: Manufacturing Chemists Association, "Acetic Acid", Chemical Safety Data Sheet, Washington, DC. (1951).

Metry 1980: Metry, A.A., The Handbook of Hazardous Waste Management, Technomic Publishing Company, Inc., Westport, CT. (1980).

MWPP 1978: Rehau, Mechan-O-Joint Water Pressure Pipe and Fittings, Montreal, Quebec. (1978).

Narkis 1980: Narkis, N., Henesfeld-Fourrier, S., Rebhun, M., "Volatile Organic Acids in Raw Wastewater and in Physical-Chemical Treatment", Water Research, Vol. 14, pp. 1215-1223. (1980).

NFPA 1978: National Fire Protection Association, Fire Protection Guide on Hazardous Materials, Seventh Edition, Boston, MA. (1978).

NIOSH 1977: National Institute for Occupational Safety and Health, Manual of Analytical Methods, Second Edition, Vol. 2, S. 29, Cincinnati, OH. (April, 1977).

NIOSH 1978: National Institute for Occupational Safety and Health, Manual of Analytical Methods, Second Edition, Vol. 4, S. 169, Cincinnati, OH. (1978).

NIOSH Guide 1978: U.S. Department of Health, Education and Welfare, Pocket Guide to Chemical Hazards, U.S. Department of Health, Education and Welfare, and U.S. Department of Labor, Washington, DC. (1978).

NIOSH/OSHA 1981: U.S. Department of Health and Human Services, National Institute for Occupational Safety and Health (NIOSH), U.S. Department of Labor, Occupational Safety and Health Administration (OSHA), Occupational Health Guidelines for Chemical Hazards, NIOSH Publication No. 81-123. (1981).

OHM-TADS 1981: Oil and Hazardous Materials Technical Assistance Data System, U.S. Environmental Protection Agency, Oil and Special Materials Control Division, Office of Water Program Operations, Washington, DC. (1981).

Ontario E.P. Act 1971: Ontario Ministry of the Environment, "The Environmental Protection Act, Statutes of Ontario 1971", Chapter 86, as amended; and Regulation 15 (General) as amended. (1971).

Owen 1969: Owen, T.C., Characterization of Organic Compounds by Chemical Methods, Marcel Dekker, Inc., New York, NY, p. 152. (1969).

Patty 1982: Clayton, G.D., Clayton, F.E. (ed.), Patty's Industrial Hygiene and Toxicology, Vol. 2C, John Wiley & Sons Inc., New York, NY. (1982).

Perry 1973: Perry, R.H., Chilton, C.H. (ed.), Chemical Engineer's Handbook, Fifth Edition, McGraw-Hill Book Company, New York, NY. (1973).

Portman 1970: Portman, J.E., The Toxicity of 120 Substances to Marine Organisms, Shellfish Information Leaflet, Fisheries Experimental Station, Conway, N. Wales; Ministry of Agriculture, Fisheries and Food. (September, 1970).

PPH 1984: Gallant, R.W., Railey, J.M., Physical Properties of Hydrocarbons Vol. II, Gulf Publishing Company, Houston, TX. (1984).

Price 1974: Price, K.S., Waggy, G.T., Conway, R.H., "Brine Shrimp Bioassay and Seawater BOD of Petrochemicals", J. Water Pollut. Control Fed., Vol. 46, No. 1. (January, 1974).

Rouse 1961: Rouse, H., Fluid Mechanics for Hydraulic Engineers, Dover Publications, Inc., New York, NY. (1961).

RTDCR 1974: Canadian Transport Commission, Regulations for the Transportation of Dangerous Commodities by Rail, published by Supply and Services Canada, Ottawa, Ontario. (1974).

RTECS 1979: Lewis, R.J., Tatken, R.L., Registry of Toxic Effects of Chemical Substances, 1979, Vols. 1 and 2, National Institute for Occupational Safety and Health (NIOSH), Cincinnati, OH. (September, 1980).

Sax 1979: Sax, N.I., Dangerous Properties of Industrial Materials, Fifth Edition, Van Nostrand Reinhold Company, New York, NY. (1979).

Scott 1979: Scott's Industrial Directory of Ontario Manufacturers, 12th Edition, Penstock Directories Limited, Oakville, Ontario. (1979).

