DEPARTMENT OF TRANSPORTATION

COAST GUARD

CHRIS

Hazard Assessment

Handbook

COMDTINST M16465.13 (old CG-446-3)

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UNITED STATES COAST GUARD

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CHEMICAL HAZARDS RESPONSE INFORMATION SYSTEM
(CHRIS)

CG-446-3

Change No. 1

1. Purpose. This change publishes amendments to manual three of CHRIS, as announced in COMDTNOTE 16465 dated 28 October 1977.

2. Action.
   a. Remove and insert the following pages:

Remove	Insert
xi - xv	xi - xvii
59 - 69 (odd numbered pages)	59 - 69 (odd numbered pages)
73 (RB)	73 (RB)
81 - 85 (odd numbered pages)	81 - 85 (odd numbered pages)
89 (RB)	89 (RB)
95 (RB)	95 (RB)
105 - 107 (odd numbered pages)	105 - 107 (odd numbered pages)
115 - 119 (odd numbered pages)	115 - 119 (odd numbered pages)
175 (RB)	175 (RB)
177 - 179 (RB)	177 - 179 (RB)
181 (RB)	181 (RB)
183 - 185 (RB)	183 - 185 (RB)
187 - 211 (RB)	187 - 211 (RB)
213 (RB)	213 (RB)
215 - 221 (RB)	215 - 221 (RB)
223 (RB)	223 (RB)
225 - 227 (odd numbered pages)	225 - 227 (odd numbered pages)
229	229 - 230a (RB)
231 (RB)	231 (RB)
233 (RB)	233 - 234
235 (RB)	235 (RB)
237 - 247 (RB)	237 - 247 (RB)
249 - 264	249 - 264
265 - 268	265 - 268a
269 (RB)	269 (RB)
271 - 275 (RB)	271 - 276
277 (RB)	277 (RB)
279 - 281 (RB)	279 - 282
283 (RB)	283 (RB)
285 - 287 (odd numbered pages)	285 - 287 (odd numbered pages)

12 DEC 1977

2. a. (continued)

Remove	Insert
289(RB)	289 - 290c(RB)
293 - 299(odd numbered pages)	293 - 299(odd numbered pages)
301 - 303(RB)	301 - 303(RB)

b. Insert the tabbed manila sheets at the following locations:

Tab marked "D" directly precedes page 181;
Tab marked "E" directly precedes page 185;
Tab marked "G" directly precedes page 213;
Tab marked "I" directly precedes page 223;
Tab marked "K" directly precedes page 227;
Tab marked "O" directly precedes page 231;
Tab marked "P" directly precedes page 235;
Tab marked "R" directly precedes page 247;
Tab marked "T" directly precedes page 269;
Tab marked "V" directly precedes page 277;
Tab marked "X" directly precedes page 283; and
Tab marked "RR" directly precedes page 287.

c. Insert the list of effective pages (LEP 1-2) at the end of the manual.

d. Insert this transmittal letter immediately after the title page.

3. Effective Date. Effective upon receipt.

[illegible]
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CHEMICAL HAZARDS RESPONSE INFORMATION SYSTEM
COMDTINST M16465.13 (old CG-446-3)

Hazard Assessment Handbook 26 APR 1974

LETTER OF PROMULGATION

1. Chemical Hazards Response Information System. The Chemical Hazards Response Information System (CHRIS) manual is an official publication of the U.S. Coast Guard and consists of the following four volumes:

CG-446-1	A Condensed Guide to Chemical Hazards
CG-446-2	Hazardous Chemical Data
CG-446-3	Hazard Assessment Handbook
CG-446-4	Response Methods Handbook

2. Purpose. The manual provides timely information essential for proper decision-making by responsible Coast Guard personnel and others during emergencies involving the water transport of hazardous chemicals. It also provides certain basic nonemergency related information to support Coast Guard efforts to achieve improved levels of safety in the bulk shipment of hazardous chemicals. The four manuals contain chemical data, hazard-assessment methods and response guides. A full description of CHRIS appears in each volume.

3. Amendments. Changes to each volume except CG-446-1 will be by consecutively numbered amendments transmitting new or revised pages, as necessary. CG-446-1 will be reprinted and redistributed in its entirety as needs dictate.

4. Distribution. Distribution will be made in accordance with the Directives, Publications and Reports Index (CG-236).

5. Effective Date. 15 April 1974.

W. M. BENKERT
Chief, Office of Marine Environment and Systems

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RECORD OF CHANGES

Identification of Change	Date Entered	By whom entered (Signature; rank, grade or rate; name of command)
CHANGE 1	ENTERED AT PRINTING	
CHANGE 2	ENTERED AT PRINTING	

1.0 CHRIS MANUALS

1.0 CHRIS MANUALS

1.1 PURPOSE AND SCOPE

The Chemical Hazard Response Information System (CHRIS) is designed to provide timely information essential for proper decision-making by responsible Coast Guard personnel and others during emergencies involving the water transport of hazardous chemicals. A secondary purpose is the provision of certain basic non-emergency-related information to support the Coast Guard in its efforts to achieve improved levels of safety in the bulk shipment of hazardous chemicals. CHRIS consists of four reference guides or manuals, a regional contingency plan, a hazard-assessment computer system (HACS), and an organizational entity located at Coast Guard headquarters. The four manuals contain chemical data, hazard-assessment methods, and response guides. Regional data for the entire coastline are included in the Coastal Regional Contingency Plans. The headquarters staff operates the hazard-assessment computer system and provides technical assistance on request by field personnel during emergencies. In addition, it is responsible for periodic update and maintenance of CHRIS.

A brief description of each component of CHRIS and its relation to this manual – the Hazard-Assessment Handbook – is provided below.

1.2 A CONDENSED GUIDE TO CHEMICAL HAZARDS

This handbook contains information to facilitate "early response decisions" during emergency situations. It is a compact, convenient source of chemical-related information with specific reference to bulk-shipped hazardous materials. The guide is intended primarily for use by port security personnel and others who may be the first to arrive at the site of an incident and need readily available, easily understood, descriptive information about the hazardous nature of the chemical and the situation confronted. It will assist those personnel in quickly determining proper, responsible actions that must be taken immediately to safeguard life and property and to reduce, insofar as possible, further contamination of the environment. The guide contains precautionary advice on the chemical and its characteristic physical and biological hazards so that field personnel can assess the threat as a prerequisite to determining subsequent large-scale action.

Since the Condensed Guide to Chemical Hazards is the only component of CHRIS that will be initially available at the scene of an accident, it includes a list of on-scene information needs that this manual, the Hazard-Assessment Handbook, requires as inputs. The on-scene information needs of the Hazard-Assessment Handbook are listed in the Condensed Guide to Chemical Hazards as questions which must be answered and relayed to the user of this handbook as soon as possible.

1.3 HAZARDOUS CHEMICAL DATA

The Hazardous Chemical Data Manual is intended for use primarily by the On-Scene Coordinator's (OSC) office and the Regional and National Response Centers. It contains detailed, largely quantitative chemical, physical, and biological data necessary for formulating, evaluating, and carrying out response plans.

The Hazardous Chemical Data Manual is very important in the successful use of this handbook, the Hazard-Assessment Handbook. The Hazardous Chemical Data Manual contains the hazard-assessment code, which is essential to selecting the appropriate calculation procedures for the hazard assessment, and lists the needed physical and chemical property data which are required to perform the hazard-assessment calculations.

1.4 HAZARD-ASSESSMENT HANDBOOK

The Hazard-Assessment Handbook contains methods of estimating the rate and quantity of hazardous chemicals that may be released under different situations. It also provides the means of predicting the threat that the chemicals present after release. It includes methods for predicting the resulting potential toxic, fire, and explosion effects by providing procedures for estimating the concentration of hazardous chemicals (both in water and in air) as a function of time and distance from the spill.

1.5 RESPONSE METHODS HANDBOOK

The Response Methods Handbook is a compendium of descriptive information and technical data pertaining to methods of responding to threatened or actual spills of hazardous chemicals. The document has been written specifically for Coast Guard OSC personnel who have had some training or experience in pollution and hazard response. Emphasis has been placed on existing or prospectively available methodology. As new methods become available, the response handbook will be updated to include these new approaches.

In an actual emergency, an assessment of the likely extent of hazard, using the Hazard-Assessment Handbook, will be used in the choice of the appropriate response methods suggested in the Response Methods Handbook.

1.6 DATA BASE FOR REGIONAL CONTINGENCY PLAN

The information in this data base is predominantly for use by OSC personnel. It contains data pertinent to a specific region, subregion, or locale. It will provide detailed information on resources that might be threatened and the availability of response equipment. Examples of such information include an inventory of physical resources and personnel; vulnerable or exposed resources (critical water-use areas); potential pollution sources; geographical and environmental features; cooperating organizations; and recognized experts with identified skills. A good deal of this regional-specific information is in the form of Regional Contingency Plans.

1.7 HAZARD-ASSESSMENT COMPUTER SYSTEM (HACS)

The Hazard-Assessment Computer System (HACS) is the computerized counterpart of the Hazard-Assessment Handbook and enables trained headquarters specialists utilizing the computer at headquarters to obtain very detailed hazard evaluations quickly when requested by OSC personnel. Methods of utilizing HACS as an aid in hazard assessment are described in Section 8 of this handbook.

2.0 OVERALL APPROACH

2.0 OVERALL APPROACH

2.1 INTRODUCTION

This hazard-assessment handbook is concerned with the evaluation of any dangerous condition precipitated by accidents involving discharged chemicals, which have, as a foreseeable consequence, loss of life, limb, and/or property. A chemical discharge (or spill) on water can create a hazard because of its flammability, its toxicity, or both. As the spill disperses and becomes diluted, the hazard normally decreases and disappears. It is important to know how far and fast the danger of fire or poisoning can spread and at what point the chemical ceases to be hazardous.

The processes of dispersion, evaporation, combustion, and the like, which are associated with the chemicals of concern are quite complex and depend on many variables, not the least of which is the nature of the chemical itself. This handbook provides a systematic, simplified approach to identifying the appropriate processes governing a given chemical release and methods for estimating the hazard. The hazard estimate is given in terms of distances over which a toxic or flammable concentration of a given chemical may exist and the minimum safe distance between the spill site and people or combustible materials, should the chemical ignite and a fire ensue.

2.2 APPROACH

The evaluation of a hazard due to a chemical discharge will be performed using this handbook with the following sequence of action:

- Determination of the on-scene information needs by acquiring information pertinent to the accident,
- Selection of the appropriate calculation procedures, and
- Evaluation of the extent of hazard using procedures given in this manual.

Each one of these major steps is explained below.

2.2.1 Information Needs

In the event of a spill or discharge of a hazardous chemical into or onto a body of water, Coast Guard personnel will need certain on-scene information to assess the hazard presented by the spill and determine the appropriate response. This information can be considered to be of two types: (1) that which is absolutely essential for even the most basic assessment of the hazard potential; and (2) that which will permit a more refined and accurate assessment if time permits. The necessary information can best be obtained by answering a series of questions.

The list of questions which must be answered before any kind of hazard assessment is contemplated is designated the "primary list of questions." These are presented in Section 3, along with suggested ways of answering them. Examples of primary questions are: what is the identity of the chemical being discharged? What is the rate of discharge or the total quantity involved?

Also presented in Section 3 are the "secondary list of questions" which should be answered (if time permits), and which would enable the CHRIS specialist at headquarters to perform a more detailed and refined hazard assessment using HACS. Suggested sources for answering the secondary questions are also discussed in Section 3.

The primary and secondary lists of questions are repeated in the Condensed Guide to Chemical Hazards, which will be carried to the accident scene by on-scene personnel.

In the event of an emergency, Coast Guard personnel – both on-scene and at base – will concentrate on answering all the primary questions immediately, using any or all information sources provided in the handbook or otherwise available to them. Only after these questions have been answered and the immediate response procedures outlined in the Condensed Guide to Chemical Hazards have been initiated will attempts be made to answer the other questions and make a more refined assessment of the situation.

2.2.2 Selection of Calculation Procedures

Once the chemical being discharged has been identified, the hazard presented can readily be assessed, provided one could determine its interaction with water. To attempt to treat each and every chemical individually in describing its interactions with water would lead to a very large and unwieldy document. A more logical approach is to generalize the various chemical-water interactions that can occur and represent them in the form of a hazard-assessment tree. This tree, which is to be used with this handbook, is shown in Figure 2.1. If one knows the properties of the chemical, he can follow the appropriate vertical path(s) in the tree and determine which calculation procedures he must use to assess the hazards presented by the chemical. Both the hazard-assessment path and the needed physical properties are provided by the Hazardous Chemical Data Manual.

The first box (beneath ACCIDENT) in Figure 2.1 is designated by the letter A and represents a quantitative description of the discharge; e.g., the chemical, its rate of flow or total quantity discharged, the state of the discharged chemical, and significant parameters, such as temperature and pressure. Methods of identifying the chemical, quantity in transport, and rate of release constitute on-scene information needs and are provided in Section 3, entitled "Information Needs." Once the chemical has been identified, its physical properties can be obtained for the Hazardous Chemical Data Manual.

Depending on the state of the released chemical (gas, liquid, solid, or mixture), it can be said to belong to one or more of the vertical paths shown in Figure 2.1.

- Gases

- Liquids
  - Non-reacting with water
    - Boiling point below ambient temperature of water
    - Boiling point above ambient temperature of water
  - Reactive with water
  - Self-reacting (polymerization, decomposition, etc.)
- Solids
  - Soluble
  - Insoluble
  - Reactive.

The oval boxes along each path represent decision points that are based upon physical properties, and the triangles are decision points set by environmental conditions. The rectangular boxes identify physical phenomena (boiling, dispersion, etc.) which are mathematically represented by calculation procedures in this handbook. While these procedures simply indicate how rapidly certain physical processes are taking place, they are essential because they help determine the extent of the hazard. Each rectangle is designated by a letter, so that a particular path may be referred to by a series of letters. This series of letters is called the "hazard-assessment code" and is identified in the Hazardous Chemical Data Manual for each chemical. Each path eventually leads to one or more circles, which are points of evaluation.

To illustrate the use of the hazard-assessment tree, consider the discharge of a material that boils at temperatures below the local water temperature, is not soluble (immiscible) in water, is lighter than water, and is not ignited either because it is non-flammable or because there is no ignition source present (path A-D-F-G). For such a chemical, we would wish to know how fast it spreads on water, boils, and disperses in air under the existing atmospheric conditions so as to determine over what distances flammable and toxic concentrations of the chemical may exist. Generalized procedures for calculating these rates are also provided in this handbook. As inputs, such procedures require information about physical properties, environmental conditions, and any special restrictions (e.g., shorelines) that might limit the chemical spreading in one or more directions. Once the path is defined, the threat can be assessed, because the critical toxicity levels and ignition limits are known and provided in the Hazardous Chemical Data Manual and hazard-assessment procedures are described here.

Other paths introduce the same, or similar, types of calculations. By indicating which calculations must be performed and providing generalized methods of making the desired calculations, this hazard-assessment manual will allow one to progress along the appropriate path and determine the potential hazard presented by a chemical discharge.

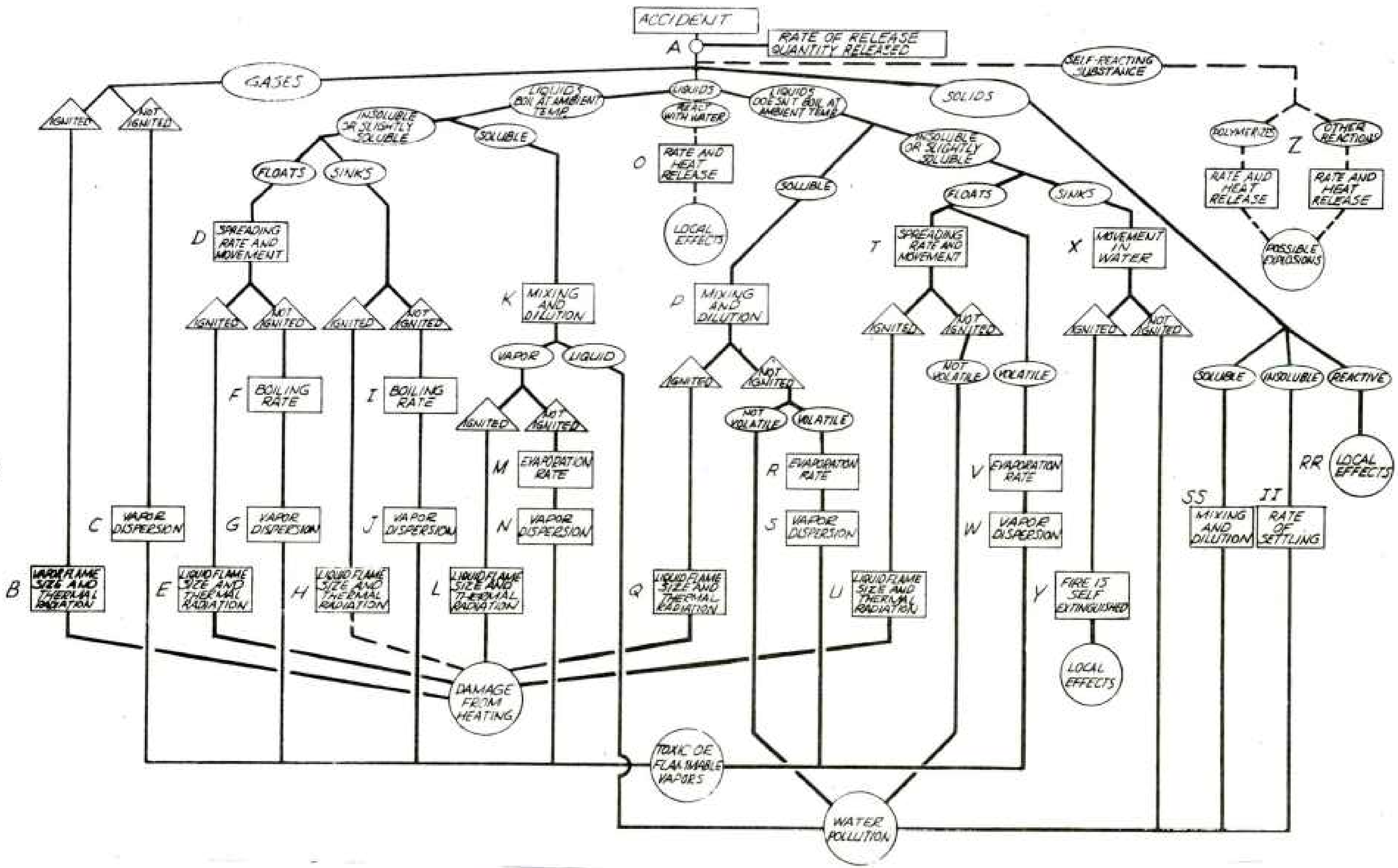

FIGURE 2-1 HAZARD ASSESSMENT TREE: (Events Chart)

In the event of an emergency, once the chemical being discharged has been identified and the needed on-scene information collected by answering the primary questions, proceed to the Hazardous Chemical Data Manual and obtain the hazard-assessment code for the chemical. The hazard-assessment code is given as item 11 in the Hazardous Chemical Data Manual and provides the key to selecting the appropriate calculation procedures as described in Section 4 of this handbook.

2.3 HAZARD ASSESSMENT

Once the identity of the discharged chemical and the associated hazard-assessment code have been established, one can proceed to the final step of actually making the hazard assessment. The hazard assessment will require calculations utilizing the graphs and tables presented in Section 6. Corresponding to each letter in the hazard-assessment code is a calculation procedure displayed in graphic or tabular form. Some procedures are generalized and can apply to several chemicals, whereas others are specific for an individual chemical. Actual instructions for using the graphs and tables and making the hazard assessment are given in Section 5. Furthermore, worksheets are provided for each hazard assessment code with a solved example of a hypothetical assessment on the left side of the worksheet and blanks to be filled out for the real emergency situation on the right side of the worksheet. The worksheets, graphs, and tables needed for calculations are indexed according to the hazard-assessment code they represent.

In the event of an emergency, once the chemical being discharged is identified, the needed on-scene information collected and hazard-assessment code obtained from the Hazardous Chemical Data Manual, proceed to that part of Section 5 (Hazard Assessment) indexed by the letters of the hazard-assessment code and make the actual assessment. Instructions for the required calculations and solved examples are provided on worksheets in that section of the handbook.

3.0 INFORMATION NEEDS

3.0 INFORMATION NEEDS

3.1 ORGANIZATION OF INFORMATION NEEDS

When a hazardous chemical is discharged into water, it is essential that certain on-scene information be obtained to assess the hazard presented by the discharge and initiate the appropriate response. The needed on-scene information requirements are presented in this section as a series of questions which must be answered as soon as possible by the Coast Guard personnel who first arrive at the scene of the incident. The information absolutely necessary for any level of hazard assessment is obtained by answering the "primary questions" given in Section 3.2. If time permits, attempts should be made to collect additional information which will allow a more refined and accurate assessment utilizing the hazard-assessment computer system (HACS) at CHRIS headquarters. This additional information is to be collected by answering the "secondary questions" given in Section 3.3.

As a guide and aid for answering the primary and secondary questions, a list of information sources is provided in Section 3.4. For each question to be answered, possible sources of information are listed for use by both on-scene personnel as well as base personnel. The list of primary and secondary questions – as well as the sources of information – is also provided in the Condensed Guide to Chemical Hazards. This guide should be made available to emergency personnel at the scene of the incident.

Finally, a more detailed description of the sources of information is presented in Section 3.5. Personnel who will be called upon to make the hazard assessment, as well as those likely to be sent on-scene, should thoroughly familiarize themselves beforehand with the detailed contents of Section 3.5 and rely only on the questions and brief source listing (Sections 3.2, 3.3, and 3.4) to obtain the needed on-scene information during an emergency.

3.2 PRIMARY LIST OF QUESTIONS

In the event of an emergency, Coast Guard personnel, both on-scene and at base, should concentrate on answering *all* the primary questions as soon as possible, using any or all information sources provided here or otherwise available to them. The on-scene personnel should call in the answers to the primary questions to the hazard-assessment personnel at base as early as possible. *The on-scene personnel must answer all the primary questions either from well established information or else by estimation.*

Questions of Primary Importance:

Primary Question No.

1. What is the specific name of the chemical being spilled or discharged? Try and verify the chemical identity from more than one source.

2. At what time did the spill occur or the discharge begin?

Primary Question No.

3. Where did the spill, discharge or accident occur?

4. How much of the chemical was originally in the leaking tank or hold?

5. What is the wind speed and direction?

6. What fraction of the sky is covered with clouds? (totally overcast, partially cloudy, no clouds)

7. What is the set and drift of the current?

8. If the spill has occurred on a water body which is affected by the ocean's tides, what is the maximum amplitude of tidal velocity?

9. What is the approximate width and depth of the waterway?

10. If gas is being vented, what is the approximate hole diameter?

3.3 SECONDARY LIST OF QUESTIONS

After the primary list of questions has been answered and the information transmitted to the hazard-assessment personnel at base, the questions of secondary importance should be answered.

Questions of Secondary Importance:

Secondary Question No.

1. How fast is the chemical being released or about how long did it take for the tank or hold to empty or stop leaking? How much, if any, is left in the tank? What is the size and shape of the hole, and the length, width, and shape of the leaking tank? What is or was the height of the liquid level above the bottom of the hole or the water level, whichever was or is higher?

2. What is the temperature of the water?

3. What is the average depth of the water in the vicinity of the spill or discharge?

4. If the spill or discharge has occurred on a river or channel, what is the average width of the river or channel?

5. What is the temperature of the air?

6. If the spill has occurred on a water body which is affected by the ocean's tides, how long is it from the beginning of the spill or discharge until the next high tide?

7. If it can be seen, how large is the pool of spilled chemical?

8. What is or was the action of the chemical upon release? Did it seem to boil on the surface of the water, mix with the water, sink into the water, or what?

9. Is or was there a vapor cloud forming over the spilled chemical? If so, and it could or can be seen, is or was it lying close to the water or rising?

10. What condition is the vessel in? Is it taking on water? Is it listing (how many degrees)? Is it grounded on sand or rocks? Is it drifting?

11. What type of vessel is it? What are its length and width and what is the distance from its main deck to the bottom of its hull?

Answers to the secondary questions will allow the specialists operating the hazard-assessment computer system to make a more refined and accurate estimate of hazard. Note that the information obtained by answering the primary questions is sufficient for the operation of HACS. Additional information obtained by answering the secondary questions will result in a more accurate estimate of the hazard by utilizing HACS.

3.4 LIST OF INFORMATION SOURCES

Both the on-scene and base personnel should attempt to answer the primary and secondary list of questions. The sources of information that each may contact is given in this section.

3.4.1 Suggested List of Sources for Answering the Primary Questions

- **Primary Question 1: Relating to the Identity of Chemical Being Spilled or Discharged**

  On-Scene Personnel:

  a) Captain or crew of vessel
  b) Shipping papers, cargo manifests
  c) Cargo information cards
  d) Cargo warning signs
  e) Placards or labels
  f) Certificates of inspection
  g) Observable characteristics.

Base Personnel:

a) Vessel operator
b) Shipping agent
c) Where cargo was loaded
d) Compilations of vessel information
e) Coast Guard records
f) Trade names

- **Primary Question 2: Relating to the Time at Which Incident Occurred or Discharge Began**

On-Scene Personnel:

a) Captain or crew
b) Nearby vessels or observers

Base Personnel:

a) Time at which distress call received
b) Nearby vessels or observers

- **Primary Question 3: Relating to the Location of Incident**

On-Scene and Base Personnel:

a) Navigation charts or aids
b) Captain or crew of vessel
c) Nearby vessels or observers

- **Primary Question 4: Relating to the Quantity of Chemical Originally in Vessel or Tank**

On-Scene Personnel:

a) Captain or crew of vessel
b) Shipping papers, cargo manifests
c) Certificates of inspection
d) Estimation techniques (see Section 3.5).

Base Personnel:

a) Vessel operator
b) Shipping agent
c) Compilations of vessel information
d) Coast Guard records

- **Primary Questions 5 and 6: Relating to Wind Speed, Direction, and Cloud Cover**

  On-Scene Personnel:

  a) Estimation or measurement techniques

  Base Personnel:

  a) Weather Bureau

- **Primary Questions 7 and 8: Relating to Current Drift and Set and Maximum Amplitude of Tidal Velocity**

  On-Scene Personnel:

  a) Estimation or measurement techniques
  b) On-scene observation

  Base Personnel:

  a) Published sources (e.g., Atlas of Surface Currents, see Section 3.5).

- **Primary Question 9: Relating to the Width and Depth of the Waterway**

  On-Scene Personnel:

  a) Make approximate visual estimate

  Base Personnel:

  a) Navigation charts or aids.

- **Primary Question 10: Relating to the Hole Diameter for Gas Release**

  On-Scene Personnel:

  a) Make approximate estimate visually.

3.4.2 Suggested List of Sources for Answering the Secondary Questions

- **Secondary Question 1: Relating to Chemical Release Rate, Residual Amount, etc.**

  On-Scene Personnel:

  a) Captain or crew of vessel
  b) Estimation or measurement techniques
  c) On-scene observation

  Base Personnel:

  a) Estimations based upon data received from on-scene personnel

- **Secondary Questions 2,3, and 4: Relating to Waterway Temperature, Depth, and Width**

  On-Scene Personnel:

  a) Estimation or measurement techniques
  b) On-scene observations

  Base Personnel:

  a) Published sources (e.g., Navigational Charts, see Section 3.5).

- **Secondary Question 5: Relating to Air Temperature**

  On-Scene Personnel:

  a) Estimation or measurement techniques

  Base Personnel:

  a) Weather Bureau

- **Secondary Question 6: Relating to Time to Next High Tide**

  Base Personnel:

  a) Published sources (e.g., Tidal Current Tables, 1974, Atlantic Coast of N. America, see Section 3.5).

The remainder of the secondary questions can only be answered by on-scene personnel as the answers depend on visual observation of the incident.

3.5 DETAILED DESCRIPTIONS OF INFORMATION SOURCES

3.5.1 Identity and Quantity of Chemical:

The information sources available for determining the identity and quantity of the chemical are numerous and rather complexly interrelated. Many of them can either lead directly to the desired answer or can lead to another information source which can provide the answer. Descriptions of the information sources listed in Section 3.4 follow.

- **Crew of Vessel:**

The crew of the vessel, especially the captain, can be the most valuable source of information. It may provide the information desired directly or provide leads to numerous other sources of pertinent information.

- **Shipping Papers, Cargo Manifests, etc.**

Every vessel which travels U.S. waters and transports a hazardous chemical is required to have aboard certain documents which describe its cargo. For bulk shipments, these documents will include the common chemical name of the cargo. For shipments other than those made in bulk quantities, the common chemical name has to be given only if the material is specifically mentioned by name in the Code of Federal Regulations. Otherwise, certain general names which are found in the regulations for various categories of chemicals may be present. An example of one of these general names is the phrase "Alcohol-N.O.S." where N.O.S means "not otherwise specified." A substance thus identified might be any of the large number of alcohols which are not specifically named in the regulations. Other abbreviations which are commonly used in place of N.O.S. in shipping papers include:

N.O.I. – not otherwise indexed

N.O.I.B.N. – not otherwise indexed by name.

Table 3.1 lists the information items which are typically required to be present in the shipping papers of vessels carrying dangerous cargoes. The information presented should not be used for enforcement purposes since it does not point out important exceptions or qualifications.

TABLE 3-1

INFORMATION REQUIRED IN PAPERS CARRIED BY VESSELS

Data Item	All Ships-Hazardous Cargoes	Barges-Hazardous Cargoes
Bulk and Non-Bulk Cargoes:		
Identification of cargo	X	X
Approximate quantity by compartment	X	X
Name and address of shipper		X
Location of loading point		X
Consignee's or cargo owner's name and address	X	X
Name of vessel	X	
Official number or international radio call sign of the vessel	X	
Nationality of vessel	X	
Classification of substances aboard (such as explosive, flammable liquid, etc.)	X	
Stowage provided for substance	X	
Non-Bulk Cargoes Only:		
Number of packages	X	
Weight and type of packages	X	
Shipping or loading marks and numbers on packages	X	
Labels applied to package (if required)	X	

- **Vessel Operator's Dispatching Office**

If the crew, shipping papers, or other sources of information described below give sufficient information to lead to the vessel operator's office or dispatching office, this office can be contacted, both to notify it of the accident and to obtain necessary information.

- **Shipper of cargo, consignee (receiver) of cargo, etc.**

Once sufficient information is obtained to contact these people, further information about the cargo can be obtained from them. They should know what they shipped, or what they ordered.

- **Where cargo was loaded**

If the specific location and name of the facility is known, it can be contacted. Presumably, it will have some record of what cargo personnel at the facility loaded aboard the vessel.

- **Cargo Information cards**

By suggestion of the Manufacturing Chemist's Association, many barges and ships now carry a Cargo Information Card for each type of cargo aboard. This card will generally be carried on the bridge or in the pilot house of the vessel, readily available for use by the person in charge of the watch. The cards may also be carried aboard each barge, mounted near the warning sign which is discussed below. The minimum card size allowable is 7" x 9½". Data listed for each chemical aboard include:

a. Identification of cargo,

b. Appearance and odor,

c. Statement of hazards involved and instructions for safe handling, and as applicable, the need for special cargo environments,

d. Emergency procedures and precautions, and

e. Fire-fighting procedures and precautions.

The response and hazards information given on these cards is similar to that given in the Condensed Guide to Chemical Hazards. The presence of a card indicates that the particular chemical the card describes is likely to be aboard.

- **Cargo warning signs – Barges**

Barges carrying certain dangerous cargoes will be marked by warning signs 3 feet wide by 2 feet high with black letters on a white background. Warnings will include one or more of the following:

Warning
Dangerous Cargo
No Visitors – (indicates possible poisonous cargo)
No Smoking } (indicate a flammable cargo)
No Open Lights }

These signs are often found welded onto the barge and are never taken off, even if the particular cargo is not so hazardous as indicated by the sign, or if the barge is empty. Nevertheless, *the sign should never be taken for granted.* If the barge is loaded, which can be determined by how deeply it sits in the water, it should be assumed that it does have a hazardous cargo aboard and should be approached carefully. If the name of a chemical is displayed on this warning sign, then that is the only chemical aboard. This is further discussed under "Placards."

Under no circumstances should the absence of a sign be taken as proof that the cargo is not hazardous.

- **Placards – Barges**

If more than one type of chemical is aboard a barge, one of which is considered hazardous, there should be either an individual sign or placard at or on each tank or hold of the barge giving its contents, or there should be one sign posted listing what each tank or hold contains. When a barge is carrying only one type of cargo, then the warning sign may have the name of the substance on it and no other signs need be aboard. Thus, if the warning sign gives the name of one chemical, it is likely that no other chemicals are present in the barge.

- **Compilations of Vessel Information**

Two compilations of information on vessels exist for each Coast Guard district, and they can quickly provide information about vessels operating in the area. Each is described below and generally will be on-hand in the duty office of the nearest Coast Guard base.

The first of these is a U.S. Army Corps of Engineers booklet, which contains information on the waterborne transportation lines which operate in various areas of the country. There are three such compilations at present – one for the Mississippi River System and the Gulf Inter-Coastal Waterway (series 4), one for the Great Lakes System (series 5), and one for the Atlantic, Gulf, and Pacific Coasts (series 3). Each of these contain the two tables which are described below.

The names of the vessel operators are listed alphabetically in Table 1. Each entry gives the name and address of the operator. Table 2 lists the operators in alphabetical sequence and, under the name of each, gives the names of all vessels operated by him and lists for each the net register tonnage, register and overall length, register and overall breadth, draft (both loaded and light), horsepower, capacity in short tons or units of cargo, number of passengers, heights of fixed superstructures, cargo handling equipment, vessel operating base, and year built or rebuilt. (Note: 1 short ton = 2000 lb).

The second compilation of vessel information is the Department of Transportation – U.S. Coast Guard's "Merchant Vessels of the U. S." which contains a number of useful tables of data *about all registered vessels* of the United States.

Table 1, List of Vessels, provides an alphabetical list by name of the vessels, giving the official number of the vessel, signal and radio-call letters, type of rig, gross and net tonnage, length, breadth, width, hull type, when and where built, type of service used for, horsepower, name of owner, and home port.

Another table, Signal Letters, is an alphabetized list by *signal and radio call letters* giving the name of the vessel, and may be useful in the rare event that the signal letters of the vessel are known, but no other information is available.

The final Table, Index of Managing Owners, is an alphabetical list of the owners of the vessels, giving their names, addresses, and the names of the vessels they own. Having looked up the name of the owner in the first list, one may refer to this list for further information.

- **Limitations**

The Corps of Engineers booklet unfortunately, does not include an alphabetical listing by name of the vessel. If the name of the vessel is something like "Exxon 101" it may be self-evident who owns the vessel, but if it is a name such as "Intruder" or "Mary Lou," it is virtually impossible to find who the owner is by use of this compilation. Yet it is this compilation which is most complete, for it lists all registered *and* certified vessels which operate in a region. The major limitation of the DOT-USCG book is that it only lists the *registered vessels.* Most barges are certified but not registered. A large number of the open-hopper type may be neither.

- **Certificates of Inspection**

Another source of information, especially for barges, is the certificate of inspection which each vessel must carry. For barges, this document, which is generally sealed in a tube or "mailbox" on the deck of the vessel, lists the dangerous cargoes which the barge may carry. Other information given includes:

a) The maximum cargo weight (short tons),

b) The maximum density of the cargo (lbs/gal) which can be exceeded in some cases if maximum weight of cargo is not exceeded, and

c) The name and address of the owner of the barge.

This information is obviously limited, but the list of dangerous cargoes limits the number of hazardous cargoes that have to be checked. Also, it may help identify the chemical from its observable characteristics (discussed below).

The name and address of the owner of the vessel may lead to the shipping agent for the particular cargo being transported, which in turn can lead to identification of the chemical.

- **Coast Guard Records**

The U.S. Coast Guard presently requires that the Captain of the Port (COTP) be notified 24 hours in advance whenever shipments of any of 40 specific dangerous cargoes are scheduled to arrive. Thus, the port captain's office nearest to the area where a spill or discharge has occurred may have received such notification for the vessel in question if it was headed for, or had recently left, a port where this regulation is observed, and was carrying one of these specially regulated substances. A list of these chemicals is given below.

Acetaldehyde	Carbon disulfide	Hydrochloric acid	Propane
Acetone cyanohydrin	Chlorine	Methane	Propylene
Acetonitrile	Chlorohydrins, crude	Methyl acrylate	Propylene oxide
Acrylonitrile	Crotonaldehyde	Methyl bromide	Sulfuric acid
Allyl alcohol	1,2 dichloropropane	Methyl chloride	Sulfuric acid, spent
Allyl chloride	Dichloropropane	Methyl methacrylate (Monomer)	Tetraethyl lead
Ammonia, anhydrous	Epichlorohydrin	Nonyl phenol	Tetraethyl lead mixtures
Aniline	Ethylene	Oleum	Vinyl acetate
Butadiene	Ethyl ether	Phenol	Vinyl chloride
Carbolic oil	Ethylene oxide	Phosphorus, elemental	Vinylidene chloride

Also Class A explosives and certain oxidizing and radioactive materials.

- **Trade Names**

Many chemicals with long, complicated technical names are commonly known by simple trade names. If such a name is given for the chemical instead of its chemical name, then Coast Guard personnel will have to determine to which specific chemical the trade name refers.

A thesaurus of chemical name synonyms is given in the Condensed Guide to Chemical Hazards and the Hazardous Chemical Data Manual respectively, is a prime source of such information. This thesaurus lists a number of commonly used names for each chemical presently covered by CHRIS. If its name is not given there, the shipping agent, dispatching office of the carrier, or the consignee of the cargo should be called. If information is not available from these sources, then another hazardous chemical information system may be called. Such systems presently existing are described below.

- **Other Emergency Systems, Trade Names, Markings, Etc.**

Given a situation where the trade name of a substance is known from markings on tanks or packages, the substance is only partially identified, or the properties of the substance are not given by CHRIS, a number of organizations can assist in identifying the chemical and in placing Coast Guard personnel in contact with people with experience and knowledge of the substance involved.

These organizations will provide assistance in many ways during an emergency, such as providing advice regarding response methods, sending an emergency team of experts if necessary, or locating special equipment and operators. To ensure smooth emergency communication, they should be provided with both the number of a telephone and with all the information about the accident that is initially available. The telephone numbers of each organization are given below. These organizations are in contact with one another and calling either will usually provide the resources of both. Both organizations are further discussed in the Response Methods Handbook.

Within the United States

Chemical Transportation Emergency Center — CHEMTREC

Continental United States:

* 800-424-9300 (toll free)
*483-7616 in District of Columbia

Alaska:

*202-483-7616

Within Canada or near the border:

Transportation Emergency Assistance Plan — TEAP

Western Ontario:	* 519-337-8282	(Dow Chemical)
Central Ontario:	* 416-356-8310	(Cyanamid)
Eastern Ontario:	* 613-348-3616	(DuPont)
Northern Ontario:	* 705-682-2881	(Can. Ind.)
Southwest Quebec:	* 514-373-7570	(Allied Chemical)
North Central Quebec:	* 819-537-1123	(Gulf Oil)

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*Long distance prefix if required.

- **Observable Characteristics**

The identification of a chemical by its observable characteristics (e.g., color, odor, state, etc.) is difficult. So many chemicals resemble each other and have characteristics, such as odor, which are difficult to describe in words, that there will be very few cases where a positive identification can be made in this manner. Nevertheless, once a chemical has been identified from one of the other sources of information discussed, the characteristics which are given for the chemical should serve as an aid in the confirmation of the identification.

In other cases where the list of possibilities has been narrowed down to relatively few by use of other sources of information, these characteristics may be enough to identify the chemical or narrow down the list further.

3.5.2 Rate-of-Release Estimation Techniques – Unpressurized Tanks*

- **Cargo Losses from Damaged Ships and Barges – Unpressurized Tanks**

When a ship carrying hazardous liquid cargo has grounded, or is damaged to the extent that an outflow of the dangerous material is taking place, it is desirable to estimate the rate of loss and the amounts involved. However, exact calculations require detailed data as to the size and shape of the hull, tank arrangement, and capacities, elapsed time since the casualty, and complicated mathematical procedures which are usually impractical to use during an emergency.

In the case of a tank ship, the irregularity of the hull shape makes rough estimates unreliable; cargo loss quantity and rate cannot be merely related to simple measures such as the list of the ship. Because of this, the type and size of rupture and the height of the liquid above the rupture may be the only principal measures by which cargo loss can be estimated.

Barges, however, are generally rectangular and therefore their cargoes are easier to approximate. Not only is the hull usually box-shaped, but the individual tanks within the hull are also rectangular. Therefore, it is possible to establish guidelines for barges which will assist in estimating the cargo loss either by relating the loss to the trim or list or to the type and size of rupture and height of the liquid above the rupture.

Note that the guidelines given here for barges are *approximations* based on the following assumptions:

The barge is rectangular in shape.

The hull tanks initially were fully loaded, that is, they contained liquid cargo from the bottom of the hull to the main deck. This is the dimension called "D" in the plots.

*NOTE: The information given by the estimation techniques in this section is desirable but not necessary to or required by any other part of this manual.

The tanks are all of similar capacity and there are "N" tanks within the hull.

The tank is not pressurized.

In each of the estimation procedures it is preferable to work with measurements taken from plans or specifications of the craft. If the owner of the barge can be contacted, he can probably provide such information. Without such data, the necessary dimensions have to be estimated by eye, which may be difficult if the vessel is offshore or cannot be approached due to the release of its hazardous cargo. Nevertheless, with the use of these aids, the order of magnitude of the spillage can be estimated.

- **Rate-Of-Release Estimation Techniques Based on Shape and Size of Opening (hull fracture) of Leaking Tank:**

Nomograms for three different types of hull fracture are shown in Figures 3.1 through Figure 3.3. Figure 3.1 is for the case of a rectangular, slot-shaped opening. To use it, draw a line between the value for b on the first vertical line to the value for h on the third vertical line. The intersection of this line with the second vertical line gives the flow in gallons per minute (gpm). For example, given that b is 1 foot and h is 4 feet, the flow is found to be about 14,000 gpm from the second vertical line.

The second nomogram (Figure 3.2) covers the case of a notch-shaped, triangular opening. To use this nomogram, it is necessary to use the first and fourth vertical lines with values of b and d, respectively, to find the point of intersection with the second vertical line, and then to use this point along with the value of h on the fifth vertical line to determine the flow from the third vertical line. For example, given that b is about 0.6 feet and d is about 3.75 feet, the point found on the second line is about 0.8. Using this point and an h of 2.7 feet, we find that the flow is about 1400 gpm.

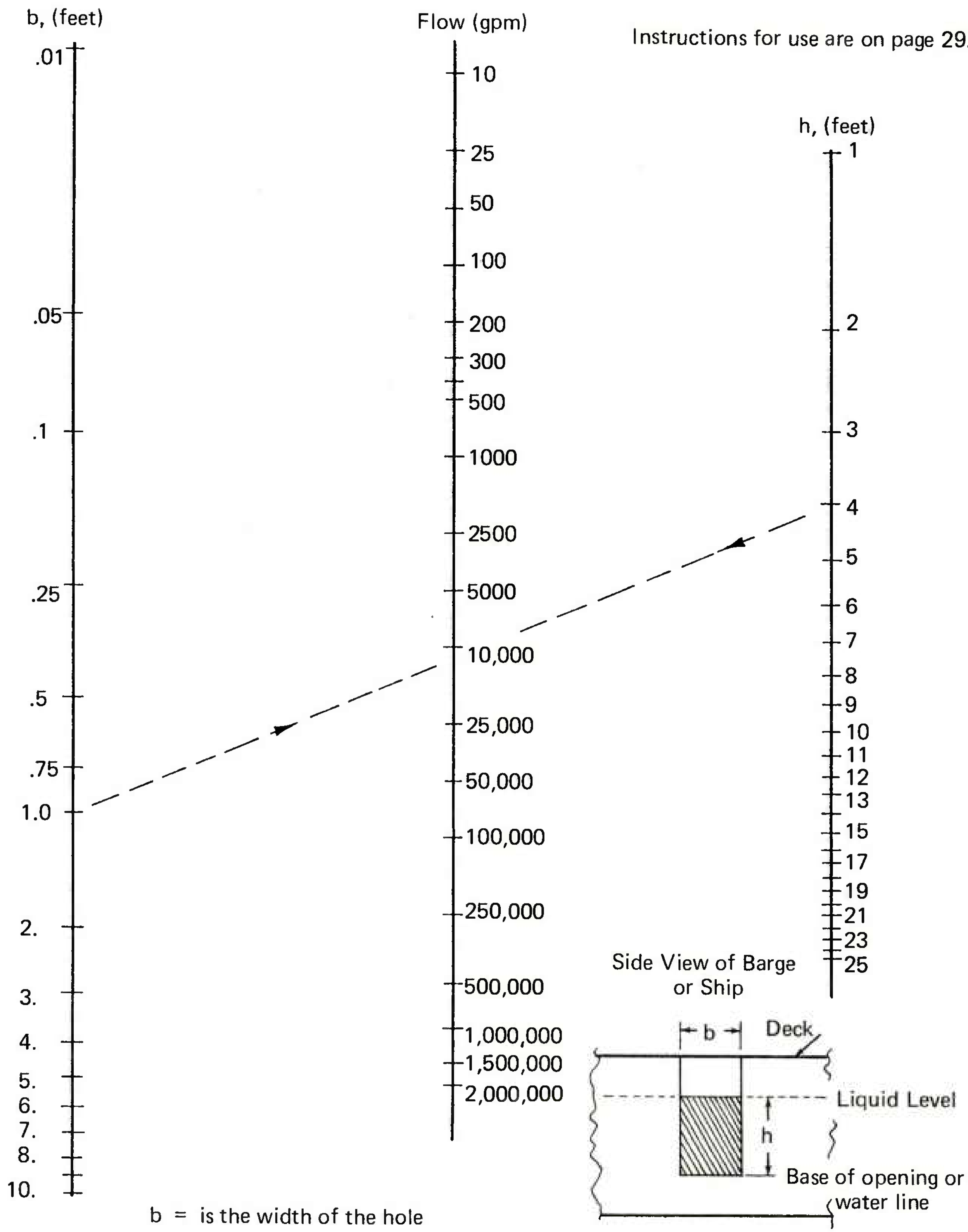
Figure 3.3 covers the case of an irregularly shaped hole. Given the estimated area of the hole, A, and the liquid level, h, the flow is determined in a manner similar to that used in Figure 3.1.

In all three cases, the rate of outflow "q" decreases with time as the tank empties and the liquid level "h" diminishes. However, as the weight of the liquid cargo leaves the tank, the hull tends to rise and usually gives the barge both list and trim, depending upon the location of the tank in the geometry of the hull. The outflow stops when the "head" of liquid inside the tank equalizes with that of the water outside the tank.

The shapes of these curves of outflow "q" against time are indicated in a plot (Figure 3.4) following the three nomograms. These are examples only and show the approximate comparisons between the three types of hull damage for ruptures of similar size under similar conditions.

As further aids for using these estimation techniques and the others following, a list of conversion factors is presented in Table 3.2.

Instructions for use are on page 29.