Streeter 1971: Streeter, V.L., Fluid Mechanics, Fifth Edition, McGraw-Hill Book Company, New York, NY. (1971).

Sussex 1977: Pedley, J.B., Rylance, J., Sussex-N.P.L. Computer Analysed Thermochemical Data: Organic and Organometallic Compounds, University of Sussex, Sussex, Brighton, England. (1977).

TCM 1979: General American Transportation Corporation, Tank Car Manual, Chicago, IL. (May, 1979).

TDB (on-line) 1981: Toxicity Data Base, Toxicology Information On-Line, Available from National Library of Medicine, Washington, DC. (1981).

TDGC 1980: Transport Canada, Transportation of Dangerous Goods Code, Vol. 1 (Lists), Vol. 2, Ottawa, Canada. (June, 1980).

TLV 1983: American Conference of Governmental Industrial Hygienists, TLV's Threshold Limit Values for Chemical Substances and Physical Agents in the Workroom Environment with Intended Changes for 1983-84, Cincinnati, OH. (1983).

TPS 1978: GSR Fluid Handling, Thermoplastic Piping Systems, Sun Valley, CA. (1978).

TSA 1980: Shuckrow, A.J., Pajak, A.P., Osheka, J.W., Concentration Technologies for Hazardous Aqueous Waste Treatment, Touhill, Shuckrow and Associates, Inc., Pittsburgh, PA. (1980).

Ullmann 1975: Ullmanns Encyklopaedie der technischen Chemie, Verlag Chemie, Weinheim. (1975).

USDHEW 1977: U.S. Department of Health, Education and Welfare, Occupational Diseases. A Guide to Their Recognition, National Institute for Occupational Safety and Health, DHEW (NIOSH) No. 77-181. (1977).

Verschueren 1984: Verschueren, K., Handbook of Environmental Data on Organic Chemicals, Van Nostrand Reinhold Company, New York, NY. (1984).

Wilton 1974: Wilton, R.W., Some Infrared and X-Ray Properties of the High Pressure Polymorph of Solid Acetic Acid, Thesis presented to the Department of Chemistry, University of Alberta, Edmonton, Alberta. (1974).

WQC 1963: McKee, J.E., Wolf, H.W., Water Quality Criteria, Second Edition, Resources Agency of California, State Water Quality Control Board. (1963).

WQCDB-3 1972: Water Quality Criteria Data Book - Vol. 3. Effects of Chemicals on Aquatic Life, U.S. Environmental Protection Agency, Washington, DC. (1972).

WQCDB-5 1973: Water Quality Criteria Data Book - Vol. 5. Effects of Chemicals on Aquatic Life, U.S. Environmental Protection Agency, Washington, DC. (1973).

## 12.2 Bibliography

American Conference of Governmental Industrial Hygienists (ACGIH), Documentation of Threshold Limit Values, Fourth Edition, Cincinnati, OH. (1981).

American Conference of Governmental Industrial Hygienists, TLV\*s Threshold Limit Values for Chemical Substances and Physical Agents in the Workroom Environment with Intended Changes for 1983-84, Cincinnati, OH. (1983).

American Society for Testing and Materials, Annual Book of ASTM Standards, Part 31: Water, Philadelphia, PA, D2908-74, D1192-70, D3370. (1979).

American Water Works Association, Standard Methods for the Examination of Water and Wastewater, 15th Edition, American Public Health Association, Washington, DC, Method 504B. (1981).

Atlas Steel, Atlas Stainless Steels, Toronto, Ontario. Not dated.

Bauer, W.H., Borton, D.N., et al., Agents, Methods and Devices for Amelioration of Discharge of Hazardous Chemicals on Water, Rensselaer Polytechnic Institute for the U.S. Coast Guard, Washington, DC, CG-D-38-76. (August, 1975).

BDM Corporation, The AAR Hazardous Materials Data Base, Prepared for the Association of American Railroads, Parts I and II, McLean, VA. (May, 1981).

Bretherick, L., Handbook of Reactive Chemical Hazards, Second Edition, Butterworths, London, England. (1979).

Buchan, Lawton, Parent Ltd., A Survey of Self-Contained Breathing Apparatus and Totally-Encapsulated Chemical Protection Suits, Unedited Version. Not dated.

Canadian Transport Commission, Regulations for the Transportation of Dangerous Commodities by Rail, published by Supply and Services Canada, Ottawa, Ontario. (1974).

Cairns, J., Scheier, A., "A Comparison of the Toxicity of Some Common Industrial Waste Components Tested Individually and Combined", Progr. Fish. Cult., Vol. 30, No. 1, pp. 3-8. (1968).

"Celanese Plans Giant VAM Plant", Canadian Chemical Processing, Vol. 65, No. 7, p. 10. (October, 1981).

Celanese Canada Inc., Material Safety Data Sheet, Montreal, Quebec. (1978).

Celanese Chemical Company, Inc., Product Bulletin - Glacial Acetic Acid, New York, NY. (1976).

Celanese Chemical Company, Inc., Material Safety Data Sheet, Dallas, TX. (November, 1979).

Clayton, G.D., Clayton, F.E. (ed.), Patty's Industrial Hygiene and Toxicology, Vol. 2C, John Wiley & Sons Inc., New York, NY. (1982).

Corpus Information Services Ltd., "Acetic Acid", Chemical Product Profiles, Don Mills, Ontario. (September, 1983).

Dean, J.A. (ed.), Lange's Handbook of Chemistry, 12th Edition, McGraw-Hill Book Company, New York, NY. (1979).

M.M. Dillon, Survey of Countermeasures Systems for Hazardous Material Spills, Environment Canada, Ottawa, Canada. (1982).

DOM-X, DOM-X Plastic Pipe Engineering Data, Toronto, Ontario. (1967).

Dow Chemical Company, Dow Chemical Resistance Guide for Dow Plastic Lined Piping Products, Midland, MI. (1978).

Dow Chemical Company, Dow Plastic Lined Valves, Midland, MI. (1972).

Fang, H.H.P., Chian, E.S.K., "Reverse Osmosis Separation of Polar Organic Compounds in Aqueous Solution", Environ. Sci. Technol., Vol. 10, No. 4, p. 364-369. (1976).

Gallant, R.W., Railey, J.M., Physical Properties of Hydrocarbons Vol. II, Gulf Publishing Company, Houston, TX. (1984).

General American Transportation Corporation, Tank Car Manual, Chicago, IL. (May, 1979).

General Electric Company, Material Safety Data Sheets, Material Safety Information Services, Schenectady, NY. (October/December, 1980).

GF Plastic Systems Inc., GF Plastic Systems, Santa Ana, CA. Not dated.

Grayson M., Eckroth, D. (ed.), Kirk-Othmer Encyclopedia of Chemical Technology, Third Edition, Vol. 1, John Wiley & Sons Inc., New York, NY. (1978).

GSR Fluid Handling, Thermoplastic Piping Systems, Sun Valley, CA. (1978).

Hansch, C., Leo, A., Substitute Constants for Correlation Analysis in Chemistry and Biology, John Wiley & Sons Inc., New York, NY. (1979).

Hatayama, H.K., Chen, J.J., deVera, E.R., Stephens, R.D., Storm, D.L., A Method for Determining the Compatibility of Hazardous Wastes, Municipal Environmental Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, OH. (April, 1980).

Holmes, J.L., Lossing, F.P., "Gas-phase Heats of Formation of Keto and Enol Ions of Carbonyl Compounds", J. Amer. Chem. Soc., Vol. 102, p. 1591. (1980).

Huibregtse, K.R., et al., Manual for the Control of Hazardous Material Spills - Volume One - Spill Assessment and Water Treatment Techniques, U.S. Environmental Protection Agency, National Environmental Research Center, Cincinnati, OH, EPA 600/2-77-227. (November, 1977).

Hydraulic Institute, Hydraulic Institute Standards, 12th Edition, New York, NY. (1969).

Imperial Chemical Industries (ICI), Treatment of Organic Compounds, Appendix 7, Cheshire, England. (April, 1982).

Jenkins Brothers, Jenkins Corrosion Resistant Stainless Steel Valves, New York, NY. (1979).

Jones, H.R., "Environmental Control in the Organic and Petrochemical Industries", Noyes Data Corp., NJ. (1971).

Kvo, P.P.K., Chian, E.S.K., Chang, B.J., "Identification of End Products Resulting from Ozonation and Chlorination of Organic Compounds Commonly Found in Water", Environ. Sci. Technol., Vol. 11, No. 13, pp. 1177-1181. (1980).