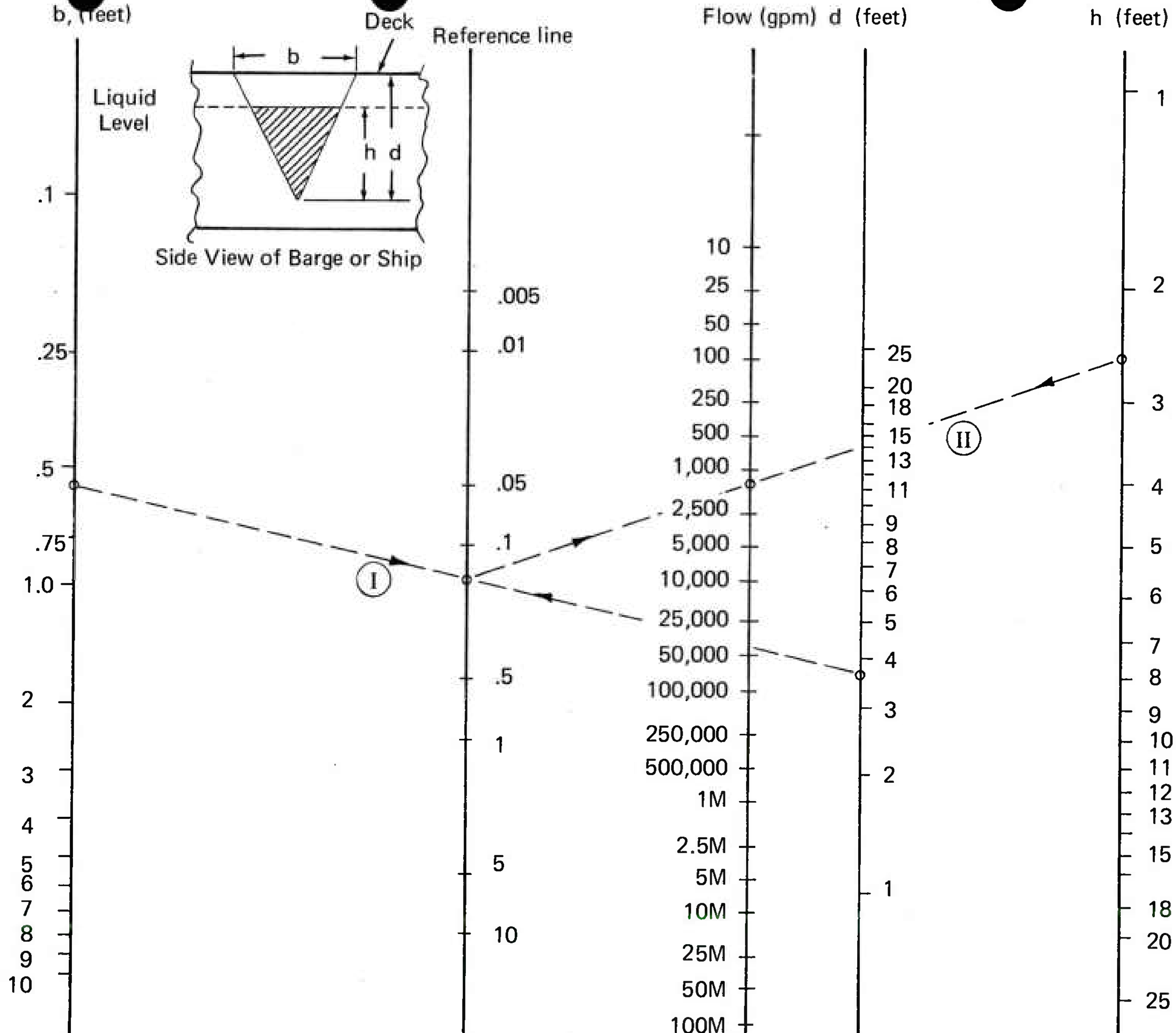


b = is the width of the hole

h = is the height of the liquid level above the bottom of the hole or the water level, whichever is higher.

FIGURE 3.1 RATE OF CHEMICAL DISCHARGE FROM A RECTANGULAR SLOT-SHAPED OPENING

Instructions for use are on page 29.



b = is the width of the hole

d = is the distance from the deck to the bottom of the hole

h = is the height of the liquid level above the bottom of the hole

FIGURE 3.2 RATE OF CHEMICAL DISCHARGE FROM TRIANGULAR NOTCH-SHAPED OPENINGS

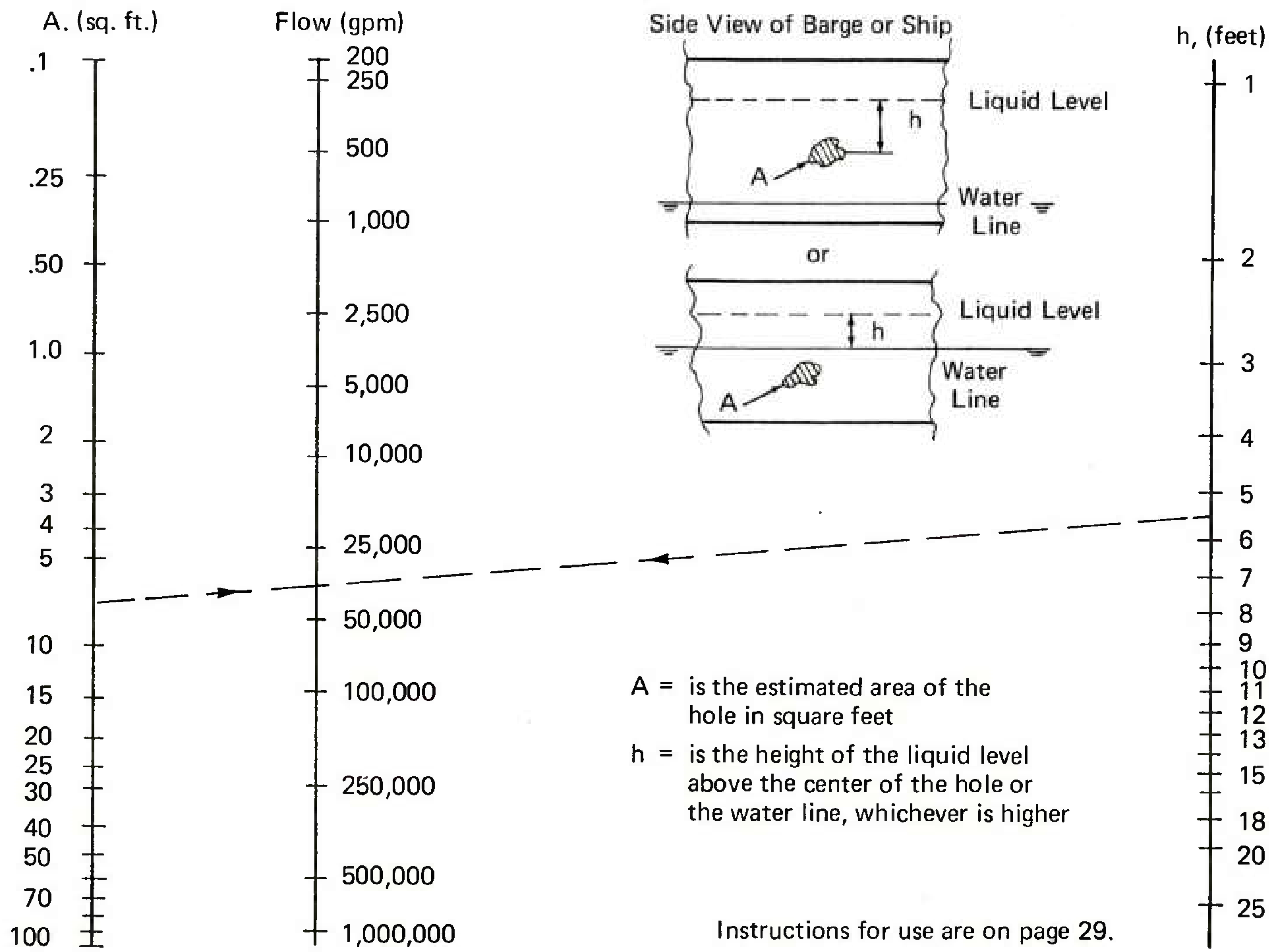


FIGURE 3.3 CHEMICAL DISCHARGE FROM IRREGULARLY SHAPED HOLES

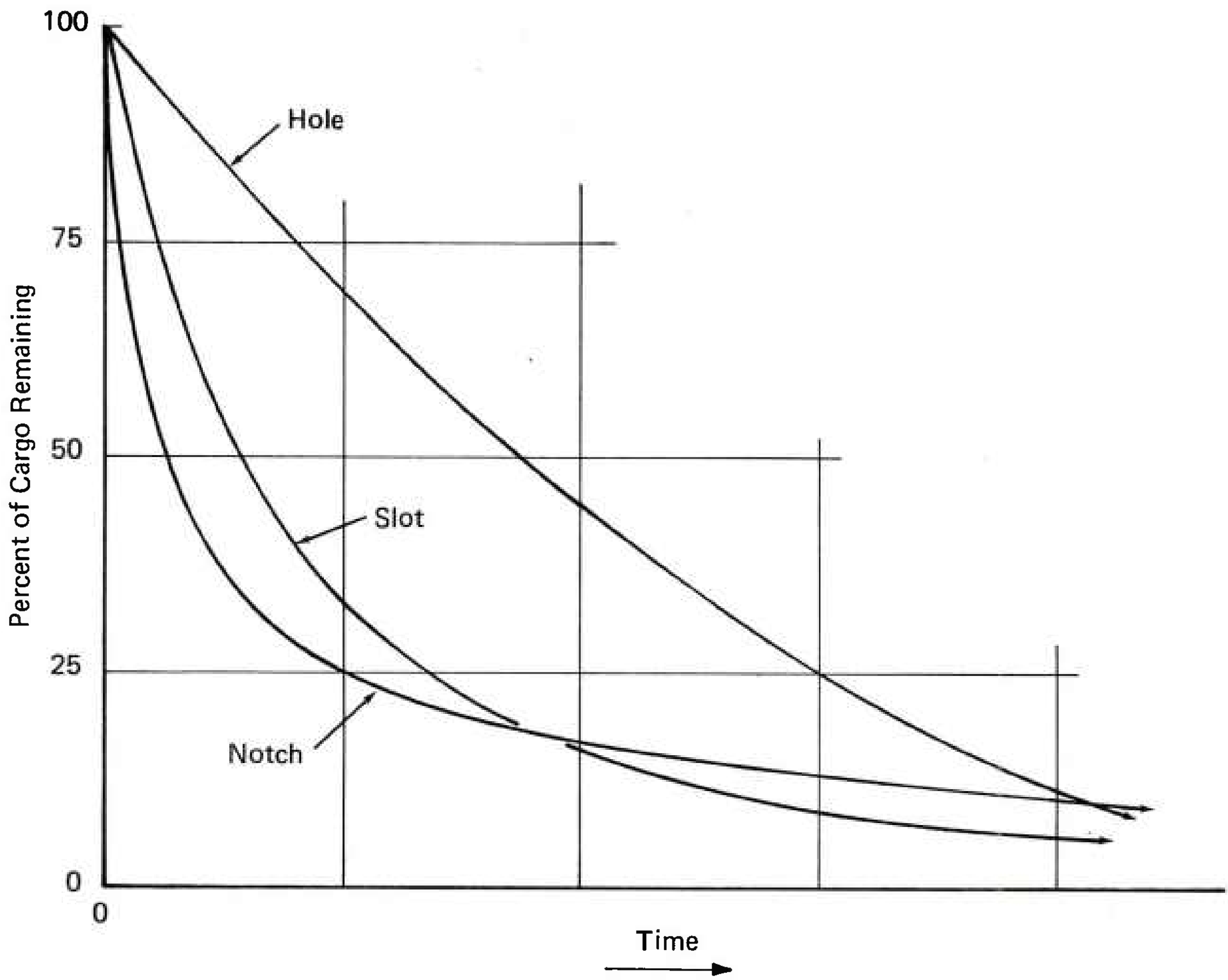


FIGURE 3.4 COMPARATIVE CARGO LOSS VERSUS TIME FOR THREE TYPES OF OPENING

TABLE 3.2

USEFUL CONVERSION FACTORS

7.48 gallons = 1 cubic foot

35 cubic feet of seawater	= 262 gallons	= 1 long ton
31.25 cubic feet of seawater	= 234 gallons	= 1 short ton

1 cubic foot of seawater = 64 pounds

1 long ton = 2240 pounds
1 short ton = 2000 pounds

$$\text{Specific gravity} = \frac{\text{Weight of 1 cu ft of liquid}}{64}$$

$$\text{Gallons of liquid per long ton} = \frac{262}{\text{Specific gravity}}$$

$$\text{Gallons of liquid per short ton} = \frac{234}{\text{Specific gravity}}$$

1 long ton = 1.12 short ton

- **Estimation Techniques (for barges only) for Determining the Capacity of an Individual Tank, the Quantity of Cargo Remaining in a Tank, and the Quantity already Lost:**

To assist in the estimate of the situation, two other nomograms are given. Figure 3.5 can be helpful in estimating the capacity of an individual tank once the length, beam and depth (L, B, D) of the barge hull, and the number (N) of tanks have been determined. As noted before, this information may be estimated, but preferably should be obtained from a description of the particular barge. Allowances have already been made for voids at the ends of the barge and for double-skinned sidewalls as this should help simplify the matter.

To use the figure, it is necessary to use the values of L and B on the first and third vertical lines, respectively, to find the point of intersection with the second such line. The values for D and N are then used on the fifth and seventh vertical lines, respectively, to find the point of intersection with the sixth line. The connection of the points found on the second and sixth lines results in the determination of the capacity from the intersection of this line with the fourth line.

Figure 3.6 can be helpful in estimating the quantity of cargo which is still in the tank. Also, since the capacity of the tank, in gallons, can be estimated from the previous nomogram and the amount left in the tank, also in gallons, from this nomogram, the amount which has already been lost overboard becomes the tank capacity less the remaining or residual amount, or

$$\text{Loss} = C - R.$$

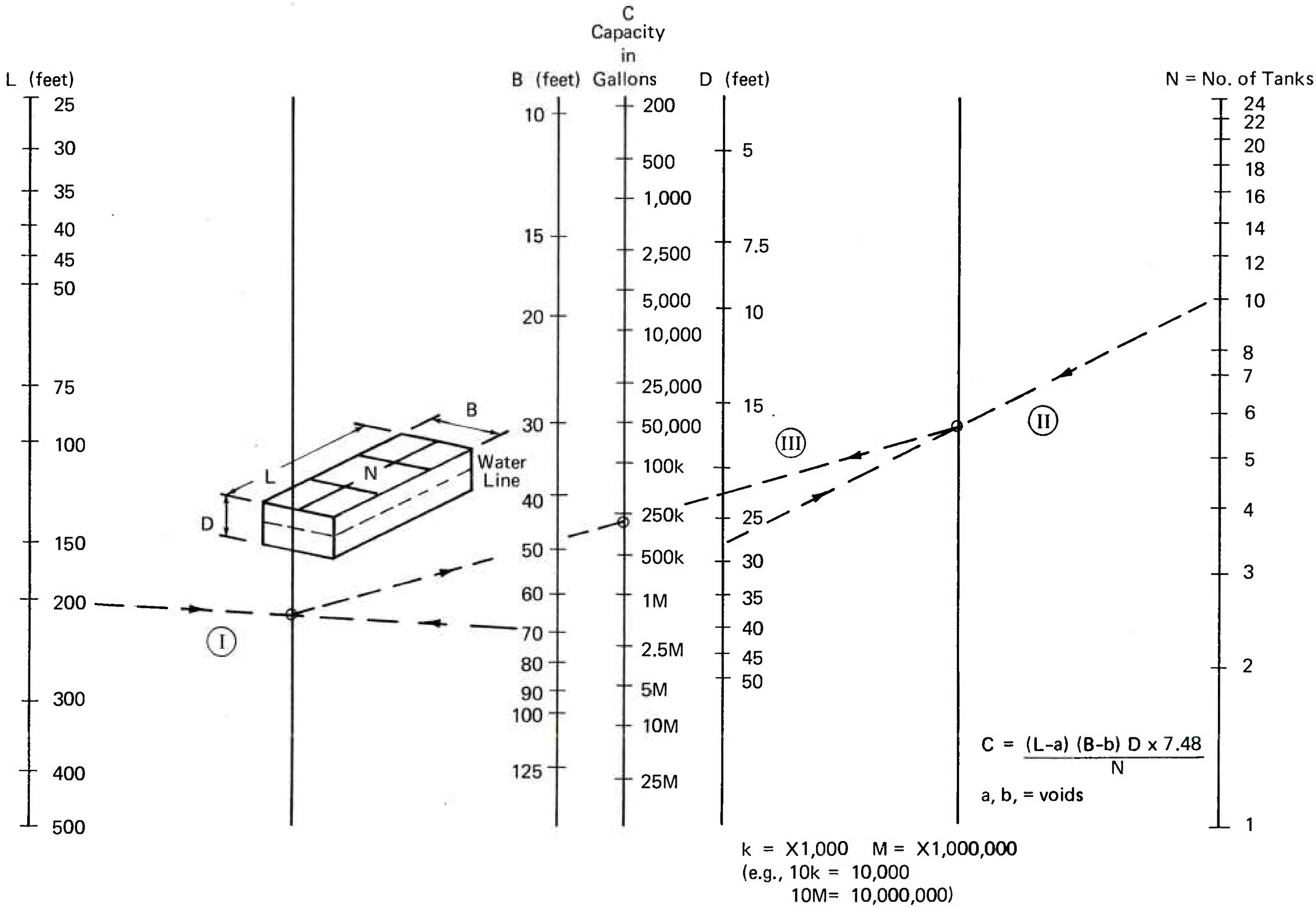


FIGURE 3.5 ESTIMATION OF CAPACITY OF AN INDIVIDUAL TANK

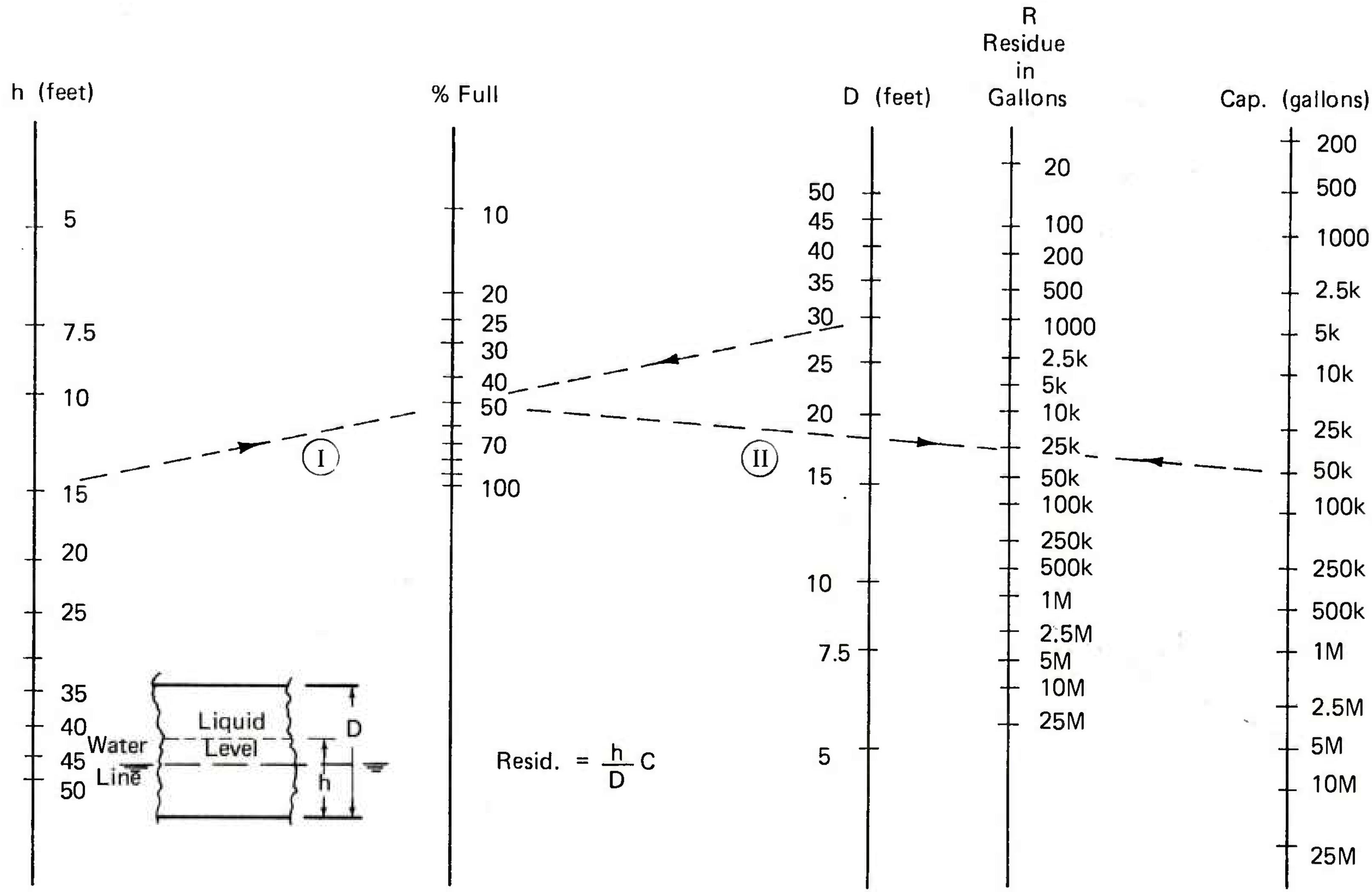


FIGURE 3.6 ESTIMATION OF RESIDUAL AMOUNT OF CHEMICAL IN TANK

To use the nomogram, the values of h and D are used on the first and third vertical lines, respectively, to find what percent the tank is full. This percent and the capacity of the tank on the second and fifth vertical lines, respectively, are then used to find the residue left in the tank from the fifth such line.

Another technique for estimating the above two items is described near the end of the section. This rate-of-release estimation technique is based upon actual liquid-level measurements which may be taken by on-scene personnel if they can safely board the stricken vessel, and the technique is applicable to both barges and tanker ships.

- **Rate-of-Release Estimation Techniques Based Upon List or Trim of Hull (for barges only):**

The most appropriate equation to relate the list or trim of a vessel to the amount of cargo released is the one which is used for determining the metacentric height of the vessel. However, this equation does not take into account the rise in the hull at the damaged point due to the angles of list and trim and the fact that the draft at that point will therefore be *less* than that which can be estimated and the lost volume of chemical (down to the new waterline) will be *greater*. Therefore, this approach is limited to *small angles* between 0 and 15 degrees. For larger angles, the errors become large and a very complicated calculation procedure is required for even rough approximations.

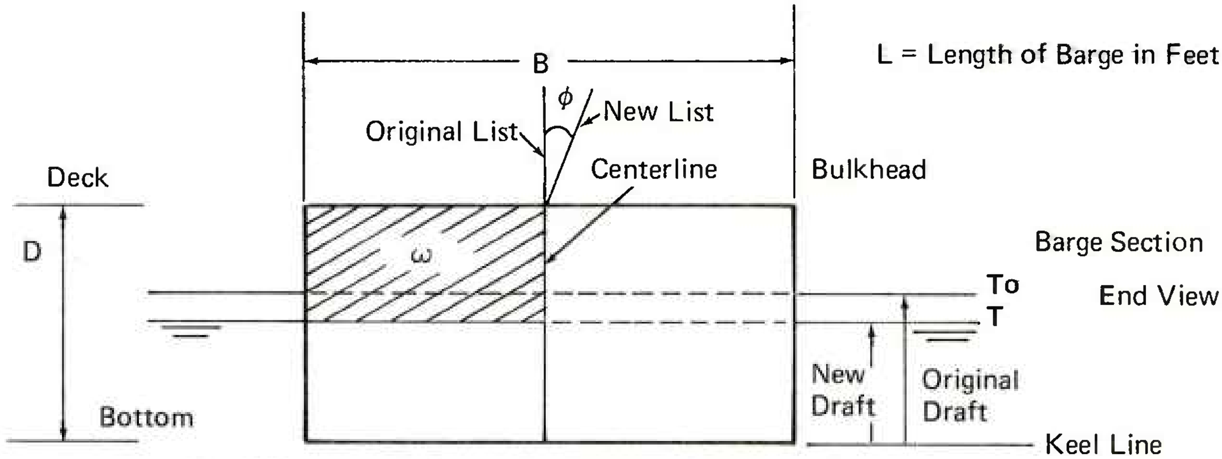
Also, situations can be stipulated where there will be no angular displacement (list or trim) of the hull, even though the entire contents of the tank are lost. For example, this will occur whenever the specific gravity of the cargo, its density relative to water, is equal to the ratio of the draft of the barge to the distance from its deck to the bottom of its hull (T/D).

In addition, some rather important secondary effects have been omitted. These lie in the "free surface effects" which may reduce the metacentric height appreciably and which therefore may influence the final answer. It is assumed in the given solution, as noted previously, that the tank is fully loaded.

Furthermore, to simplify the equation to a form which can be used somewhat quickly in the field, we have assumed that the hull of the barge is divided by a longitudinal centerline bulkhead dividing a set of port and starboard tanks. This assumption will sometimes be invalid.

Nevertheless, because of a lack of a more accurate or simpler method at this time, the estimation technique given below can be used to make a rough estimation of the cargo loss of a listing, box-shaped vessel such as a barge. The above limitations are stressed first, however, so that the user will be aware of the pitfalls inherent in this type of simplified and extrapolated simplification.

- **Calculation Procedure:**



SCHEMATIC OF BARGE DIMENSIONS NEEDED TO CALCULATE CARGO RELEASE AS A FUNCTION OF LIST

For a given size barge with dimensions L, B, D, and T_o and with a list of ϕ degrees, the amount of chemical lost, "w" is given by the equation:

$$w = 1.12\left(\frac{LB\ [B^2 - 6\ T_o^2\ (D/T_o - 1)]}{\dfrac{105\ B}{\tan\ \phi} - 210\ T_o\ (D/T_o - 1)}\right)$$

where "w" is in short tons (1 short ton = 2000 lbs).

Figure 3.7 can be used to quickly determine the quantity $105B/\tan\phi$.

As a numerical example, assume:

L	=	100 ft	
B	=	35 ft	
D	=	12 ft	(A typical small barge)
T_o	=	8 ft	

Then,

$$w = \frac{0.4049360}{\dfrac{3675}{\tan\ \phi} - 840}$$

For ϕ = 5°, $\dfrac{105B}{\tan\ \phi} \cong$ 42,000, w = 98.3 tons

10°, $\cong$ 20,800, w = 202.3 tons

15°, $\cong$ 13,700, w = 314.7 tons

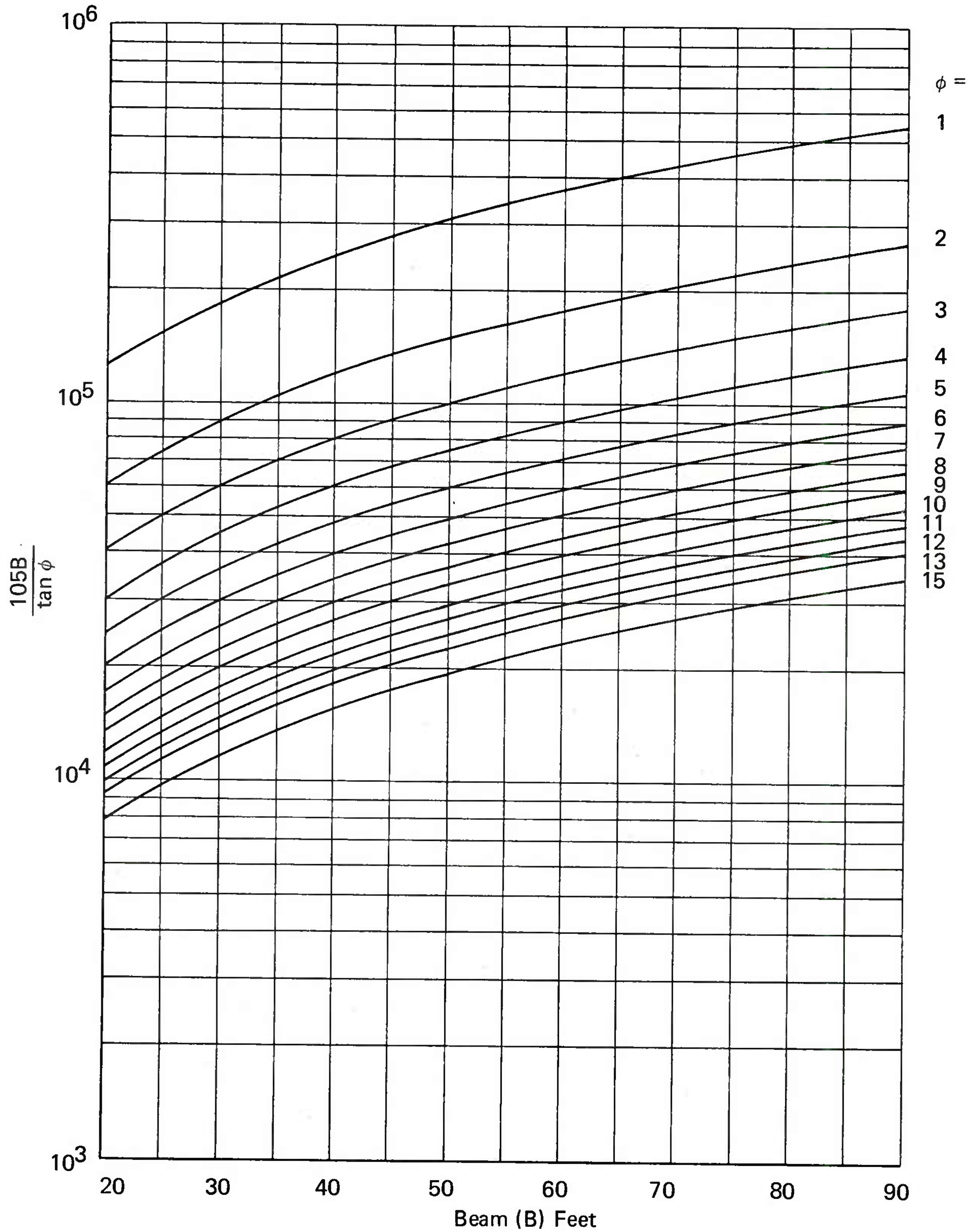


FIGURE 3.7 DETERMINATION OF 105B/TAN ϕ

Within this range of angles (0° – 15°) one could make a general approximation and say that there is a loss of 20 tons per degree of list, since the results are nearly linear.

In the event that the *release rate* is desired, the total amount of chemical which has been lost to produce a given list can be divided by the time which has elapsed from the beginning of the discharge to yield an estimate. For example, if the barge used in the example above developed a 10° list in 10 minutes, the average release rate would be given by:

$$\frac{202.3}{10\ \text{min}} = 20.2\ \frac{\text{tons}}{\text{min}}$$

- **Rate-of-Release Estimation Based Upon Liquid Level Measurements for Unpressurized Tanks**

Given a situation where the chemical being discharged is not poisonous, or personnel wearing fully protective clothing and self-contained breathing apparatus are capable of safely boarding the vessel, a simple, more accurate estimation technique can be used. The procedure to be followed is described below.

1) Determine the length and width of the leaking tank.

2) Stick a long, straight pole (gage pole) or "dipstick" down into the tank either through an "ullage" hole, or through a hatch cover, pull it up, note what time it is, and measure the length of the pole which is "wet."

3) Wait 15 minutes or so if the leak is slow, or a shorter period of time if it is relatively fast.

4) Repeat step 2 above.

5) Subtract the length the pole was "wet" in step 4 from the length it was "wet" in step 2. If the measurements were made in inches, divide the number resulting by 12 to put it into units of feet.

6) Multiply this number by the width and length of the tank (both in units of feet). This gives the volume of chemical which was lost during the time interval recorded. Dividing this volume by the time interval (in minutes, for example) produces the volumetric release rate in units of cubic feet per minute.

7) Multiply this number by 7.48 to determine the release rate of the chemical in gallons per minute.

An example follows:

Steps 2-4:

At time 10:30 a.m. a "dipstick" is put down into a 20-foot long by 10-foot wide tank. It is pulled up and it is noted that 96 inches of the pole are "wet." At 10:45 a.m. the procedure is repeated and it is determined that 72 inches of the pole are "wet."

Step 5

$96'' - 72'' = 24''$

$24'' \times 1 \text{ ft}/12'' = 2 \text{ ft}$

Step 6:

$2 \text{ ft} \times 20 \text{ ft} \times 10 \text{ ft} = 400 \text{ cubic ft.}$

$$\frac{400 \text{ cubic ft}}{15 \text{ min}} = 26.66 \frac{\text{cubic ft}}{\text{min}}$$

Step 7:

$$26.66 \frac{\text{cubic ft}}{\text{min}} \times \frac{7.48 \text{ gal.}}{\text{cubic ft}} = 199.3 \frac{\text{gal.}}{\text{min.}} = \text{rate of release}$$

- **Helpful Hints, Improvements, and Determination of Total Amount of Chemical in the Tank:**

Many towboats carry gage poles for measuring liquid levels. They are generally marked in one-foot intervals by alternating colors. Towboats may also carry "water finder," a greasy-like substance which, when smeared on the gage pole, turns color on contact with water. It is used to check on the leakage of water into tanks containing petroleum products.

The above estimation technique assumes that if there is any water in the bottom of the tank, the level of the water will not change during the time interval between measurements. However, if the tank contains a petroleum product, and it is known or suspected that water is present, "water finder" can be used to determine the level of the water at the same time the two measurements are made.

If the water levels are different, the following example, based on the above one, can be followed to give a more accurate answer.

At 10:30 a.m. the water level is found to be 18 inches. At 10:45 a.m. the water level is 24 inches.

$$96'' - 18'' = 78'' = \text{depth of chemical at } 10{:}30$$
$$72'' - 24'' = 48'' = \text{depth of chemical at } 10{:}45$$

Then, as above:

$$\frac{78'' - 48''}{12''} = \frac{30''}{12''} = 2.5 \text{ ft}$$

$$2.5 \text{ ft} \times 20 \text{ ft} \times 10 \text{ ft} = 500 \text{ cubic ft.}$$

$$\frac{500 \text{ cubic ft}}{15 \text{ min.}} \times 7.48 \ \frac{\text{gal.}}{\text{cubic ft}} = 249.24 \text{ gal/min} = \text{rate of release}$$

The total amount of chemical in the tank can also be estimated from the above. For example, if the depth of the chemical is 96", as it is at 10:30 a.m. in the first example, the tank contains:

$$96'' \times 1 \text{ ft}/12'' \times 20 \text{ ft} \times 10 \text{ ft} \times 7.48 \text{ gal/cubic ft} = 11{,}968 \text{ gallons}$$

Note also that the capacity (in gallons) of the tank would simply be its width x length x height x 7.48.

If the vessel is carrying a Class B poison or some other chemical which is toxic or otherwise dangerous, it may have a closed gaging device for indicating the quantity of material (level of liquid) in each tank. These devices are very similar to the liquid level gages found in home oil tanks, and if present, preclude the necessity of opening the tank to use a gage pole. The levels at two different times can simply be read off and used in the first procedure above.

3.5.3 Wind Speed and Direction, Air Temperature, and Other Weather Conditions

All of these data items can be grouped together under the heading of meteorological (weather) data and, as such, might be available from the National Weather Service Forecasting Office which is nearest the spill or discharge site, or from any other operation (e.g., off-shore drilling platform) which has need of accurate and complete meteorological data in the area of interest. All such operations, including the weather bureau, are listed and described in the Regional Contingency Plan (RCP) in a section entitled "Meteorological Agencies," along with information on how to contact them.

Specific information which is needed includes:

1. Wind speed in knots (1 mph = 0.8684 knots, 1 knot = 1.15 mph)
2. Wind direction
3. Air temperature
4. Weather conditions

a. Fraction of sky which is covered by clouds
b. Whether it is a cloudy, dull day or sunny
c. Whether it is raining or snowing in any way.

However, if an accurate estimate of the conditions at the spill site cannot be readily provided, or if Coast Guard personnel at the scene desire an immediate estimate of the conditions to make a preliminary hazard assessment using this handbook, a number of "rules-of-thumb" are available for their use. Selected examples are given below.

- **Estimation of Wind Speed from the Effects of the Wind on the Sea or on Land**

  The modern Beaufort scale is presented in Table 3.3. Given observations of the effects of the wind on the sea or on land, it is possible to estimate the wind speed or vice versa.

- **Estimation of Wind Direction**

  The direction from which the wind is blowing is usually a simple matter to determine. It can be done either by noting the direction in which a flag or pennant is blowing, or by generating some smoke and observing in which direction it is borne, or in several other ways, and by then referring this direction to a compass heading.

- **Determination of Air Temperature**

  If a thermometer is handy, the temperature can be readily determined. If one is not available, then the temperature must be estimated.

- **Estimation of Weather Conditions**

  An on-scene observer can easily estimate the fraction of the sky which is covered by clouds, whether it is raining or snowing in any way, and whether it is a dull, cloudy, or sunny day at the spill site.

3.5.4 Water Body Characteristics and Tidal Data

- **Determination of Water Temperature**

If a thermometer is handy, a bucket of water can be hauled in and its temperature measured. If not, then it can be estimated based on past experience, or might be determined by consultation of one of the information sources listed in the "Waterways Characteristics" or "Water Quality Agencies" sections of the RCP.

TABLE 3.3

MODERN BEAUFORT SCALE

Beaufort number	Wind Speed: knots	Wind Speed: mph	Hydrographic Office: Term and height of waves, in feet	International: Term and height of waves, in feet	Estimating wind speed: Effects observed at sea	Estimating wind speed: Effects observed on land
0	under 1	under 1	Calm, 0		Sea like mirror.	Calm: smoke rises vertically
1	1-3	1-3	Smooth, less than 1	Calm, glassy, 0	Ripples with appearance of scales, no foam crests.	Smoke drift indicates wind direction; vanes do not move.
2	4-6	4-7	Slight, 1-3	Rippled, 0-1	Small wavelets; crests of glassy appearance, not breaking	Wind felt on face; leaves rustle; vanes begin to move.
3	7-10	8-12	Moderate, 3-5	Smooth, 1-2	Large wavelets; crests begin to break; scattered whitecaps.	Leaves, small twigs in constant motion; light flags extended.
4	11-16	13-18		Slight, 2-4	Small waves, becoming longer; numerous whitecaps.	Dust, leaves, and loose paper raised up; small branches move
5	17-21	19-24	Rough, 5-8	Moderate, 4-8	Moderate waves, taking longer form; many whitecaps; some spray.	Small trees in leaf begin to sway.
6	22-27	25-31		Rough, 8-13	Larger waves forming; whitecaps everywhere; more spray.	Larger branches of trees in motion; whistling heard in wires.
7	28-33	32-38			Sea heaps up; white foam from breaking waves begins to be blown in streaks.	Whole trees in motion; resistance felt in walking against wind.
8	34-40	39-46	Very rough, 8-12	Very rough, 13-20	Moderately high waves of greater length; edges of crests begin to break into spindrift; foam is blown in well-marked streaks	Twigs and small branches broken off trees; progress generally impeded.
9	41-47	47-54	High, 12-20		High waves; sea begins to roll; dense streaks of foam; spray may reduce visibility.	Slight structural damage occurs; slate blown from roofs.
10	48-55	55-63	Very high, 20-40	High, 20-30	Very high waves with overhanging crests; sea takes white appearance as foam is blown in very dense streaks; rolling is heavy and visibility reduced.	Seldom experienced on land; trees broken or uprooted; considerable structural damage occurs.
11	56-63	64-72	Mountainous, 40 and higher	Very high, 30-45	Exceptionally high waves; sea covered with white foam patches; visibility still more reduced.	Very rarely experienced on land; usually accompanied by widespread damage.

*Adapted from N. Bowditch (1958 edition), *American Practical Navigator,* U.S. Navy Hydrographic Office Publication No. 9, p. 1059.

†Since January 1, 1955, weather-map symbols have been based upon wind speed in knots, at five-knot intervals, rather than upon Beaufort number.

- **Determination of Width of a Channel or Depth**

Width of a channel may be estimated by eye, determined from navigation charts or maps of the area, or determined by consulting the information sources listed in the "Waterways Characteristics" section of the RCP.

Depths may either be determined by taking soundings, or by consulting navigation charts or information sources listed in the above mentioned section of the RCP.

- **Determination of Current Drift and Set in Rivers Not Influenced by Tides**

The drift of the current can either be estimated based on observations and experience gained through previous estimates, or the information sources listed in the RCP in the "Waterways Characteristics" section can be consulted for more accurate, up-to-date data.

- **Determination of Current Drift and Set in Rivers Affected by Tides (Estuaries)**

The exact set of a current can be found in the Tidal Current Tables published yearly by the U.S. Department of Commerce.

The drift (velocity) of the current of such a tidal-action affected area is that velocity of the river which is constant and not affected by the tides (velocity of fresh water inflow). It can be determine by taking the difference between the flood and ebb maximum velocities, found also in the current tables noted above, and dividing it by 2.

- **Determination of Current Drift and Set in Coastal Waters**

In coastal waters, currents are usually caused by tides and they change in direction (set) and velocity (drift) as the state of the tide changes. In some places the currents so caused will be of the reversing type which abruptly change direction approximately 180° between flood and ebb. In other places, the set will change in small increment so as to create a constant rotary current. Variations of these tidal effects may also be found. The exact effect of the tide on currents in any specific area may be found by consulting current tables, current charts, pilot charts, or even local harbor or river pilots. Local knowledge is of great value in dealing with movements of tidal currents. While the changes in the set of tidal currents have a tendency to nullify the cumulative effect, they must be considered in computing the direction in which a spilled chemical will travel for the following reasons:

(a) Often, with reversing currents, the effect of the current in one direction is greater than in the other so that, over a period of time, the cumulative effect is more in one direction than the other.

(b) Even over short periods of time, the flow of tidal current will cause changes in the probable position of the chemical for any given time for which a hazard may exist.

Since most areas affected by tidal currents will be close to land masses, local wind current, as discussed below, will not be a factor in determining current direction. Because of this, the determination of the most probable direction and velocity a pool of a spilled chemical will travel will be equivalent to the set and drift of the tidal current only.

If the situation extends over several days, the cumulative effect of reversing tidal currents may be such as to thrust the pool of chemical into areas where sea current takes effect. In such cases, surface current considerations may shift from tidal current to sea current in the later stages of the incident.

- **Determination of the Maximum Amplitude of the Tidal Drift (Velocity) and Tidal Period for Coastal Waters**

The maximum amplitude of the tidal drift (velocity) can be found by determining from the tidal current tables the maximum drift of the flood and ebb currents for the spill area, and taking their average.

The length of the tidal period can be determined by looking up in the same table the time between two high or low tides (usually about 12.4 hours or 44,700 seconds).

- **Determination of Current Drift and Set Offshore**

The set of the current offshore can be found by the use of the average sea current and/or the local wind current. Information sources for these are described below and their inter-relationships explained.

The *average sea current* is that current present in the open sea which is caused by factors other than local winds. It has its greatest effect in those portions of the sea affected by the major ocean currents. Average sea current can best be estimated by use of U.S. Naval Oceanographic Office Charts and Publications (H. O. Publications). Those which are used for this purpose are: (1) A series of publications known as the *Oceanographic Atlas* – Example: *H. O. 700 – Section I of the* Oceanographic Atlas of the North Atlantic Ocean, and (2) A series of publications known as the *Atlas of Surface Currents* – Example: H. O. 570 – *Atlas of Surface Currents for the Northeast Pacific.* (These are being replaced by the former but they may still be used.) Additional technical information on ocean currents may be found in technical reports issued by the Naval Oceanographic Office, the Environmental Science Services Administration, and the surveys conducted locally by interested agencies. Methods for finding the average sea current follow.

(a) Section I of the Oceanographic Atlas

Use of the Oceanographic Atlas is the preferred method determining average sea current, when the publication is available for the area in question. For the set of the current, the red and blue arrows on the pages identified as the *prevailing surface currents* for the season desired are used. Green and black arrows represent relatively unsteady currents which are ignored. The drift of the current is given on the adjacent plastic overlay pages identified as the *mean current speed.* Use the speeds given by the nearest contour lines and visually interpolate to the nearest 0.1 knot. For spring and autumn currents, use averages of the direction and speed from the winter and summer charts. In this case the current obtained from a green arrow may be averaged with that from a red or blue arrow.

(b) Atlas of Surface Currents

The Atlas of Surface Currents is no longer available in those areas for which the Oceanographic Atlas has been completed. In other areas they will have to be used until the issuance of the replacement Oceanographic Atlas. Use the black arrows and numerals (the resultant currents) shown in the 1-degree quadrangles as the basic figure and note the set and drift. To determine the current steadiness, use the green arrow from the current rows in the 5-degree quadrangle which most nearly approaches the set of the resultant current (black arrow) and compare it with the scale of frequent percentage. If the steadiness is less than 40%, the average sea current is considered unsteady and should be ignored in computations of current direction.

(c) Pilot Charts

Select the Pilot Chart for the body of water, the month, and the year involved. Check the descriptive information on ocean currents for the month. Obtain the current set and drift from the current arrows displayed on the chart. If the currents in the area under consideration are weak, variable, or doubtful, ignore average sea current in computations. Pilot charts should be used only when no other method is available.

- *Local Wind Current* is the current generated by the wind which acts upon the surface of the water for a period of time. In any one area, this current factor will change as the weather patterns change. This horizontal movement of the water results from the exchange of energy between air and sea. The effect grows as a function of the wind force, its duration, and the area over which the wind is blowing, eventually reaching a limiting velocity. The set of this current is not necessarily downwind. As latitude is increased, the effect of coriolis force deflects it to the right of the local wind's downwind direction in the northern hemisphere and to the left in the southern hemisphere (see Figure 3.8). A caution which must be observed in using *local wind current computations* is that the assumptions on which the data are based are such that they *are only valid for the open sea where land masses do not interfere* with the action of the wind on the water or on the currents generated by them. Methods for finding local wind current are:

(a) Use of Figures 3.8 and 3.9 to Determine Wind Current

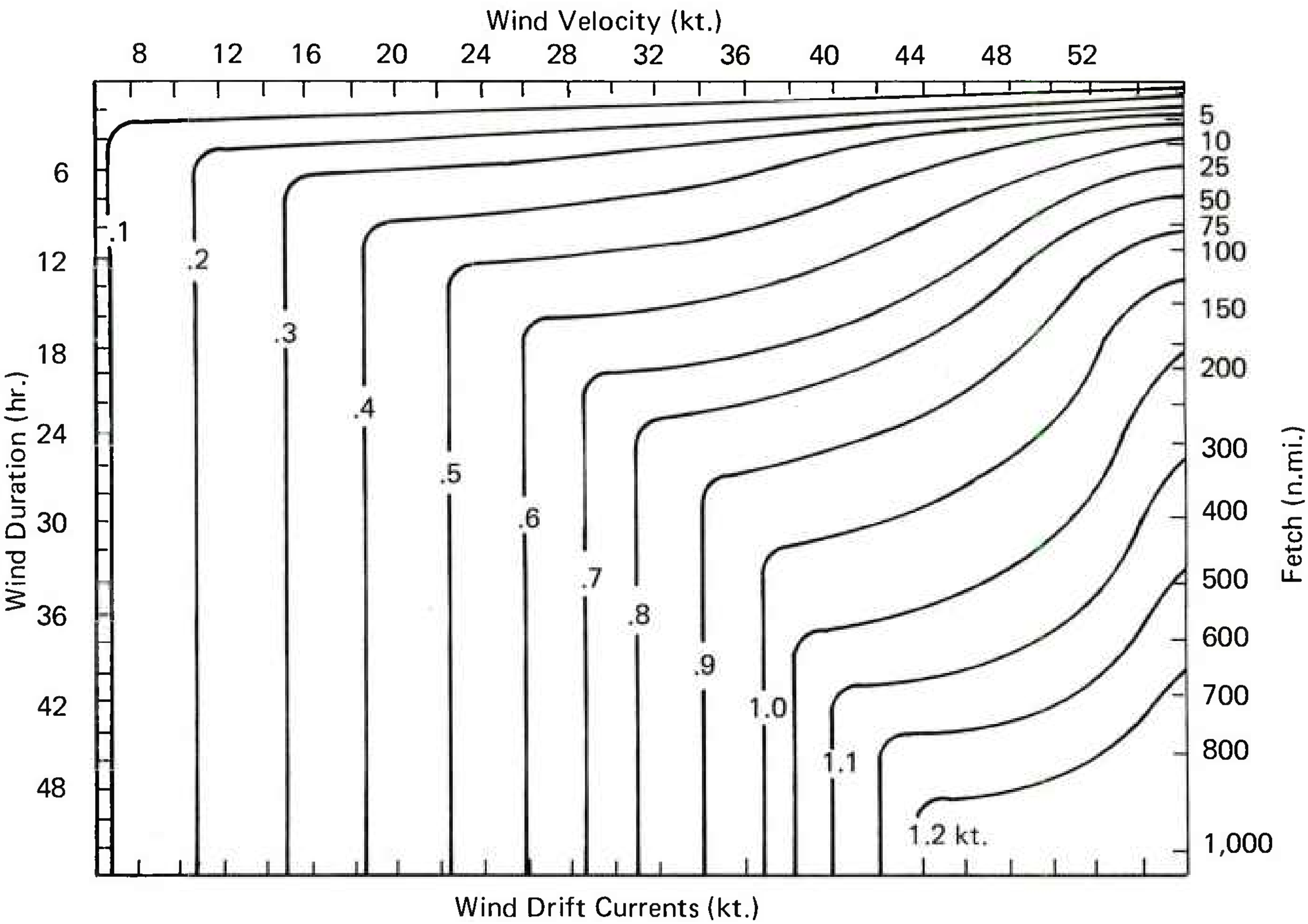
From the best sources of meteorological information, obtain an estimate of the wind speed and direction (from which it has blown) and, if possible, an estimate of the fetch (distance in nautical miles over which the wind has been acting on the water upwind) for the previous 24-hour period. This information may be obtained from ships, island stations, aircraft, the weather bureau, information sources listed in the Regional Contingency Plan in the "Meteorological Agencies" section, or by use of the estimation techniques described previously in the wind speed and direction section. Enter Figure 3.8 with the latitude and obtain the deflection. Apply this to the downwind course of the wind to obtain the set of the local wind current. Enter Figure 3.9 with the wind speed at the top of the graph and drop vertically to the wind-duration value. Read the current drift at this point. Repeat this step, but use fetch distance instead of duration. Whichever step gives the lower current speed is the limiting case, and the associated speed is the correct one to use. For example: Assume a 28-knot wind blowing for the past 24 hours over a fetch of 100 nautical miles. Entering Figure 3.9 with 28 knots and 24 hours duration, current speed is found to be 0.67 knot. Entering Figure 3.9 with 28 knots and a fetch of 100 nautical miles, current drift is found to be 0.49 knot. The latter, being the smaller quantity, would be the correct value to use. If the fetch is unknown, use the value found with wind speed and duration.

Figure 3.9 gives the current that would develop for a given wind, starting from zero drift. With increasing wind speed, the procedure must be modified to compensate for prior currents. That is, the current for 12 hours of a 40-knot wind is not the same as for the same wind preceded by 12 hours of a 20-knot wind. Compensation for existing drift is accomplished by computing the duration in hours required by the present wind speed to generate the current already present. This duration called "equivalent duration" is then added to the true duration of the wind. For example, if the wind blows for 12 hours at 12 knots, then for 12 hours at 24 knots, the procedure is as follows. During the first 12 hours, the 12-knot wind generates a current of 0.22 knot. A wind speed of 24 knots could create the same current in 4 hours, a value which is obtained by entering Figure 3.9 with a current speed of 0.22 knot and a wind speed of 24 knots to read 4 hours on the left. Adding this 4 hours duration to the 12 hours the 24-knot wind actually blows, gives an effective duration of 16 hours. Using 16 hours, rather than 24 hours with the 24-knot wind speed gives the correct current speed of 0.54 knot. This procedure, in effect, accumulates the energy that has been placed in the water by the wind and is necessary whenever the wind changes speed appreciably.

For small wind changes in direction or speed (less than 45° or 10 kts), mean values will suffice for using Figures 3.8 and 3.9. With more radical variations, wind current should be determined for smaller periods and the total effect of wind current is then found by vector addition of these currents.

Wind Current Deflection	
Latitude	Deflection
0^{o} to 10^{o}	None
10^{o} to 20^{o}	10^{o}
20^{o} to 60^{o}	20^{o}
Greater than 60^{o}	30^{o}
Note: Deflection will be to the right in the Northern Hemisphere and to the left in the Southern Hemisphere.	

FIGURE 3.8
WIND CURRENT DEFLECTION



Note 1: Wind drift currents in above graph are the same as local wind current in text.

Note 2: The use of parallel rules is recommended to ensure accuracy when entering this graph.

FIGURE 3.9
WIND DURATION VERSUS WIND DRIFT CURRENTS

(b) Use of Synoptic Charts

Synoptic current charts, prepared by the U.S. Navy, are currently in the experimental state. They are distributed by Fleet Weather Centrals. When using these charts, care must be used to determine if the specific chart shows only local wind current or a combination of local wind current and sea current. If they are of the latter type, then average sea current should not be included in computations.

- **Estimation of Current Set and Drift Offshore**

If the average sea current is to be used together with the local wind current direction (as determined above), the two directions and the magnitudes of their velocities must be added vectorially to determine the direction and velocity with which a spill will travel. This is done as in the following example.

Suppose that the average sea current has been determined to set directly southwesterly at 5 knots, and that the local wind current has been determined at 1 knot directly west. Let 1 inch arbitrarily represent a velocity of 2 knots and draw a line, as shown in Figure 3.10, in a southwesterly direction of a length which represents the current velocity (5 knots = 2.5″ if 2 knots = 1″). Note that this line or vector, as it is commonly called, is drawn from a point selected to represent the spill site and represents both the velocity and direction of the average sea current. From the end of this vector, a vector is then "added" to represent the local wind current. In the example below, this is the line which heads directly west and is 0.5 inch (1 knot) in length. The velocity and direction which a pool of spilled chemical will take is given by the angle and length of the line (dashed line below) which joins the spill site point with the end of this second vector.

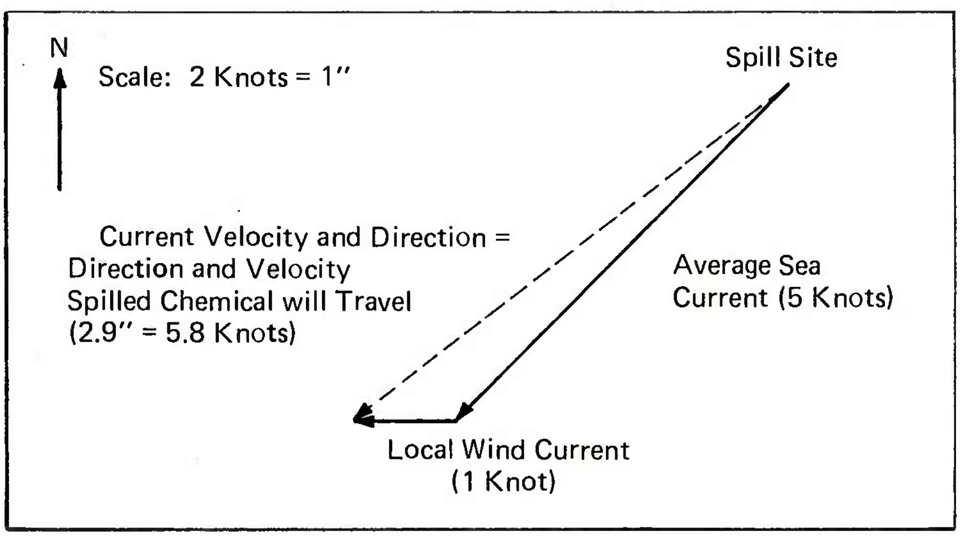


FIGURE 3.10 VECTORIAL ADDITION OF SEA AND WIND CURRENTS

4.0 SELECTION OF CALCULATION PROCEDURES

4.0 SELECTION OF CALCULATION PROCEDURES

When all of the on-scene information needed for assessing spill hazards has been collected, the selection of an appropriate calculation procedure for determining the hazards can be made. The starting point in all calculation procedures is a knowledge of the specific chemical which has been spilled.

4.1 HAZARD–ASSESSMENT AND CALCULATION CODES

Once the chemical being discharged has been identified and the needed on-scene information has been collected by answering the "primary questions," one should refer to the Hazardous Chemical Data Manual, and determine the Hazard-Assessment Code for that particular chemical. The Hazard-Assessment Code is given as Item 11 in the Hazardous Chemical Data Manual and provides the key to selecting the appropriate calculation procedure. The page on which data on the specific chemical are carried in the Hazardous Chemical Data Manual should be left open, because additional data may be needed as the calculations proceed.

The Hazard-Assessment Code associated with each chemical must be examined very carefully because it contains information needed for selecting calculation procedures and an error in reading the Hazard-Assessment Code will result in an incorrect assessment of the spill situation. Each Hazard-Assessment Code includes a number of letters representing all of the hazards associated with this particular chemical. For example, a chemical, such as liquefied natural gas, has the Hazard-Assessment Code ABCDEFG. This means that the following hazards must be estimated using appropriate calculation procedures as defined by a series of *Hazard Calculation Codes* that make up the *Hazard-Assessment Code.* The Hazard Calculation Codes for liquefied natural gas are:

AB – venting gas fire,
AC – gas dispersion,
ADE – liquid fire, and
ADFG – vapor dispersion.

A locally reproduced copy of Table 4.1 will enable rapid identification and listing of the chemical and physical data needed to complete the calculation procedures in this manual.

4.2 CHOICE OF CALCULATION PROCEDURE

With a knowledge of the Hazard-Assessment Code, one should next refer to the hazard-assessment index tabs of this manual and determine which tab either matches or contains most of the letters of the code for the particular chemical being considered. The Hazard-Assessment Code for some chemicals may have only some of the letters in the primary Hazard-Assessment Codes tabulated in this manual (for example, triethylamine has a code of APQ and would be treated under index tab APQRS), or the Hazard-Assessment Code for some chemicals may have letters from two or three of the primary Hazard-Assessment Codes tabulated in this manual (for example, hydrogen chloride has a code of ACKMNO and would be treated under index tab ABCKLMN and AO). This simply means that only the Hazard-Calculation Codes associated with the given letters in the code for the chemical need to be calculated.

The procedure is to open this manual to the tabulated Hazard-Assessment Codes which contain the letters of the Hazard-Assessment Code of the chemical in question and find the specific Hazard-Calculation Codes corresponding only to the letters in the chemical code. *The Hazard-Assessment Code and the Hazard-Calculation Code are both indexed in the upper right hand corner of each page.*

After locating the proper Hazard-Assessment Code and identifying the Hazard-Calculation Codes, the introductory material associated with each Hazard-Assessment Code must be read and understood. This background material explains in general terms the properties of the material, the hazards associated with the spill of the materials, and, in most cases, presents both a sample calculation procedure and, immediately along side of it, an area where the exact hazard for the material under consideration may be calculated. Calculations can then be made right on the page along side of the sample calculation. The calculation should be made in pencil, so that the results may be erased and the calculation sheet reused. The sample calculation should be studied carefully to understand how the answers are derived for the sample calculation before proceeding with calculation of the hazards for the chemical spill under consideration.

4.3 CALCULATION TABLES AND FIGURES

In the course of calculating the hazards associated with a given chemical spill, reference is often made to either a specific table or figure. These tables and figures* are found in the Section 6.0, following the Hazard-Assessment Calculation Codes, and are located under the indexed tabs which bear the initial letter of the table or figure. For instance, table and figure numbers beginning with G will be found under the figure tab G of this manual. The figure and table numbers are located directly under each table or figure. Often, when doing a calculation, it will be convenient to circle the value or to make a mark on the graph corresponding to the value being determined. This should be done with care to make sure that a light mark is placed on the figure or table with a pencil so that the marks may be erased.

Some Helpful Hints on Using the Figures and Tables:

1. Do not use the sample's figure or table number by mistake for your own calculations. Do not use any of the numerical values from the sample calculations when calculating the hazards for the chemical spill under consideration. *Be sure to use the figures or tables or values which are specific to your own calculation.*

2. The on-scene information might not be obtained in units compatible with the assessment graphs and tables. *Be sure to convert the on-scene information to the appropriate units, utilizing the conversion factors in Appendix A before proceeding with the assessment.*

*Note that some tables and figures have the same number. For example, there is a Figure G-1 and a Table G-1. Do not confuse them.

CHRIS DATA REQUIREMENTS

Note: The chemical and physical data needed for assessment are found in the Hazardous Chemical Data Manual (date item numbers are in parenthesis).

Primary Code ABCDEFG

Code AB - Venting Gas Fire Assessment
- Material ____________
- Hole Diameter ____________ in

Code AC - Gas Dispersion Assessment
- Material ____________
- Molecular Weight(13.2) ____________
- Lower Flammable Limit (6.2) ______ %
- Threshold Limit Value(5.4) ______ ppm
- Spill Amount ____________ tons
- Wind Velocity ____________ knots
- Wind Direction ____________ °true
- Weather ____________

Code ADE - Liquid Fire Hazard Assessment
- Material ____________
- Spill Amount ____________ tons
- Specific Gravity(13.7) ____________ gm/cm
- Burning Rate(6.9) ____________ mm/mi
- Molecular Weight(13.2) ____________
- Boiling Point(13.3) ____________ knots
- Wind Direction ____________ °true

Code ADFG Vapors - Dispersion Assessment
- Material ____________
- Spill Amount ____________ %
- Low Flammable Limit(6.2) ______
- Molecular Weight(13.2) ______
- Threshold Limit Value(5.4) ______ ppm
- Wind Velocity ____________ knots
- Wind Direction ____________ ° true
- Weather ____________

Primary Code ACIJ

Code AC - Gas Dispersion Assessment (Toxic hazard only)
- Material ____________
- Molecule Weight(13.2) ____________
- Threshold Limit Value(5.4) ______ ppm
- Spill Amount ____________ tons
- Wind Velocity ____________ knots
- Wind Direction ____________ °true
- Weather ____________

Code AIJ - Boiling Rate of Sinking Linking and Vapor-Dispersion Assessment
- Material ____________
- Molecular Weight(13.2) ____________
- Threshold Limit Values(5.4) ______ ppm
- Spill Amount ____________ tons
- Wind Velocity ____________ knots
- Wind Direction ____________
- Weather ____________

Primary Code ABCKLMN

Code AB - Venting Gas Fire Assessment
- Material ____________
- Hole Diameter ____________ in

Code ATU - Fire Assessment
- Material ____________
- Spill Amount ____________ tons
- Specific Gravity(13.7) ____________ gm/cm3
- Molecule Weight(13.2) ____________
- Burning Rate(6.9) ____________
- Wind Velocity ____________ knots
- Wind Direction ____________ true
- Stream Width ____________ feet
- Stream Velocity ____________ knots

Code AVW - Vapor Dispersion Assessment
- Material ____________
- Spill Amount ____________ tons
- Stream Velocity ____________ knots
- Molecule Weight(13.2) ____________
- Low Flammable Limit(6.2) ______ %
- Threshold Limit Value(5.4) ______ ppm
- Wind Velocity ____________ knots
- Wind Direction ____________ true
- Weather ____________

Primary Code RR, RR-C

Code RR - Reaction Product Assessment
- Material ____________
- Spill Amount ____________

TABLE 4.1
CHRIS DATA REQUIREMENTS

Code RR-C - Reaction Product Assessment
- Material ______
- Spill Amount ______ tons
- Hole Diameter(If Applicable ______ in
- Molecule Weight(13.2) ______ %
- Low Flammable Limit(6.2) ______ %
- Threshold Limit Value(5.4) ______ ppm
- Wind Velocity ______ knots
- Wind Direction ______ true
- Weather ______

Primary Code SS

Code SS - Water Pollution Assessment
- Material ______
- Toxicity by Ingestion(5.6) ______ mg/kg or gm/kg
- Stream Width ______ feet
- Stream Depth ______ feet
- Stream Velocity ______ knots
- Spill Amount ______ tons
- Specific Gravity(Density)(13.7) ______ gm/cm3

Primary Code APQRS

Code APQ - Liquid Fire Assessment
- Material ______
- Spill Amount ______ tons
- Specific Gravity ______ gm/cm^3
- Boiling Point(13.3) ______ k
- Burning Rate(6.9) ______ mm/min
- Molecule Weight(13.2) ______
- Wind Velocity ______ knots
- Wind Direction ______ true
- Water Depth ______ feet
- Stream Width ______ feet
- Stream Velocity ______ knots

Code AKL - Liquid Fire Assessment
- Material ______
- Spill Amount ______ tons
- Specific Gravity(13.7) ______ gm/cm3
- Burning Rate(6.9) ______ mm/min
- Molecule Weight(13.7) ______
- Boiling Point(13.3) ______
- Wind Velocity ______ Knots
- Wind Direction ______ °true

Code AD - Water Pollution Assessment
- Material ______
- Toxicity by Ingestions(5.6) ______ gm/kg or ______ mg/kg
- Steam Width ______ feet
- Steam Depth ______ feet
- Steam Velocity ______ knots
- Specific Gravity(density)(13.7) ______ gm/cm3

Code AC - Gas Dispersion Assessment
- Material ______
- Molecular Weight(13.2) ______
- Lower Flammable Limits(6.2) ______ %
- Threshold Limit Value(5.4) ______ ppm
- Spill Amount ______ tons
- Wind Velocity ______ knots
- Wind Direction ______ ° true
- Weather ______

Code AKMN - Liquid Pool Dispersion Assessment
- Material ______
- Spill Amount ______ tons
- Lower Flammable Limits(6.2) ______ %
- Molecular Weight(13.2) ______
- Threshold Limit Value(5.4) ______ ppm
- Wind Velocity ______ knots
- Wind Direction ______ ° true
- Weather ______

Primary Code AO

Code AO - Reaction Product Assessment
- Material ______
- Spill Amount ______ tons

Primary Code AZ

Code AZ - Explosion Assessment
No data required - no calculation

Primary Code II

Code II - Water Pollution Assessment
No data required - no calculation

Primary Code ATUUW

TABLE 4.1 (CONTINUED)
CHRIS DATA REQUIREMENTS

Code AT - Spreading Pool Assessment
- Material ____________
- Spill Amount ____________
- Specific Gravity(13.7) ________ gm/cm3
- Wind Velocity ________ knots
- Wind Direction ________ true
- Stream Width ________ feet
- Stream Velocity ________ knots

Code AP - Water Pollution Assessment
- Material ____________
- Toxicity by Ingestions(5.6) ______ mg/kg or ____________ gm/kg
- Stream Width ________ feet
- Stream Depth ________ feet
- Stream Velocity ________ knots
- Spill Amount ________ tons
- Specific Gravity(Density) (13.7) ____________ gm/cm3

Code APRS - Vapor Dispersion Assessment
- Material ____________
- Stream Depth ________ feet
- Stream Width ________ feet
- Stream Velocity ________ knots
- Spill Amount ________ tons
- Molecule Weight(13.2) ________
- Lower Flammable Limit(6.2) ______ %
- Threshold Limit Value(5.4) ______ ppm
- Wind Velocity ________ knots
- Wind Direction ________ true
- Weather ____________

Primary Code AXY

Code AX - Water Pollution Assessment
- Material
- Surface Tension(13.8) dynes/cm
- Specific Gravity(Density)(13.7) gm/cm3
- Stream Depth feet
- Stream Velocity knots

Code AXY - Fire Assessment
- No data required - no calculation

Conversions:

tons = (gallons) (8.33) (Specific Gravity)

$$\text{tons} = \frac{(\text{Cu ft gas})(\text{Molecular Weight})}{718{,}000}$$

TABLE 4.1 (CONTINUED)
CHRIS DATA REQUIREMENTS

5.0 HAZARD ASSESSMENT

The hazard assessment calculation procedures described in this section assume that the released chemical is *instantly* spilled on water. This section does not treat the case of a *continuous* release of chemical on water. A hazard assessment based on an instantaneous release provides conservative estimates of the hazard.

HAZARD ASSESSMENT CODE – ABCDEFG

A material with Hazard Assessment Code ABCDEFG can exist as a gas, a liquid, or a combination of both. To assess the hazards associated with a spill or release of a material with this hazard code, one must know if the material is released as a gas or as a liquid. If both gas and liquid are released together, consider that it is all released as a liquid.

The most common chemicals in this code are liquefied natural gas (LNG) and liquefied petroleum gas (LPG).

- For *gas* releases, follow the hazard assessments in Hazard Calculation Code ABC (below).
- For *liquid* releases, follow the hazard assessments in Hazard Calculation Code ADEFG (on page 71).

A. VENTING GAS – CODE ABC

1. Background Information

A material with Hazard Calculation Code ABC has these properties:

- Compressed gas; may either be lighter or heavier than air when released. (may or may not be toxic)
- Flammable.

The hazards are:

- Fire (Hazard Calculation Code AB) – the venting gas may ignite and burn as a jet. (see page 59)
- Vapor dispersion (Hazard Calculation Code AC) – the venting gas will generate a cloud of toxic and/or flammable vapor. (Flammable only if letter B is in code also.) (see page 61)

For the flammability hazard AB, the important items to be determined are:

- Flame length (flame height),
- Safe distance for people (away from the flame)
- Safe distance for people in fire-protective clothing (away from the flame), and

- Safe distance for wooden structures (away from the flame).

For the vapor dispersion hazard AC, the important items to be determined are:

- Distance over which flammable hazards may persist, and
- Distance over which human toxic concentration hazards may persist.

	SAMPLE CALCULATION	*CALCULATION PROCEDURE* (use pencil so it can be erased)
Material:	*Propylene*	________
Quantity:	*50 tons*	________
Conditions:	*Venting as gas through a broken 6-in. line; wind blowing at 25 knots.*	________ ________ ________

2. Gas Fire Hazard Assessment (Code AB)

Determine the flame length from Figure B1, using the venting hole diameter and the curve corresponding to the specific chemical.

	SAMPLE CALCULATION	*CALCULATION PROCEDURE*
	Curve 33 in Figure B1 applies to propylene gas. For a 6-in. hole.	
Flame length	= *145 feet*	= ________ feet

In the same manner, use Figure B2 to find the equivalent pool radius.

Equivalent pool radius	= *7.4 feet*	= ________ feet

Determine the safe separation distance for people, people in fire-protective clothing, and for wooden structures from the equivalent pool radius and Figure B3.

	SAMPLE CALCULATION	*CALCULATION PROCEDURE*
	Figure B3 gives the following data for an equivalent pool radius of 7.4 feet:	
Safe separation distance for people	= *250 feet*	= ________ feet
People in fire-protective clothing	= *90 feet*	= ________ feet
Wooden structures	= *11 feet*	= ________ feet

3. Gas Dispersion Assessment (Code AC)

The chemical and physical data needed for assessment of vapor dispersion hazards are found in the Hazardous Chemical Data Manual (data item numbers are in parentheses). Enter the appropriate data below.

Material	Propylene	
Molecular weight (item 13.2):	*42.08*	= ______
Low flammable limit (item 6.2):	*2.0 volume %*	= ______ volume %
Threshold limit value (item 5.4):	*4000 ppm*	= ______ ppm

Convert the low flammability limit from volume percent to gm/cm^3 using the molecular weight and Figure G1. The lower flammability limit in gm/cm^3 is designated in LFL.

For a molecular weight of 42 and a low flammability limit of 2% for propylene.

Low flammability limit (LFL) = *4.0×10^{-5}* gm/cm^3 | (LFL) = ______ gm/cm^3

Convert the threshold limit value from parts per million (ppm) to gm/cm^3 using the molecular weight and Figure G2. The threshold limit value in gm/cm^3 is designated TLV.

For a molecular weight of 42 and a threshold limit value of 4000 ppm for propylene.

Threshold limit value (TLV) = *7×10^{-6} gm/cm^3* | (TLV) = ______ gm/cm^3

Using the spill size in tons and the LFL, find the parameter $(M/C)_{LFL}$ with Figure G3. Be careful to get the correct exponential power of 10.

For a 50-ton spill and a LFL of 4×10^{-5} gm/cm^3

$(M/C)_{LFL}$ = *1.3×10^{6}* | $(M/C)_{LFL}$ = ______

Using the spill size in tons and the TLV, find the parameter $(M/C)_{TLV}$ with Figure G3. Be careful to get the correct exponential power of 10.

For a 50-ton spill and a TLV of 7×10^{-6} gm/cm^3,	
$(M/C)_{TLV}$ = 7×10^6	$(M/C)_{TLV}$ = ________

In the listing below place a check mark next to the weather conditions which most closely describe those under consideration and note the tables to be used in determining the maximum extent and the maximum half-width of the hazards.

In our example, the wind velocity was given as 25 knots; therefore, weather condition D applies.

Tables to be used in determining:

			Maximum Extent	Maximum Half-Width
Weather Condition – F				
Wind less than 5 knots and one of the following:				
• Overcast day	____	____	G1	G2
• Nighttime	____	____		
• Severe inversion present	____	____		
Weather Condition – D				
• All other wind and weather conditions	✓	____	G3	G4

Weather condition F is the poorest for dispersing the vapor cloud.

Determine the maximum downwind extent of flammability from Table G1 or G3 as applicable, using the parameter $(M/C)_{LFL}$ and the pool radius.

For a gas release, consider that all material is released instantaneously at one point and that the pool radius is minimum (0 to 25 feet).

From Table G3 (weather condition D), for $(M/C)_{LFL} = 1.3 \times 10^6$	
Maximum downwind extent of flammability = 0.6 nautical mile	= ________ nautical miles

Determine the maximum half-width of flammability from the parameter $(M/C)_{LFL}$ and either Table G2 or G4, depending on the weather condition.

From Table G4 (weather condition D), for $(M/C)_{LFL}$	= *1.3×10^6*		
Max. half-width of of flammability	= *230 feet*	= ______	feet

Determine the maximum downwind extent of the toxic hazard using either Table G1 or G3 with the parameter $(M/C)_{TLV}$, and the pool radius.

From Table G3 (weather condition D) and $(M/C)_{TLV}$	= *7×10^6*		
Max. downwind Extent of toxic hazard	= *1.1 nautical miles*	= ______	nautical miles

Determine the maximum half-width of the toxic hazard using either Table G2 or G4 and the parameter $(M/C)_{TLV}$.

From Table G4, for $(M/C)_{TLV}$	= *7×10^6*		
Max. half-width of toxic hazard	= *400 feet*	= ______	feet

Calculate the maximum duration of flammability hazard from the maximum extent of flammability and the wind velocity.

For the 50-ton propylene spill, the maximum extent of flammability was found to be 0.6 nautical mile.

Dividing this by the wind velocity (25 knots),

Maximum flammability

Duration = *0.6/25* = *0.024 hour* = ______ hours

Convert to minutes by multiplying by 60:

Maximum flammability

Duration = (.024) (60) = 1.44 minutes = ______________ minutes

Round off to the highest minute.

Maximum flammability

Duration = 2 minutes = ______________ minutes

Calculate maximum duration of toxic hazard from the maximum downwind extent of toxic hazard and the wind velocity.

For the propylene spill, the maximum extent of toxic hazard was found to be 1.1 nautical miles.

Divide this by the wind velocity (25 knots):

Maximum duration of toxic hazard = 1.1/25 = 0.044 hour = ______________ hours

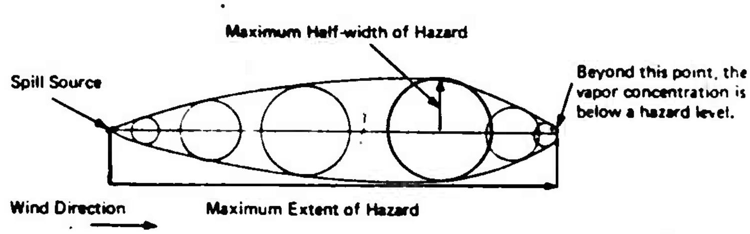
Convert to minutes by multiplying by 60.

Maximum duration of toxic hazard = (0.044) (60) = 2.6 minutes = ______________ minutes

Round off to the next highest minute.

Maximum duration of toxic hazard = 3 minutes = ______________ minutes

Schematically, the plan view of the flammable gas or vapor cloud looks as shown below. This is a time history of the growth of the cloud.



The half-width dimension refers to either the *flammable* or *toxic* portion of the cloud. The significance of the abrupt ending of the hazard is that the cloud quite suddenly becomes too dispersed to support combustion or remain a toxic hazard. The maximum half-width always occurs at downwind distances less than the maximum extent of the hazard.

4. Summary of Gas Fire and Dispersion Hazards (Code ABC)

For a 50-ton spill of propylene venting as a gas through a broken 6-in. line in a 25-knot wind, the following hazards exist:

Burning Hazards (Code AB)

Flame length	= *145 feet*	= ______	feet
Safe separation distances for:			
People	= *250 feet*	= ______	feet
People in fire-protective clothing	= *90 feet*	= ______	feet
Wooden structures	= *11 feet*	= ______	feet

Gas Dispersion Hazards (Code AC)

Maximum downwind flammability extent	= *0.6 nautical miles*	= ______	nautical miles
Maximum half-width of flammability	= *230 feet*	= ______	feet
Duration of fire hazard	= *2 minutes*	= ______	minutes
Max. downwind toxic hazard	= *1.1 naut. miles*	= ______	nautical miles
Max. half-width of toxic hazard	= *400 feet*	= ______	feet
Duration of toxic hazard	= *3 minutes*	= ______	minutes

B. POOL OF VOLATILE LIQUID – CODE ADEFG

1. Background Information

A material with Hazard (Calculation) Code ADEFG has these properties:

- Liquid
- Flammable
- Extremely volatile, because its boiling temperature is less than ambient temperature,
- Immiscible or slightly soluble in water,
- Density less than that of water – floats on water.

The hazards are:

- Fire (Hazard Calculation Code ADE) – The spill may spread on the water and ignite. (see page 73)
- Vapor dispersion (Hazard Calculation Code ADFG) – In the absence of ignition, the spill may spread on the water, evaporate, and generate a cloud of toxic and/or flammable vapor. (Flammable only if letter E is in code also.) (see page 79)

For the flammability hazard (ADE), the important items to be determined are:

- Size of the spill pool,
- Flame height,
- Safe distance for people,
- Safe distance for people in fire-protection clothing, and
- Safe distance for wooden structures.

For the vapor dispersion hazard (ADFG), the important items to be determined are:

- Size of the spill pool, and
- Distances over which flammable and/or (human) toxic concentration hazards may persist.

SAMPLE CALCULATION	*CALCULATION PROCEDURE (use pencil so it can be erased)*
Material: *Propylene*	______
Quantity: *50 tons*	______
Conditions: *Total instantaneous release, wind blowing at 25 knots.*	______

2. Liquid Fire Hazard Assessment (Code ADE)

The chemical and physical data needed for assessment of the liquid fire hazards are found in the Hazardous Chemical Data Manual, CG-446-2 (data item numbers are in parentheses). Enter the appropriate data below.

Specific gravity (item 13.7):	ρ	= *0.609 gm/cm³*	______	gm/cm³
Boiling point (item 13.3):	T_b	= *225.3 °K*	______	°K
Burning rate (item 6.9):	*R*	= *8.0 mm/min*	______	mm/min
Molecular weight (item 13.2):	*M*	= *42.08*	______	

Find the *maximum size of the spill pool* from the nature and amount of the chemical and Table D1, as follows:

For a 30 to 60-ton spill of propylene, Table D1 gives the size of the pool as —

Pool radius = *160 feet* | = ______ feet

Calculate the product (ρR) from the above values.

$\rho R = (0.609)\ (8.01) = 4.87$ | ρR = ( ) ( ) = ______

Round off to the nearest whole number.

ρ R (rounded off) = *5* | ρR (rounded off) = ______

Determine the flame height from the pool radius, the product (ρR), and either Figure E1 or E2, depending on the pool radius. Accuracy of interpolation between graphed values of (ρR) is not important. For a pool radius of less than 250 feet, use Figure E1; for a radius between 250 and 1500 feet, use Figure E2; and for a larger radius, use the value for 1500 feet on Figure E2.

For a pool radius of 160 feet, use Figure E1. Since curves are shown only for even values of ρR, it is necessary to interpolate between values of 4 and 6 for $\rho R = 5$.

Flame height = *300 feet* = ______________ feet

Calculate the ratio (M/T_b) from the molecular weight (M) and the boiling point (T_b) for the specific chemical.

For propylene:

$M/T_b = \frac{42}{225} = 0.19$ $M/T_b = \frac{(\ \ )}{(\ \ )} =$ ________

In the listing below, place a check mark next to the range in which the pool radius found earlier falls. Note the corresponding graph to be used in determining the flame angle.

Since the radius of the propylene pool was found to be 160 feet, Figure E6 is used to determine flame angle.

Pool Radius (ft)		Figure to be used in Determining the Flame Angle	
0-30	________	E-3	________
30-150	________	E-4	________
150-300	✓	E-5	________
300-900	________	E-6	________
over 900	________	E-7	________

Determine the flame angle from the wind velocity, the ratio M/T_b, and the appropriate graph among Figures E3 through E7. Great accuracy is not necessary in interpolating between the curves for M/T_b. Round off the value of flame angle to the nearest 5 degrees.

For the propylene spill, the wind velocity is 25 knots and M/T_b is 0.19. From Figure E5	
Flame angle = 50 deg. from vertical	= _______ degree from vertical

In the listing below, place a check mark next to the ρR range into which the value calculated earlier falls and note the corresponding graphs to be used in determining the safe separation distances for people, for people in fire-protection clothing, and for wooden structures. Where a choice of ranges is possible, use the higher one.

Since the ρR for the 50-ton propylene spill was found to be 5, use the range 5-7.

Figures to be Used in Determining Safe Separation Distance for:

ρR		*People*	*People in Fire-Protection Clothing*	*Wooden Structures*	
0-3	________	*E8*	*E14*	*E20*	____
3-5	________	*E9*	*E15*	*E21*	____
5-7	✓	*E10*	*E16*	*E22*	____
7-9	________	*E11*	*E17*	*E23*	____
9-11	________	*E12*	*E18*	*E24*	____
over 11	________	*E13*	*E19*	*E25*	____

Determine the safe separation distances for people, for people in fire-protective clothing, and for wooden structures from the appropriate figures identified above, using the pool radius and the flame angle. Accurate interpolation between the curves is unnecessary.

Use Figures E10, E16, and E22 for the propylene spill. For a pool radius of 160 feet and a flame angle of 50 degrees.

Safe distances from the pool edge for:

People (Fig. E10)	= *2000 feet*	=	______	feet
People in fire-protective clothing (Fig. E16)	= *800 feet*	=	______	feet
Wooden Structures (Fig. E22)	= *300 feet*	=	______	feet

3. Vapor-Dispersion Assessment (Code ADFG)

The chemical and physical data needed for assessment of vapor dispersion hazards are found in the Hazardous Chemical Data Manual (data item numbers are in parentheses). Enter the appropriate data below:

Chemical	*Propylene*		
Spill amount	*50 tons*	______	tons
Molecular weight (item 13.2):	*42.08*	______	
Low flammable limit (item 6.2):	*2.0 volume %*	______	volume %
Threshold limit value (item 5.4):	*4000 ppm*	______	ppm

Find the *maximum size of the spill pool* from the spill amount (in tons) and Table D1.

For a 50-ton spill of propylene Table D1 gives the following value:

Pool radius	= *160 feet*	=	______	feet

Find the maximum time for complete evaporation of the chemical spill from the spill amount in tons and Table D2 and enter it below.

For the 50-ton spill,

Maximum time for complete evaporation	*2 minutes*	______	minutes

In the following calculations be careful not to confuse Figures G1 – G2 with Tables G1 – G3.

Convert the low flammability limit (given above in volume percent) to units of gm/cm^3, using the molecular weight and Figure G1. When expressed in gm/cm^3, the lower flammability limit is designated LFL.

For a molecular weight of 42 and a low flammability limit of 2%, *Low flammability limit (LFL)* = $\underline{4.0 \times 10^{-5}}$ gm/cm^3	(LFL) = ________ gm/cm^3

Convert the threshold limit value (given above in parts per million) to units of gm/cm^3 using the molecular weight and Figure G2. When expressed in gm/cm^3, the threshold limit valus is designated TLV.

For a molecular weight of 42 and a threshold limit value of 4000 ppm, *The threshold limit value (TLV)* = $\underline{7 \times 10^{-6}}$ *gm/cm*^{3}	(TLV) = ________ gm/cm^3

Convert the spill size in tons and the LFL to the parameter $(M/C)_{LFL}$ with Figure G3. Be careful to get the correct exponential power of 10.

For a 50-ton spill and a LFL of 4×10^{-5} gm/cm^3, Figure G3 reads as follows: $(M/C)_{LFL}$ = $\underline{1.3 \times 10^6}$	$(M/C)_{LFL}$ = ________

Again using Figure G3, convert the spill size in tons and the threshold limit value TLV to the parameter $(M/C)_{TLV}$. Be careful to get the correct exponential power of 10.

For a 50-ton spill and a TLV of 7×10^{-6} gm/cm^3 $(M/C)_{TLV}$ = $\underline{7 \times 10^6}$	$(M/C)_{TLV}$ = ________

In the listing below place a check mark next to the weather conditions which most closely describe those under consideration and note the tables to be used in determining the maximum extent and the maximum half-width of the hazards.

In our example, the wind velocity was given as 25 knots; therefore, weather condition D applies.

		Maximum Extent	Maximum Half-Width
Weather Condition — F			
Wind less than 5 knots and one of the following:			
• *Overcast day*	____ ____	G1	G2
• *Nighttime*	____ ____		
• *Severe Inversion present*	____ ____		
Weather Condition — D			
All other wind and weather conditions	____ ____	G3	G4

Weather condition F is the poorest for dispersing the vapor cloud.

Determine the maximum downwind extent of flammability from Table G1 or G3, as applicable, using the parameter $(M/C)_{LFL}$ and the pool radius.

From Table G3 (weather condition D), for a pool radius of 160 feet and $(M/C)_{LFL} = 1.3 \times 10^6$

Max. downwind extent of flammability = 0.4 nautical mile = ____________ nautical miles

Determine the maximum half-width of flammability from the parameter $(M/C)_{LFL}$ and either Table G2 or G4, depending on the weather condition.

From Table G4 (weather condition D), for $(M/C)_{LFL} = 1.3 \times 10^6$

Max. half-width of flammability = 230 feet = ____________ feet

Determine the maximum downwind extent of the toxic hazard using either Table G1 or G3 with the parameter $(M/C)_{TLV}$ and the pool radius;

From Table G3 (weather condition D),

for a pool radius of 160 feet, and
$(M/C)_{TLV}$ $= 7 \times 10^6$

Max. downwind

Extent of toxic hazard = *0.9 nautical mile* = ________ nautical miles

Determine the maximum half-width of toxic hazard using either Table G2 or G4 and the parameter $(M/C)_{TLV}$

From Table G4, for $(M/C)_{TLV}$
$= 7 \times 10^6$

Max. half-width of
toxic hazard = *400 feet* = ________ feet

Calculate the maximum duration of flammability hazard from the maximum extent of flammability and the wind velocity.

For the 50-ton propylene spill, the maximum extent of flammability was found to be 0.4 nautical mile. Dividing this by the wind velocity (25 knots)

Max. flammability
duration = *0.4/25 = .016 hour* = ________ hours

Convert to minutes by multiplying by 60.

Max flammability
duration = *(.016) (60) = .96 minutes* = ________ minutes

Round off to the next highest minute.

Max flammability
duration = *1 minute* = ________ minutes

Note: *In the case of a tank which takes a long time to empty, the maximum duration of flammability (or toxic hazard) is equal to the sum of the calculated flammability (or toxicity) hazard, plus the time required for the tank to empty.*

Maximum duration = *Maximum duration of hazard* + *Time for tank to empty*

Calculate the maximum duration of toxic hazard from the maximum downwind extent of toxic hazard and the wind velocity.

For the 50-ton propylene spill, the maximum extent of toxic hazard was found to be 0.9 nautical mile

Divide this by the wind velocity (25 knots):

Maximum duration of toxic hazard = 0.9/25 = 0.036 hours | = ____________ hours

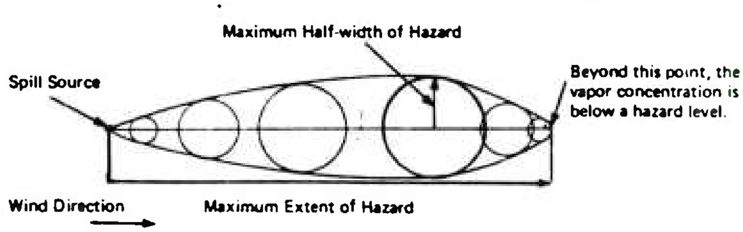
Convert to minutes by multiplying by 60.

Maximum duration of toxic hazard = (0.036) (60)
= 2.2 minutes | = ____________ minutes

Round off to the next highest minute.

Maximum duration of toxic hazard = 3 minutes | = ____________ minutes

Schematically, the plan view of both the flammable gas or vapor cloud looks as shown below. This is a time history of the growth of the cloud and does not indicate the instantaneous hazard zones at various times.



The half-width dimension refers to either the *flammable* or *toxic* portion of the cloud. The significance of the abrupt ending of the hazard is that the cloud quite suddenly becomes too dispersed to support combustion or remain a toxic hazard. The maximum half-width always occurs at downwind distances less than the maximum extent of the hazard.

4. Summary of Liquid Fire Hazards and Vapor Dispersion Hazards (Code ADEFG)

For a 50-ton instantaneous spill of liquid propylene on water in a 25-knot wind, the following hazards exist:

Burning Hazards (Code ADE)

Pool radius	= *160 feet*	= __________ feet
Flame height	= *300 feet*	= __________ feet
Flame angle	= *50 deg. from vertical*	= ____ deg. from vertical
Maximum safe distance for :		
People	= *2000 feet*	= __________ feet
People in fire-protective clothing	= *800 feet*	= __________ feet
Wooden structures	= *300 feet*	= __________ feet

Vapor Dispersion Hazards (Code ADFG)

Max. downwind flammability extent	= *0.4 naut. mile*	= __________ naut. mi
Max. half-width of flammability	= *230 feet*	= __________ feet
Duration of fire hazard	= *1 minute*	= __________ minutes
Max. downwind toxic hazard	= *0.9 naut. mi*	= __________ naut. mi
Max. half-width of toxic hazard	= *400 feet*	= __________ feet
Duration of toxic hazard	= *3 minutes*	= __________ minutes

HAZARD ASSESSMENT CODE – ACIJ

The chemicals in Hazard Assessment Code ACIJ can exist as a gas or as a combination of a gas and a liquid. The chemicals have boiling temperatures less than ambient and, in the liquid state, have densities greater than water (i.e., as liquids they sink). There is no fire hazard associated with the chemicals in this code; however, there is a vapor-dispersion hazard because many of the chemicals are toxic.

Chlorine is the most common chemical in this primary hazard code. The chemicals in this code are summarized in Table I.1, along with the relevant chemical and physical data needed for the calculations.

There are two vapor dispersion hazards in this code:

- Venting gas dispersion – Code AC
- Boiling liquid and vapor dispersion – Code AIJ.

A. GAS DISPERSION ASSESSMENT – CODE AC (Toxic hazard only)

Because there is no fire hazard associated with the chemicals in the primary hazard code, only the maximum extent, half-width and duration of the toxic hazard need be calculated. The chemical and physical data needed for assessment of vapor-dispersion hazards are listed in the above Table I.1. Enter the appropriate data below:

Total spill size _____ tons

Chemical name ___________________

Molecular weight _________________

Threshold limit value ___ ppm.

Proceed to Calculation Code AC (found in Hazard Assessment Code ABCDEFG, Hazard Calculation Code ABC/AC) on page 61 and calculate only the maximum extent, half-width, and duration of the toxic hazard.

B. BOILING RATE OF SINKING LIQUID AND VAPOR-DISPERSION ASSESSMENT – CODE AIJ

The liquids in the Primary Hazard Code will sink when spilled on water and, at the same time, will boil if the water temperature is above the boiling temperature of the particular chemical (Table I.1). In addition, if the chemical sinks below a critical depth (Table I.1), the material will not boil because the water pressure at the critical depth is higher than the vapor pressure at a water temperature of 20°C (68°F, 293°K).

Several types of liquid spills may be considered in the Hazard Calculation Code AIJ:

- Liquid venting from a tank at a depth above the critical depth. Under these circumstances, the liquid will rapidly evaporate and the vapor dispersion toxic hazard can be calculated for a total spill by Hazard Calculation Code AC. (page 61).

- Liquid venting from a tank, or a sudden total release below the critical depth. In these cases, the liquid will not boil, and will continue to spread out on the bottom or sink to a lower depth, thus posing no vapor hazard.

- Total spill above the critical depth. In this case, all chemicals except trichlorofluoromethane will either evaporate in less than 60 seconds, or sink below the critical depth and not pose a vapor hazard. The vapor-dispersion toxic hazard (including that of trichlorofluoromethane) can be calculated for a total spill by Hazard Calculation Code AC. (page 61)

The chemical and physical data needed for assessment of the boiling liquid vapor-dispersion hazard are listed in Table I.1. Enter the appropriate data below:

Total spill size ________________ tons

Chemical name ________________

Molecular weight ________________

Threshold limit value ________________ ppm

Critical depth ________________ feet.

Proceed to Calculation Code AC (found in Hazard Assessment Code ABCDEFG, Hazard Calculation Code ABC/AC) on page 61 and calculate only the maximum extent, half-width, and duration of the toxic hazard.

HAZARD ASSESSMENT CODE – ABCKLMN

The chemicals in Hazard Assessment Code ABCKLMN are soluble in water and have boiling temperatures less than ambient. They can exist as gases at ambient temperature, or as liquids at reduced temperature and when pressurized.

The chemicals in this code include:

Acetaldehyde	Hydrogen chloride
Ammonia, anhydrous	Hydrogen cyanide
Cyanogen	Hydrogen fluoride
Dimethylamine	Methylamine
Dimethyl ether	Methyl mercaptan
Ethylamine	Sulfur dioxide
Ethylene oxide	Trimethylamine
Hydrogen bromide	

There are two fire hazards, a water pollution hazard, and two vapor-dispersion hazards as follows:

- Venting gas fire (Calculation Code AB) – The venting gas may ignite and burn as a jet. (see page 97)

- Liquid fire (Calculation Code AKL) – The liquid may spill and spread on the water and ignite, and the fire will continue until the chemical is consumed, or until enough mixing and dilution in the water occurs to quench it. (see page 97)

- Water pollution (Calculation Code AK) – The liquid may spill and spread and at the same time mix with the water. The concentration of chemical in the water will remain a hazard until dilution by mixing and diffusion reduces the concentration to a value below the safe toxic limit for humans or the safe limit for industrial processes. (see page 99)

- Vapor-dispersion (Calculation Code AC) – The venting gas will generate a cloud of toxic and/or flammable vapor. (Flammable only if letter B is in code also.) (see page 101)

- Liquid pool vapor dispersion (Calculation Code AKMN) – Some of the liquid pool will evaporate and the remainder will dissolve in the water. Both the vapor evaporated from the liquid pool and the vapor which is released from the water solution may be toxic and/or flammable. (Flammable only if letter L is in code also.) (see page 103)

A. VENTING GAS FIRE – CODE AB

In this hazard, the chemical vents as a gas through a hole of known size, is ignited, and burns as a long flame.

Enter the name of the chemical and the venting hole size below:

Chemical: ______________________________

Hole size: _____________________ inches

- Determine the flame length from the venting hole diameter, the specific chemical, and Figure B.1, and enter it below.

  Flame length = ______ feet

- Determine the equivalent pool radius from the venting hole diameter, the specific chemical, and Figure B.2, and enter it below.

  Equivalent pool radius = ______ feet

- Determine the safe separation distance for people, for people in fire-protective clothing, and for wooden structures from the equivalent pool radius and Figure B.3, and enter them below.

Safe separation distances for:

People: _________________ feet

People in fire-protective clothing: ___________ feet

Wooden structures: ________ feet.

B. LIQUID FIRE – CODE AKL

The liquid chemicals in Hazard Code ABCKLMN, although soluble in water, will behave, when ignited, like insoluble, low-density, volatile liquids, and will be handled by Calculation Code ADE. Assume that the spill occurs instantaneously.

The chemical and physical data needed for assessment of the boiling liquid pool fire hazards are found in the Hazardous Chemical Data Manual (data item numbers are in parentheses). Enter the appropriate data on the next page.

Chemical: ________________

Molecular weight (item 13.2):___________ (M)

Amount spilled: _________ tons

Wind velocity: _________ knots

Specific gravity (item 13.7): _________ gm/cm³ (ρ)

Boiling point (item 13.3): _______°K (T_b)

Burning rate (item 6.9): _________ mm/min. (R)

Find the maximum size to which the pool of spilled liquid chemical will grow from the tons spilled and Table K.1 and enter it below.

Maximum pool radius: _____ feet.

Proceed to Hazard Calculation Code ADE (found in Hazard Assessment Code ABCDEFG, Hazard Calculation Code ADEFG/ADE) on page 73. Use the maximum pool radius recorded above – do *not* use Table D1. The values to be calculated are:

- Flame height,
- Flame angle,
- Safe separation distance for:

  People,
  People in fire-protective clothing, and
  Wooden structures.

C. WATER POLLUTION HAZARDS – CODE AK

The liquid chemicals in Hazard Code ABCKLMN are soluble in water and at the same time are volatile and will evaporate. It is beyond the scope of this manual to determine the amount of spilled chemical which will go into solution and the amount which will evaporate at the spill site.

To be conservative in this calculation, all the spilled chemical is assumed to have gone into solution. The information needed for assessment of the water pollution hazards should be entered below:

Chemical:

Stream width _____ feet;

Stream depth _______ feet.

Proceed to Hazard Calculation Code AP (found in Hazard Assessment Code APQRS) on page 110. The values to be calculated are:

- Safe concentration of chemical in the water,
- Concentration in the water at some downstream location, or
- The maximum downstream distance hazardous for humans.