Lefèvre, M.J., Becker, E.O., First Aid Manual for Chemical Accidents - For Use with Nonpharmaceutical Chemicals, Dowden, Hutchinson and Ross Inc., Stroudsburg, PA. (1980).

Leichnitz, K. (ed.), "Air Investigations and Technical Gas Analysis with Drager Tubes", Detector Tube Handbook, Fourth Edition, Lubeck, Germany, p. 30. (1979).

Leleu, M.J., "Les réactions chimiques dangereuses - acide perchlorique", Cahiers de Notes Documentaires, Note 815-64-72, Paris, France. (1972).

Leleu, M.J., "Les réactions chimiques dangereuses - hydroxides inorganiques", Cahiers de Notes Documentaires, Note 1023-84-76, Paris, France. (1976).

Lewis, R.J., Tatken, R.L., Registry of Toxic Effects of Chemical Substances, 1979, Vols. 1 and 2, National Institute for Occupational Safety and Health (NIOSH), Cincinnati, OH. (September, 1980).

Little, A.D. (ed.), Relationship between Organic Chemical Pollution of Fresh Water and Health, A.D. Little Inc., Cambridge, MA. (December, 1970).

Lowenheim, F.A., Moran, M.K., Faith, Keyes and Clark's Industrial Chemicals, Wiley-Interscience, New York, NY. (1975).

Manufacturing Chemists Association, "Acetic Acid", Chemical Safety Data Sheet, Washington, DC. (1951).

Mattson, V.R., Arthur, J.W., Walbridge, W.R., Acute Toxicity of Selected Organic Compounds to Fathead Minnows, U.S. Environmental Protection Agency, Duluth, MN, EPA 600/2-76-097. (1976).

McKee, J.E., Wolf, H.W., Water Quality Criteria, Second Edition, Resources Agency of California, State Water Quality Control Board. (1963).

Metry, A.A., The Handbook of Hazardous Waste Management, Technomic Publishing Company, Inc., Westport, CT. (1980).

Narkis, N., Nenesfeld-Fourrier, S., Rebhun, M., "Volatile Organic Acids in Raw Wastewater and in Physical-Chemical Treatment", Water Research, Vol. 14, pp. 1215-1223. (1980).

National Fire Protection Association, Fire Protection Guide on Hazardous Materials, Seventh Edition, Boston, MA. (1978).

National Institute for Occupational Safety and Health, Manual of Analytical Methods, Second Edition, Vol. 2, S. 29, Cincinnati, OH. (April, 1977).

National Institute for Occupational Safety and Health, Manual of Analytical Methods, Second Edition, Vol. 4, S. 169, Cincinnati, OH. (1978).

Oil and Hazardous Materials Technical Assistance Data System, U.S. Environmental Protection Agency, Oil and Special Materials Control Division, Office of Water Program Operations, Washington, DC. (1981).

Ontario Ministry of the Environment, "The Environmental Protection Act, Statutes of Ontario 1971", Chapter 86, as amended; and Regulation 15 (General) as amended. (1971).

Owen, T.C., Characterization of Organic Compounds by Chemical Methods, Marcel Dekker, Inc., New York, NY, p. 152. (1969).

Pedley, J.B., Rylance, J., Sussex-N.P.L. Computer Analysed Thermochemical Data: Organic and Organometallic Compounds, University of Sussex, Sussex, Brighton, England. (1977).

Perry, R.H., Chilton, C.H. (ed.), Chemical Engineer's Handbook, Fifth Edition, McGraw-Hill Book Company, New York, NY. (1973).

Pilie, R.J., et al., Methods to Treat, Control and Monitor Spilled Hazardous Materials, U.S. Environmental Protection Agency, National Environmental Research Center, Cincinnati, OH, EPA 670/2-75-042. (June, 1975).

Portman, J.E., The Toxicity of 120 Substances to Marine Organisms, Shellfish Information Leaflet, Fisheries Experimental Station, Conway, N. Wales; Ministry of Agriculture, Fisheries and Food. (September, 1970).

Price, K.S., Waggy, G.T., Conway, R.H., "Brine Shrimp Bioassay and Seawater BOD of Petrochemicals", J. Water Pollut. Control Fed., Vol. 46, No. 1. (January, 1974).