D. GAS DISPERSION – CODE AC

The major assumptions made in this calculation are that all the chemical is released instantaneously as a gas and that the pool radius is minimum (0 to 25 feet). The chemical and physical data needed for assessment of the vapor-dispersion hazards are found in CHRIS Manual CG-446-2 (data item numbers are in parentheses). Enter the appropriate data below:

Chemical: ____________________

Amount spilled: ____________ tons (assume all of the chemical is released instantaneously as a gas)

Molecular weight (item 13.2): __________

Low flammability limit (item 6.2): _________ volume percent

Threshold limit value (item 5.4): _________ ppm

Pool radius: 0–25 ft. (assumed)

Wind velocity: _______________ knots

Weather conditions: ____________________

Proceed to Hazard Calculation Code AC (found in Hazard Assessment Code ABCDEFG, Hazard Calculation Code ABC/AC) on page 61. The values to be calculated are:

- Maximum downwind extent of flammability hazard,
- Maximum half-width of flammability hazard,
- Maximum downwind extent of toxic hazard,
- Maximum half-width of toxic hazard,
- Maximum duration of flammability hazard, and
- Maximum duration of toxic hazard.

E. LIQUID POOL DISPERSION – CODE AKMN

The major assumptions made in the calculation of liquid pool dispersion are that (1) the chemical spill is released instantaneously as a liquid which then spreads out on the water and evaporates, and (2) no liquid goes into solution in the water or reacts with the water. The chemical and physical data needed for assessment of the liquid pool vapor dispersion hazards are found in the Hazardous Chemical Data Manual (data item numbers are in parentheses). Enter the appropriate data below:

Chemical: ____________________

Spill amount: ________________ tons (assume all of the chemical is released as a liquid)

Molecular weight (item 13.2): ____________

Threshold limit value (item 5.4): _________ ppm

Wind velocity: _______________ knots

Weather conditions: __________________
____

Low flammability limit (item 6.2):_________volume %.

Find the maximum size to which the pool of spilled liquid chemical will grow from the spill amount in tons and Table K.1 and enter it below.

Maximum pool radius: ______ feet

Find the maximum time for complete evaporation of the chemical spill from the spill amount in tons and Table K.2 and enter it below:

Maximum time for complete evaporation: ___ minutes.

Proceed to Hazard Calculation Code ADFG (found in Hazard Assessment Code ABCDEFG, Hazard Calculation Code ADEFG/ADFG) on page 79. Use maximum pool radius and evaporation time recorded above – do not use Tables D1 and D2. The values to be calculated are:

- Maximum downwind extent of flammability hazard,
- Maximum half-width of flammability hazard,
- Maximum downwind extent of toxic hazard,
- Maximum half-width of toxic hazard,
- Maximum duration of flammability hazard, and
- Maximum duration of toxic hazard.

HAZARD ASSESSMENT CODE AO

Materials with Hazard Assessment Code AO are liquids which react with water (often violently), release heat, and form specific reaction products which are hazardous. The most common chemical in this code is oleum which reacts violently with water to form only sulfuric acid. The hazard-assessment procedure is to determine the reaction products and their amounts (based on the spill amount and the water reaction) from Table O.1, and then evaluate the product hazards.

Materials with multiple hazards, including O, in their assessment codes are first treated by those codes not including O, and then the products of the water reaction (code O) should be investigated to determine the product hazards.

A. HAZARD CALCULATION CODE AO

SAMPLE CALCULATION	*CALCULATION PROCEDURE (use pencil so it can be erased)*
Material: chlorosulfonic acid	______
Quantity: 50 tons	______
Conditions: instantaneous spill	______
wind 5 knots	______

Determine the products of reaction, their hazard codes, and the weight fraction of each product from Table O.1 and list them below. The weight fractions need not add up to 1.0.

The 50-ton spill of chlorosulfonic acid will react violently with water, and both sulfuric acid and hydrogen chloride gas will be formed. *
From Table O.1:

		Code		Code
Product #1	*sulfuric acid (spent)*	*AP*	______	
weight fraction #1	*0.85*		______	
Product #2	*hydrogen chloride*	*AC*	______	
weight fraction #2	*0.31*		______	

*Some of the gas will go into solution with water to form hydrochloric acid. For this example, we will assume that only gas is generated.

Calculate the amount of each product generated by the spill from the weight fraction of each product, the spill amount, and the formula:

Amount of product = (weight fraction) (spill amount)

For the 50-ton spill of chlorosulfonic acid, 0.85 of it will become sulfuric acid and 0.31 hydrogen chloride gas, some of which will go into solution in the water.	
Amount of sulfuric acid = (0.85) (50) = 42.5 tons	Amount of ( ) = ( ) ( ) = ______ tons
Amount of hydrogen chloride = (0.31) (50) = 15.5 tons	Amount of ( ) = ( ) ( ) = ______ tons

Summarize the products, the amounts of each, and the Hazard Assessment Codes to be used in evaluating the hazards.

For the 50-ton spill of chlorosulfonic acid, two products would evolve in a violent reaction with water.

Product	*Code*	*Amount (tons)*	Product	Code	Amount (tons)
Sulfuric acid	*AP*	*42.5*	______	____	______
Hydrogen chloride	*AC*	*15.5*	______	____	______

Evaluate the hazards associated with each of the products by proceeding to the hazard calculation codes given above.

HAZARD-ASSESSMENT CODE – APQRS

Chemicals in Hazard Assessment Code APQRS are characterized by the following properties:

- Soluble in water,
- Liquid at ambient temperature,
- Boiling temperature is greater than ambient – chemicals can be either volatile (high vapor pressure) or non-volatile (low vapor pressure), depending on how high the boiling temperature is above the ambient temperature.

The most common chemicals in this code are:

- methyl alcohol, ethyl alcohol, isopropyl alcohol;
- acetone;
- methyl ethyl ketone.

There are two hazards to persons and material and one water pollution hazard in this Hazard-Assessment Code.

- Fire (Calculation Code APQ) – The spill may spread and burn before enough mixing and dilution in the water occurs to quench the fire. (see page 110)
- Water pollution (Calculation Code AP) – The spill pool will both spread and mix with the water at the same time. The concentration of chemical in the water will remain a hazard until dilution by mixing and diffusion reduces the concentration below toxic limits. (see page 110)
- Toxic and flammable vapors (Calculation Code APRS) – Most of the liquid spill will dissolve in the water and part of it will evaporate. Both the vapor evaporated from the spilled liquid and the vapor which is released from water solution may be toxic and/or flammable. (Flammable only if letter Q is in code also.) (see page 123)

Spills which occur in flowing streams are of particular concern because soluble chemicals, once in solution, will be confined by the banks of the stream, and will remain a hazard as they flow downstream. Spills which occur in tidal areas are not usually confined, particularly during ebb tide, and rapid mixing occurs to reduce the concentration in the water. Spills which occur on calm, current-free water are not common in navigable waters.

A. LIQUID FIRE HAZARD CALCULATION – CODE APQ

Evaluation of the fire hazard depends, to a large extent, on the circumstances of the spill. One of the following spill descriptions may be used to evaluate the hazard.

- **Large amount of low-density (specific gravity less than 1) chemical in a confined or shallow area.**

For example, an amount of chemical equal to or greater than the volume of water in the confined area. Under these circumstances, thorough mixing and dilution may take a long time and the pool of chemical, if ignited, will behave like a pool fire, until the chemical is consumed by the fire, and, at the same time, is diluted below flammability limits in the water. For this type of spill and fire, use Hazard Calculation Code ATU, using a pool radius in the calculation which is equal to one half of the largest characteristic dimension of the spill.

- **Large amount of low-density (specific gravity less than 1) chemical on still water.**

Under these circumstances the chemical will spread out on the water surface and begin to be diluted by diffusion (a much slower process than mixing under the action of wind, waves and currents). When ignited, the flame will initially flare up like a pool fire, but will then rapidly die down, eventually ending as a wispy, low-to-the-surface fire as dilution continues and the concentration of chemical on the water surface falls below the flammability limit. There is no extended fire hazard and there is no fire calculation procedure for this condition.

- **Large amount of low-density (specific gravity less than 1) chemical on flowing water.**

Under these circumstances, the concentration of flammable chemical floating on the water surface will be rapidly reduced. When ignited, the flame will initially flare up and then very rapidly die down as dilution continues. There is no extended fire hazard and there is no fire calculation procedure for this condition.

B. WATER POLLUTION HAZARD – CODE AP

1. Background

A spill of soluble chemical on water presents a water pollution hazard. For many of the water soluble chemicals in this hazard code, there are no established water quality criteria for either human exposure or for commercial usage. Only recently have efforts been made to gather these desired water quality standards, and efforts to establish water standards are expected to continue.

For calculation purposes, an arbitrary procedure has been established in this manual for calculating the human toxic limits for chemicals dissolved in water. This calculation procedure is based on the following assumptions:

a. Sixteen ounces of contaminated water will be consumed;

b. The person weighs 100 pounds;

c. There is a safety factor of 3;

d. The properties of the spilled chemical are such that the chemical, in high concentrations, may pass undetected through a water purification system and then into the public water supply.

However, since there are no established water quality criteria, and since the calculation procedure presented below can give only a rough, quick estimate of the manner in which the spilled chemical will disperse, the following precautions should always be taken to insure that the hazard is not underestimated:

- The State Health Department (or other agencies which have responsibility for municipal waterworks) and the State Water Pollution Control Agency should be immediately notified. These agencies will be listed in the Regional Contingency Plan in the Water Quality Agencies section.

- A state-regulated waterworks warning network plan should be activated, if one exists for the waterbody involved. Such plans, if they do exist, should be listed in the Waterworks Warning Network Plan Section of the RCP.

- If a time-of-arrival, dye-tracer-type study has been conducted on the waterbody involved (as should be noted in either of the RCP sections previously mentioned), personnel familiar with its results should be asked to provide an estimation of the "peak-concentration profile" which can be expected downstream.

- All facilities with water intakes downstream from the spill site should be notified of the spill situation and given the best-possible estimate of the time when the chemical contaminant would be expected to reach their intake water. A procedure is suggested at the end of the following calculation procedure for determining the decrease in concentration of chemical contaminant as the chemical flows downstream.

2. Calculation Procedure for Determining Human Toxic Limits:

Determine the toxicity by ingestion from the Health Hazards sector of CHRIS Manual CG-446-2 and enter it below. Be careful to note whether toxicity is in mg/kg or gm/kg.

SAMPLE CALCULATION	*CALCULATION PROCEDURE* *(Use pencil so it can be erased)*
Chemical: Acetone	______________
Toxicity by ingestion (CG-446-2 data item 5.6): ______ *mg/kg* *or* 5 *gm/kg*	______________ *mg/kg* *or* ______________ *gm/kg*

Calculate the maximum safe concentration in water from the toxicity by ingestion and one of the following toxic equations for determining the toxicity. (The factors 30 and 30,000 incorporate the assumptions described on page 111).

For toxicity in mg/kg
Safe concentration = 30 x [toxicity (mg/kg)]
or
For toxicity in gm/kg
Safe concentration = 30,000 x [toxicity (gm/kg)]

For an acetone spill, the toxicity by ingestion is 5 gm/kg, thus, the second equation is used

Safe concentration = 30 ( )	= 30 ( )
= ______ mg/liter	= ______________ mg/liter
or	*or*
Safe concentration = 30,000 (5)	*= 30,000 ( )*
= 150,000 mg/liter	= ______________ mg/liter

3. Procedure for Industrial Hazards

The effect that any specific chemical will have upon a particular industrial facility which takes in water for process use will depend not only upon the concentration of the chemical in its intake water, but also upon the specific manner in which the contaminated water will be used. Unfortunately, because this specific manner may vary even between different plants in the same industry because of the age of the plant design, operating practices, and the normal quantity and quality of the available water supply, it is not practical to assign numerical values to the chemical concentrations which may cause fire, explosion, employee exposure to toxic atmospheres, or product deterioration for industry in general.

It is therefore suggested that in the event of a hazardous chemical spill or discharge, Coast Guard personnel estimate what the concentration of the chemical involved will be at various points downstream from the spill site and notify those downstream facilities which take in water that contaminated water will pass by their facility at a certain time and at a certain peak concentration. The personnel responsible for these plants will be best qualified to determine the extent of hazard which would be presented to their facility by the contaminated water and the proper response to the situation which they should take.

The Regional Contingency Plan, in a section entitled "Water Intakes" or "Waterworks Warning Network Plan," includes all information necessary in the region in which the spill has occurred for Coast Guard personnel to quickly and efficiently notify all facilities downstream from the spill.

- **Spill of Low-Density Chemical on a Flowing Stream** **(for other conditions, see pages 121 and 123)**

When a low-density chemical spill occurs on a flowing stream, two calculations can be made, depending upon the parameters given and the results desired: (1) the concentration in the water of the chemical at some distance downstream from the spill site, or (2) the distance downstream from the spill site where the chemical concentration in water is no longer a hazard to humans.

Downstream concentration at any point:

Tabulate below the information required for calculating the water pollution hazards in a flowing stream at some distance downstream from the spill site.

SAMPLE CALCULATION	*CALCULATION PROCEDURE (use pencil so it can be erased)*
Chemical: Acetone	________
Amount spilled 50 tons	________ tons
Stream width, W 350 feet	W = ________ feet
Stream depth, d 30 feet	d = ________ feet
Select a distance x of interest downstream. For example x = 0.5 nautical mile downstream of the spill.	x = ________ nautical miles

Place a check mark next to the stream width which most closely matches the above tabulated stream width, and determines the figure to be used in the calculation procedure. For stream widths on the border, use the smaller category.

Stream Width (feet)	Figure to be Used		
0-75	P1	______	______
75-200	P2	______	______
200-400	P3	✓	______
400-800	P4	______	______
800-1200	P5	______	______
1200-1800	P6	______	______
1800-2200	P7	______	______
2200-2800	P8	______	______
2800-3400	P9	______	______
greater than 3400	P10	______	______

Determine the chemical concentration per ton spilled factor (C/T) from the stream depth (d), the distance downstream from the spill (x), and the figure identified above. Do not interpolate between stream depths; use the next smaller stream depth.

For the 50-ton spill of acetone in a stream which is 350 feet wide and 30 feet deep, use the 20-foot depth curve on Figure P3 to determine the concentration factor (C/T) of acetone 0.5 nautical mile downstream of the spill.

Concentration Factor (C/T) = *800 mg/liter per ton spilled* | = ______________ mg/liter per ton spilled

Calculate the concentration at the downstream sitc from the factor (C/T) and the following equation.

$$\text{Concentration } C = (C/T)\ (\text{Tons spilled})$$

For the 50-ton spill of acetone, the factor C/T = 800 mg/liter per ton spilled and the tons spilled T = 50	
C = (800) (50) = 40,000 mg/liter at X = 0.5 nautical mile downstream	C = ( ) ( ) = ________ mg/liter

Downstream extent of hazard to humans:

To determine the distance downstream from the spill site where the chemical concentration is no longer a hazard to humans, enter below the calculated human toxic safe concentration limit in water for the specific chemical (calculated on page 113).

For the 50-ton acetone spill	
Safe limit for humans = 150,000 mg/liter	mg/liter

Calculate the concentration factor for humans $(C/T)_H$ from the safe limit for humans and the following equation:

$$(C/T)_H = \frac{(\text{safe limit for humans})}{(\text{tons spilled})}$$

For the 50-ton acetone spill	
$(C/T)_H = \frac{(150{,}000)}{50}$ *= 3000 mg/liter per ton spilled*	= $\frac{(\quad)}{(\quad)}$ = ______ mg/liter per ton spilled

Determine the maximum downstream extent of hazard for humans from the factor $(C/T)_H$, the stream depth (d), and the figure identified above.

For the 50-ton acetone spill in a stream which is 350 feet wide and 30 feet deep, use the 20-foot depth curve on Figure P3 and a $(C/T)_H$ *= 3000 to determine the maximum downstream distance where there is a hazard to humans.*	
Maximum hazardous distance for humans = 0.20 nautical mile	= ________ nautical miles

The peak concentration at any intermediate point between the spill site and the maximum hazardous distance for humans – and for that matter any point beyond this maximum distance – can be read directly off the figure used above by just following the depth curve and reading the concentrations at various downstream distances. These concentrations are based on "per ton of chemical spilled," and therefore must be multiplied by the number of tons spilled to give the actual peak concentrations. In addition, the time that the peak concentration of the chemical will reach a given point downstream is simply that distance divided by the stream velocity. However, some of the chemical may reach a given point downstream well before the peak concentration does.

- **Spill of Low-Density (specific gravity less than 1) Chemical in a Tidal Area**

(for other conditions, see pages 115, 121 and 123)

Although no calculation model exists for the spill of a low-density chemical in a tidal area, the following rules-of-thumb are suggested:

a. Calculate the human toxic safe concentration limit in water.

b. Determine the maximum up-tide or down-tide safe separation distance for humans during the first half tidal cycle from the spill size, and the safe concentration limit for humans, from the following rule-of-thumb table. For the second and consecutive tidal cycles, divide the values by 2 for each cycle.

Human Toxic Safe Concentration Limit (mg/liter)	Safe Separation Distance (nautical miles) Less than 1 ton	1-10 tons	Greater than 10 tons
Less than 0.1	1	10	20
0.1 to 10	.5	6	10
Greater than 10	.1	.5	1

- **Spill of Low-Density (specific gravity less than 1) Chemical on Still Water**

(for other conditions, see pages 115, 121 and 123)

Although no calculation model exists for a spill of a low-density chemical on still water, the following rules-of-thumb are suggested:

a. Use the density of the chemical, the spill size in tons, and Table T1 to determine the maximum pool radius (assumes no mixing);

b. Calculate the human toxic safe concentration limit in water; and

c. With this safe limit, enter the table below to determine a safety multiplier.

Human Toxic Safe Concentration Limit (mg/liter)	Safety Multiplier
less than 0.1	16
0.1 to 10	8
greater than 10	4

d. Multiply the maximum pool radius by the safety multiplier to obtain the estimated extent of the unsafe-to-humans limit.

- **Spill of High-Density (specific gravity greater than 1) Chemical**

(for other conditions, see pages 115 and 121)

Usually a high-density chemical sinks to the bottom and dissolves into the water. Although there is no calculation model for this type of spill, the following rules-of-thumb are suggested.

a. Calculate the human toxic safe concentration limit in water;

b. Estimate the depth of water into which the chemical has spilled;

c. Estimate the extent (in feet) of the hazard to humans from the following equation:

$$\text{Extent of Hazard} = 2 \times 10^4 \sqrt{\frac{\text{(tons spilled)}}{\text{(max. safe conc.) (water depth)}}}$$

C. VAPOR DISPERSION CALCULATION – CODE APRS

The chemicals in the vapor-dispersion calculation code are soluble in water, have boiling points above ambient temperature, and have a high enough vapor pressure at ambient temperature to evaporate and cause both a toxic vapor hazard and a flammability hazard. This calculation procedure applies only to spills on flowing streams.

The chemical and physical data needed for assessment of vapor dispersion hazards of soluble chemicals spilled on a flowing stream are found in CHRIS Manual CG-446-2 (data item numbers are in parentheses). Enter the appropriate data below:

Specific chemical: acetone		
Low flammability limit (item 6.2):	*2.6 volume %*	volume %
Threshold limit value (item 5.4):	*1000 ppm*	ppm
Molecular weight (item 13.2):		

Information concerning the spill should be entered below:

Spill amount *50 tons*	______	tons
Stream width *350 feet*	______	feet
Stream depth *40 feet*	______	feet
Stream velocity *0.2 knots*	______	knots

Find the hydraulic radius (RH) of the spill from the depth of the stream, the width of the stream, using either Figure R1 or R2. Use Figure R1 for stream depths less than 20 feet, and Figure R2 for stream depths greater than 20 feet. Approximate interpolation must be made for intermediate stream widths.

For the 50-ton acetone spill, the stream is 30 feet deep and 350 feet wide. The hydraulic radius (RH) is found in Figure R2.	
RH = 26 feet	RH = ______ feet

Place a check mark next to the specific chemical which was spilled and determine the figure to be used in evaluating the amount evaporated.

Chemical	*Figure*		
Acetone	*R3*	✓	
Acetonitrile	*R4*		
Acrolein	*R5*		
Acrylonitrile	*R6*		
Ammonium hydroxide (28% solution)	*R7*		
tert-Butyl alcohol	*R8*		
n-Butylamine	*R9*		
sec-Butylamine	*R10*		
tert-Butylamine	*R11*		
Butylene oxide	*R12*		
Dimethylamine	*R13*		
Diisopropylamine	*R14*		
1,1-Dimethylhydrazine	*R15*		
Ethyl alcohol	*R16*		
Ethylene glycol dimethyl ether	*R17*		
Ethyleneimine	*R18*		
Ethyl formate	*R19*		
Isobutylamine	*R20*		
Isopropyl alcohol	*R21*		
Isopropylamine	*R22*		
Isopropyl mercaptan	*R23*		
Methyl acetate	*R24*		

Chemical	Figure		
Methyl alcohol	R25		
Methyl ethyl ketone	R26		
Methyl formal	R27		
Methyl formate	R28		
Methylhydrazine	R29		
Methyl vinyl ketone	R30		
Nitromethane	R31		
Propyleneimine	R32		
Propylene oxide	R33		
Prvidine	R34		
Tetrahydrofuran	R35		
Triethylamine	R36		

Determine the factor (tons x knots) from the hydraulic radius (RH), the tons spilled, and the figure identified above.

For the 50-ton acetone spill and with the RH = 26, the (tons x knots) from Figure R3 is

(tons x knots) = 0.015 ton-knots | ____________ ton-knots

Calculate the tons of chemical evaporated from the following equation

$$\text{Tons evaporated} = \frac{(\text{tons x knots})}{(\text{stream velocity})}$$

For the 50-ton acetone spill:

Tons evaporated $= \frac{0.015}{0.2} = 0.075$ *ton* | $= \frac{(\quad)}{(\quad)} =$ ____________ tons

Determine the gas flammability and gas toxicity hazards from the Gas Dispersion Assessment Code ABC/AC on page 61, but do not take any action based upon these results until the remainder of the calculations in Code APRS have been completed. Flammability need not be considered unless the letter Q appears in the chemical's hazard assessment code. Use amount evaporated in place of spill amount in Code AC. Enter the data required below for this calculation procedure: **(use pool radius 0-25 feet)**

Specific chemical	*acetone*		
Amount evaporated	*0.075 ton*		tons
Molecular weight	*58*		
Low flammability limit	*2.6 volume %*		volume %
Threshold limit value	*1000 ppm*		ppm
Wind velocity			

The values to be calculated are:

- Maximum downwind flammability extent,
- Maximum half-width of flammability,
- Duration of fire hazard,
- Maximum downwind toxic hazard,
- Maximum half-width of toxic hazard, and
- Duration of toxic hazard.

However, *do not* take any action based upon these figures until the remaining calculations in this section are completed.

The maximum downstream extent of the flammability and toxic vapor dispersion hazard is assumed to be reached when the chemical concentration in the water decreases to 5 mol percent. At this water concentration, not much vapor will be generated above the water and, depending on the chemical and its toxic and flammability limits, the distance within which a hazard will exist could be anywhere between the spill site and the maximum downstream limit.

Place a check mark next to the range of molecular weights which most closely matches the molecular weight of the spilled chemical and determine the figure to be used in the calculation procedure.

For the 50-ton acetone spill,
the molecular weight of acetone is 58.
Figure R39 is to be used

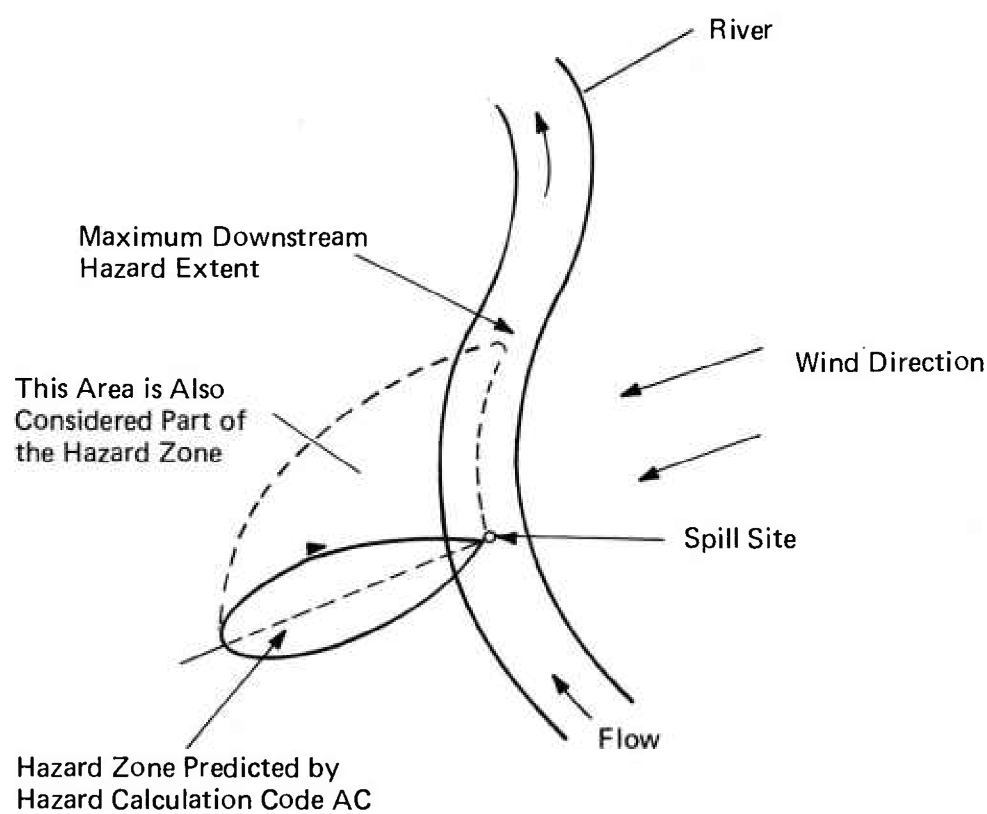
Molecular Weight Range	Figure to be Used		
Less than 30	*R37*		
30-50	*R38*		
50-70	*R39*	✓	
70-90	*R40*		
Greater than 90	*R41*		

Determine the maximum downstream extent of the hazard from the hydraulic radius (RH), the tons of chemical spilled, and the figure identified above.

For the 50-ton acetone spill, the hydraulic radius (RH) is 26 and from Figure R39 the maximum downstream hazard is:		
Maximum downstream hazard = 1.9 nautical miles	=	______ nautical miles

The realistic area over which a flammable or toxic hazard will exist is slightly different from that which Hazard Assessment AC or the maximum downstream distance just calculated describe. This is especially true whenever the wind direction is not the same as the direction of streamflow – a case which will occur often. In such instances it is suggested that the hazard zone not only be considered to envelop the predicted zones, but also the areas between them. An example of such a situation is illustrated below.

EXAMPLE:



HAZARD ASSESSMENT CODE – ATUVW

Chemicals in Primary Hazard Code ATUVW are characterized by the following properties:

- Liquid at ambient temperature,
- Boiling temperature is greater than ambient – chemicals can be either volatile (high vapor pressure) or non-volatile (low vapor pressure), depending on how high the boiling temperature is above ambient temperature,
- Immiscible or slightly soluble in water,
- Density less than water – floats on water.

The most common chemicals encountered in this code are:

- Crude oil
- Petroleum distillates – gasoline, diesel and jet fuels.

There is one water pollution hazard and two hazards to persons and material in the Primary Hazard Code:

- Water pollution (Hazard Calculation AT) – The spill pool will spread and, if the vapor pressure of the liquid is low, the chemical will not evaporate but will remain on the water. (see page 135)
- Fire (Hazard Calculation ATU) – the spill pool may spread, and ignite. (page 149)
- Toxic or flammable vapors (Hazard Calculation AVW) – The spill pool will spread and, if the vapor pressure of the liquid is high, the chemical will evaporate to form a toxic and/or flammable cloud. (Flammable only if letter U is in code also.) (page 151)

SAMPLE CALCULATION		*CALCULATION PROCEDURE (use pencil so it can be erased)*
Material:	*Oil, crude*	
Quantity:	*20 Tons*	
Conditions:	*Various – see specific calculation procedures*	

A. HAZARD CALCULATION CODE AT – SPREADING POOL ASSESSMENT

The chemical and physical data needed for assessment of the spreading pool hazard are found in the Hazardous Chemical Data Manual (data item numbers are in parentheses). Enter the appropriate data below:

For crude oil, the specific gravity is (item 13.7) *ρ = 0.70-0.98* *	= ______________ (use .9 if ρ greater than .9)

In the following calculations be careful not to confuse Table T1 with Figure T1.

Determine the following parameters from the spill size in tons, the chemical specific gravity, and Table T1. The parameters R, T, and F are characteristic parameters used to nondimensionalize the time of interest, t (real time), and the radius, r (real pool radius). Do not interpolate for either the spill size or density; use the next larger value for both.

For chemicals with codes AT or ATU, determine maximum pool radius from Table T1. For chemicals with codes ATUVW or ATVW determine maximum pool radius from Table V1 and evaporation time from Table V2. (Do not use times greater than the evaporation time to calculate pool sizes.)

For a 20-ton spill of crude oil of specific gravity (ρ) = 0.80	
R = 9.29 feet;	______________ feet
T = 1.20 sec;	______________ sec
F = 246;	______________
Maximum pool radius = 880 feet	______________ feet**

The maximum pool radius is the size of the maximum polluted area in the absence of wind or stream effects.

---

*Use 0.80

The pool size (r) at any time up to the maximum can be calculated with this information and Figure T1 as follows:

Convert the time of interest (t in minutes, hours, days or weeks) to seconds by one of the following:

Multiply Time in	by	to obtain
minutes	60	seconds
hours	3.6×10^3	seconds
days	8.64×10^4	seconds
weeks	6.05×10^5	seconds

For the crude oil spill and a time of interest t = 4 hours The time in seconds is given by:	Time of interest: ________________
(4) $(3.6 \times 10^3) = 14.4 \times 10^3$ sec.	( )( ) = sec.

Calculate the non-dimensional time ratio (t/T) from the time of interest (t) in seconds and the factor (T).

For the 20-ton spill of crude oil $t = 14.4 \times 10^3$ sec. and	
$T = 1.20$ sec.	
$t/T = (14.4 \times 10^3)/(1.20)$ $= 12.0 \times 10^3$	t/T = ( )/( )
$t/T = 1.2 \times 10^4$	t/T = ________________

Determine the non-dimensional pool radius ratio (r/R) from the ratio (t/T), the factor (F) and Figure T1. Sometimes the given value of (t/T) will not intersect with the selected (F) line. In this case, read the value of (r/R) at the point where the (t/T) line intersects the dashed line in Figure T1.

For the 20-ton crude oil spill, $(t/T) = 1.2 \times 10^4$ (F) = 246 (use 250 and interpolate) r/R = 120;	r/R = ________________

Calculate the pool radius (r) at the time of interest from the ratio (r/R) and the factor (R) with the following equation: $r = (r/R)\ (R)$

For a 20-ton spill of crude oil (r/R) = 120 and R = 9.29.	
The pool radius after 4 hours is:	
r = (120) (9.29) = 1115 ft;	r = ( ) ( ) =
Round off to two significant figures	
r = 1100 feet	r = ________________ feet

In this calculation, the radius (r) at the time of interest exceeds the maximum pool radius; thus the pool has already reached its maximum pool radius and will not grow larger than this radius. The calculated value in this procedure is valid only if it is less than, or equal to, this maximum value.

For the 20-ton spill of crude oil, the pool will grow to a radius of 880 feet in 4 hours. This is as large as it will grow because the maximum pool radius is 880 feet.

The above calculation procedure and example are for a spill on open water with no wind. However, there are additional conditions which may be encountered, depending on the configuration of the surrounding body of water, the wind, and stream effects, or tidal effects.

Choose one of the following conditions which most closely fits the situation under consideration:

a. Open water with no wind, stream, or tidal effects. (see page 141)

b. Open water with wind – The spill will grow radially and also move at 3 percent of the wind velocity; ignore wind effects. (see page 141)

c. Narrow flowing stream – The spill will grow radially until it reaches the confines of the stream; it will also move at the stream velocity; ignore wind effects. (see page 143)

d. Tidal river basin – The spill moves with the tide; ignore wind effects; note that part of the spill can be expected to return in about 12 hours. (see page 147)

1. Open Water with No Wind, Stream, or Tidal Effects

For these conditions, the spill can be expected to expand until it reaches the maximum pool radius. The pool radius can be calculated at any time up to the time when the pool reaches its maximum radius. (See above calculation procedures and example.)

2. Open Water With Wind

The pool will grow to maximum size as in the above calculations; in addition, the center of the circular pool will move at 3 percent of the wind velocity.

For a 20-ton crude oil spill on open water, determine the forward velocity and the distance it will move in 12 hours when the wind velocity is 10 knots.	

Determine the forward velocity of the spill (V_s) from the wind velocity (V_w) and the following equation:

Spill velocity in the influence of wind $V_s = 0.03\ (V_w)$

For the 20-ton crude oil spill and a wind velocity of 10 knots, the spill velocity is	
$V_s = 0.03\ (10) = \underline{0.3\ knot;}$	$V_s = 0.03$ ( ) = ________ knots

Determine the distance (X_s) that the center of the spill will move during the time interval of interest (t) from the following equation:

$$X_s = (V_s)\ (t)$$

For the 20-ton crude oil spill, the spill velocity is $V_s = 0.3$ knot and the time interval of interest is t = 12 hours. Therefore, the distance the spill moves is	
$X_s = (0.3)\ (12) = \underline{3.6\ nautical\ miles}$	x_s = ( ) ( ) = ________ nautical miles.

3. Narrow Flowing Stream

An instantaneous spill occurring on a narrow flowing stream can be expected to form a circular pool which will grow until it reaches the confining banks of the stream. Thereafter, the spill will continue to grow along the stream until it reaches a maximum length (L_{max}). At the same time, the spill will be transported downstream at the velocity of the stream. The important parameters to be calculated are:

- Maximum pool radius or, if it fills the stream,
- Maximum length of full stream with contamination (L_{max}),
- Distance (s) the center will move in a given period of time (t),
- Time of arrival (t_a) of the spill at a downstream location, and
- Time for the complete spill to flow past a point (t_p) on the bank of the stream:

If the chemical's hazard assessment code is AT or ATU, determine the maximum pool radius from the spill size, the specific gravity, and Table T1.

If the chemical's hazard assessment code is ATUVW or ATVW, determine the maximum pool radius from the spill size, the specific gravity, and Table V1.

For the 20-ton spill of crude oil of specific gravity = 0.80	
maximum pool radius = 880 feet	= ________ feet

If the maximum pool radius is greater than half of the stream width, then the spill will completely fill the stream and the maximum length (L_{max}) must be calculated from this formula (all dimensions must be in feet):

$$L_{max} = \frac{3.14\ (\text{Max Pool Radius})^2}{(\text{Stream Width})}$$

For the 20-ton crude oil spill, in a 200-foot wide stream	
$L_{max} = \frac{(3.14)\ (880)\ (880)}{(200)}$	$= \frac{(3.14)\ (\quad)\ (\quad)}{(\quad)}$
L_{max} *= 12,200 feet*	= ________ feet

Convert L_{max} to nautical miles by dividing by 6076.

For the 20-ton crude oil spill, *L_{max} = 12,200 feet*	
$L_{max} = \frac{12,200}{6076}$	$= \frac{(\quad)}{6076}$
L_{max} = *2.0 nautical miles*	= ______ nautical miles

The whole spill will move at stream velocity and the distance the center has moved downstream from the spill site can be calculated from

$$S = \text{(stream velocity) (elapsed time)}$$

For the 20-ton crude oil spill in a stream with a 2-knot current; the distance traveled in 12 hours is:	
S = (2) (12) = 24 nautical miles;	= ( ) ( ) nautical miles

Calculate the time of arrival (t_a) at a downstream location from

$$t_a = \frac{\text{(Distance Downstream)} - (L_{max}/2)}{\text{(Stream Velocity)}}$$

For the 20-ton crude oil spill in a stream with a 2-knot current, the time of arrival at a location 6 nautical miles downstream is:	*Downstream location of interest* ______ *nm*
$t_a = \frac{(6) - (2.0/2)}{2}$	$= \frac{(\quad) - (\quad /2)}{(\quad)}$
= 2.5 hours	= ______ hours

Calculate the time required (t_p) for the spill to pass a given point on the bank from L_{max} (in nautical miles) and the stream velocity (in knots):

$$t_p = \frac{L_{max}}{\text{(Stream Velocity)}}$$

For the 20-ton crude oil spill

$t_p = \frac{(2.0)}{2} =$ | $= \frac{(\quad)}{(\quad)}$

t_p = *1.0 hour* | = ________ hours

4. Tidal River Basin

For this condition, an instantaneous spill can be expected to form a circular pool, one side of which will contact the shoreline. It will also move with the tide, alternately flowing out at ebb tide and returning with the flood tide. The pool size at any time can be calculated as if the spill occurred on open water without wind as outlined above. When the tide comes in, the pool can be expected to spread along the beach.

(No calculation model)

5. Summary of Spreading Pool Hazards – Code AT

a. Open Water with No Wind

For a 20-ton crude oil spill:

Maximum pool radius = 880 feet; | = ________ feet

Four hours after the spill has occurred, the pool radius has increased to 880 feet which means that it has reached full size.

b. Open Water with Wind

For a 20-ton crude oil spill in a 10-knot wind, the velocity of the spill is:

Spill velocity (V_S) = 0.3 knot; | = ________ knots

After 12 hours the spill center has gone

Time after spill (t) = 12 hours; | = ________ hours

Distance spill moves = 3.6 nautical miles | = ________ nautical miles

c. Narrow Flowing Stream

For 20-tons of crude oil spilled in a flowing stream	
Stream width (W) = 200 feet; ______	______ feet
Stream velocity (V_s) = 2 knots: ______	______ knots
Maximum length of stream polluted	
(L_{max}) = 12,200 feet; ______	______ feet
(L_{max}) = 2.0 nautical miles ______	______ nautical miles
Time until spill passes (t_p) = 1.0 hours. ______	______ hours

B. FIRE HAZARD – CODE ATU

A spreading pool of flammable material, when ignited, presents a fire hazard to both people and the surroundings. The fire hazard is assessed by first determining the pool radius at a given time by Hazard Calculation Code AT, or the maximum pool radius from Table T1 or Table V1, and then using the radius in Calculation Procedure Code ADE.

The chemical and physical data needed for assessment of the spreading pool size and the fire hazard are found in the Hazardous Chemical Data Manual, CG-446-2 (data item numbers are in parentheses). Enter the appropriate data below:

Specific gravity (item 13.7): ρ = ________

Boiling point (item 13.3): T_b = ________ °K

Burning rate (item 6.9): R = ________ mm/min.

Molecular weight (item 13.2): M = ________

Determine the pool radius after (t) hours or the maximum pool radius (whichever is appropriate to the spill being considered) by using the calculation procedures in Code AT.* Enter the pool radius below: (see page 135)

Pool radius = ________ *feet*

Determine the liquid fire hazards by using the above pool radius and Hazard Calculation Code ADE (page 73). Use the pool radius recorded above – do not use Table D1.

- Flame height,
- Flame angle,
- Safe separation distances for people, for people in fire-protective clothing, and for wooden structures.

C. VAPOR-DISPERSION ASSESSMENT – CODE AVW

The chemical and physical data needed for assessment of the evaporation rate and vapor dispersion hazards are found in the Hazardous Chemical Data Manual (data item numbers are in parentheses). Enter the appropriate data below:

Specific chemical = ________

Spill amount = ________ tons

Molecular weight (item 13.2) = ________

Low flammability limit (item 6.2) = ________ volume %

Threshold limit value (item 5.4) = ________ ppm

Find the maximum size to which the pool of spilled chemical will grow from the specific chemical, the spill amount (in tons), and Table V-1, and enter it below:

Maximum pool radius = ________ feet

*Do not use Code AT if a large amount of soluble, low-density chemical (specific gravity less than 1) has spilled into a confined or shallow area. In such a case, use a pool radius which is equal to half the largest dimension of the confined area. This represents an approximate way of treating soluble chemical fires and the hazard assessment is not expected to be accurate.

Enter the current velocity of the water body below:

Current velocity = ———— knots

Find the time for complete evaporation of the spill from the specific chemical, the spill amount (in tons), and Table V-2, and enter it below:

Time for complete evaporation = ———— hours: minutes

Round-off the time for complete evaporation to the closest number of hours and enter it below:

Time for complete evaporation (rounded-off) = ———— hours

Multiply the current velocity in knots by the time for complete evaporation in hours to give the distance downstream the pool of chemical will travel before disappearing.

Current velocity x time for complete evaporation (rounded-off)

= ——— x ——— = ————n.mi.

If this distance is less than one, determine the vapor dispersion hazards by using the above maximum pool radius and Hazard Calculation Procedure Code AC (page 61). The values to be calculated are:

- Maximum downwind flammability extent,
- Maximum half-width of flammability,
- Duration of fire hazard,
- Maximum downwind toxic hazard extent,
- Maximum half-width of toxic hazard, and
- Duration of toxic hazard.

If the distance calculated is one or greater, divide the total amount of chemical spilled (in tons) by this distance and enter it below:

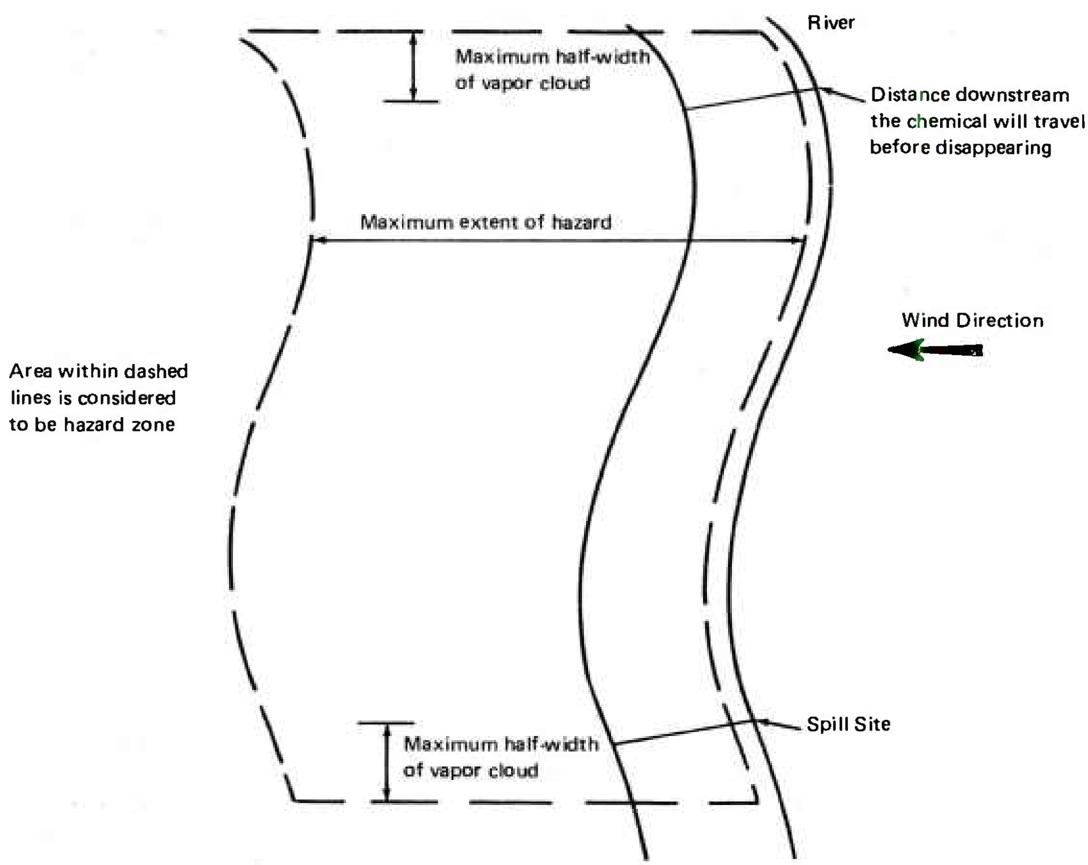
$$\frac{\text{Spill amount}}{\text{Nautical Miles}} = \text{————} \text{ tons/n. mi.}$$

Determine the vapor dispersion hazards by using the numerical value for tons/n. mi. as the spill amount and Hazard Calculation Procedure ADFG (page 79). Use the maximum pool radius and evaporation time recorded above – do not use Tables D1 and D2. The values to be calculated are:

- Maximum downwind flammability extent,
- Maximum half-width of flammability.

- Maximum downwind toxic hazard extent, and
- Maximum half-width of toxic hazard.

A chemical which is insoluble, floats, and evaporates as it moves downstream will present a vapor dispersion hazard zone which is more rectangular in shape than elliptical. The length of the hazard zone will be approximately the distance downstream the pool will travel before it disappears plus twice the half-width of the vapor cloud. The width of the hazard zone will be the maximum downwind extent of hazard. An example of how to determine the zone is given below:



HAZARD ASSESSMENT CODE AXY

The chemicals in Hazard Assessment Code AXY are characterized by the following properties:

- Insoluble (or slightly soluble) in water,
- Liquid at ambient temperature, and
- Heavier than water.

The most common chemicals in this code are:

- Trichloroethylene,
- Liquid sulfur,
- Tetraethyl lead, and
- Mercury.

There are two possible hazards in this code:

- Water pollution (Code AX) – The material will sink to the bottom where it will remain intact and be a source of water and sediment pollution, and
- Fire (Code AXY – There is no calculation procedure at this time) – The material is flammable and will burn in air. However, it will be extinguished by the water as it sinks (heavier than water).

A. WATER POLLUTION – CODE AX

No formal evaluation can be made of the water pollution hazard of the chemicals in this code because they sink to the bottom and are either insoluble or only slightly soluble in water. It is often important to know where the majority of the material settles after spill. In non-flowing waters, the spill will settle directly under where the spill occurs and, if the spill is large, the mass of material will flow out on the terrain of the bottom. On flat-bottom terrain the spilled material will assume a circular shape which has greatest thickness in the center.

For spills in flowing water, the material will be transported downstream as it settles. Those materials with densities considerably greater than that of water will settle close to the spill location and remain concentrated, while those with densities only slightly greater than that of water may be transported long distances and become spread out for a considerable distance on the bottom. The location on the bottom and the time it takes for the spill to sink are dependent on the velocity at which the material sinks. This velocity is a function of the material density and the material surface tension. These properties are found in the Hazardous Chemical Data Manual (data item numbers are in parentheses). List them below:

SAMPLE CALCULATION		*CALCULATION PROCEDURE (use pencil so it can be erased)*
Chemical:	*trichloroethylene*	______
Specific gravity (item 13.7):	*1.48 gm/cm³*	______ gm/cm³
Surface tension (item 13.8): *	*30 dynes/cm*	______ dynes/cm
Stream velocity:	*8 knots*	______ knots
Stream depth:	*60 feet*	______ feet

Determine the sinking velocity of the spill from the material surface tension, the material density, and Figure X.1.

For a trichloroethylene spill, the density is 1.48 (use a value of 1.5), and the surface tension is 30 dynes/cm.
From Figure XI, the sinking velocity is:

Sinking velocity = 0.65 feet/sec. — Sinking velocity = ______ feet/sec.

Calculate the time for the material to sink to the bottom from the following equation.

$$\text{Time to sink} = \frac{\text{(Stream Depth)}}{\text{(Sinking Velocity) (3600)}}$$

* The surface tension for most organic liquids is between 25 and 30 dynes/cm. If no surface tension is given, use a value of 30 dynes/cm.

For the trichloroethylene spill, the depth is 60 feet and the velocity is 0.65 feet/sec.	
Time to sink $= \frac{60}{(0.65)\ (3600)}$	Time to sink $= \frac{(\quad)}{(\quad)\ (3600)}$
$=$ *0.0256 hour*	$=$ ______ hours

Calculate the distance downstream where the material comes to rest from the following equation:

Distance downstream = (stream velocity) (time to sink)

For the trichloroethylene spill, the time to sink is 0.0256 hour and the stream velocity is 8 knots. Round off to the nearest 0.1 nautical mile.	
Distance downstream = (8) (0.0256)	Distance downstream = ( ) ( )
= 0.2 nautical mile	= __________ nautical miles

HAZARD-ASSESSMENT CODE AZ

Materials with Hazard-Assessment Code AZ may be self-reactive when released. The reaction is usually accompanied by the release of heat which, in turn, accelerates the reaction. It often results in an explosion. Not enough rate-of-reaction data are available on chemicals with Code AZ to perform an explosion-hazard analysis. All chemicals with Hazard Assessment Code AZ also have additional Hazard Calculation Codes which should be evaluated.

HAZARD-ASSESSMENT CODE II

The chemicals in Hazard-Assessment Code II are solids most of which sink in water and are insoluble. No formal evaluation can be made of the water pollution hazard of the chemicals in this code; however, it is important to know where most of the chemicals settle after the spill. The eventual location of the material is dependent upon the material particle size, its density, and the water conditions surrounding the spill.

In non-flowing waters, the material will settle directly under where the spill occurs. Fine particulate materials will remain in suspension in water for a longer period of time than will granular size materials or chunks of materials, but the whole mass will eventually settle directly under the spill site.

For spills in flowing water, the material will be transported downstream as it settles. Those materials with density considerably greater than water and in granular or chunk sizes will settle close to the spill location and remain concentrated. Materials of density only slightly greater than water, or of very fine particulate consistency, may be transported long distances and become spread out for a considerable distance on the bottom.

HAZARD-ASSESSMENT CODE RR, RR-C

Materials with Hazard-Assessment Code RR and RR-C are solids which react with water (often violently) and form specific reaction products which are hazardous. The most common chemicals in this code are:

- Sodium (metal), and
- Calcium carbide.

The code RR-C designates a reactive solid which generates a hazardous gas which should also be treated with Hazard-Assessment Code ABC.

The hazard-assessment procedure consists of determining the reaction products and their amounts (based on the spill amount and the water reaction) from Table RR.1, and then evaluating the product hazards.

A. HAZARD CALCULATION CODE RR, RR-C

HAZARD CALCULATION	*CALCULATION PROCEDURE (use pencil so it can be erased)*
Material: *calcium carbide*	________
Quantity: *1.0 ton*	________ tons
Conditions: *instantaneous spill, wind 5 knots*	________

Determine the products of reaction, their hazard codes, and the weight fraction of each product from Table RR.1 and list them below.

For the 1.0-ton spill of calcium carbide, a violent reaction with water will occur, and both acetylene and calcium hydroxide will be formed. From Table RR.1.:

		Code		Code
Product #1	*acetylene*	*ABC*	________	____
weight fraction = 0.40			________	
Product #2	*calcium hydroxide*	*II*	________	____
weight fraction = 1.16			________	

Calculate the amount of each product generated by the spill from the weight fraction of each product, the spill amount, and the formula:

Amount of product = (weight fraction) (spill amount).

Example	Your calculation
For the 1.0-ton spill of calcium carbide, 0.40 of it becomes acetylene gas and 1.16 becomes insoluble calcium hydroxide	
Amount of acetylene = (0.40) (1.0) = 0.40 ton	Amount of ( ) = ( ) ( ) = ________ tons
Amount of calcium hydroxide = (1.16) (1.0) = 1.16 tons	Amount of ( ) = ( ) ( ) = ________ tons

Summarize the products, the amount of each, and the Hazard-Calculation Codes to be used to evaluate the hazards:

For the 1.0-ton calcium carbide spill, two products evolve in a violent reaction with water:

Product	*Code*	*Amount (tons)*	Product	Code	Amount (tons)
acetylene	*ABC*	*0.40*	________	____	______
calcium hydroxide	*II*	*1.16*	________	____	______

Evaluate the hazards associated with each of the products by proceeding to the Hazard Calculation Codes given above.

HAZARD-ASSESSMENT CODE SS

Materials in Hazard-Assessment Code SS are solids which sink in water and are soluble. They present a water pollution hazard which can be evaluated by selected portions of Hazard Calculation Code AP.

Proceed to Hazard Calculation Code AP (found in Hazard Assessment Code APQRS) and use the following calculation sections:

- Calculation procedure for human toxic limits,
- Procedure for industrial hazards, and
- Spill of high density (specific gravity greater than 1) chemical.

6.0 FIGURES AND TABLES

6.0 FIGURES AND TABLES

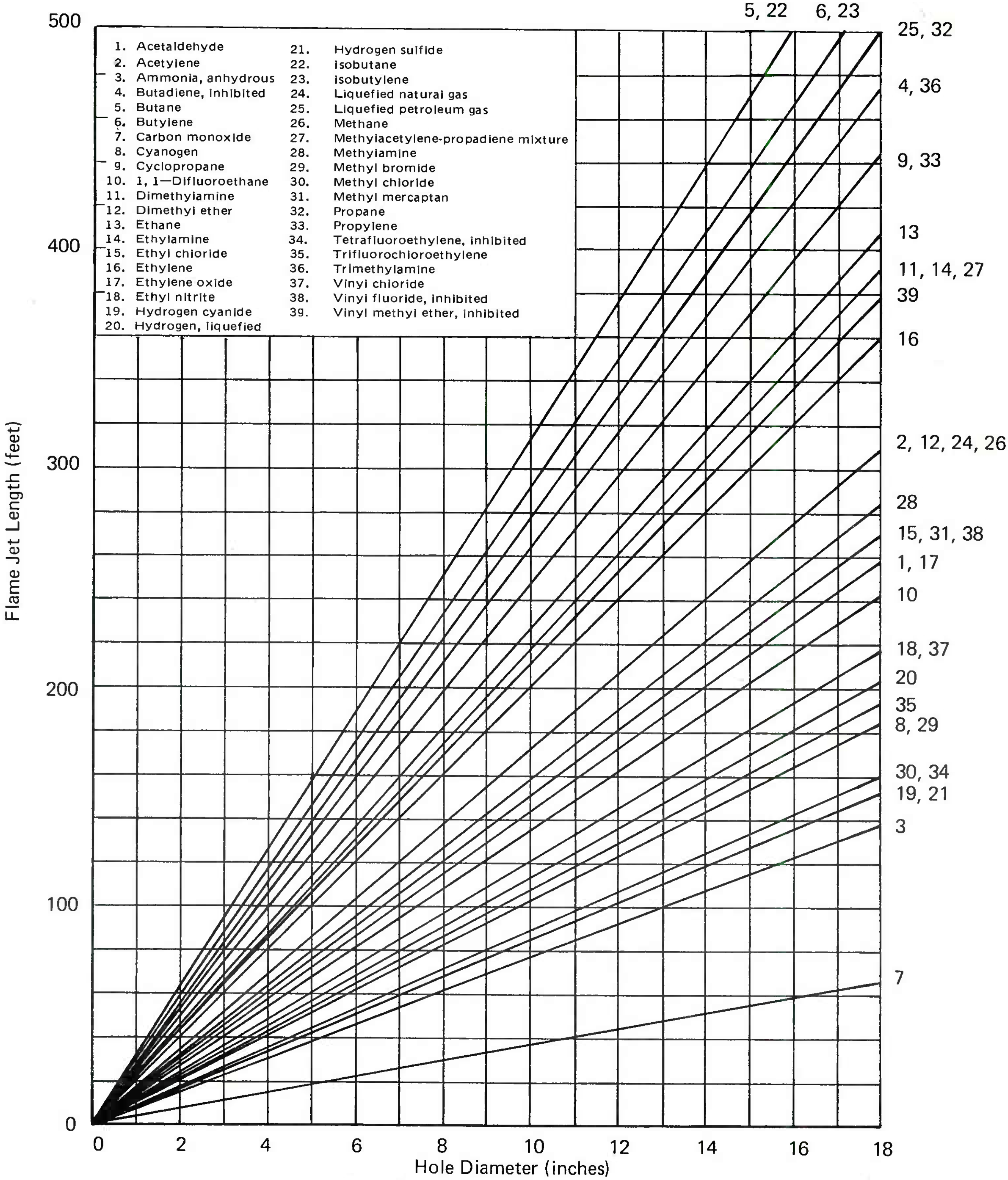
FIGURES FOR CALCULATION PROCEDURE B

Hazard calculation procedure B may be used to assess the flammability hazard of escaping flammable vapor or gas that might be caused by:

1. A leak in a tank of pressurized gas, or
2. A leak in a tank carrying a refrigerated cargo of flammable liquid with a boiling point less than ambient whose refrigeration system has malfunctioned, or
3. A leak in a tank carrying a cargo of a flammable liquid with a boiling point less than ambient under pressure.

Three figures are presented for use with hazard calculation procedure B:

- Figure B1 gives the initial flame length for gases venting through holes in the tank.
- Figure B2 gives an equivalent pool radius for the "cone" of flame, and
- Figure B3 uses the equivalent pool radius to give the safe separation distance from the axis of the flame for people, people in minimum fire-protective clothing, and wooden structures.



Note: For hole sizes larger than 18", the tank will empty so quickly that there will be no sustained thermal radiation from the flame. A short duration, high intensity fire will result.

FIGURE B1 FLAME LENGTH FOR GASES VENTING THROUGH HOLES

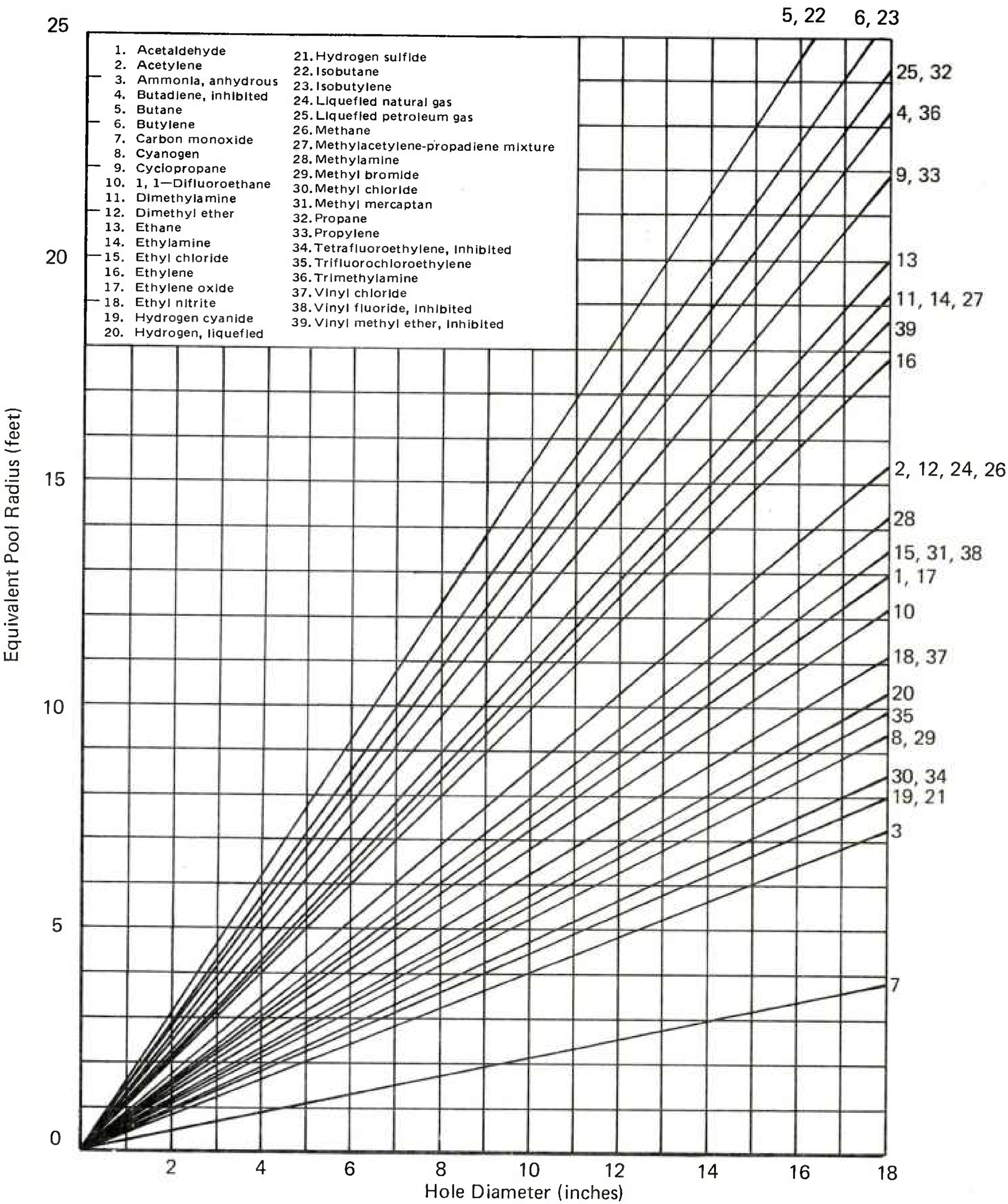


FIGURE B2 EQUIVALENT POOL RADIUS FOR GASES VENTING THROUGH HOLES

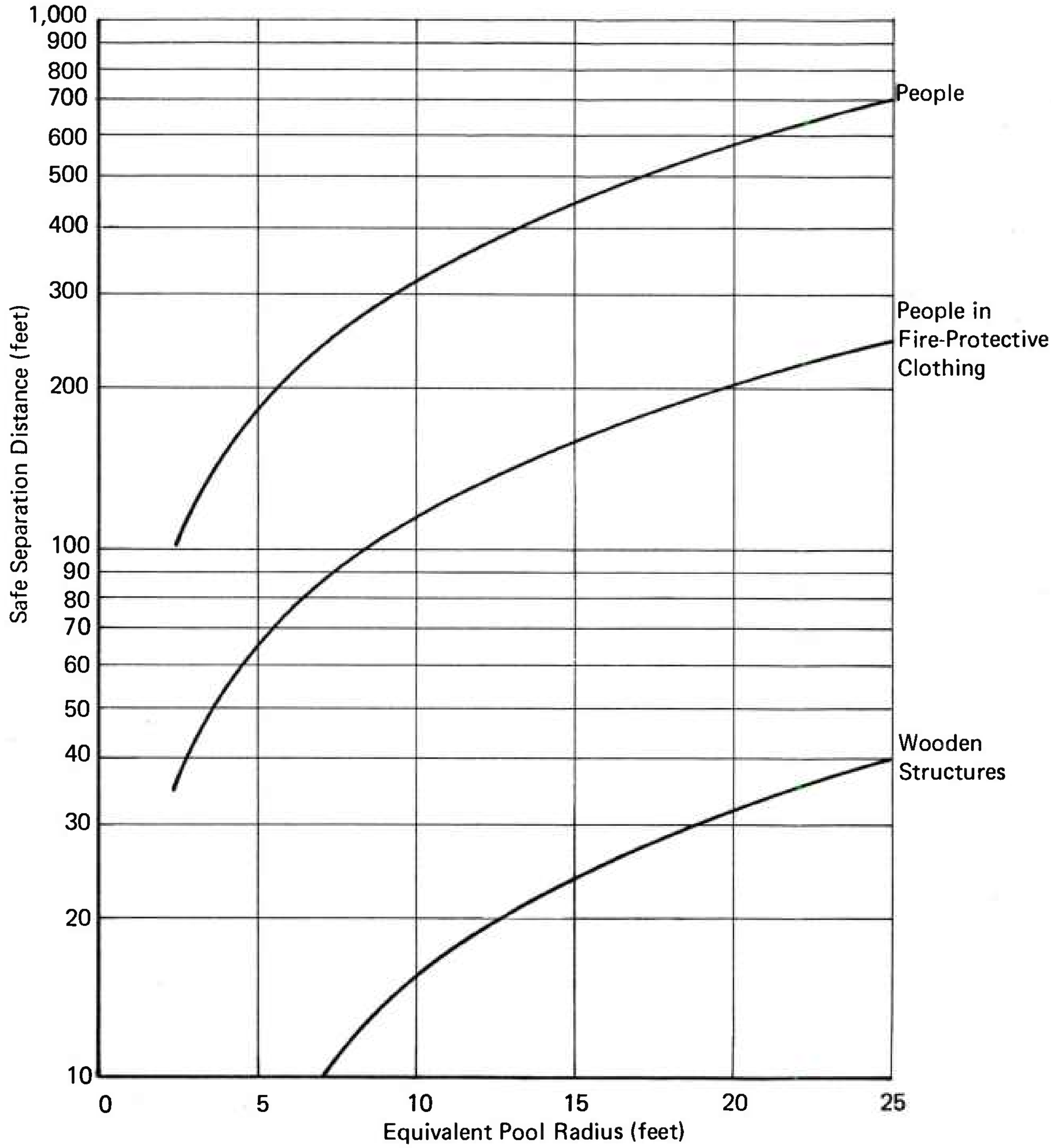


FIGURE B3 SAFE SEPARATION DISTANCE FROM VENTING GAS FLAMES

FIGURES FOR CALCULATION PROCEDURE D

Hazard calculation procedure D is primarily used to determine the maximum pool size which an amount of a lighter than water, insoluble liquid with a boiling point less than ambient will form if released onto water. It can also be used to determine how long it will take for the entire pool of the chemical to evaporate.

Two tables are presented for use with the procedure.

Table D-1 gives the maximum pool radii for various spill amounts of the chemicals listed.

Table D-2 gives the time it will take for various amounts of these chemicals to completely evaporate.

TABLE D-1

MAXIMUM RADIUS OF POOL FOR VARIOUS SPILL AMOUNTS

(Radius is given in feet)

Chemical**	Spill Amount (Tons)* 0-.1	.1-.5	.5-1	1-5	5-10	10-30	30-60	60-125	125-250	250-500	500-1000	1000-2000	2000-4000	4000-8000	Over 8000
Butadiene, inhibited	15	25	35	60	85	120	170	230	300	390	510	670	880	1150	1400
Butane	15	25	35	60	90	130	180	230	310	410	530	700	920	1200	1450
Butylene	15	25	35	60	85	120	170	230	300	390	510	670	870	1150	1400
Carbon monoxide	10	15	20	35	50	70	95	130	160	210	280	360	460	600	730
Cyclopropane	15	20	30	50	75	110	150	200	270	350	460	600	780	1000	1250
1,1-Difluoroethane***	10	20	25	40	60	90	120	160	210	280	370	490	630	820	1000
Ethane	15	20	30	50	75	110	150	200	250	330	430	560	730	960	1150
Ethyl chloride	15	20	30	50	75	110	150	200	270	360	470	620	810	1050	1300
Ethylene	15	20	30	50	70	100	140	180	240	320	410	540	700	910	1100
Ethyl nitrite	20	30	40	70	100	150	210	270	360	470	610	800	1050	1400	1700
Hydrogen, liquefied	20	25	40	65	90	130	180	230	300	390	510	660	850	1100	1350
Hydrogen sulfide***	10	15	25	40	60	85	120	150	200	260	340	450	590	770	930
Isobutane	15	25	35	55	80	120	160	220	290	370	500	640	840	1100	1350
Isobutylene	15	25	35	60	85	120	170	230	300	390	510	670	880	1150	1400
Liquefied natural gas (LNG)	15	20	30	50	70	110	140	190	250	320	420	550	710	920	1100
Liquefied petroleum gas (LPG)	15	20	30	55	75	110	150	200	270	350	460	600	780	1000	1250
Methane	15	20	30	50	70	110	140	190	250	320	420	550	710	920	1100
Methylacetylene-propadiene mixture***	15	25	35	55	80	120	160	210	280	360	470	620	810	1050	1300
Methyl chloride	10	10	15	30	40	60	80	110	140	190	240	320	420	540	660
Nitrogen, liquefied***	5	10	15	20	30	45	65	80	110	140	180	240	310	400	480
Propane	15	20	30	55	75	110	150	200	270	350	450	590	780	1000	1200
Propylene	15	20	30	55	75	110	160	200	260	340	450	590	760	1000	1200
Vinyl chloride	10	15	20	40	55	80	110	150	190	250	330	440	570	740	910
Vinyl fluoride, inhibited	10	15	25	40	60	85	120	150	200	270	350	450	590	770	940
Vinyl methyl ether, inhibited	15	25	35	55	80	120	170	220	290	390	510	670	870	1150	1400

*Tons = 2000 lb

**Computations based on assumed water temperature of 20°C (68°F).

***Certain chemical property data for substance were unavailable. Table numbers are very rough estimates.

TABLE D-2

TIME FOR COMPLETE EVAPORATION OF VARIOUS SPILL AMOUNTS
(time in minutes)

Chemical**	Spill Amounts (Tons)*													
	0-.1	.1-.5	.5-1	1-5	5-10	10-30	30-60	60-125	125-250	250-500	500-1000	1000-2000	2000-4000	4000-8000	Over 8000
Butadiene, inhibited	0.9	1.2	1.4	1.9	2.4	3.0	3.6	4.3	5.1	5.9	7.0	8.3	9.8	11.5	13.0
Butane	0.9	1.2	1.4	2.0	2.4	3.0	3.7	4.3	5.1	6.0	7.0	8.3	9.8	11.6	13.1
Butylene	0.8	1.0	1.3	1.7	2.1	2.7	3.2	3.8	4.5	5.3	6.3	7.4	8.8	10.4	11.7
Carbon monoxide	0.2	0.3	0.3	0.5	0.6	0.8	0.9	1.1	1.3	1.6	1.9	2.3	2.7	3.2	3.6
Cyclopropane	6.0	0.8	1.0	1.3	1.6	2.1	2.5	3.0	3.6	4.2	5.0	5.9	7.0	8.3	9.4
1,1-Difluoroethane***	0.8	1.0	1.2	1.6	2.0	2.6	3.1	3.7	4.4	5.2	6.1	7.2	8.6	10.1	11.5
Ethane	0.3	0.4	0.6	0.8	1.0	1.2	1.5	1.8	2.2	2.6	3.0	3.6	4.3	5.1	5.8
Ethyl chloride	3.1	3.9	4.7	6.3	7.7	9.5	11.3	13.2	15.4	17.9	20.8	24.3	28.4	33.2	37.2
Ethylene	0.3	0.4	0.5	0.7	1.0	1.2	1.4	1.7	2.1	2.4	2.9	3.4	4.1	4.9	5.5
Ethyl nitrite	6.2	7.9	9.7	13.3	16.3	20.3	24.3	28.5	33.4	39.1	45.6	53.3	62.3	72.8	81.7
Hydrogen, liquefied	0.1	0.1	0.2	0.2	0.3	0.4	0.4	0.5	0.6	0.8	0.9	1.1	1.3	1.5	1.7
Hydrogen sulfide***	0.8	1.0	1.3	1.8	2.2	2.8	3.4	4.0	4.8	5.6	6.7	7.8	9.3	11.0	12.5
Isobutane	0.7	0.9	1.1	1.4	1.8	2.2	2.7	3.2	3.8	4.5	5.3	6.3	7.4	8.8	9.9
Isobutylene	0.8	1.0	1.2	1.7	2.1	2.6	3.2	3.8	4.4	5.2	6.2	7.3	8.6	10.2	11.6
Liquefied natural gas (LNG)	0.2	0.3	0.4	0.5	0.7	0.9	1.0	1.3	1.5	1.8	2.1	2.5	3.0	3.5	4.0
Liquefied petroleum gas (LPG)	0.5	0.6	0.8	1.1	1.3	1.7	2.0	2.4	2.8	3.4	4.0	4.7	5.6	6.7	7.5
Methane	0.2	0.3	0.4	0.5	0.7	0.9	1.0	1.3	1.5	1.8	2.1	2.5	3.0	3.5	4.0
Methylacetylene-propadiene mixture***	0.7	0.9	1.1	1.5	1.8	2.3	2.8	3.3	4.0	4.7	5.5	6.5	7.7	9.1	10.3
Methyl chloride	2.3	2.9	3.6	5.1	6.3	8.0	10.0	11.5	13.7	16.2	19.2	22.7	26.9	31.9	36.2
Nitrogen, liquefied***	0.5	0.6	0.8	1.1	1.4	1.7	2.1	2.6	3.0	3.6	4.3	5.1	6.1	7.2	8.2
Propane	0.5	0.6	0.7	1.0	1.3	1.6	2.0	2.4	2.8	3.3	3.9	4.7	5.5	6.6	7.4
Propylene	0.5	0.6	0.7	1.0	1.3	1.6	2.0	2.3	2.8	3.3	3.9	4.6	5.5	6.5	7.4
Vinyl chloride	1.3	1.8	2.2	3.0	3.7	4.7	5.7	6.7	8.0	9.4	11.1	13.2	15.6	18.5	20.9
Vinyl fluoride, inhibited	0.5	0.6	0.7	1.2	1.3	1.6	2.0	2.3	2.8	3.3	3.9	4.6	5.5	6.5	7.4
Vinyl methyl ether, inhibited	1.6	2.0	2.4	3.3	4.0	5.0	6.0	7.0	8.2	9.6	11.3	13.2	15.6	18.3	20.6

*Tons = 2000 lb

**Computations based on assumed water temperature of 20°C (68°F).

***Certain chemical property data for substance were unavailable. Table numbers are very rough estimates.

FIGURES FOR CALCULATION PROCEDURE E

Hazard calculation procedure E may be used to assess the flammability hazard of a burning pool of flammable liquid or one which has the potential of being ignited.

Twenty-five figures are presented for use with this procedure.

Figures E1 and E2 give the height of the resulting flame as a function of the parameter ρR (specific gravity of liquid x burning rate) and the pool radius.

Figures E3 to E7 give the angle of the flame as a function of the wind speed and the parameter M/T_b (molecular weight/boiling point in °K) for various pool radii ranges.

Figures E8 through E13 give the safe separation distance for people as a function of the flame angle and pool radius for various ranges of the parameter ρR.

Figures E14 through E19 give the safe separation distance for people in minimum fire-protective clothing as a function of flame angle and pool radius for various ranges of the parameter ρR.

Figures E20 through E25 give the safe separation distance for wooden structures in a similar manner.

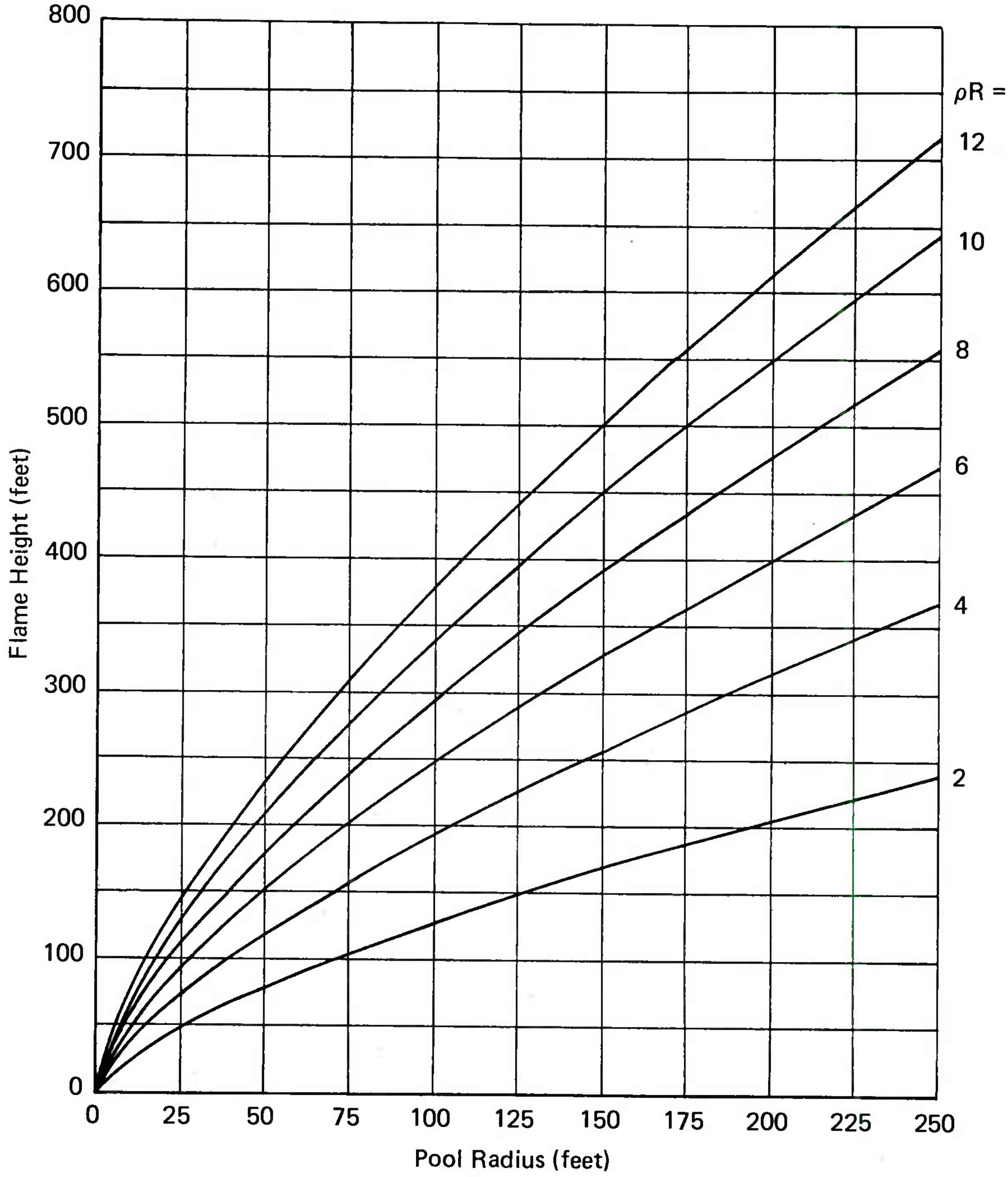


FIGURE E1 FLAME HEIGHT FOR SMALL POOLS

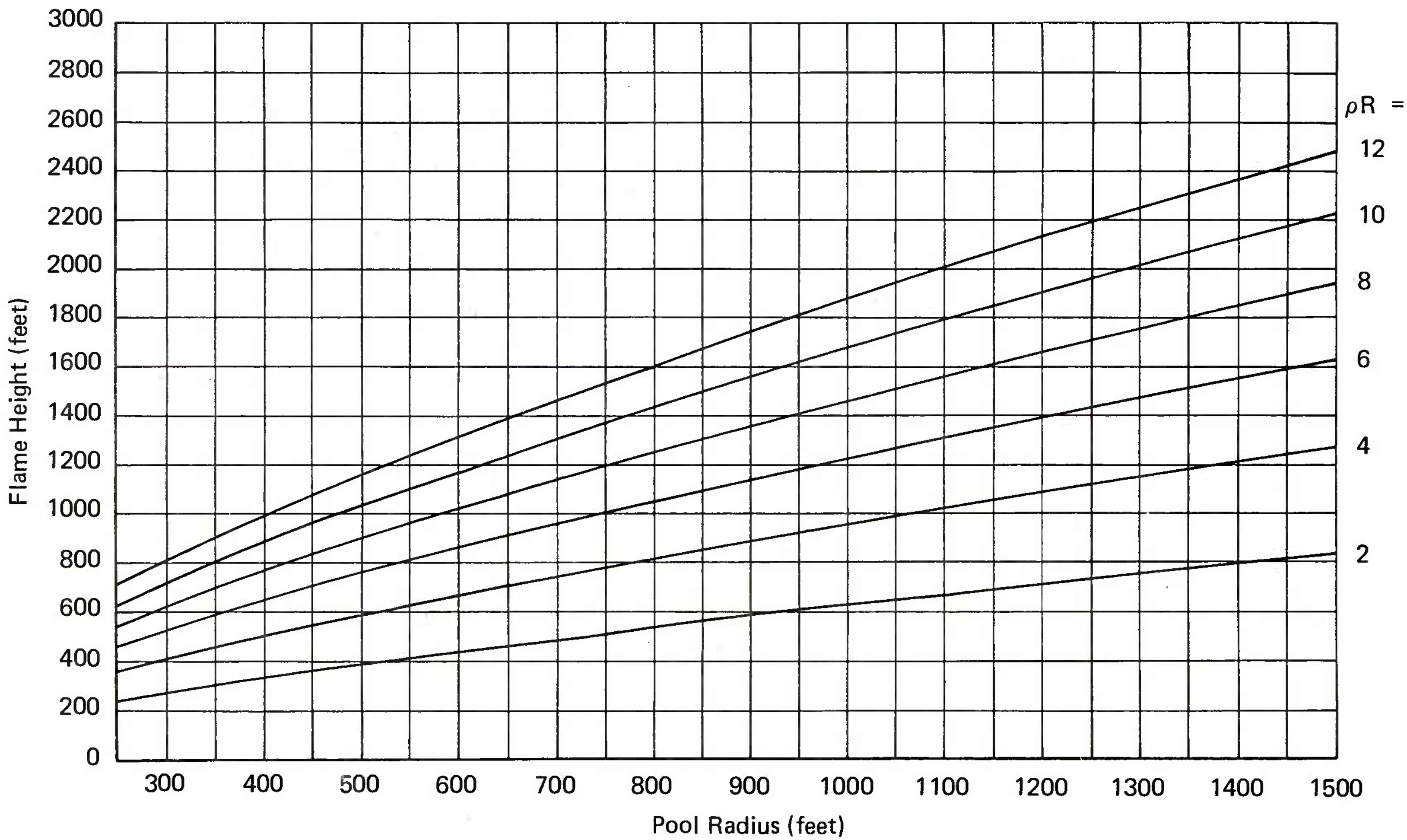


FIGURE E2 FLAME HEIGHT FOR LARGE POOLS

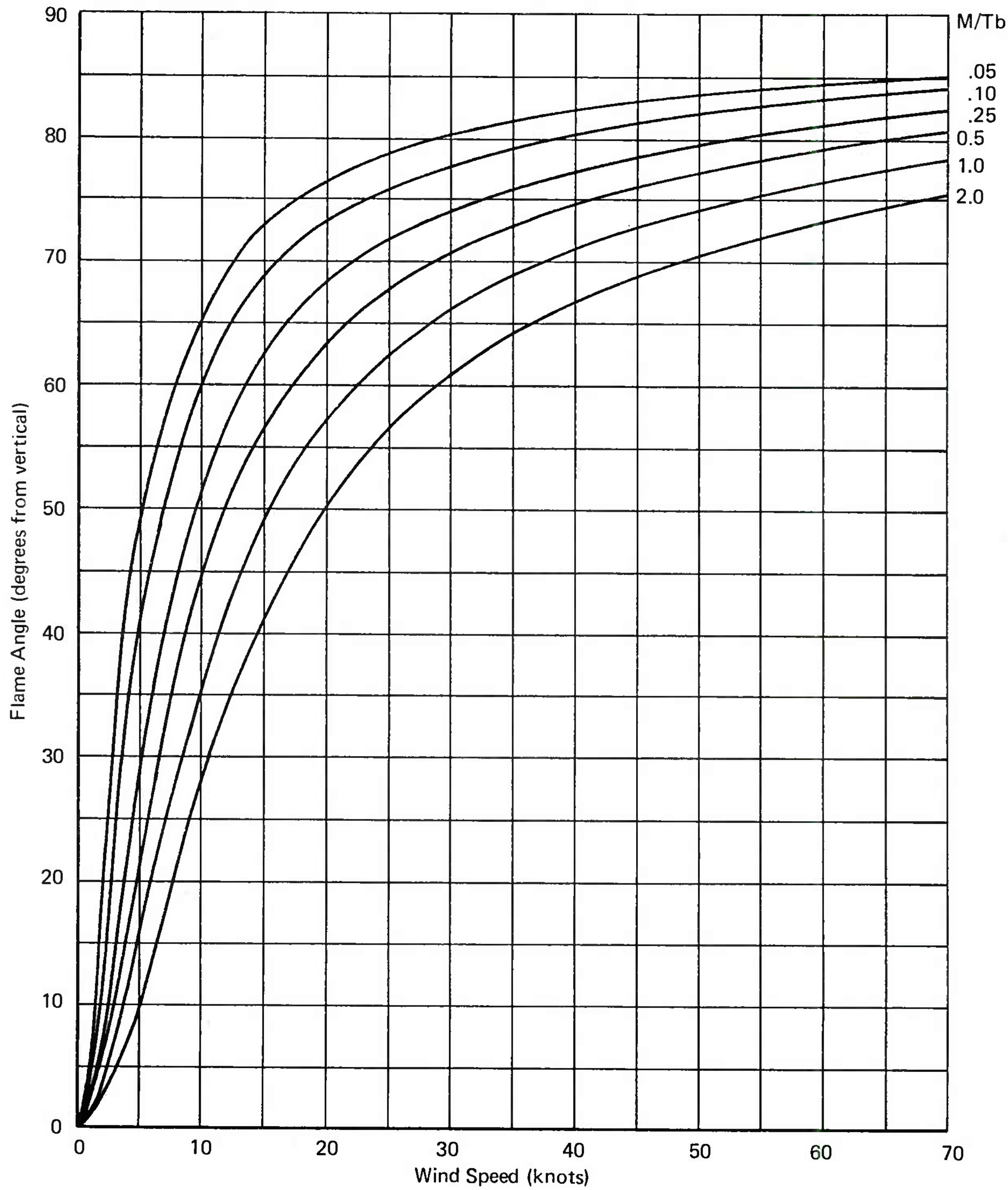


FIGURE E3 FLAME ANGLE AS A FUNCTION OF WIND SPEED AND M/T_b
(Pool Radius = 0–30 feet)

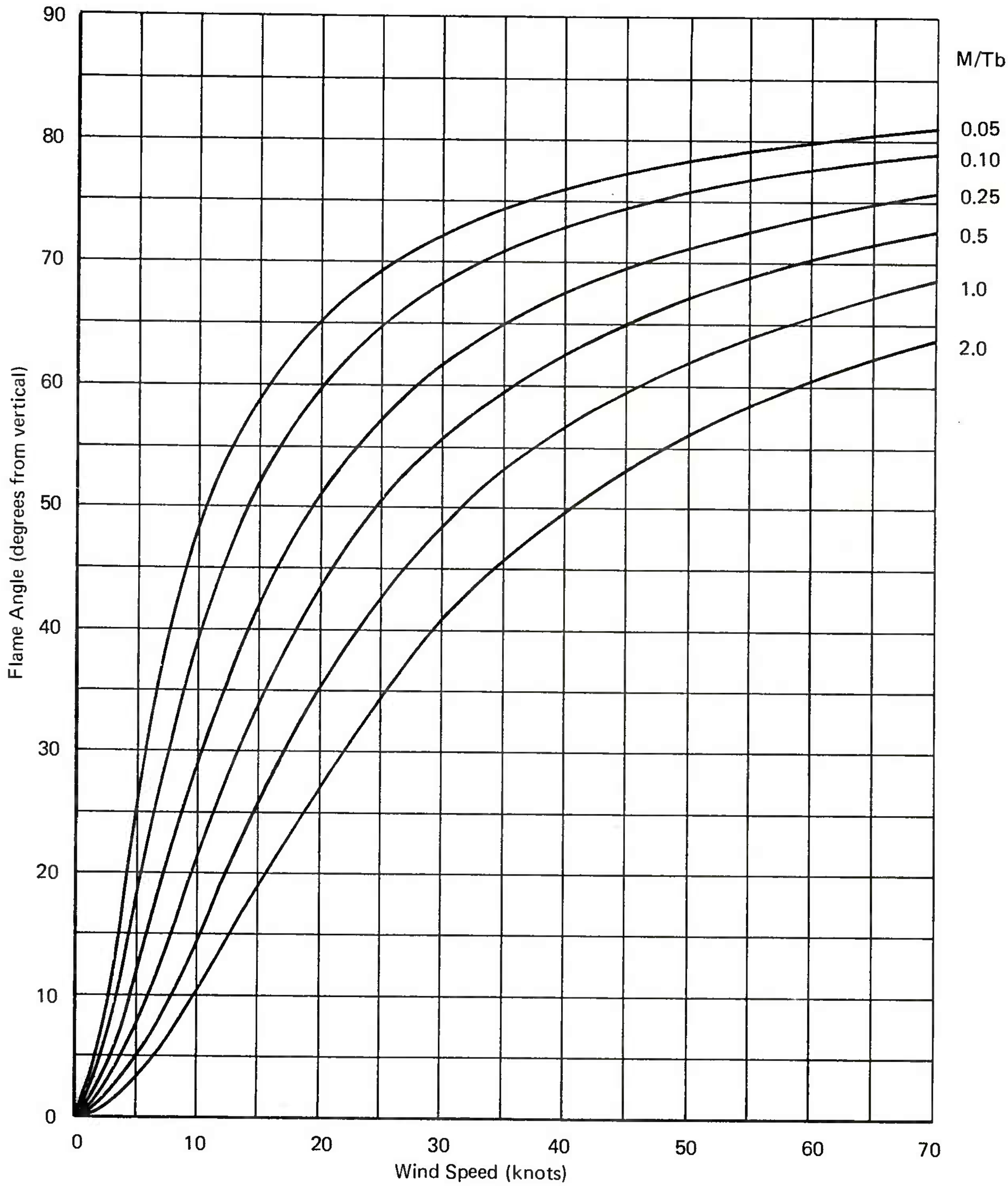


FIGURE E4 FLAME ANGLE AS A FUNCTION OF WIND SPEED AND M/T_b
(Pool Radius = 30–150 feet)

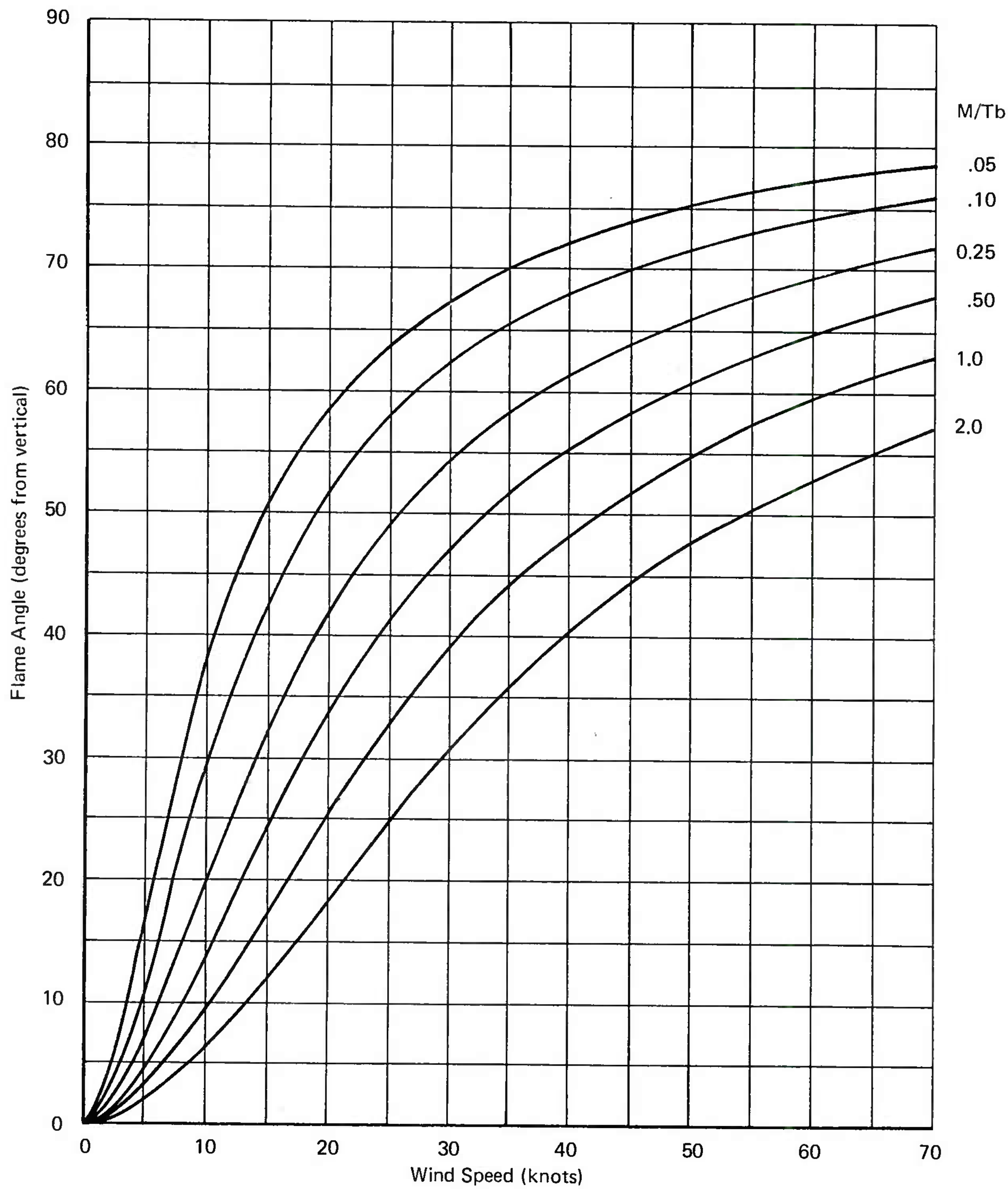


FIGURE E5 FLAME ANGLE AS A FUNCTION OF WIND SPEED AND M/T_b
(Pool Radius = 150–300 feet)

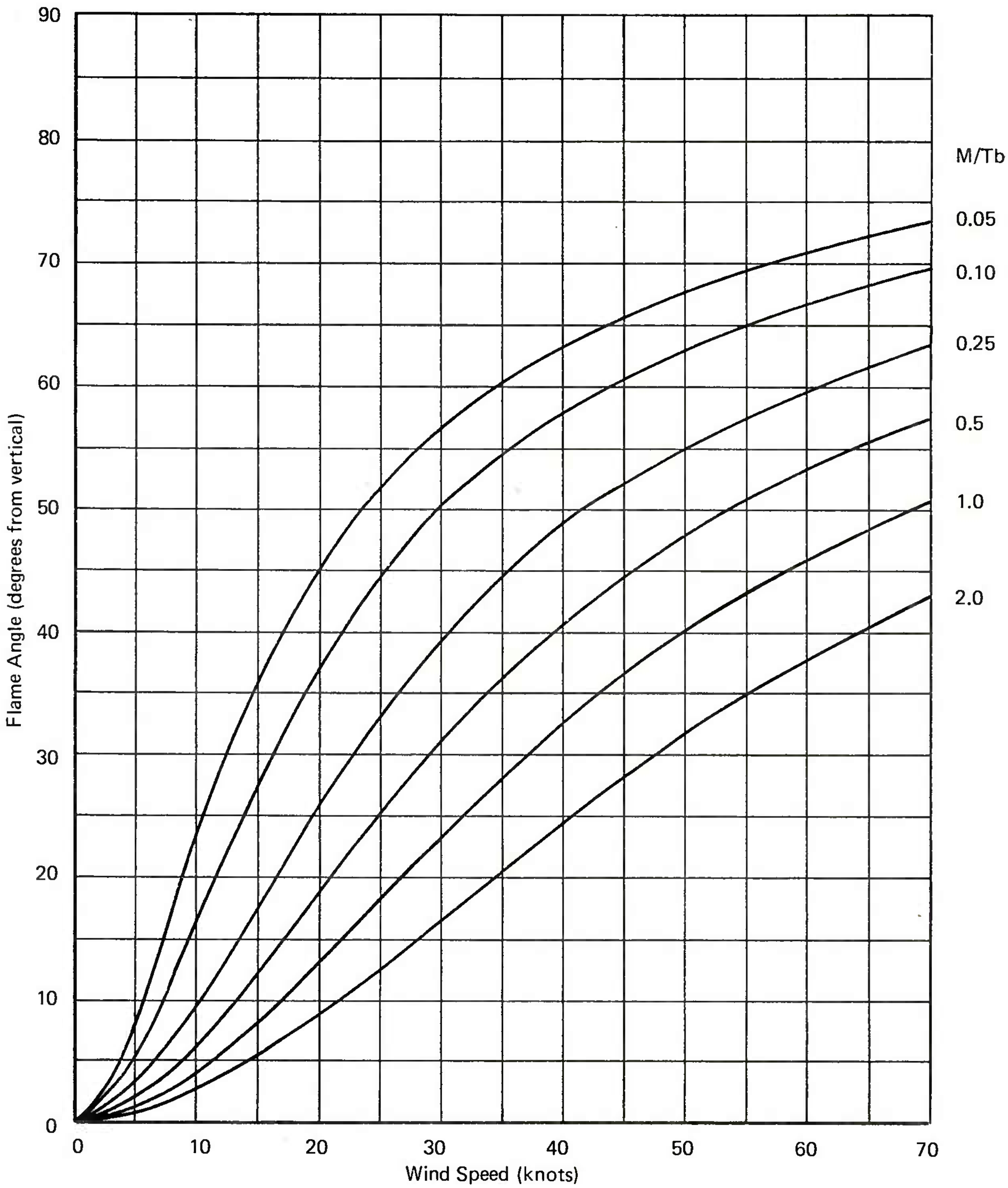


FIGURE E6 FLAME ANGLE AS A FUNCTION OF WIND SPEED AND M/T_b
(Pool Radius = 300–900 feet)