Rehau, Mechan-O-Joint Water Pressure Pipe and Fittings, Montreal, Quebec. (1978).

Rouse, H., Fluid Mechanics for Hydraulic Engineers, Dover Publications, Inc., New York, NY. (1961).

Sax, N.I. (ed.), Dangerous Properties of Industrial Materials Report, Vol. 1, No. 3, pp. 23-25. (March/April, 1983).

Sax, N.I., Dangerous Properties of Industrial Materials, Fifth Edition, Van Nostrand Reinhold Company, New York, NY. (1979).

Schwoppe, A.D., Costas, P.P., Jackson, J.D., Weitzman, P.J., Guidelines for the Selection of Chemical Protective Clothing, Arthur D. Little, Inc., for U.S. Environmental Protection Agency, Washington, DC. (1983).

Scott's Industrial Directory of Ontario Manufacturers, 12th Edition, Penstock Directories Limited, Oakville, Ontario. (1979).

Shuckrow, A.J., Pajak, A.P., Osheka, J.W., Concentration Technologies for Hazardous Aqueous Waste Treatment, Touhill, Shuckrow and Associates, Inc., Pittsburgh, PA. (1980).

Southam Business Publications Ltd., "1981 Chemical Buyers' Guide", Canadian Chemical Processing, Vol. 64, No. 9, Don Mills, Ontario. (December, 1980).

Streeter, V.L., Fluid Mechanics, Fifth Edition, McGraw-Hill Book Company, New York, NY. (1971).

Supplement to Development Document: Hazardous Substances Regulations, Section 311 Federal Water Pollution Control Act, U.S. Environmental Protection Agency, Office of Water and Standards, Washington, DC, EPA 440/9-75-009. (November, 1975).

Toxicity Data Base, Toxicology Information On-Line, Available from National Library of Medicine, Washington, DC. (1981).

Transport Canada, Transportation of Dangerous Goods Code, Vol. 1 (Lists), Vol. 2, Ottawa, Canada. (June, 1980).

Ullmanns Encyklopaedie der technischen Chemie, Verlag Chemie, Weinheim. (1975).

Uniroyal Inc., Guide to Polymer Properties, Mishawaka, IN. Not dated.

U.S. Department of Health, Education and Welfare, Pocket Guide to Chemical Hazards, U.S. Department of Health, Education and Welfare, and U.S. Department of Labor, Washington, DC. (1978).

U.S. Department of Health, Education and Welfare, Occupational Diseases. A Guide to Their Regulation, National Institute for Occupational Safety and Health, DHEW (NIOSH) No. 77-181. (1977).

U.S. Department of Health and Human Services, National Institute for Occupational Safety and Health (NIOSH), U.S. Department of Labor, Occupational Safety and Health Administration (OSHA), Occupational Health Guidelines for Chemical Hazards, NIOSH Publication No. 81-123. (1981).

U.S. Department of Transportation, CHRIS Hazard Assessment Handbook, U.S. Coast Guard, Washington, DC, CG-446-3. (April, 1974).

U.S. Department of Transportation, Hazardous Materials, 1980 Emergency Response Guidebook, Research and Special Programs Administration, Materials Transportation Bureau, Washington, DC. (1980).

U.S. Department of Transportation, Coast Guard, Chemical Hazards Response Information System (CHRIS), Washington, DC. (1978).

Verschuere, K., Handbook of Environmental Data on Organic Chemicals, Van Nostrand Reinhold Company, New York, NY. (1984).

Water Quality Criteria Data Book - Vol. 3. Effects of Chemicals on Aquatic Life, U.S. Environmental Protection Agency, Washington, DC. (1972).

Water Quality Criteria Data Book - Vol. 5. Effects of Chemicals on Aquatic Life, U.S. Environmental Protection Agency, Washington, DC. (1973).

Weast, R.C. (ed.), CRC Handbook of Chemistry and Physics, 60th Edition, Chemical Rubber Publishing Company, Cleveland, OH. (1980).

Wilton, R.W., Some Infrared and X-Ray Properties of the High Pressure Polymorph of Solid Acetic Acid, Thesis presented to the Department of Chemistry, University of Alberta, Edmonton, Alberta. (1974).



EnviroTIPS  
Common Abbreviations

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