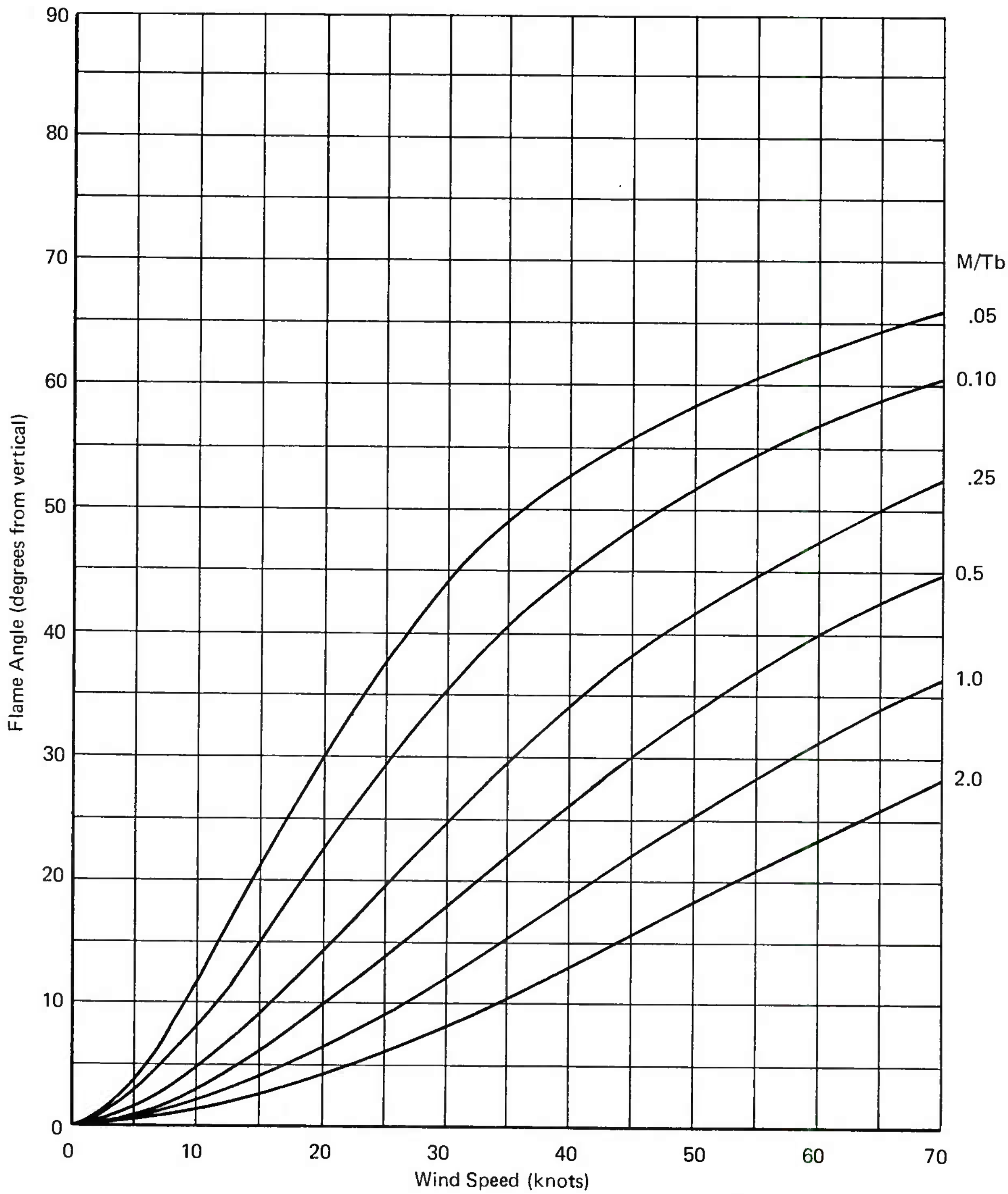


FIGURE E7 FLAME ANGLE AS A FUNCTION OF WIND SPEED AND M/T_b
(Pool Radius greater than 900 feet)

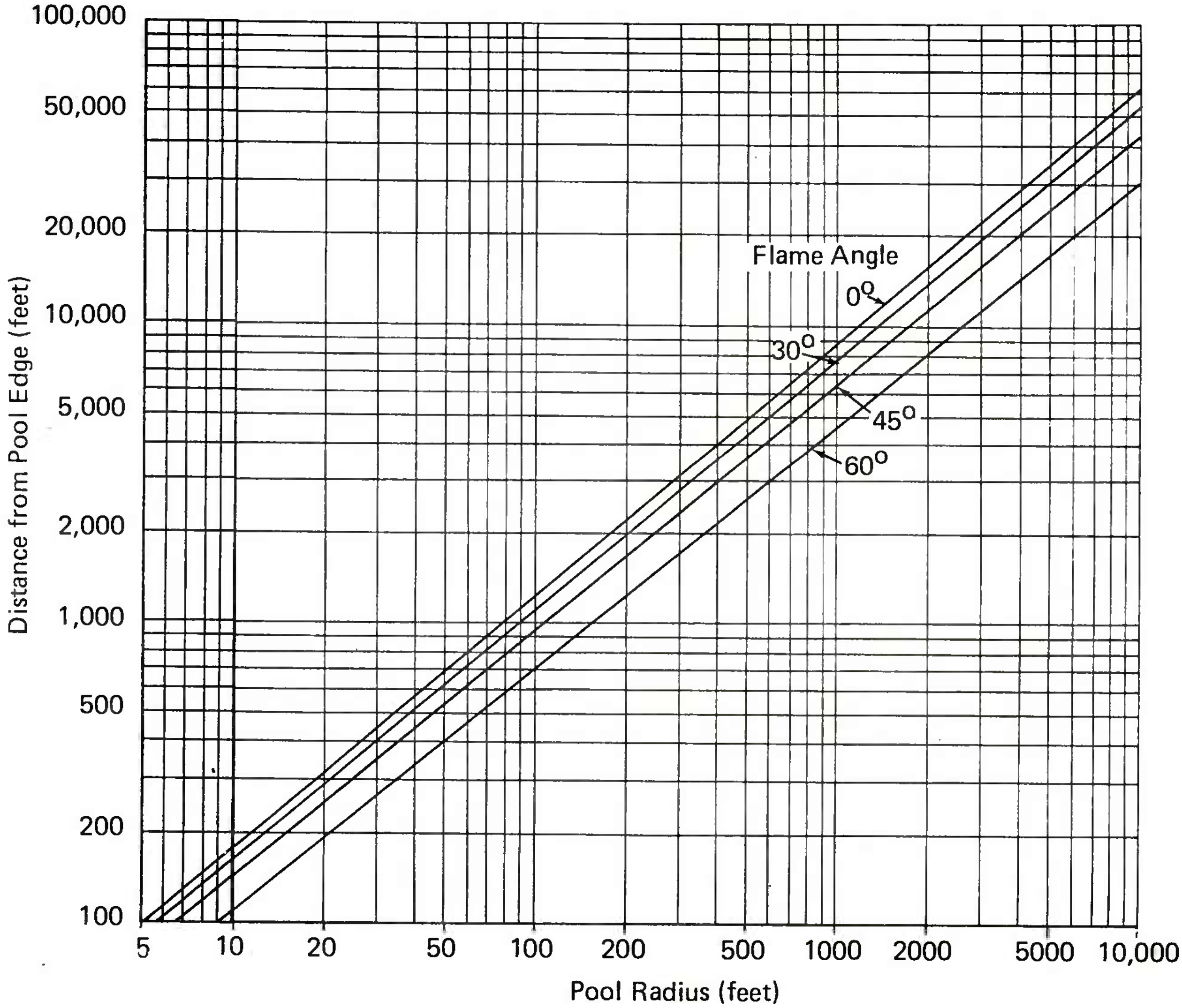


FIGURE E8 SAFE SEPARATION DISTANCE FOR PEOPLE
(Fire Radiant Intensity = 450 Btu/hr-ft^2 ; ρR less than 3)

Note: In the event that the chemical on fire is a heavy hydrocarbon (such as fuel oil or other petroleum products), the fire will be extremely sooty. *Substantially less heat is radiated from extremely sooty fires and safe separation distances are less than calculated from the figure above.* The calculated safe separation distances represents a conservative estimate of hazard from a safety point of view.

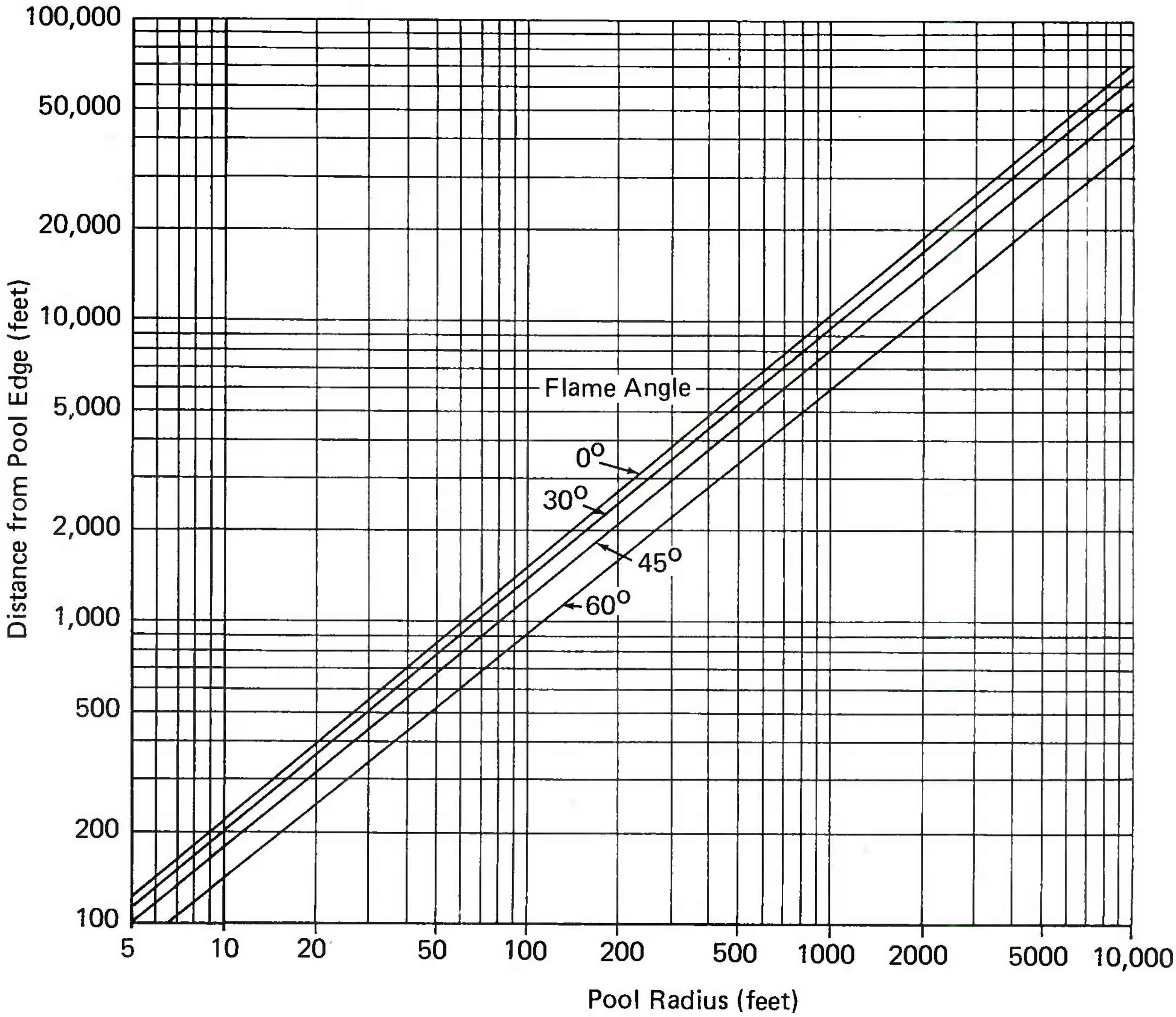


FIGURE E9 SAFE SEPARATION DISTANCE FOR PEOPLE (Fire Radiant Intensity = 450 Btu/hr-ft^2 ; ρR = 3 - 5)

Note: In the event that the chemical on fire is a heavy hydrocarbon (such as fuel oil or other petroleum products), the fire will be extremely sooty. *Substantially less heat is radiated from extremely sooty fires and safe separation distances are less than calculated from the figure above.* The calculated safe separation distances represents a conservative estimate of hazard from a safety point of view.

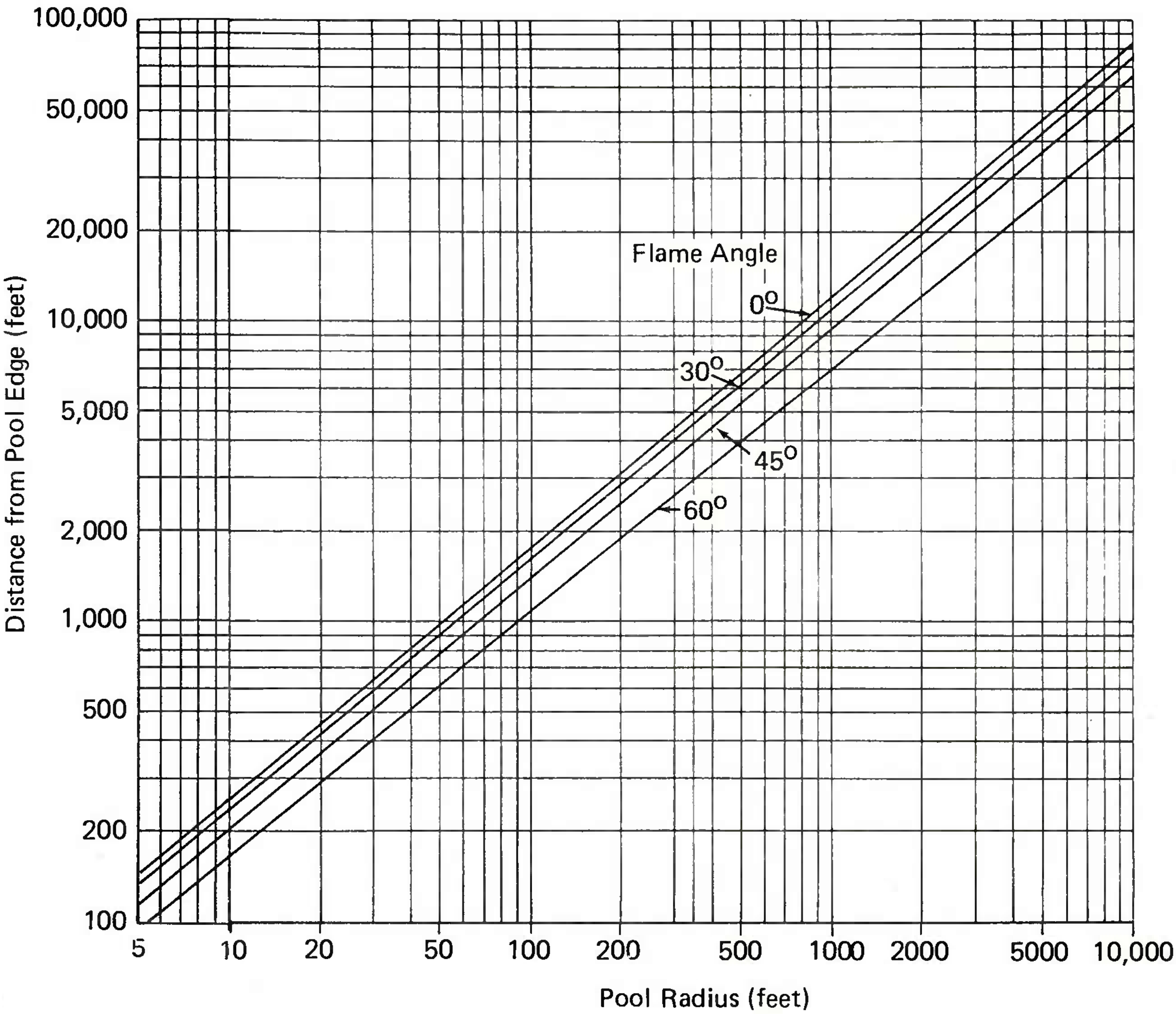


FIGURE E10 SAFE SEPARATION DISTANCE FOR PEOPLE
(Fire Radiant Intensity = 450 Btu/hr-ft^2 ; ρR = 5 - 7)

Note: In the event that the chemical on fire is a heavy hydrocarbon (such as fuel oil or other petroleum products), the fire will be extremely sooty. *Substantially less heat is radiated from extremely sooty fires and safe separation distances are less than calculated from the figure above.* The calculated safe separation distances represents a conservative estimate of hazard from a safety point of view.

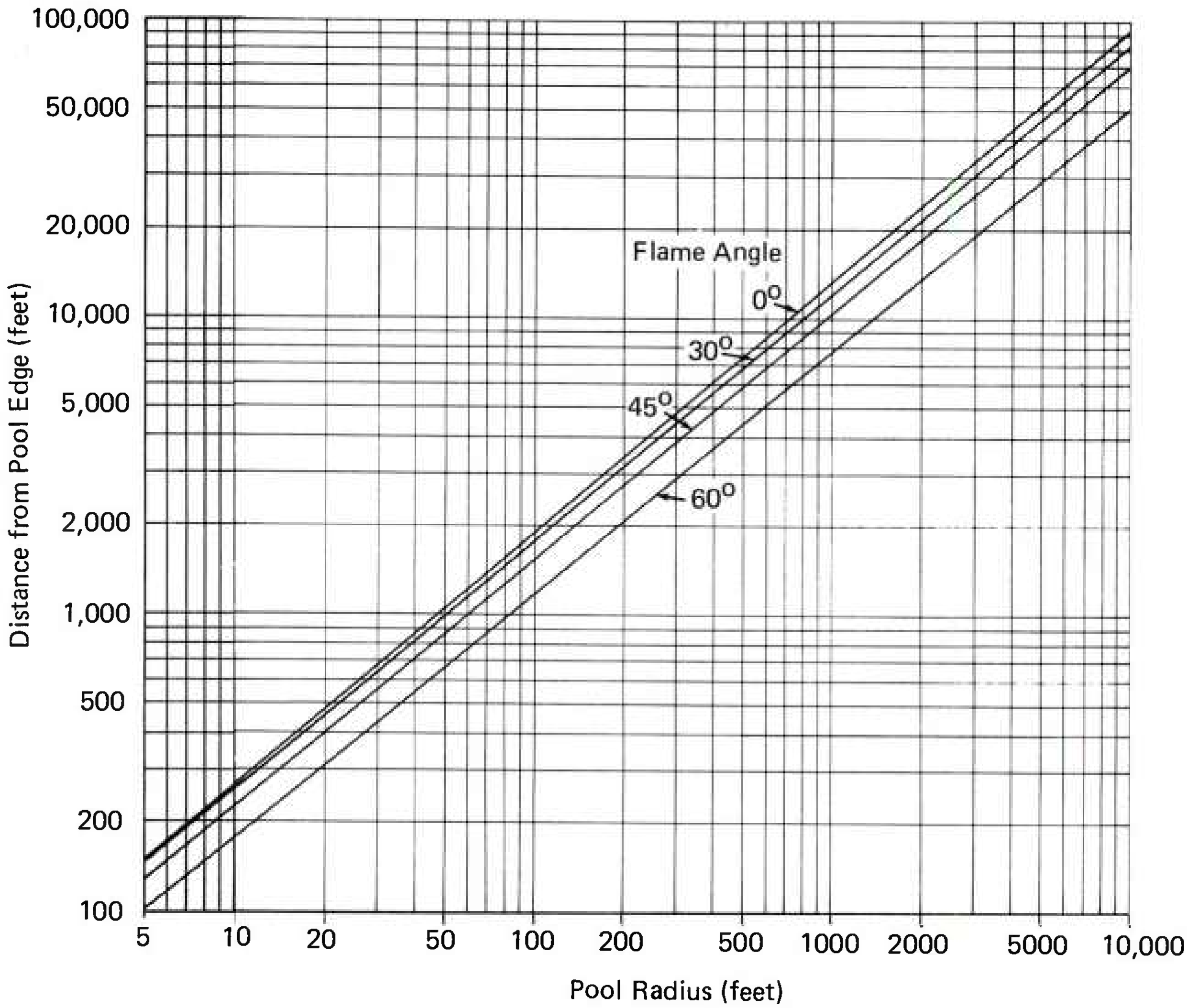


FIGURE E11 SAFE SEPARATION DISTANCE FOR PEOPLE
(Fire Radiant Intensity = 450 Btu/hr-ft^2 ; ρR = 7 - 9)

Note: In the event that the chemical on fire is a heavy hydrocarbon (such as fuel oil or other petroleum products), the fire will be extremely sooty. *Substantially less heat is radiated from extremely sooty fires and safe separation distances are less than calculated from the figure above.* The calculated safe separation distances represents a conservative estimate of hazard from a safety point of view.

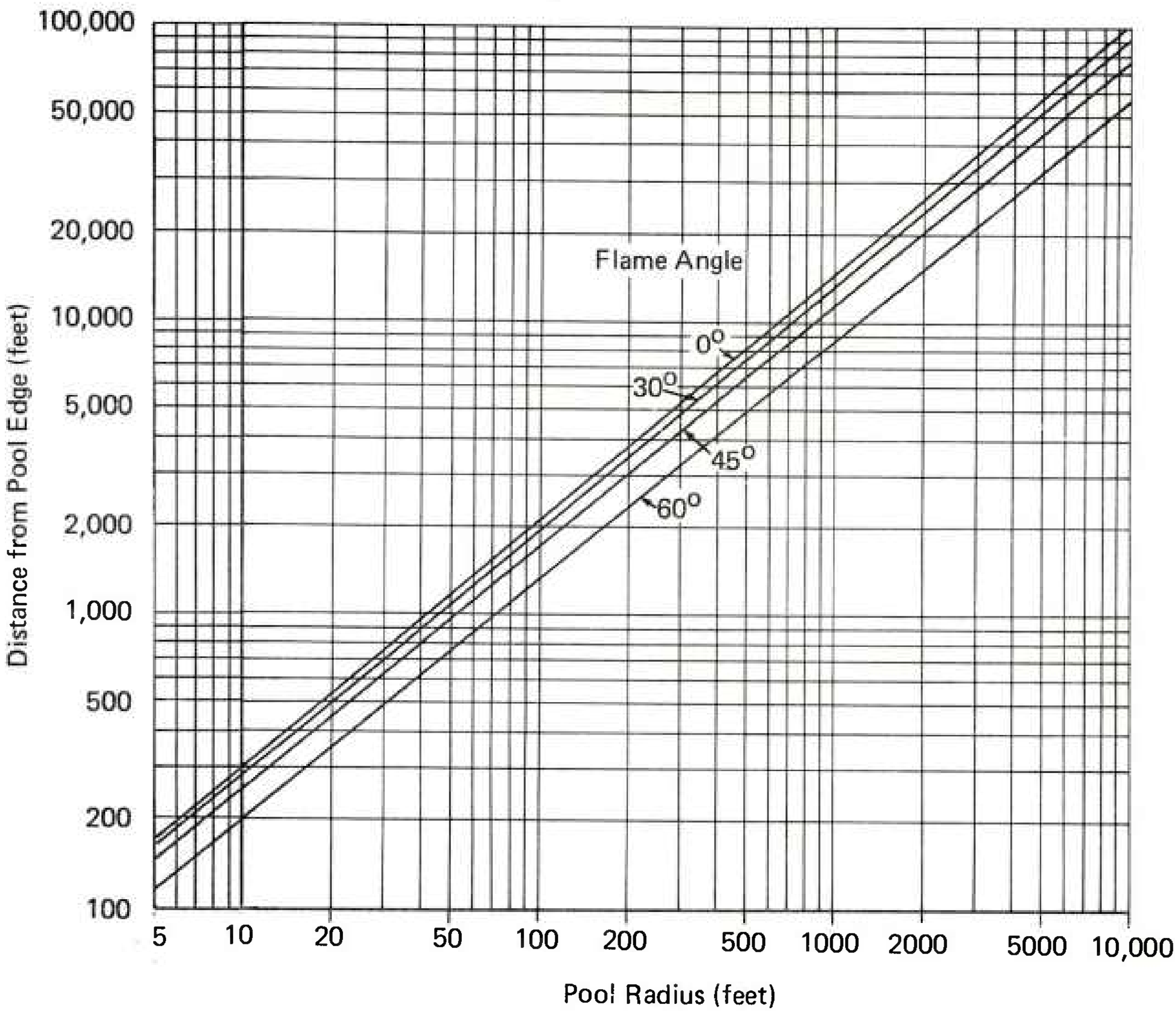


FIGURE E12 SAFE SEPARATION DISTANCE FOR PEOPLE (Fire Radiant Intensity = 450 Btu/hr-ft^2; ρR = 9 - 11)

Note: In the event that the chemical on fire is a heavy hydrocarbon (such as fuel oil or other petroleum products), the fire will be extremely sooty. *Substantially less heat is radiated from extremely sooty fires and safe separation distances are less than calculated from the figure above.* The calculated safe separation distances represents a conservative estimate of hazard from a safety point of view.

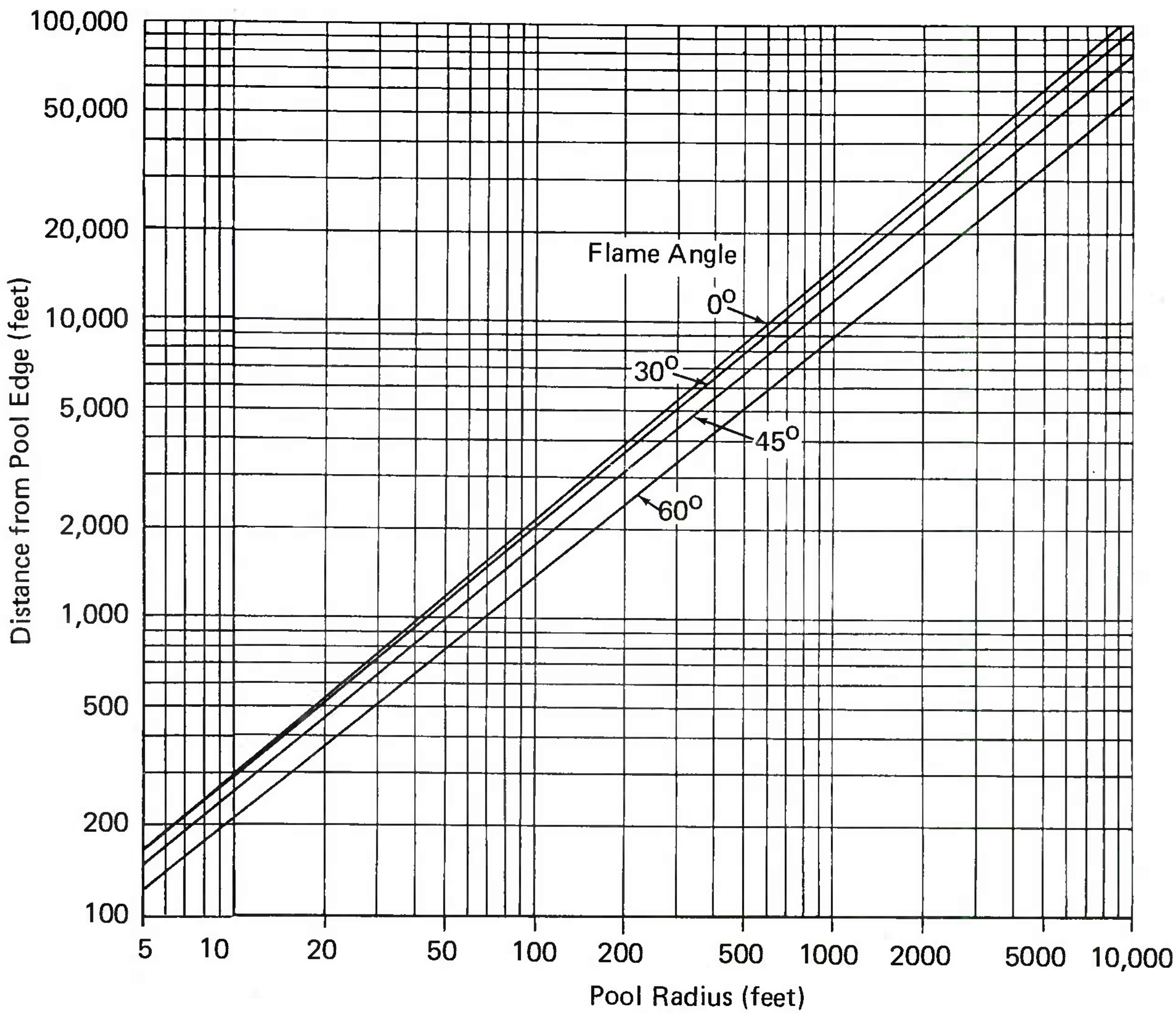


FIGURE E13 SAFE SEPARATION DISTANCE FOR PEOPLE (Fire Radiant Intensity = 450 Btu/hr-ft^2 ; ρR greater than 11)

Note: In the event that the chemical on fire is a heavy hydrocarbon (such as fuel oil or other petroleum products), the fire will be extremely sooty. *Substantially less heat is radiated from extremely sooty fires and safe separation distances are less than calculated from the figure above.* The calculated safe separation distances represents a conservative estimate of hazard from a safety point of view.

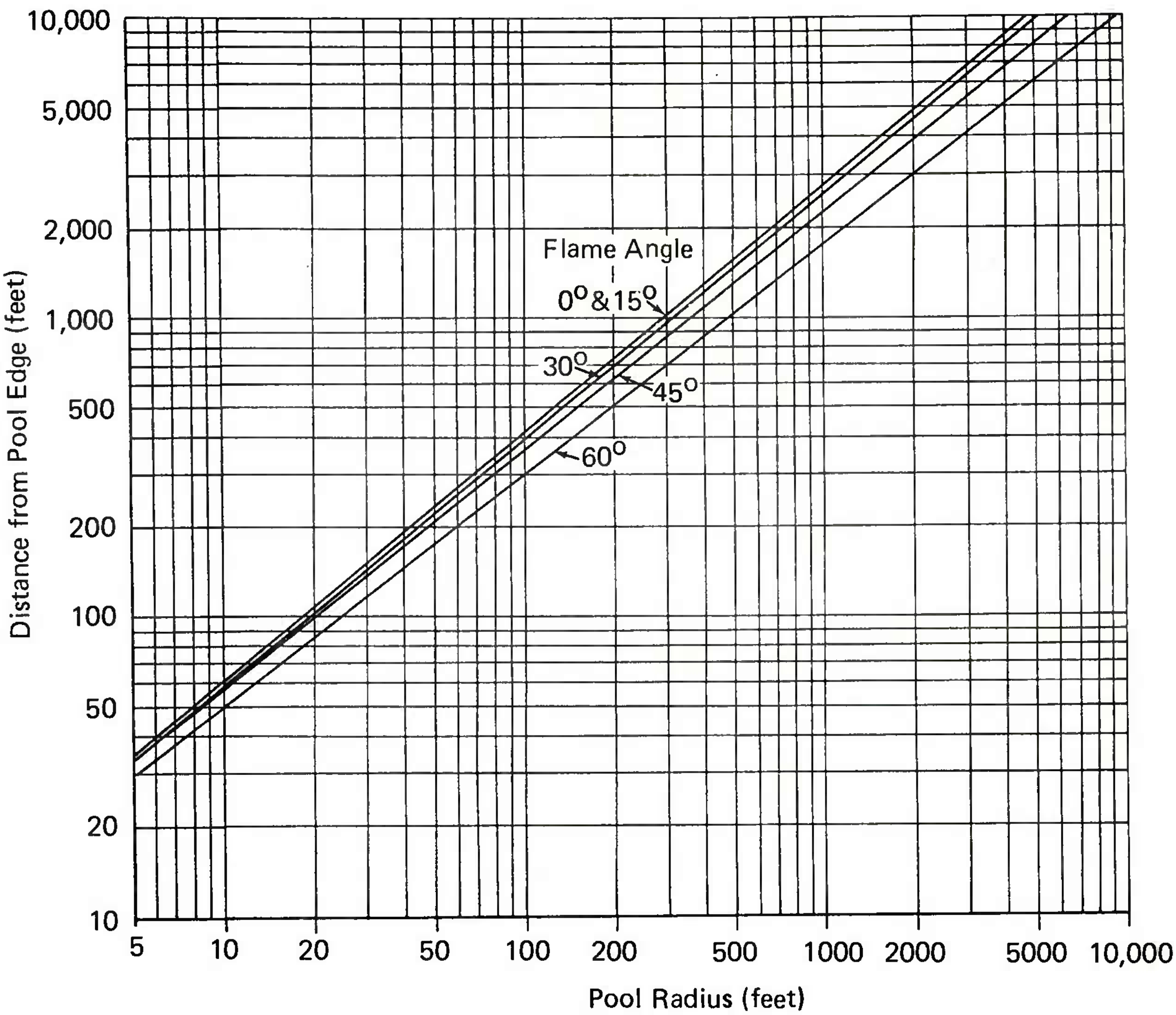


FIGURE E14 SAFE SEPARATION DISTANCE FOR PEOPLE IN FIRE-PROTECTIVE CLOTHING (Fire Radiant Intensity = 1500 Btu/hr-ft^2 ; ρR less than 3)

Note: In the event that the chemical on fire is a heavy hydrocarbon (such as fuel oil or other petroleum products), the fire will be extremely sooty. *Substantially less heat is radiated from extremely sooty fires and safe separation distances are less than calculated from the figure above.* The calculated safe separation distances represents a conservative estimate of hazard from a safety point of view.

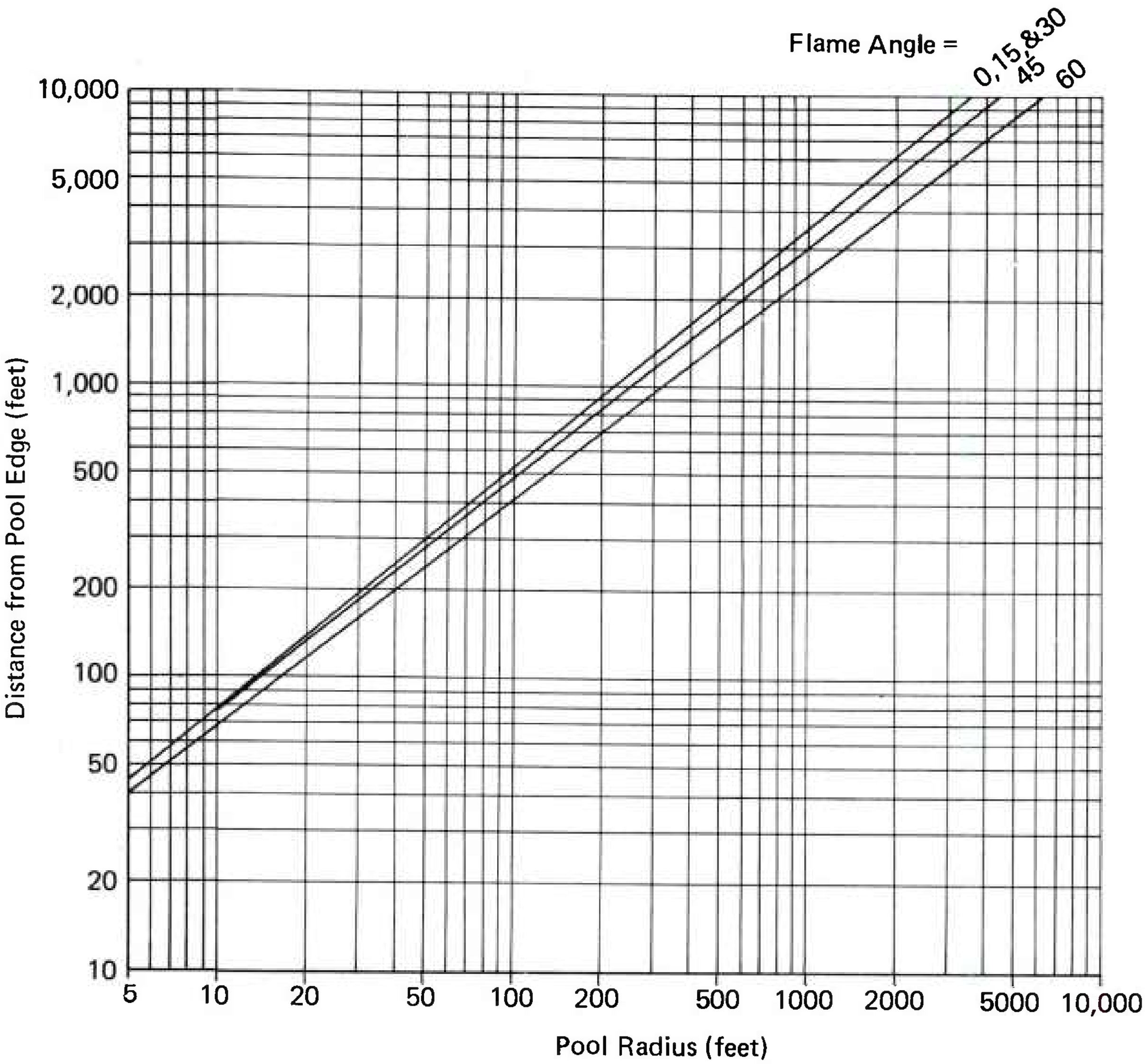


FIGURE E15 SAFE SEPARATION DISTANCE FOR PEOPLE IN FIRE-PROTECTIVE CLOTHING
(Fire Radiant Intensity = 1500 Btu/hr-ft^2 ; ρR = 3–5)

Note: In the event that the chemical on fire is a heavy hydrocarbon (such as fuel oil or other petroleum products), the fire will be extremely sooty. *Substantially less heat is radiated from extremely sooty fires and safe separation distances are less than calculated from the figure above.* The calculated safe separation distances represents a conservative estimate of hazard from a safety point of view.

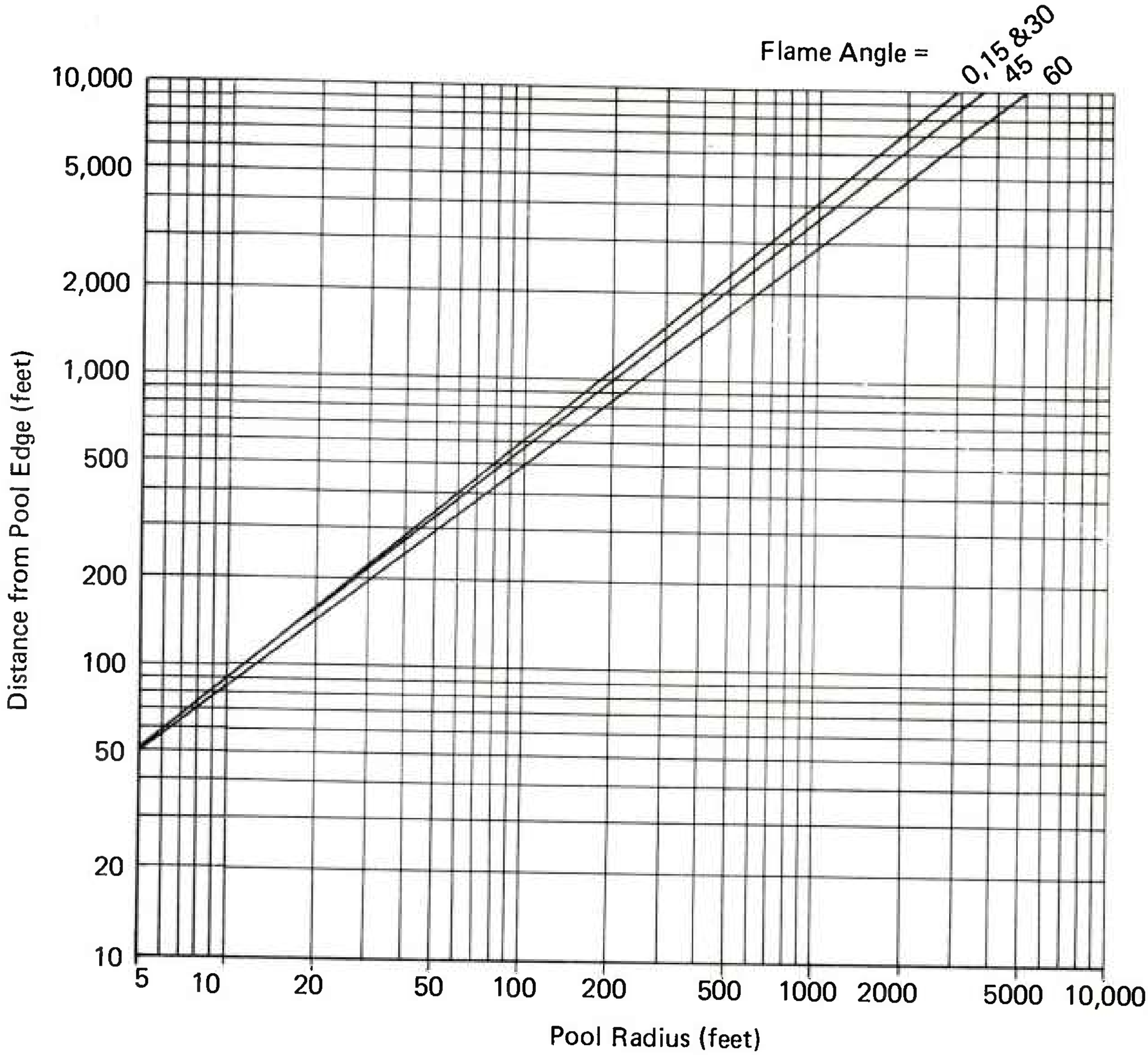


FIGURE E16 SAFE SEPARATION DISTANCE FOR PEOPLE IN FIRE-PROTECTIVE CLOTHING
(Fire Radiant Intensity = 1500 Btu/hr-ft^2 ; ρR = 5 –7)

Note: In the event that the chemical on fire is a heavy hydrocarbon (such as fuel oil or other petroleum products), the fire will be extremely sooty. *Substantially less heat is radiated from extremely sooty fires and safe separation distances are less than calculated from the figure above.* The calculated safe separation distances represents a conservative estimate of hazard from a safety point of view.

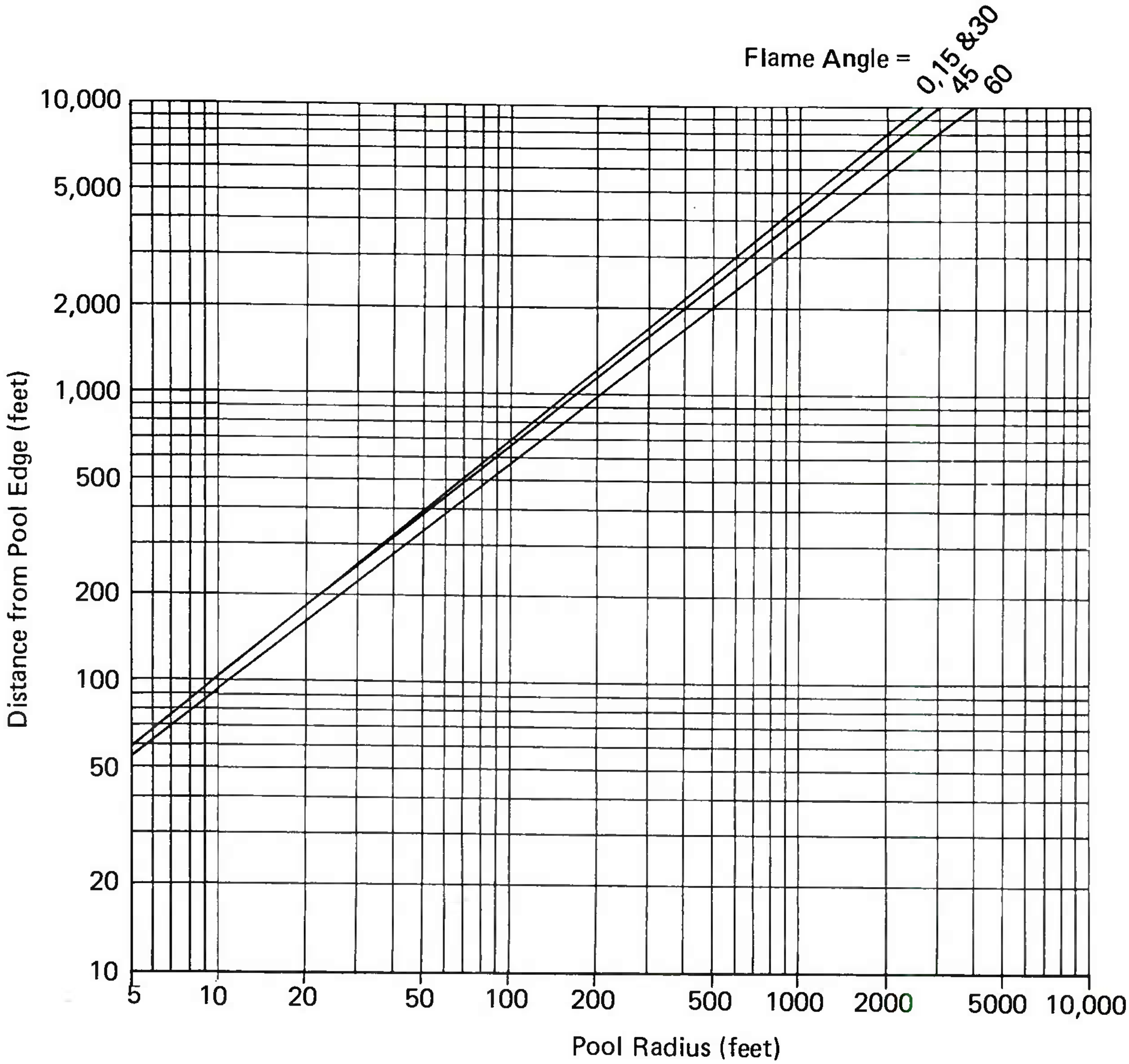


FIGURE E17 SAFE SEPARATION DISTANCE FOR PEOPLE IN FIRE-PROTECTIVE CLOTHING (Fire Radiant Intensity = 1500 Btu/hr-ft^2 ; ρR = 7–9)

Note: In the event that the chemical on fire is a heavy hydrocarbon (such as fuel oil or other petroleum products), the fire will be extremely sooty. *Substantially less heat is radiated from extremely sooty fires and safe separation distances are less than calculated from the figure above.* The calculated safe separation distances represents a conservative estimate of hazard from a safety point of view.

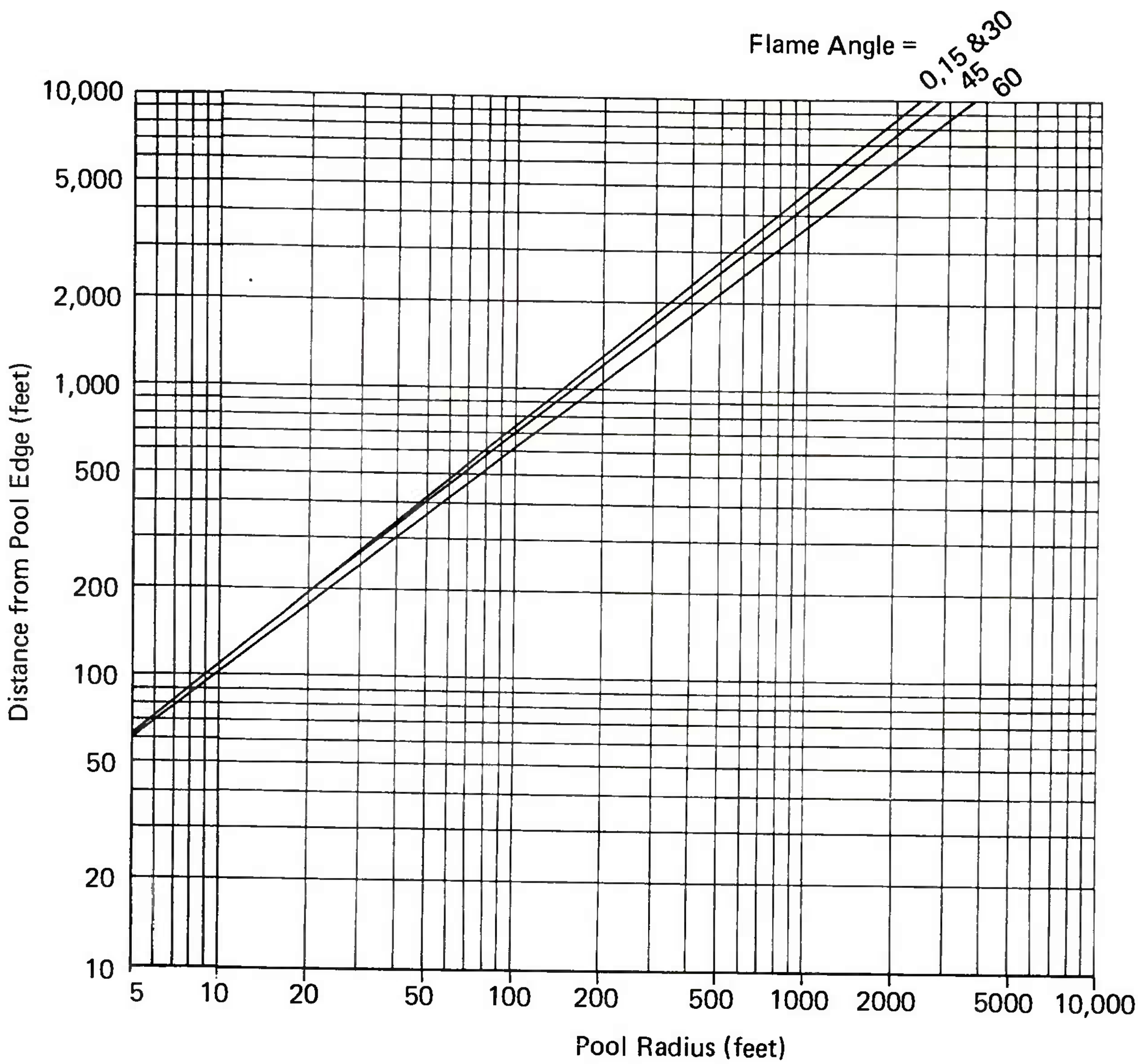


FIGURE E18 SAFE SEPARATION DISTANCE FOR PEOPLE IN FIRE-PROTECTIVE CLOTHING (Fire Radiant Intensity = 1500 Btu/hr-ft^2 ; ρR = 9 – 11)

Note: In the event that the chemical on fire is a heavy hydrocarbon (such as fuel oil or other petroleum products), the fire will be extremely sooty. *Substantially less heat is radiated from extremely sooty fires and safe separation distances are less than calculated from the figure above.* The calculated safe separation distances represents a conservative estimate of hazard from a safety point of view.

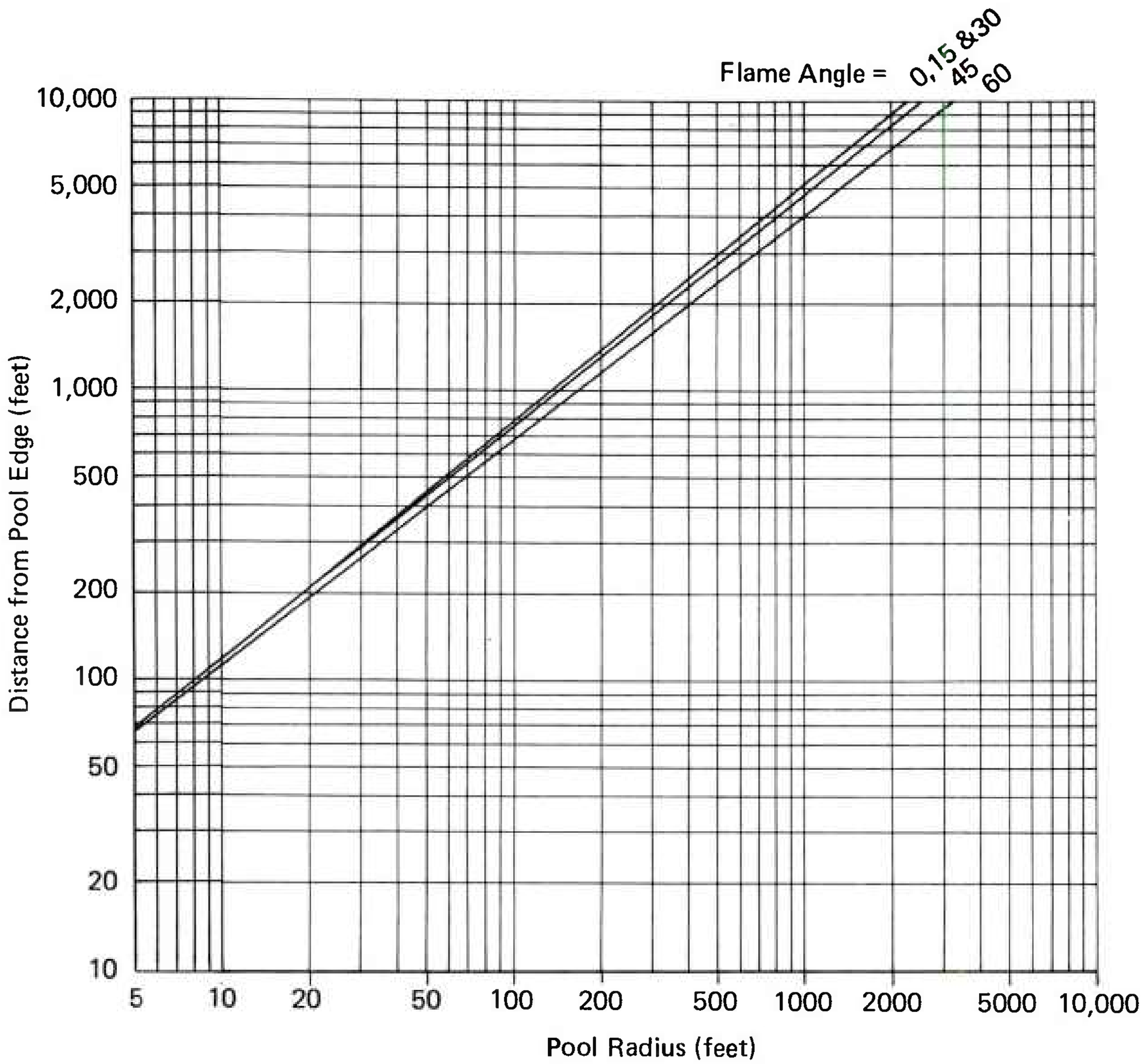


FIGURE E19 SAFE SEPARATION DISTANCE FOR PEOPLE IN FIRE-PROTECTIVE CLOTHING
(Fire Radiant Intensity = 1500 Btu/hr-ft^2 ; ρR = greater than 11)

Note: In the event that the chemical on fire is a heavy hydrocarbon (such as fuel oil or other petroleum products), the fire will be extremely sooty. *Substantially less heat is radiated from extremely sooty fires and safe separation distances are less than calculated from the figure above.* The calculated safe separation distances represents a conservative estimate of hazard from a safety point of view.

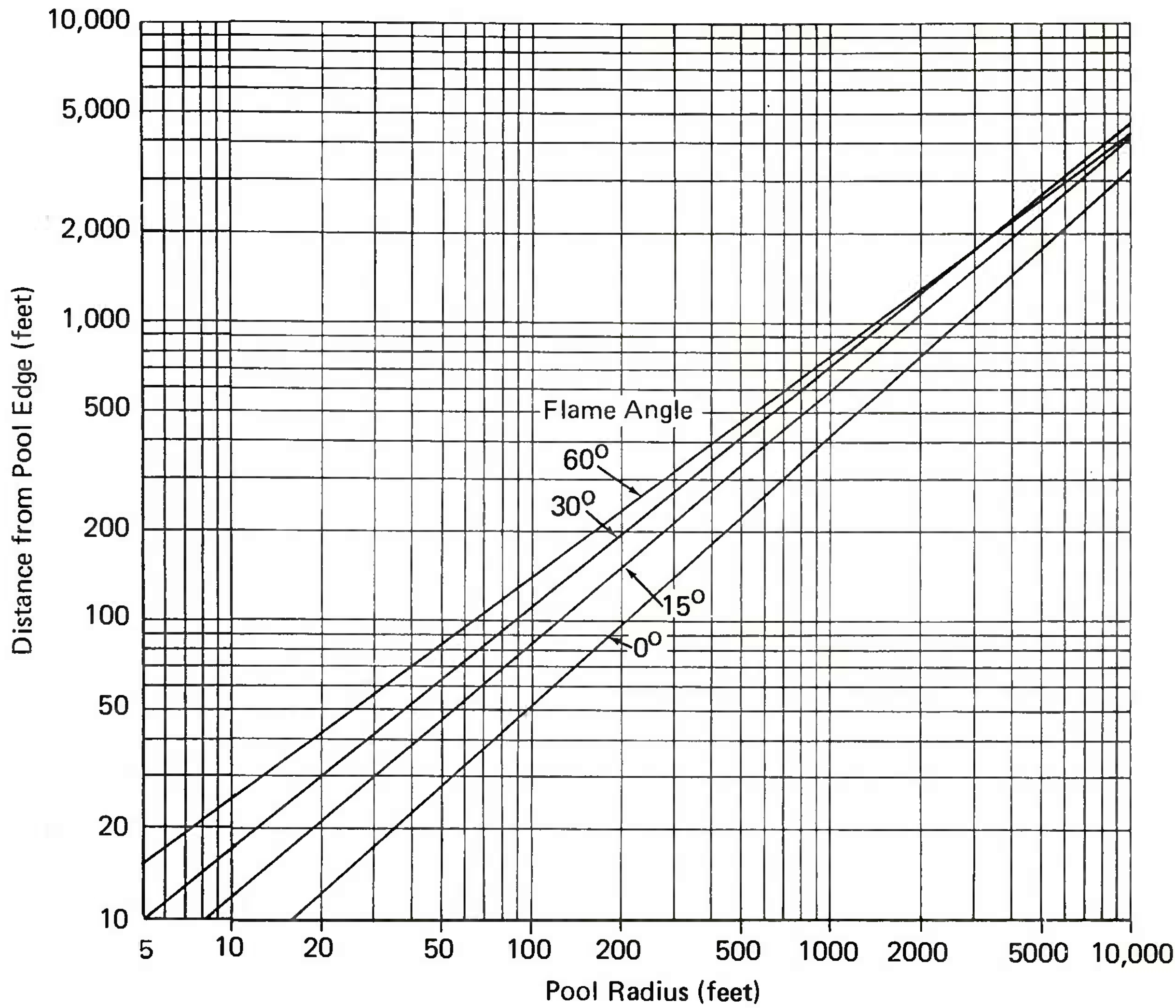


FIGURE E20 SAFE SEPARATION DISTANCE FOR WOODEN STRUCTURES (Fire Radiant Intensity = 10,000 Btu/hr-ft^2 ; ρR less than 3)

Note: In the event that the chemical on fire is a heavy hydrocarbon (such as fuel oil or other petroleum products), the fire will be extremely sooty. *Substantially less heat is radiated from extremely sooty fires and safe separation distances are less than calculated from the figure above.* The calculated safe separation distances represents a conservative estimate of hazard from a safety point of view.

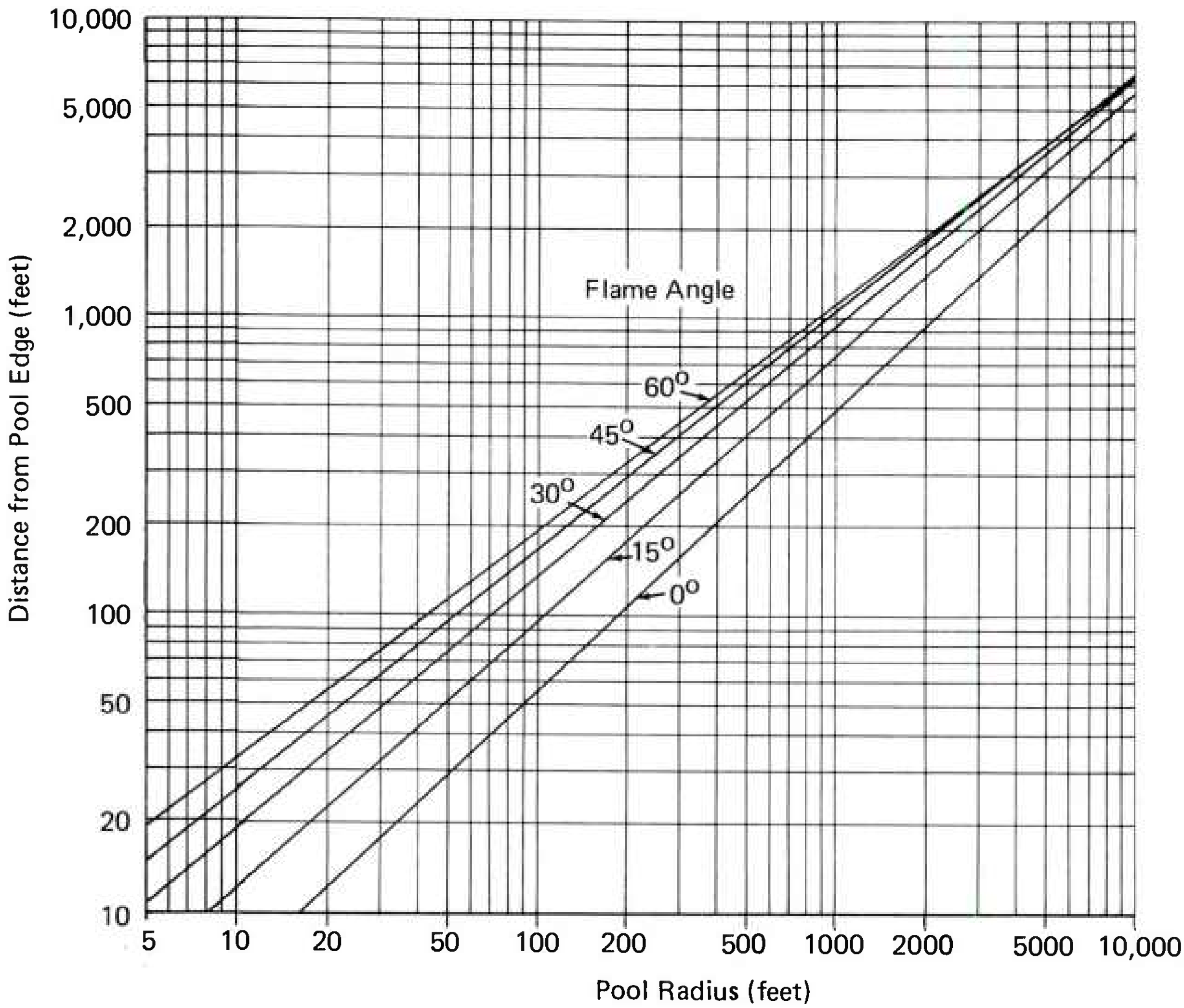


FIGURE E21 SAFE SEPARATION DISTANCE FOR WOODEN STRUCTURES
(Fire Radiant Intensity = 10,000 Btu/hr-ft^2 ; ρR = 3–5)

Note: In the event that the chemical on fire is a heavy hydrocarbon (such as fuel oil or other petroleum products), the fire will be extremely sooty. *Substantially less heat is radiated from extremely sooty fires and safe separation distances are less than calculated from the figure above.* The calculated safe separation distances represents a conservative estimate of hazard from a safety point of view.

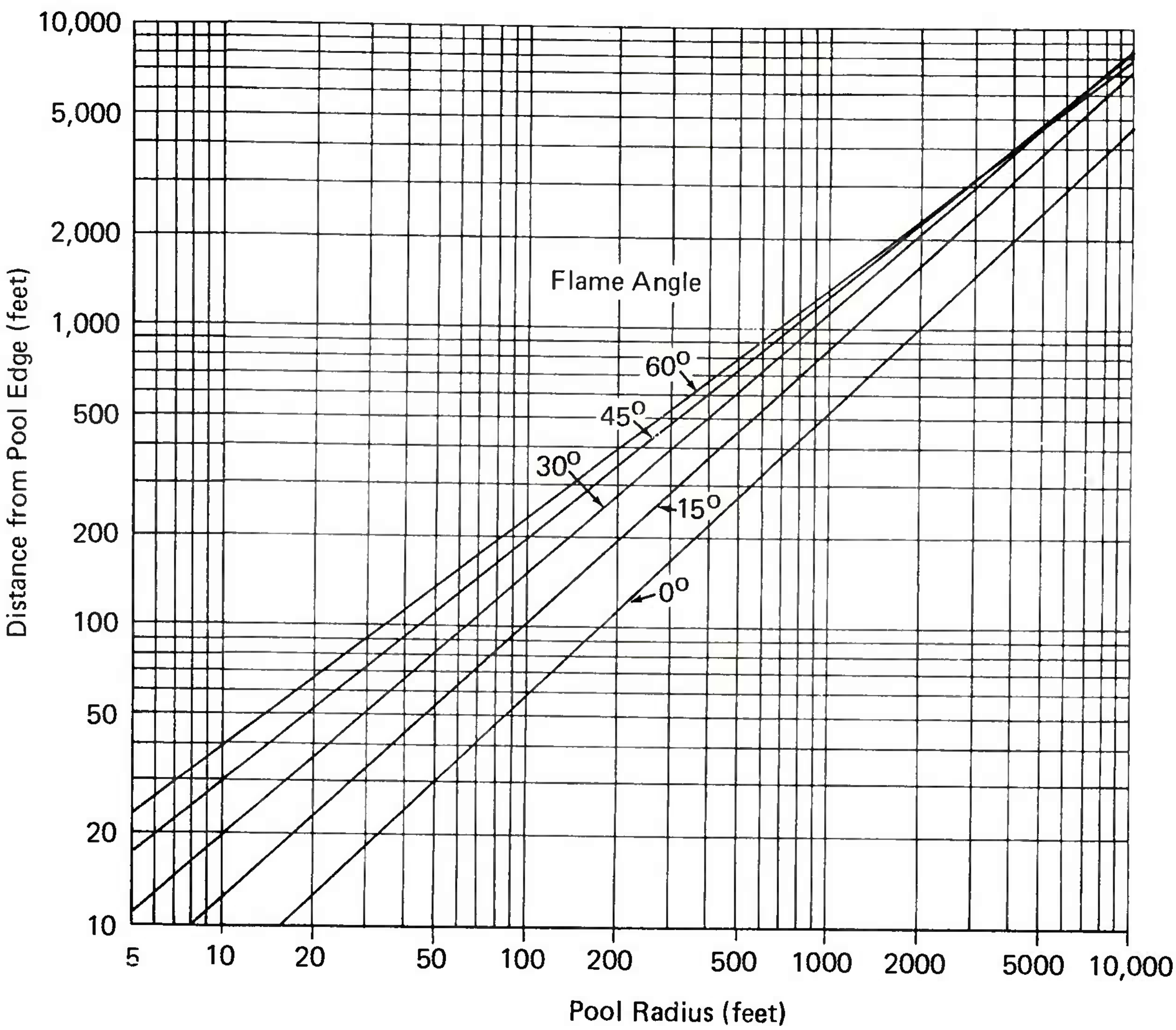


FIGURE E22 SAFE SEPARATION DISTANCE FOR WOODEN STRUCTURES (Fire Radiant Intensity = 10,000 Btu/hr-ft^2; ρR = 5–7)

Note: In the event that the chemical on fire is a heavy hydrocarbon (such as fuel oil or other petroleum products), the fire will be extremely sooty. *Substantially less heat is radiated from extremely sooty fires and safe separation distances are less than calculated from the figure above.* The calculated safe separation distances represents a conservative estimate of hazard from a safety point of view.

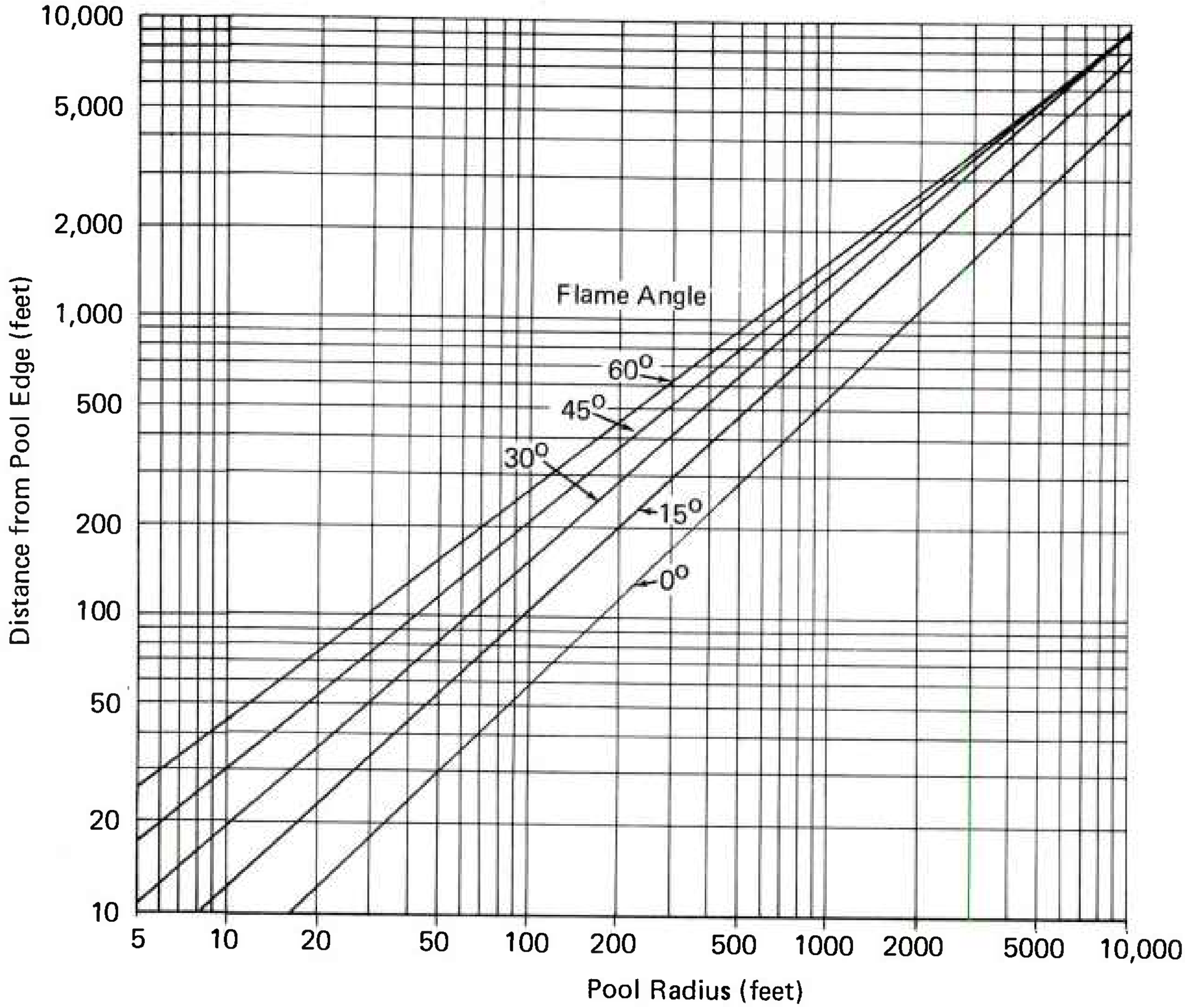


FIGURE E23 SAFE SEPARATION DISTANCE FOR WOODEN STRUCTURES (Fire Radiant Intensity = 10,000 Btu/hr-ft^2 ; ρR = 7– 9)

Note: In the event that the chemical on fire is a heavy hydrocarbon (such as fuel oil or other petroleum products), the fire will be extremely sooty. *Substantially less heat is radiated from extremely sooty fires and safe separation distances are less than calculated from the figure above.* The calculated safe separation distances represents a conservative estimate of hazard from a safety point of view.

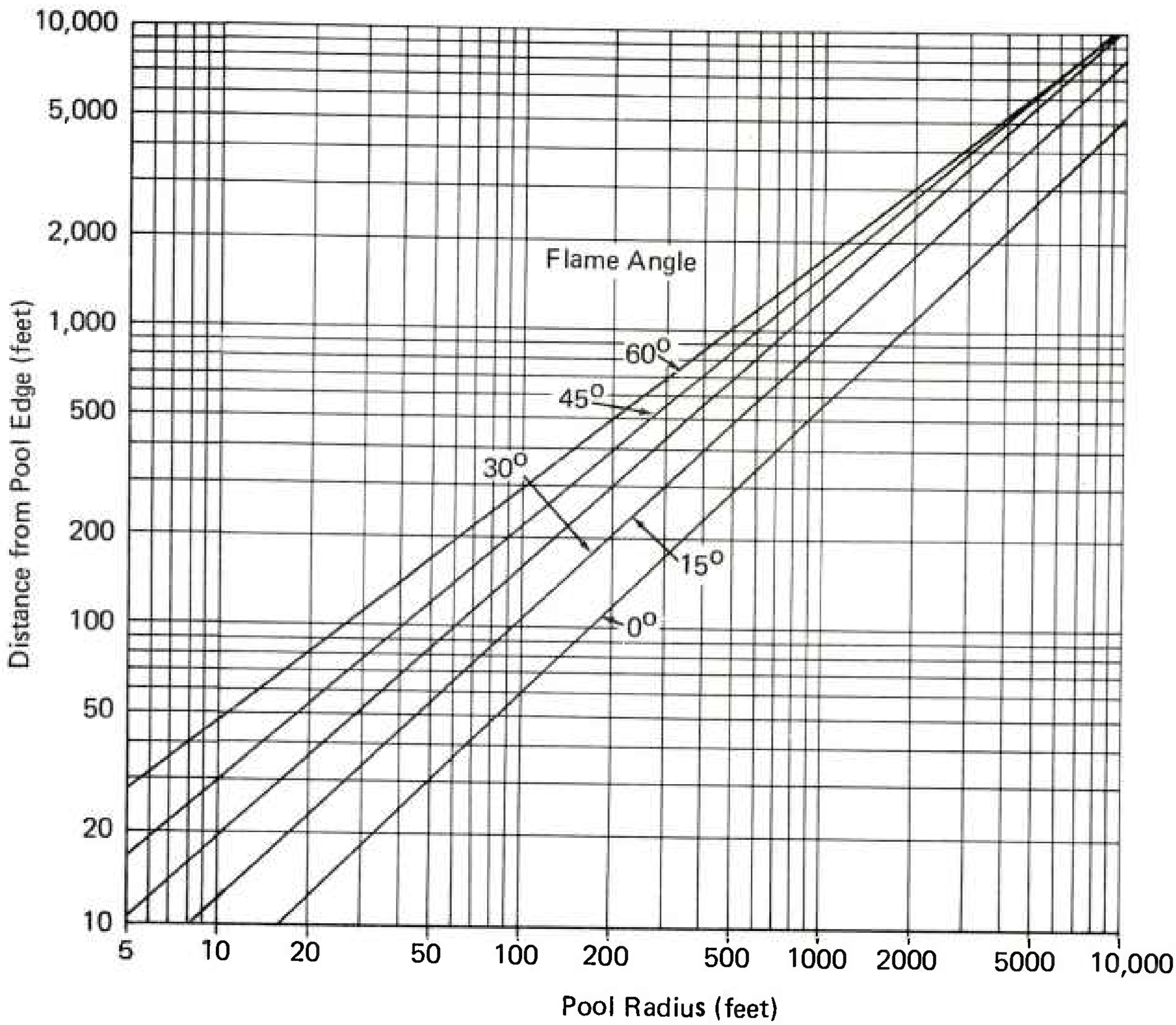


FIGURE E24 SAFE SEPARATION DISTANCE FOR WOODEN STRUCTURES (Fire Radiant Intensity = 10,000 Btu/hr-ft^2 ; ρR = 9–11)

Note: In the event that the chemical on fire is a heavy hydrocarbon (such as fuel oil or other petroleum products), the fire will be extremely sooty. *Substantially less heat is radiated from extremely sooty fires and safe separation distances are less than calculated from the figure above.* The calculated safe separation distances represents a conservative estimate of hazard from a safety point of view.

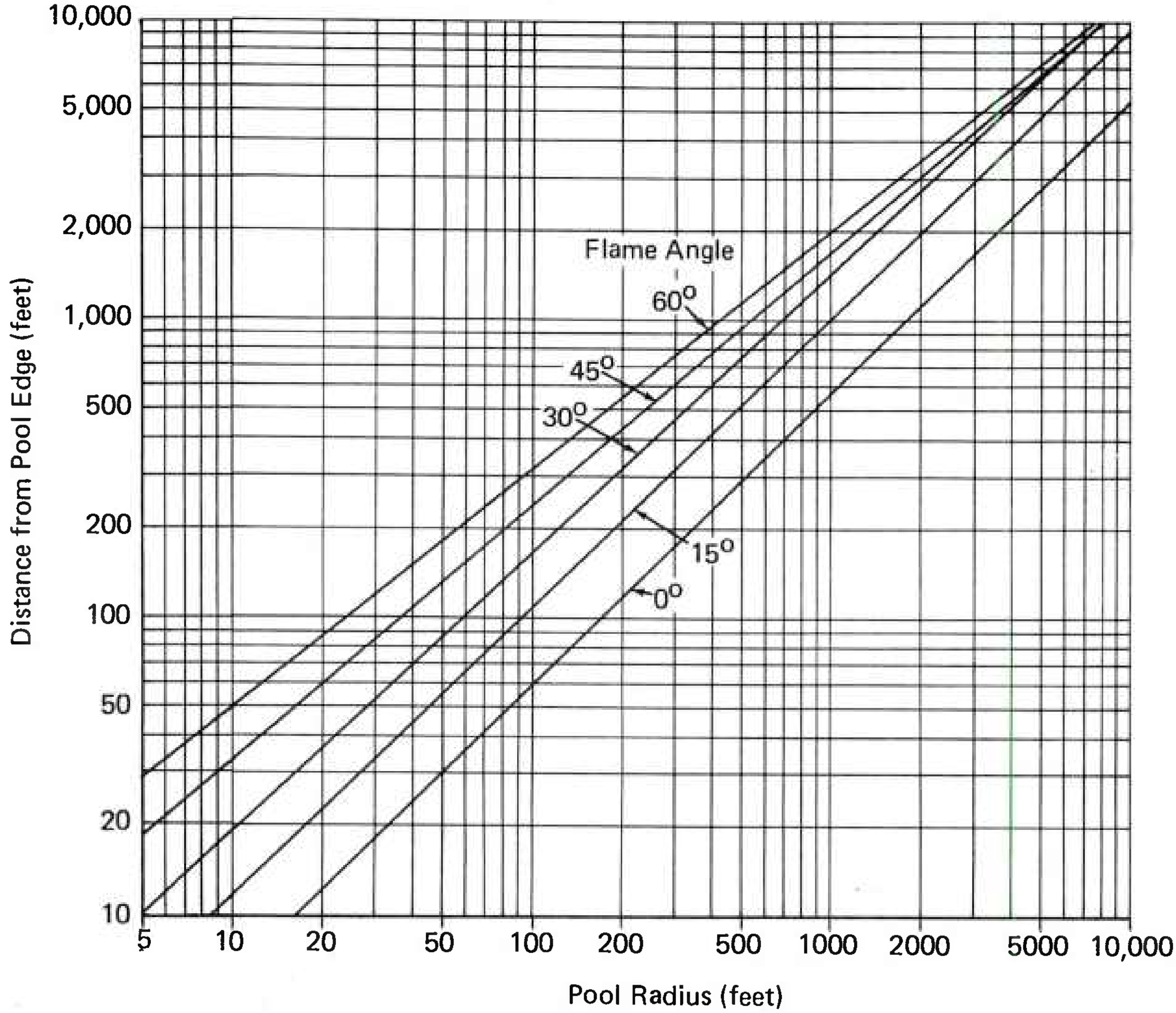


FIGURE E25 SAFE SEPARATION DISTANCE FOR WOODEN STRUCTURES (Fire Radiant Intensity = 10,000 Btu/hr-ft^2 ; ρR = greater than 11)

Note: In the event that the chemical on fire is a heavy hydrocarbon (such as fuel oil or other petroleum products), the fire will be extremely sooty. *Substantially less heat is radiated from extremely sooty fires and safe separation distances are less than calculated from the figure above.* The calculated safe separation distances represents a conservative estimate of hazard from a safety point of view.

FIGURES FOR CALCULATION PROCEDURE G

Hazard calculation procedure G may be used to assess the downwind toxic or flammable hazard resulting from the escape of a gas or evaporation of a pool of liquid with a boiling point less than ambient.

Three figures and four tables are presented for use with this procedure.

Figure G1 is used to convert the lower flammability limit of the vapor or gas from volume percent to the LFL concentration in gm/cm^3.

Figure G2 is used to convert the threshold limit value in ppm to the TLV concentration in gm/cm^3.

Figure G3 is used to determine the parameter M/C from either the LFL or TLV concentrations in gm/cm^3 and the amount of chemical released.

Table G-1 gives for weather condition F the maximum extent of downwind hazard as a function of the parameter M/C for either the toxicity or flammability limit and the pool radius.

Table G-2 gives the maximum half-width of the vapor cloud for weather condition F as a function of the parameter M/C.

Table G-3 is similar to Table G-1 but gives the hazard extents for weather condition D.

Table G-4 is similar to Table G-2 but gives the maximum half-widths for weather condition D.

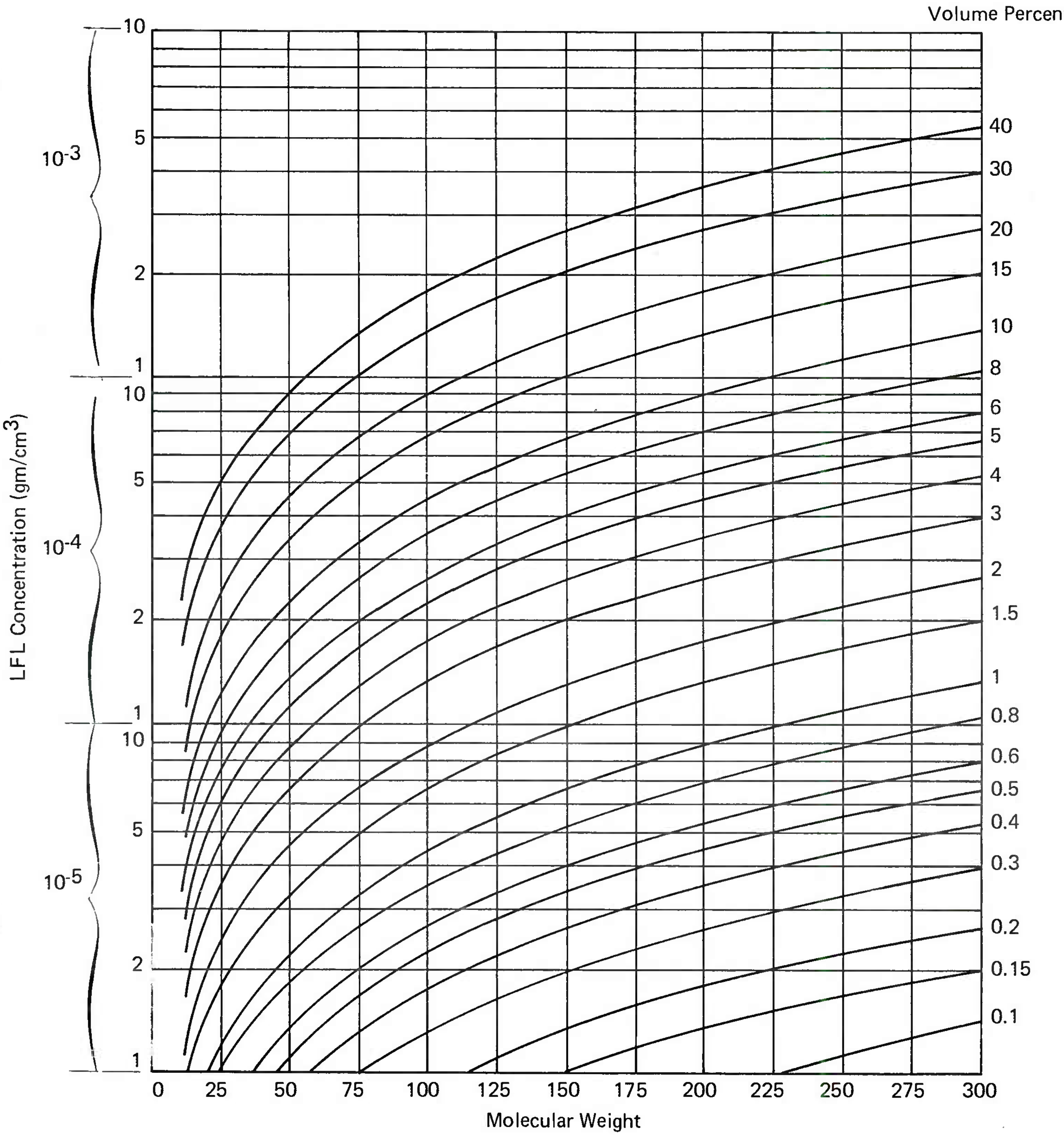


FIGURE G1 CONVERSION OF LOW FLAMMABILITY LIMIT TO LFL

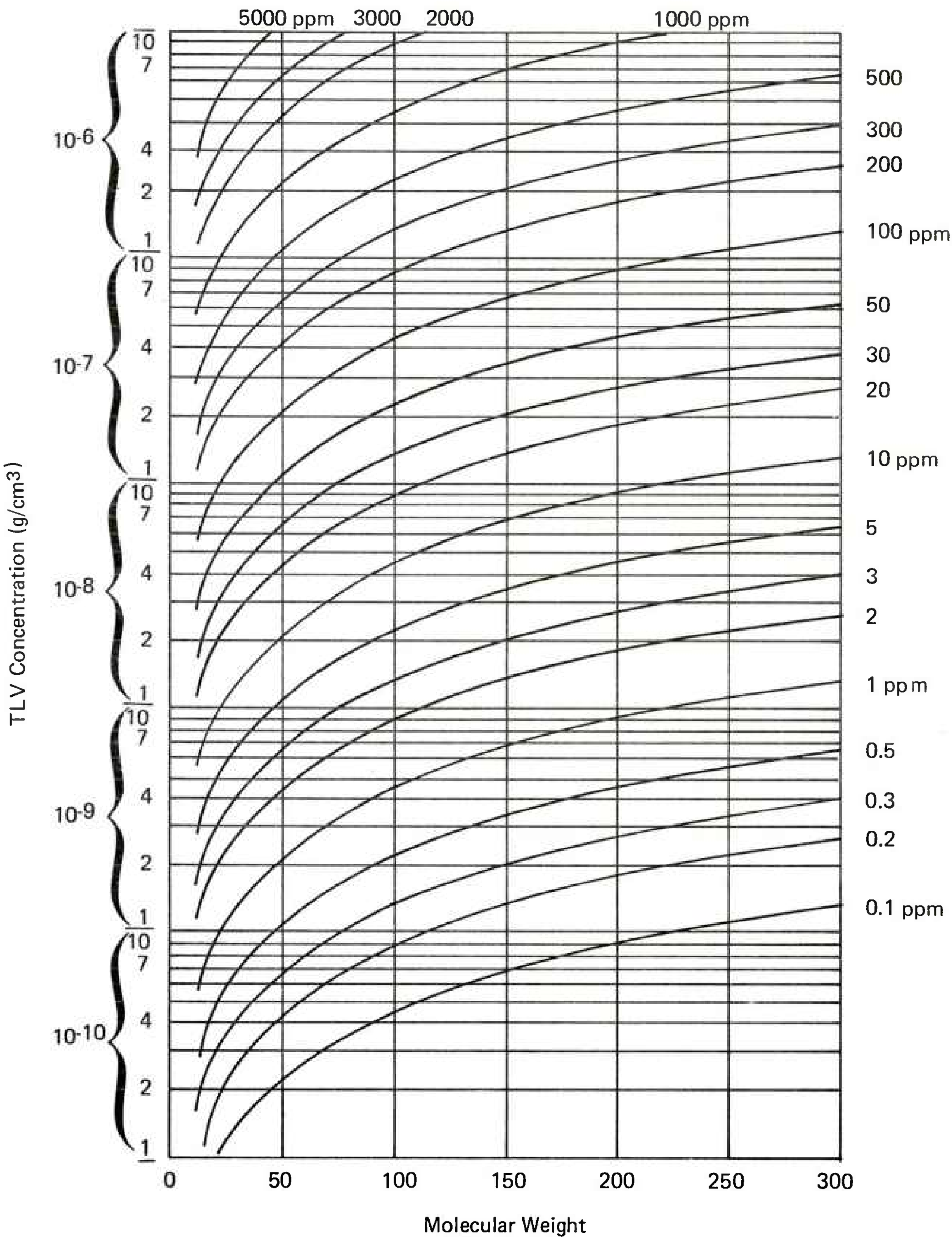
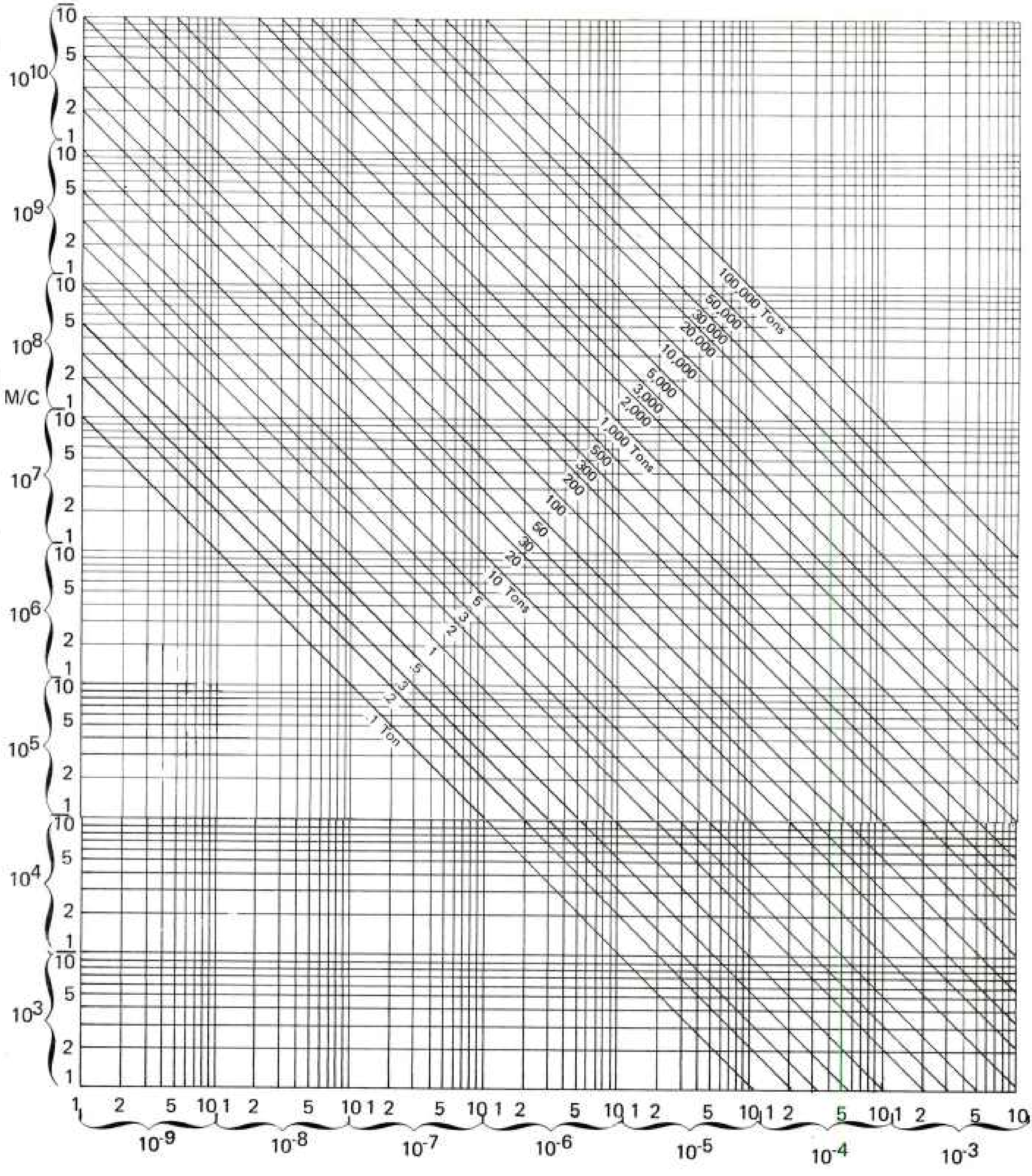


FIGURE G2 CONVERSION OF THRESHOLD LIMIT VALUE TO TLV



Note: M/C is the spill size in tons divided by the concentration in gm/cm^3

FIGURE G3 DETERMINATION OF PARAMETER M/C

TABLE G-1

MAXIMUM EXTENT OF VAPOR CLOUD FOR WEATHER CONDITION F

(Distances in Nautical Miles Unless Shown to be in Feet with ')

Pool Radius (feet)

M/C	0-25	25-100	100-200	200-500	500-1000	1000-2000	2000
1×10^3	240'	–	–	–	–	–	–
2	390'	–	–	–	–	–	–
4	575'	–	–	–	–	–	–
7	.1	–	–	–	–	–	–
10×10^3 or 1×10^4	.2	165'	–	–	–	–	–
2	.2	520'	–	–	–	–	–
4	.3	.2	–	–	–	–	–
7	.4	.2	470'	–	–	–	–
1×10^5	.5	.4	.3	.2	–	–	–
2	.6	.5	.4	.3	–	–	–
4	.8	.7	.6	.5	–	–	–
7	1.0	.9	.8	.7	.2	–	–
10×10^5 or 1×10^6	1.1	1.0	.9	.8	.3	–	–
2	1.5	1.4	1.3	1.2	.7	–	–
4	2.1	2.0	1.9	1.8	1.3	.5	–
7	2.7	2.6	2.5	2.4	1.9	1.1	–
10×10^6 or 1×10^7	3.1	3.0	2.9	2.8	2.3	1.5	–
2	4.2	4.1	4.0	3.9	3.4	2.6	.9
4	5.8	5.7	5.6	5.5	5.0	4.2	2.5
7	7.6	7.5	7.4	7.3	6.8	6.0	4.3
10×10^7 or 1×10^8	9.0	8.9	8.8	8.7	8.2	7.4	5.7
2	12.	12.	12.	12.	11.	10.	8.7
4	18.	18.	18.	18.	17.	16	15.
7	23.	23.	23.	23.	22	21	20.
10×10^8 or 1×10^9	28.	28.	28.	28	27	26	25.
2	40	40	40	40	39	38	37.
4	59	59	59	59	58	57	56.
7	80	80	80	80	79	78	77.
10×10^9 or 1×10^{10}	98	98	98	98	97	96	95.

1 Nautical Mile = 6076 Feet = 1.15 Mile

Note: For a gas release, it is assumed that all material is released instantaneously at one point and that the pool radius is minimum (0 to 25 ft.)

TABLE G-2

MAXIMUM HALF-WIDTH OF VAPOR CLOUD FOR WEATHER CONDITION F

M/C	Maximum Half-Width (feet)
$1x10^3$	20
2	25
4	35
7	40
$10x10^3/1x10^4$	45
2	55
4	70
7	90
$10x10^4/1x10^5$	100
2	130
4	150
7	200
$10x10^5/1x10^6$	250
2	300
4	400
7	450
$10x10^6/1x10^7$	550
2	700
4	950
7	1,200
$10x10^7/1x10^8$	1,400
2	1,800
4	2,400
7	3,000
$10x10^8/1x10^9$	3,600
2	4,800
4	6,700
7	8,400
$10x10^9$	10,000

TABLE G-3

MAXIMUM EXTENT OF VAPOR CLOUD FOR WEATHER CONDITION D

(Distances in Nautical Miles Unless Shown to be in Feet with ')

Pool Radius (feet)

M/C	0-25	25-100	100-200	200-500	500-1000	1000-2000	2000
1×10^3	<25'	–	–	–	–	–	–
2	40'	–	–	–	–	–	–
4	120'	–	–	–	–	–	–
7	210'	–	–	–	–	–	–
10×10^3 or 1×10^4	280'	–	–	–	–	–	–
2	430'	–	–	–	–	–	–
4	.1	–	–	–	–	–	–
7	.1	90'	–	–	–	–	–
10×10^4 or 1×10^5	.2	240'	–	–	–	–	–
2	.3	.2	–	–	–	–	–
4	.4	.3	100'	–	–	–	–
7	.5	.4	.3	.1	–	–	–
10×10^5 or 1×10^6	.5	.4	.3	.2	–	–	–
2	.7	.6	.5	.3	–	–	–
4	.9	.8	.7	.5	150'	–	–
7	1.1	1.0	.9	.8	.3	–	–
10×10^6 or 1×10^7	1.2	1.1	1.0	.9	.4	–	–
2	1.6	1.5	1.4	1.3	.8	–	–
4	2.1	2.0	1.9	1.8	1.2	.5	–
7	2.6	2.5	2.4	2.3	1.8	1.0	–
10×10^7 or 1×10^8	3.0	2.9	2.8	2.7	2.2	1.4	–
2	4.0	3.9	3.8	3.7	3.2	2.4	.7
4	5.4	5.3	5.2	5.1	4.5	3.7	2.1
7	6.9	6.8	6.7	6.6	6.0	5.2	3.6
10×10^8 or 1×10^9	8.	7.9	7.8	7.7	7.2	6.4	4.7
2	11	11	11	10	10	9.3	7.7
4	14.	14.	14.	14.	14.	13.	12
7	19.	18.	18.	18.	18.	18.	16.
10×10^9 or 1×10^{10}	22.	22.	22.	22.	21.	20.	19.
2	31.	30.	30.	30.	30.	29.	28.
4	42.	42.	42.	42.	42.	41.	39.
7	55.	55.	55.	55.	54.	54.	52.
10×10^{10}	65.	65.	65.	65.	65.	64.	62.

1 Nautical Mile = 6076 Feet = 1.15 Mile

Note: For a gas release, it is assumed that all material is released instantaneously at one point and that the pool radius is minimum (0 to 25 ft.)

TABLE G-4

MAXIMUM HALF-WIDTH OF VAPOR CLOUD FOR WEATHER CONDITION D

M/C	Maximum Half-Width (feet)
$1x10^3$	20
2	25
4	30
7	40
$10x10^3/1x10^4$	45
2	55
4	70
7	85
$10x10^4/1x10^5$	95
2	120
4	150
7	200
$10x10^5/1x10^6$	200
2	300
4	350
7	400
$10x10^6/1x10^7$	500
2	600
4	800
7	1,000
$10x10^7/1x10^8$	1,100
2	1,400
4	1,900
7	2,300
$10x10^8/1x10^9$	2,600
2	3,400
4	4,400
7	5,500
$10x10^9/1x10^{10}$	6,300
2	8,200
4	11,000
7	13,000
$10x10^{10}$	15,000

FIGURES FOR CALCULATION PROCEDURE I

Hazard calculation procedure I may be used to assess the hazard that a heavier than water, insoluble liquid with a boiling point less than ambient will present when spilled on water.

One table is presented for use with this procedure.

Table I-1 provides the boiling point, molecular weight, lower toxicity limit, critical depth, and time for complete evaporation of the liquid for each of the chemicals listed.

TABLE I.1

CHEMICALS IN PRIMARY HAZARD CODE ACIJ

Compound	Code	Boiling Point °C	Boiling Point °F	Boiling Point °K	Molecular Weight	Threshold Limit Value (ppm)	Critical Depth* (feet)	For Total Release Max. Evaporation Time at 20°C (all size spills)
Chlorine	ACIJ	-34.1	-29.4	239	70.91	1	197	less than 60 sec.
Cyanogen chloride	ACIJX	13.1	55.6	286	61.48	0.5	11	70 sec.
Dichlorofluoromethane	ACIJ	-29.8	-21.6	243	120.9	1000	Unknown	Unknown
Methyl bromide**	ABCIJ	3.6	38.5	277	94.95	15	28	less than 60 sec.
Monochlorodifluoromethane	ACIJ	-40.5	-40.9	233	86.48	1000	289	less than 60 sec.
Nitrogen tetroxide	AIJO	21.2	70.1	294	46.01 or 92.02	5 (as NO_2)	Reacts with water	less than 60 sec.
Nitrous oxide	ACIJ	-89.5	-129	184	44.0	Not toxic	1647	less than 60 sec.
Oxygen, liquefied	AI	-183	-297	90	32.0	Not toxic	26,180	less than 60 sec.
Phosgene	ACIJO	8.2	46.8	281	98.92	0.1	18	less than 60 sec.
Trichlorofluoromethane	ACIJ	23.8	74.8	297	137.4	1000	1.2	80 sec.
Trifluorochloroethylene**	ABCIJ	-28	-18	245	116.5	20	108	less than 60 sec.

*Critical depth = depth at which chemical will not boil at a water temperature of 20°C. (25°C for trichlorofluoromethane)

**Gases are also flammable. Lower flammability limits are 10% for methyl bromide; 16% for trifluorochloroethylene.

FIGURES FOR CALCULATION PROCEDURE K

Hazard calculation procedure K may be used to determine the maximum pool size which an amount of a soluble liquid with a boiling point less than ambient will form if released onto water. It can also be used to determine how long it will take for the pool of the chemical to evaporate.

Two tables are presented for use with the procedure.

Table K-1 gives the maximum pool radii for various spill amounts of the chemicals listed.

Table K-2 gives the time that is required for various amounts of these chemicals to evaporate.

TABLE K.1

MAXIMUM RADIUS OF POOL FOR VARIOUS SPILL AMOUNTS IN TONS (0-125 Tons) (RADIUS IN FEET)

Chemical Name**	Boiling Point (°F)	SPILL AMOUNTS (TONS)* 0-.1	.1-.5	.5-1.	1-5	5-10	10-30	30-60	60-125
Acetaldehyde	69	20	30	40	60	80	110	150	190
Ammonia, Anhydrous[2]	-28	20	30	40	65	85	120	150	200
Cyanogen	- 6	20	25	35	55	75	110	140	180
Dimethylamine	44	20	30	40	65	85	120	150	200
Dimethyl Ether	-13	20	30	40	60	85	120	150	190
Ethylamine	62	20	30	40	60	85	120	150	200
Ethylene Oxide	51	20	25	35	60	80	110	140	180
Hydrogen Bromide[1,2]	-88	1	2	2	3.5	5	7	9	10
Hydrogen Chloride[1,2]	-121	1	2	3	4.5	6	8	10	15
Hydrogen Cyanide[2]	78	20	30	40	60	85	120	150	200
Hydrogen Fluoride[2]	67	20	25	35	55	75	100	140	170
Methylamine	20	20	30	40	60	85	120	150	190
Methyl Mercaptan	43	20	25	35	55	80	110	140	180
Sulfur Dioxide[1]	14	1	2	3	4	6	8	10	15
Trimethylamine	37	20	30	40	65	85	120	160	200

*Ton = 2000 lb.

**Water temperature is assumed to be 68°F (20°C), except for acetaldehyde and hydrogen cyanide. For acetaldehyde, 70°F (21°C) was used; 79°F (26°C) was used for hydrogen cyanide.

(1) These chemicals sink in water; others float until dissolved or evaporated.

(2) These chemicals have hazardous reactions with water. Anhydrous ammonia reacts violently; others moderately.

TABLE K.1 (Continued)

MAXIMUM RADIUS OF POOL FOR VARIOUS SPILL AMOUNTS IN TONS (125 – >8000 Tons) (RADIUS IN FEET)

SPILL AMOUNTS (TONS)*

Chemical Name**	125-250	250-500	500-1000	1000-2000	2000-4000	4000-8000	Over 8000
Acetaldehyde	240	300	380	470	600	750	890
Ammonia, Anhydrous[2]	250	310	390	500	620	790	930
Cyanogen	220	280	350	440	560	700	830
Dimethylamine	250	310	400	500	630	790	940
Dimethyl Ether	240	310	390	490	610	770	910
Ethylamine	250	310	390	490	620	790	930
Ethylene Oxide	230	290	360	460	580	730	860
Hydrogen Bromide[1,2]	15	20	20	30	35	45	55
Hydrogen Chloride[1,2]	20	20	25	35	45	55	65
Hydrogen Cyanide[2]	250	310	390	490	620	780	930
Hydrogen Fluoride[2]	220	280	350	440	550	690	820
Methylamine	250	310	390	490	620	780	930
Methyl Mercaptan	230	290	360	450	570	720	850
Sulfur Dioxide[1]	15	20	25	30	40	50	60
Trimethylamine	250	320	400	510	640	810	960

*Ton = 2000 lb

**Water temperature is assumed to be 68°F (20°C), except for acetaldehyde and hydrogen cyanide. For acetaldehyde, 70°F (21°C) was used; 79°F (26°C) was used for hydrogen cyanide.

(1) These chemicals sink in water; others float until dissolved or evaporated.

(2) These chemicals have hazardous reactions with water. Anhydrous ammonia reacts violently; others moderately.

TABLE K.2

TIME FOR COMPLETE EVAPORATION
(Time in Minutes)

Chemical Name**	Boiling Point °F	Spill Amounts (Tons)*														
		0-.1	.1-.5	.5-1	1-5	5-10	10-30	30-60	60-125	125-250	250-500	500-1000	1000-2000	2000-4000	4000-8000	Over 8000
Acetaldehyde	69	16	21	26	35	43	53	64	75	88	100	120	140	160	190	210
Ammonia, anhydrous[2]	-28	1.2	1.6	1.9	2.6	3.2	4.1	4.9	5.8	6.8	8.0	9.4	11	13	15	17
Cyanogen	- 6	1.3	1.7	2.1	2.9	3.5	4.4	5.3	6.3	7.5	8.8	10	12	14	17	19
Dimethylamine	44	1.8	2.3	2.8	3.8	4.7	5.8	7.0	8.2	9.7	11	13	16	18	21	24
Dimethyl ether	-13	0.7	0.9	1.1	1.6	1.9	2.4	2.9	3.5	4.1	4.9	5.8	6.8	8.1	9.5	11
Ethylamine	62	5.7	7.1	8.6	11	14	17	20	23	27	31	36	41	47	55	61
Ethylene oxide	51	3.1	3.9	4.8	6.6	8.1	10	12	14	17	20	23	27	31	37	41
Hydrogen bromide[1,2]	-88					Very fast; specific times cannot be estimated.										
Hydrogen chloride[1,2]	-121					Very fast; specific times cannot be estimated.										
Hydrogen cyanide[2]	78	36	46	56	76	94	120	140	160	190	220	260	300	350	410	460
Hydrogen fluoride[2]	67	31	40	49	67	82	100	120	140	170	200	230	270	310	360	410
Methylamine	20	1.5	1.9	2.3	3.2	3.9	4.8	5.7	6.7	7.9	9.2	11	13	15	17	20
Methyl mercaptan	43	2.3	2.9	3.5	4.7	5.8	7.1	8.5	10	12	14	16	19	22	26	29
Sulfur dioxide[1]	14					Very fast; specific times cannot be estimated.										
Trimethylamine	37	1.1	1.5	1.8	2.5	3.0	3.8	4.6	5.4	6.4	7.5	8.8	10	12	14	16

*Ton = 2000 lb

**Water temperature is assumed to be 68°F (20°C), except for acetaldehyde and hydrogen cyanide. For acetaldehyde, 70°F (21°C) was used; 79°F (26°C) was used for hydrogen cyanide.

(1) These chemicals sink in water; others float until dissolved or evaporated.

(2) These chemicals have hazardous reactions with water. Anhydrous ammonia reacts violently; others moderately.

FIGURES FOR CALCULATION PROCEDURE O

Hazard calculation procedure O may by used to determine the reaction products of liquid chemicals (which react with water) and water.

One table is presented for use with this procedure.

Table O-1 lists, for each of the chemicals included, their reaction products with water and the weight fraction of the spill amount which will be converted to each product. For example, if one ton of benzoyl chloride is spilled on water, 0.85 ton of benzoic acid and $\sim$ 0.29 ton of hydrochloric acid will be formed.

TABLE O.1†

LIQUID CHEMICALS WHICH REACT WITH WATER

Reactant Compound	Products	Pertinent Code	Weight Fraction of Spill	Remarks
Acetyl bromide	Acetic acid	APQ	.49	Reacts violently.
	Hydrogen bromide	AC	some	
	Hydrobromic acid	(no code)	≤.66	
Acetyl chloride	Acetic acid	APQ	.76	Reacts vigorously.
	Hydrochloric acid	AP	≤.46	
	Hydrogen chloride	AC	some	
Allyl chloroformate	Allyl alcohol	APQ	.48	Reaction is *slow*.
	Hydrochloric acid	AP	.30	
	Carbon dioxide	AC	.37	
Allyltrichlorosilane	Silicone type polymer	(no code)	.67	Reacts vigorously.
	Hydrochloric acid	AP	.62	
	Hydrogen chloride	AC		
Ammonia, anhydrous	Ammonia, anhydrous (vapor)	ABC	~ .50	Quite vigorous dissolution with heat evolution.
	Ammonium hydroxide	APRS	~1.37	

TABLE O.1† (Continued)

Reactant Compound	Products	Pertinent Code	Weight Fraction of Spill	Remarks
n-Amyltrichlorosilane	Silicone type polymer	(no code)	.72	Reacts vigorously.
	Hydrochloric acid	AP	.53 (AP + AC)	
	Hydrogen chloride	AC		
Anisoyl chloride	Hydrochloric acid	AP	.21 (AP + AC)	Reacts slowly.
	Hydrogen chloride	AC		
	p-anisic acid	(no code)	.89	
Antimony pentachloride	Hydrochloric acid	AP	⩽.61	
	Hydrogen chloride	AC	some	
	Antimonic acid	(no code)	.62	
Antimony pentafluoride	Hydrofluoric acid	AP	.46 (AP + AC)	Reacts vigorously.
	Hydrogen fluoride	AC		
	Antimonic acid	(no code)	.85	
Arsenic trichloride	Hydrochloric acid	AP	⩽.60	Not vigorous.
	Hydrogen chloride	AC	very little	
	Antimonous acid	(no code)	.69	
Benzene phosphorus dichloride	Hydrochloric acid	AP	.60 (AP + AC)	Reacts vigorously.
	Hydrogen chloride	AC		
	Benzene phosphonous acid	(no code)	.79	

TABLE O.1† (Continued)

Reactant Compound	Products	Pertinent Code	Weight Fraction of Spill	Remarks
Benzene phosphorus thiodichloride	Hydrochloric acid	AP	⩽.35	Reaction slow unless water is hot. HCl fume unlikely unless water hot.
	Hydrogen chloride	AC	see remark	
	Benzenethiophosphonic acid	(no code)	.82	
Benzoyl chloride	Benzoic acid	II	.87	Reacts *slowly*.
	Hydrochloric acid	AP	⩽.26	
	Hydrogen chloride	AC	some	
Benzyl bromide	Benzyl alcohol	APTX	.63	Reacts *slowly*.
	Hydrogen bromide	AC	little, if any	
	Hydrobromic acid	(no code)	⩽.47	
Benzyl chloride	Benzyl alcohol	APTX	.85	Reacts *slowly*.
	Hydrochloric acid	AP	~.29	
	Hydrogen chloride	AC	little, if any	
Benzyl chloroformate	Benzyl alcohol	APTX	.63	Not vigorous in cold water.
	Hydrochloric acid	AP	.21	
	Carbon dioxide	AC	.26	
Boron tribromide	Boric acid	SS-II	.25	Reacts violently.
	Hydrogen bromide	AC }	.97	
	Hydrobromic acid	(no code) }		

TABLE O.1[†] (Continued)

Reactant Compound	Products	Pertinent Code	Weight Fraction of Spill	Remarks
Boron trichloride	Boric acid	SS-II	.55	Reacts vigorously.
	Hydrochloric acid	AP	.93	
	Hydrogen chloride	AC		
Bromine pentafluoride	Bromine	APX	.46	Reacts violently. Reactions not stoichiometric. Products and weight fractions are best guesses.
	Hydrofluoric acid	AP	.57	
	Hydrogen fluoride	AC		
	Oxygen	no hazard	.23	
Bromine trifluoride	Bromine	APX	.58	Reacts vigorously. Reactions not stoichiometric. Products and weight fractions are best guesses.
	Hydrofluoric acid	AP	.44	
	Hydrogen fluoride	AC		
	Oxygen	no hazard	.18	
Butyltrichlorosilane	Silicone type polymer	(no code)	.70	Reacts vigorously.
	Hydrochloric acid	AP	.57	
	Hydrogen chloride	AC		
Chlorine trifluoride	Chlorine	AC	.38	Reacts explosively.
	Hydrofluoric acid	AP	.65	
	Hydrogen fluoride	AC		
	Oxygen	no hazard	.26	

TABLE O.1† (Continued)

Reactant Compound	Products	Pertinent Code	Weight Fraction of Spill	Remarks
Chloroacetyl chloride	Monochloroacetic acid	AP	.84	Reacts vigorously.
	Hydrochloric acid	AP	.32	
	Hydrogen chloride	AC		
Chloromethyl methyl ether	Formaldehyde	APQ	.37	Not violent.
	Methyl alcohol	APQRS	.40	
	Hydrochloric acid	AP	⩽.45	
	Hydrogen chloride	AC	little, if any	
Chlorosulfonic acid	Sulfuric acid	AP	.84	Reacts violently.
	Hydrochloric acid	AP	.31	
	Hydrogen chloride	AC		
Chromyl chloride	Chromic acid	(no code)	<.76	Reacts violently.
	Chromium dioxide	(no code)	little, if any	
	Hydrochloric acid	AP	<.47	
	Hydrogen chloride	AC		
	Chlorine	AC	some	
	Hydrogen	ABC	maybe some	

TABLE O.1† (Continued)

Reactant Compound	Products	Pertinent Code	Weight Fraction of Spill	Remarks
Cyclohexenyltrichloro-silane	Silicone type polymer	(no code)	.73	
	Hydrochloric acid	AP	.51	
	Hydrogen chloride	AC		
Diethylzinc	Ethane	ABC	.49	Reacts violently with water and may ignite spontaneously.
	Zinc oxide	(no code)	.66	
Difluorophosphoric acid, anhydrous	Phosphoric acid	AP	.95	Reacts vigorously.
	Hydrofluoric acid	AP	.39	
	Hydrogen fluoride	AC		
Dimethyldichlorosilane	Silicone type polymer	(no code)	.70	Reacts vigorously.
	Hydrochloric acid	AP	.57	
	Hydrogen chloride	AC		
Dimethylzinc	Methane	ABC	.34	Reacts vigorously with water and may ignite spontaneously.
	Zinc oxide	(no code)	.85	
Diphenyldichlorosilane	Silicone type polymer	(no code)	.95	
	Hydrochloric acid	AP	.29	
	Hydrogen chloride	AC		

TABLE O.1[†] (Continued)

Reactant Compound	Products	Pertinent Code	Weight Fraction of Spill	Remarks
Dodecyltrichlorosilane	Silicone type polymer	(no code)	.77	
	Hydrochloric acid	AP	.36	
	Hydrogen chloride	AC		
Ethylaluminum dichloride	Ethane	ABC	.23	Reacts violently with water and may ignite spontaneously. Smoke may be irritating and cause metal fume fever.
	Hydrochloric acid	AP	.56	
	Hydrogen chloride	AC		
	Aluminum oxide	(no code)	.39	
Ethylaluminum sesquichloride	Ethane	ABC	.36	Reacts violently with water and may ignite spontaneously. Smoke may be irritating and cause metal fume fever.
	Hydrochloric acid	AP	.44	
	Hydrogen chloride	AC		
	Aluminum oxide	(no code)	.41	
Ethyl chloroformate	Carbon dioxide	AC	.41	Reaction is *slow.*
	Ethyl alcohol	APQRS	.42	
	Hydrochloric acid	AP	.34	
Ethyldichlorosilane	Silicone type polymer	(no code)	.70	Reacts vigorously.
	Hydrochloric acid	AP	.57	
	Hydrogen chloride	AC		

TABLE O.1† (Continued)

Reactant Compound	Products	Pertinent Code	Weight Fraction of Spill	Remarks
Ethylphenyldichlorosilane	Silicone type polymer	(no code)	.81	
	Hydrochloric acid	AP	.36	
	Hydrogen chloride	AC		
Ethyl phosphonothioic dichloride, anhydrous	Ethanephosphonothioic acid	(no code)	.77	
	Hydrochloric acid	AP	.45	
	Hydrogen chloride	AC		
Ethyl phosphorodichloridate	Ethyl dihydrogen phosphate	(no code)	.77	Ethyl dihydrogen phosphate may or may not react with water to form ethyl alcohol and phosphoric acid.
	Hydrochloric acid	AP	.45	
	Hydrogen chloride	AC		
Ethyl silicate	Ethyl alcohol	APQRS	.88	Products may include silica gel *or* o-silicic acid. Reaction is *slow.*
	Silica gel	(no code)	.46	
	o-silicic acid	(no code)		
Ethyltrichlorosilane	Silicone type polymer	(no code)	.64	Reacts vigorously.
	Hydrochloric acid	AP	.67	
	Hydrogen chloride	AC		

TABLE O.1† (Continued)

Reactant Compound	Products	Pertinent Code	Weight Fraction of Spill	Remarks
Fluosulfonic acid	Hydrofluoric acid	AP	.20	Reacts violently.
	Hydrogen fluoride	AC		
	Sulfuric acid	AP	.98	
Hydrogen bromide	Hydrobromic acid	(no code)	1.00	Moderate reaction with evolution of heat.
Hydrogen chloride	Hydrochloric acid	AP	1.00	Moderate reaction with evolution of heat.
Hydrogen fluoride	Hydrofluoric acid	AP	1.00	Dissolves with liberation of heat.
Methyl chloroformate	Carbon dioxide	AC	.47	Reacts slowly. Reaction can be hazardous and hydrogen chloride formed if water is hot.
	Hydrochloric acid	AP	.39	
	Hydrogen chloride	AC		
	Methyl alcohol	APQRS	.34	
Methyldichlorosilane	Silicone type polymer	(no code)	.66	Reacts violently.
	Hydrochloric acid	AP	.63	
	Hydrogen chloride	AC		

TABLE O.1† (Continued)

Reactant Compound	Products	Pertinent Code	Weight Fraction of Spill	Remarks
Methyl phosphonothioic dichloride, anhydrous	Hydrochloric acid	AP	.49	May be violent reaction.
	Hydrogen chloride	AC		
	Methanephosphonothioc acid	(no code)	.75	
Methyltrichlorosilane	Silicone type polymer	(no code)	.63	Reacts violently.
	Hydrochloric acid	AP	.73	
	Hydrogen chloride	AC		
Nitrogen tetroxide	Nitric acid	AP	.91	
	Nitric oxide	AC	.22	
Nitrosyl chloride	Hydrochloric acid	AP	.56	
	Hydrogen chloride	AC		
	Nitrogen dioxide	(no code)	.70	
	Nitrogen tetroxide	ACO		
Oleum	Sulfuric acid	AP	?	Vigorous reaction; spatters. Weight fraction depends on SO_3 content of oleum. Use 1.15 if better value not available.

TABLE O.1† (Continued)

Reactant Compound	Products	Pertinent Code	Weight Fraction of Spill	Remarks
Parathion, liquid	Ethyl alcohol	APQRS	.32	*Slow* reaction.
	4-Nitrophenol	II-SS	.48	
	Thionophosphonic acid	(no code)	.39	
Pentaborane	Hydrogen	ABC	.38	Reacts *slowly*. Not hazardous unless water is hot or unless confined.
	Boric acid	SS-II	4.89	
Perchloromethyl mercaptan	Carbon dioxide	AC	.24	Reacts only when hot.
	Hydrochloric acid	AP	.79	
	Sulfur (solid)	(no code)	.17	
Phenyldichloroarsine, liquid	Benzenearsenic acid	(no code)	.83	*Very slow* reaction.
	Hydrochloric acid	AP	.33	
Phosgene	Carbon dioxide	AC	.44	Decomposes, but not vigorously.
	Hydrochloric acid	AP	.74	
Phosphorus oxychloride	Hydrochloric acid	AP }	.71	Vigorous reaction.
	Hydrogen chloride	AC }		
	Phosphoric acid	AP	.64	

TABLE O.1† (Continued)

Reactant Compound	Products	Pertinent Code	Weight Fraction of Spill	Remarks
Phosphorus tribromide	Hydrobromic acid	(no code)	.90	Reacts violently.
	Hydrogen bromide	AC		
	Phosphorous acid	(no code)	.30	
Phosphorus trichloride	Hydrochloric acid	AP	.80	Reacts violently and may cause flashes of fire.
	Hydrogen chloride	AC		
	Phosphorous acid	(no code)	.60	
Polymethylene polyphenyl isocyanate	Carbon dioxide	AC	?	Reacts *slowly*, forming heavy scum and carbon dioxide. Reaction is not stoichiometric.
	Some sort of polymer	(no code)	?	
Polyphosphoric acid	Phosphoric acid	AP	?	Reaction not violent. Weight fraction depends upon acid content of initial reactant.
Propionic anhydride	Propionic acid	APQ	1.14	Reacts *slowly* to form weak acid.
Propyleneimine, inhibited	Monoisopropanolamine	APQ	1.31	Reaction is *slow*.

TABLE O.1† (Continued)

Reactant Compound	Products	Pertinent Code	Weight Fraction of Spill	Remarks
Silicon tetrachloride	Hydrochloric acid	AP	.86	
	Hydrogen chloride	AC		Reacts vigorously.
	Silica gel	(no code)	.57	
	o-Silicic acid	(no code)		
Sulfur monochloride	Hydrochloric acid	AP	.54	Reacts violently.
	Hydrogen chloride	AC		
	Hydrogen sulfide	ABC	< .24	
	Sulfur dioxide	AC	< .47	
	Sulfur (solid)	(no code)	?	
	Polythionic acids	(no code)	?	
Sulfuric acid	Sulfuric acid (in solution)	AP	1.00	Reacts violently with evolution of heat. Spattering occurs when water added to compound.
Sulfuryl chloride	Hydrochloric acid	AP	.54	Reacts vigorously.
	Hydrogen chloride	AC		
	Sulfuric acid	AP	.73	

TABLE O.1† (Continued)

Reactant Compound	Products	Pertinent Code	Weight Fraction of Spill	Remarks
Tetrabutyl titanate	n-Butyl alcohol	APQ	.87	
	Titanium dioxide	(no code)	.24	
Thiophosgene	Carbon dioxide	AC	.38	Reaction is slow unless water is hot.
	Hydrochloric acid	AP	.63	
	Hydrogen sulfide	ABC	.30	
Titanium tetrachloride	Hydrochloric acid	AP	.77 (Hydrochloric acid and Hydrogen chloride, bracketed)	Heat generated.
	Hydrogen chloride	AC		
	Titanium dioxide	(no code)	.42	
Trichlorosilane	Hydrochloric acid	AP	.81 (Hydrochloric acid and Hydrogen chloride, bracketed)	Reacts violently.
	Hydrogen chloride	AC		
	Silanetriol polymer	(no code)	.57	
Triethylaluminum	Aluminum oxide	(no code)	.45	Reacts violently, ignites spontaneously at all temperatures. Smoke may cause metal fume fever.
	Ethane	ABC	.79	
Triisobutylaluminum	Aluminum oxide	(no code)	.26	Reacts violently and may ignite spontaneously. Smoke may cause metal fume fever.
	Isobutane	ABC	.88	

TABLE O.1[†] (Continued)

Reactant Compound	Products	Pertinent Code	Weight Fraction of Spill	Remarks
Trimethylchlorosilane	Hydrochloric acid	AP	.34	Reacts vigorously.
	Hydrogen chloride	AC		
	Trimethylsilanol	(no code)	.83	
Vanadium oxytrichloride	Hydrochloric acid	AP	.63	
	Hydrogen chloride	AC		
	Vanadic acid	(no code)	.68	
Vinyltrichlorosilane	Silicone type polymer	(no code)	.64	Reacts vigorously.
	Hydrochloric acid	AP	.68	
	Hydrogen chloride	AC		

†Notes for Table O.1

1) The *pertinent* hazard assessment codes of this table were especially chosen to best reflect the hazards from the products of reaction. They may or may not be the same as those found for these chemicals in CG-446-2.

2) Many lists of products of reaction include hydrogen chloride and hydrochloric acid, *or* hydrogen fluoride and hydrofluoric acid, *or* hydrogen bromide and hydrobromic acid. In most cases where this occurs, it is not possible to estimate how much hydrogen chloride, fluoride, or bromide will enter the atmosphere as a vapor or acid mist, or how much will mix with the water. Consequently, one "weight fraction of spill" has been given which shows the total of the two possible products. The user must decide how to apportion the weight fraction between the two products. As a general guideline it can only be said that the slower the reaction is, the more that will mix with water, and vice versa.

3) The products of reaction and their weight fractions were estimated, with one exception, by assuming that all of the reactant compound reacts with the water. When the reactant compound boils at less than ambient temperatures or reacts slowly, however, this assumption may not be completely true. In such cases, a large portion of the chemical may vaporize or otherwise disperse before reacting. For example, about 50% of any liquid anhydrous ammonia spilled on water is known to vaporize before reacting. For such chemicals, therefore, the user may wish to assume that some portion of the originally spilled chemical does not react and to utilize the hazard assessment code for the unreacted chemical to determine additional hazards.

4) The hazard assessment code "B" should not be utilized for a product of reaction, unless the reaction takes place *within* a punctured tank or other container.

5) "No code" indicates that the chemical is not contained in CHRIS. It should not be interpreted as signifying that the substance is non-hazardous.

FIGURES FOR CALCULATION PROCEDURE P

Hazard calculation procedure P may be used to determine the downstream concentration in water of a soluble chemical which has spilled into a flowing stream.

Ten figures are presented for use with this procedure.

Figures P1-P10 give the concentration factor as a function of distance downstream from the spill site and depth of the stream for various width ranges of the stream.

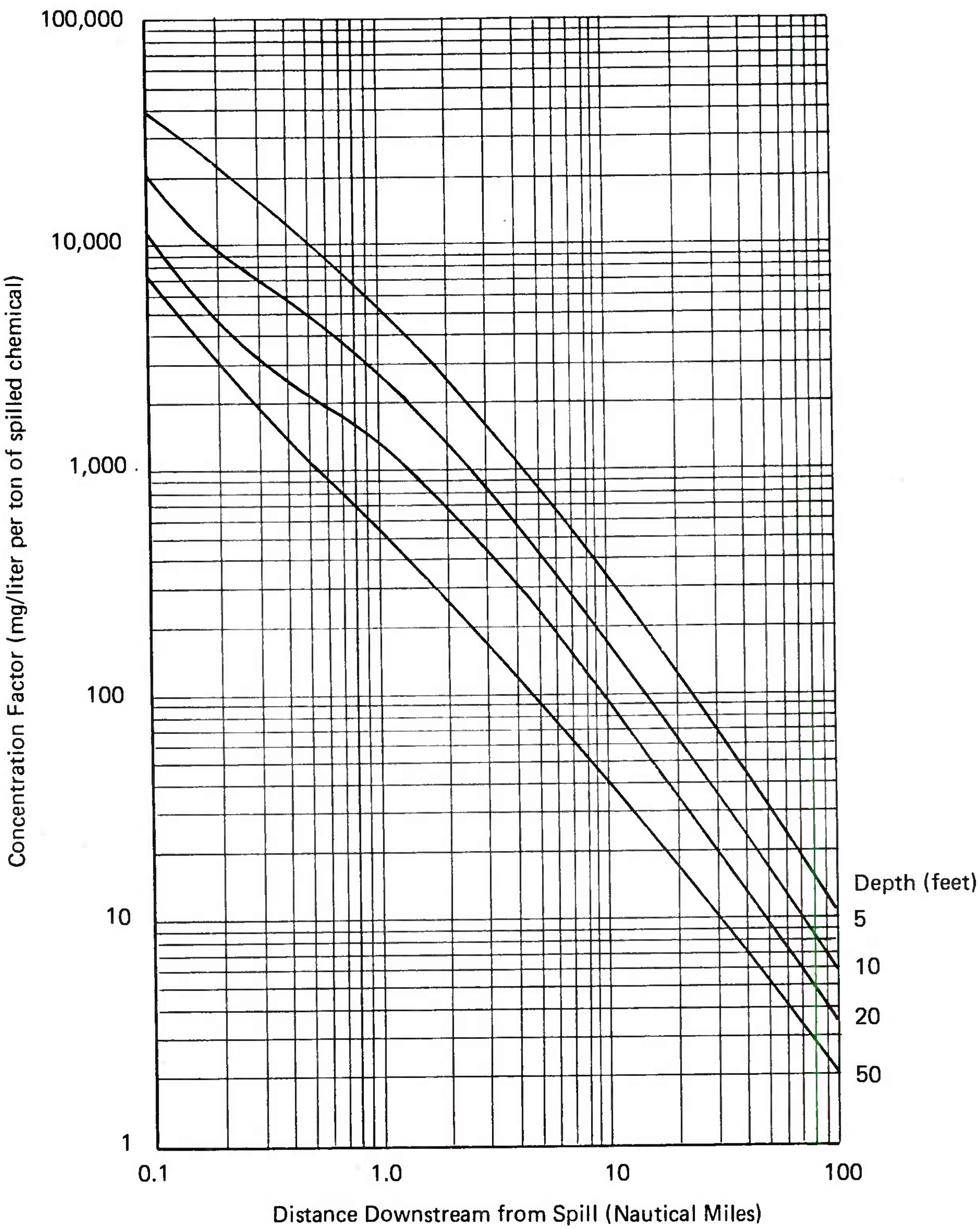


FIGURE P1 CONCENTRATION FACTOR FOR SOLUBLE CHEMICAL IN A FLOWING STREAM (WIDTH LESS THAN 75 FEET)

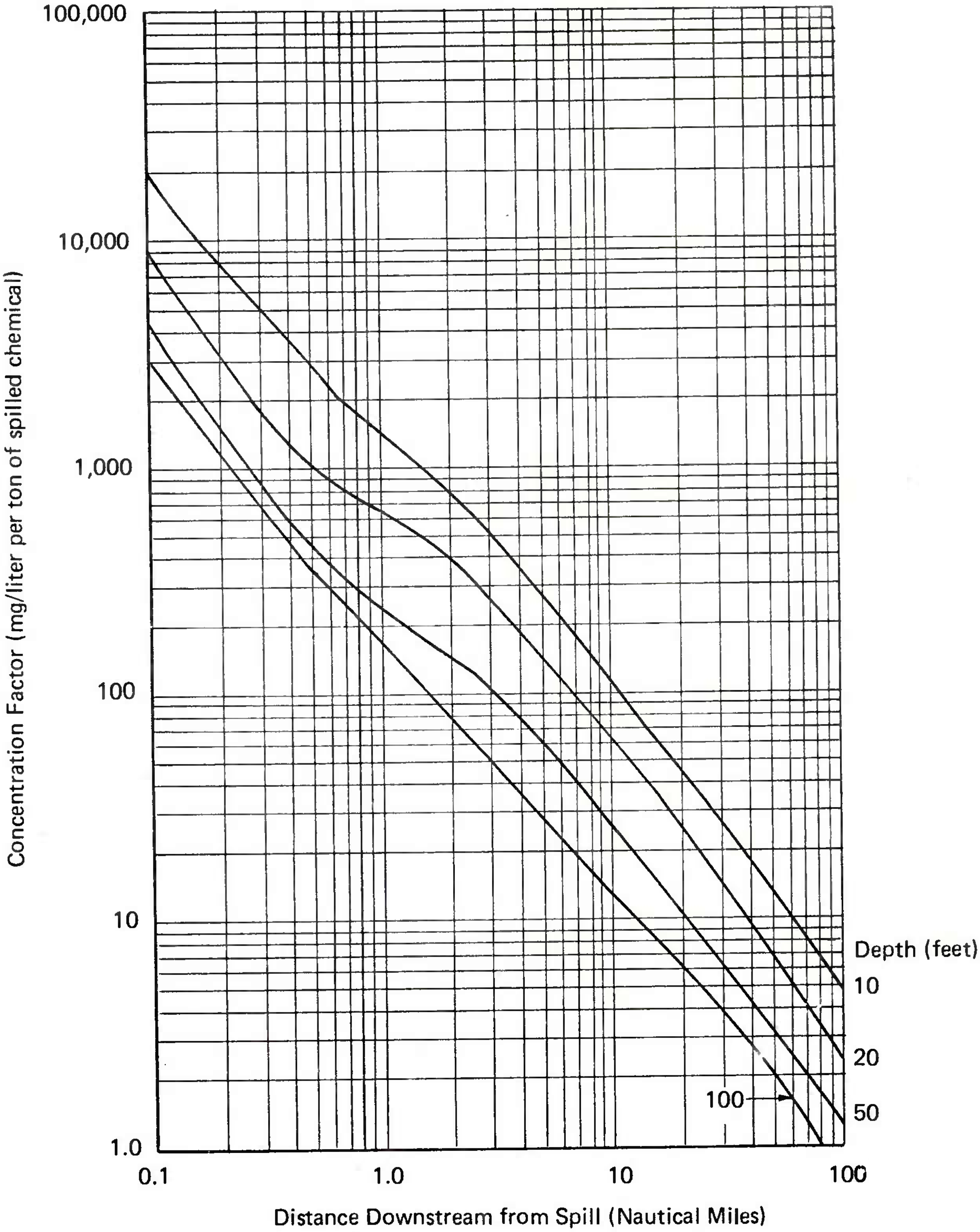


FIGURE P2 CONCENTRATION FACTOR FOR SOLUBLE CHEMICAL IN A FLOWING STREAM (WIDTH 75 TO 200 FEET)

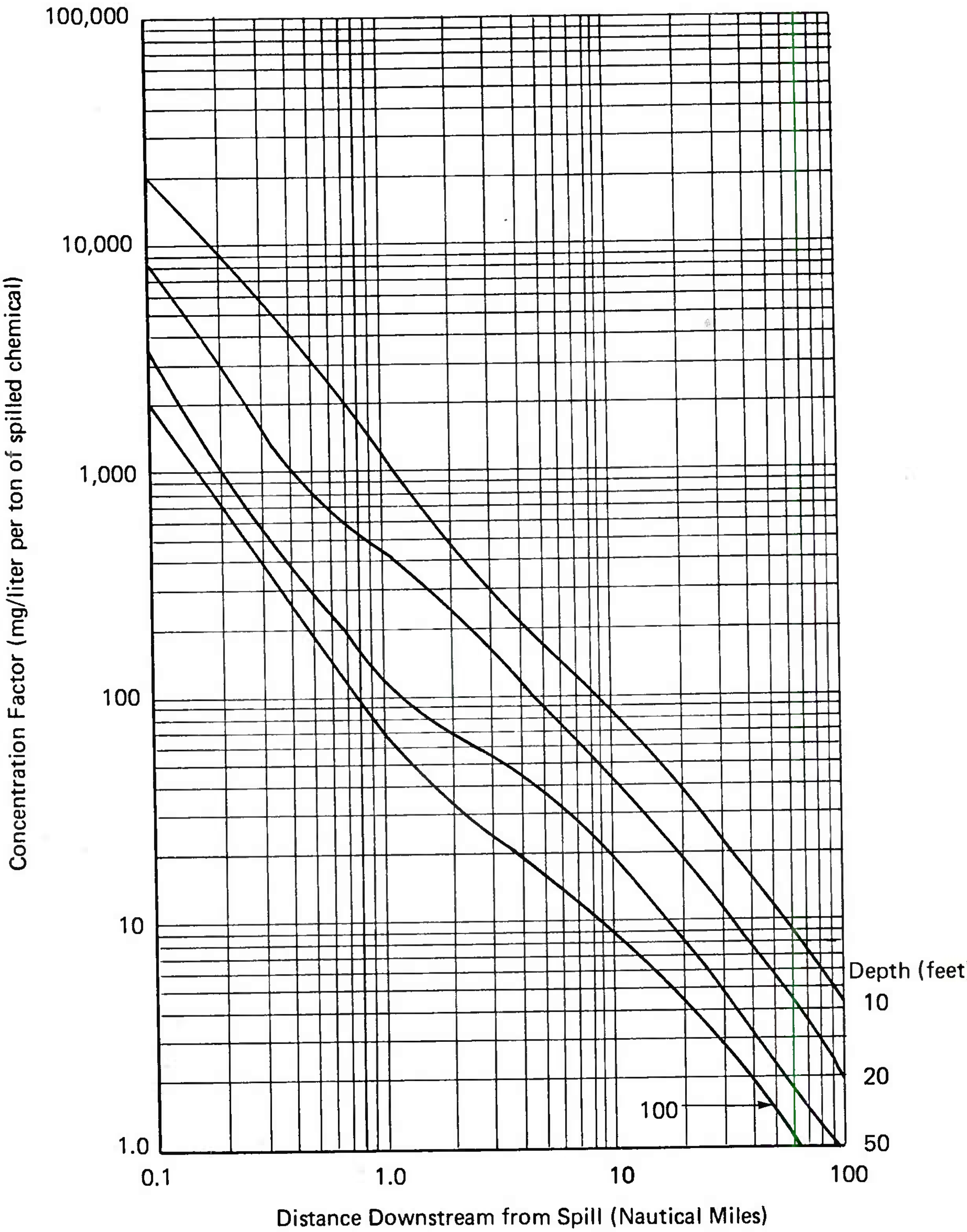


FIGURE P3 CONCENTRATION FACTOR FOR SOLUBLE CHEMICAL IN A FLOWING STREAM (WIDTH 200 TO 400 FEET)

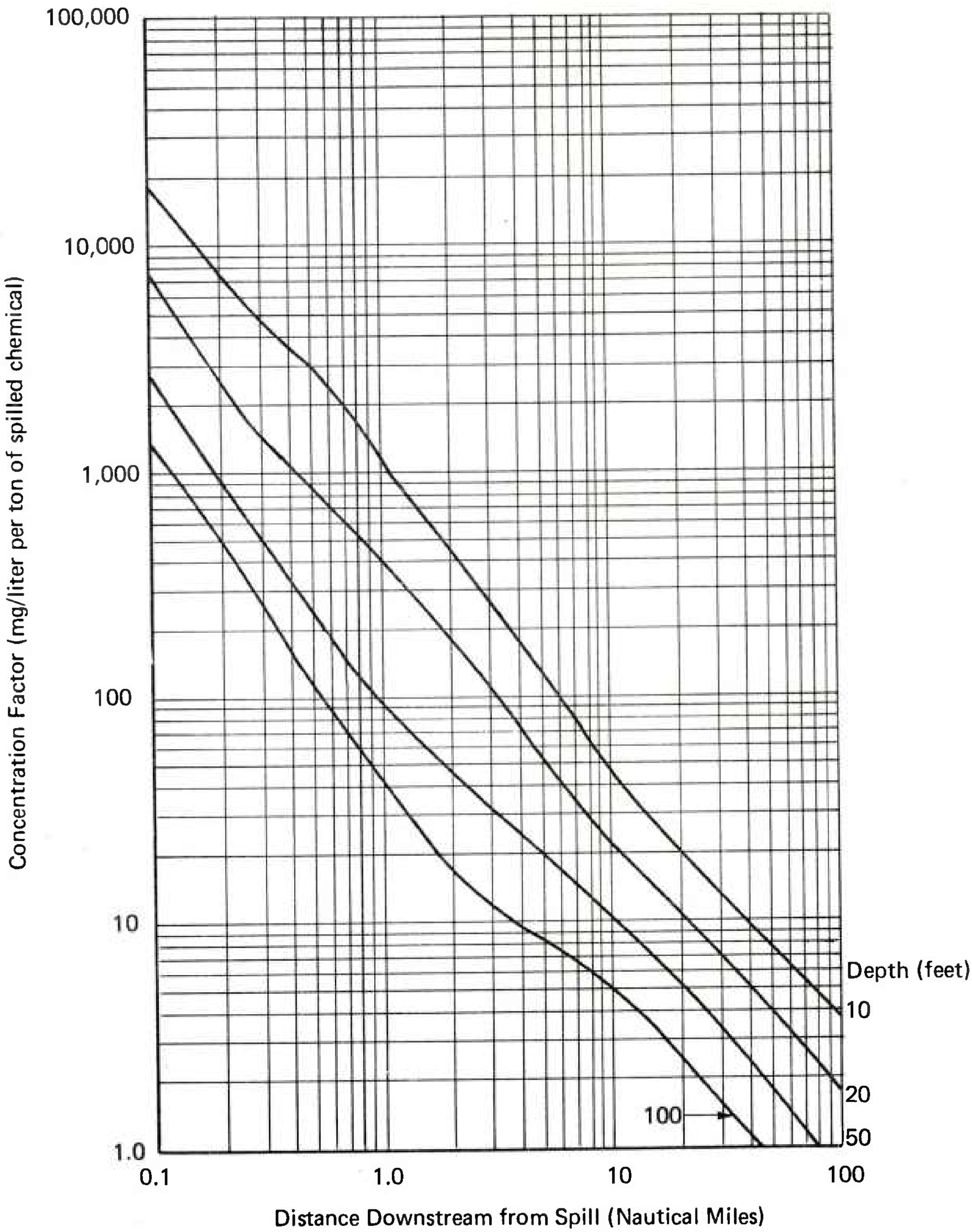


FIGURE P4 CONCENTRATION FACTOR FOR SOLUBLE CHEMICAL IN A FLOWING STREAM (WIDTH 400 TO 800 FEET)

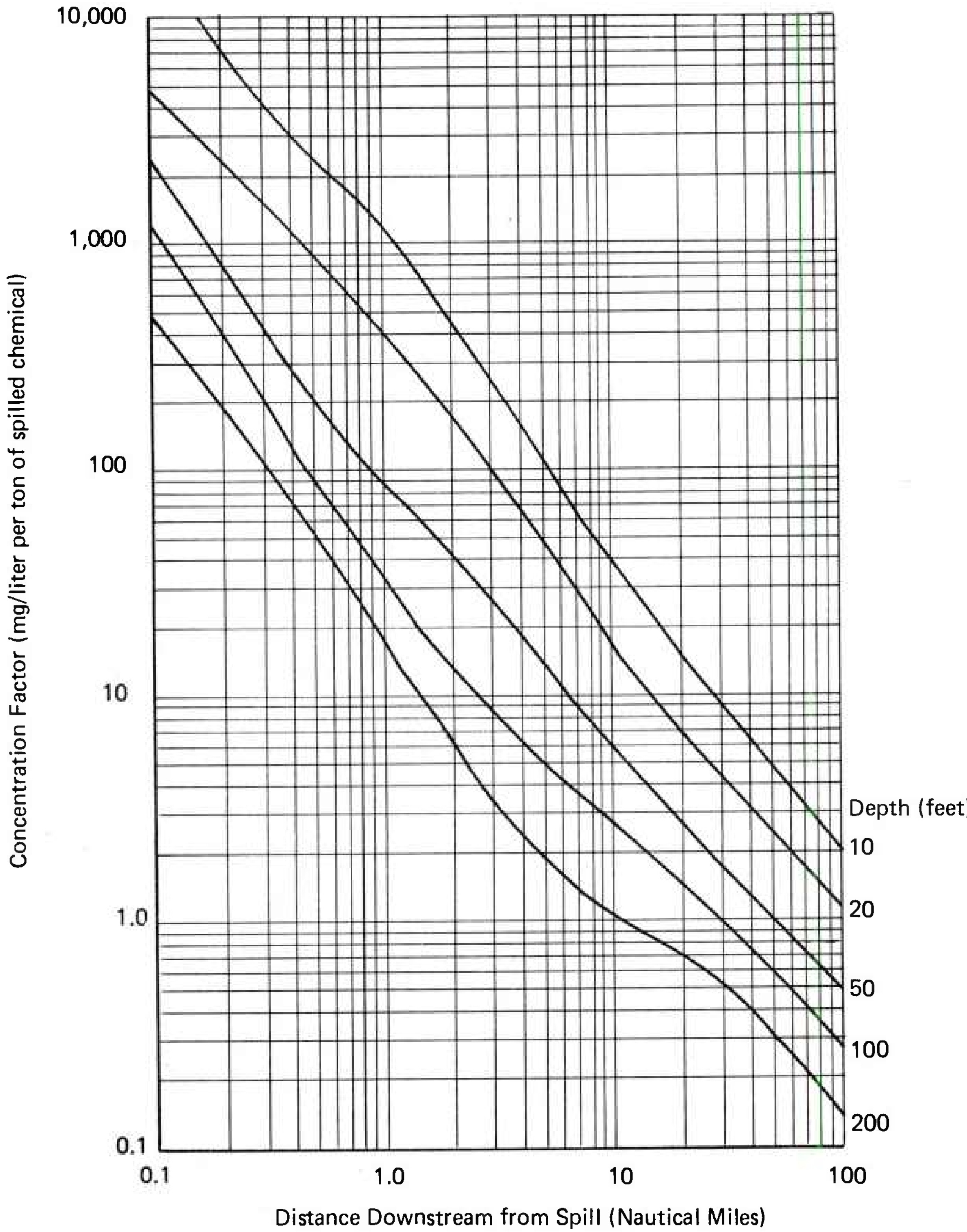


FIGURE P5 CONCENTRATION FACTOR FOR SOLUBLE CHEMICAL IN A FLOWING STREAM (WIDTH 800 TO 1200 FEET)

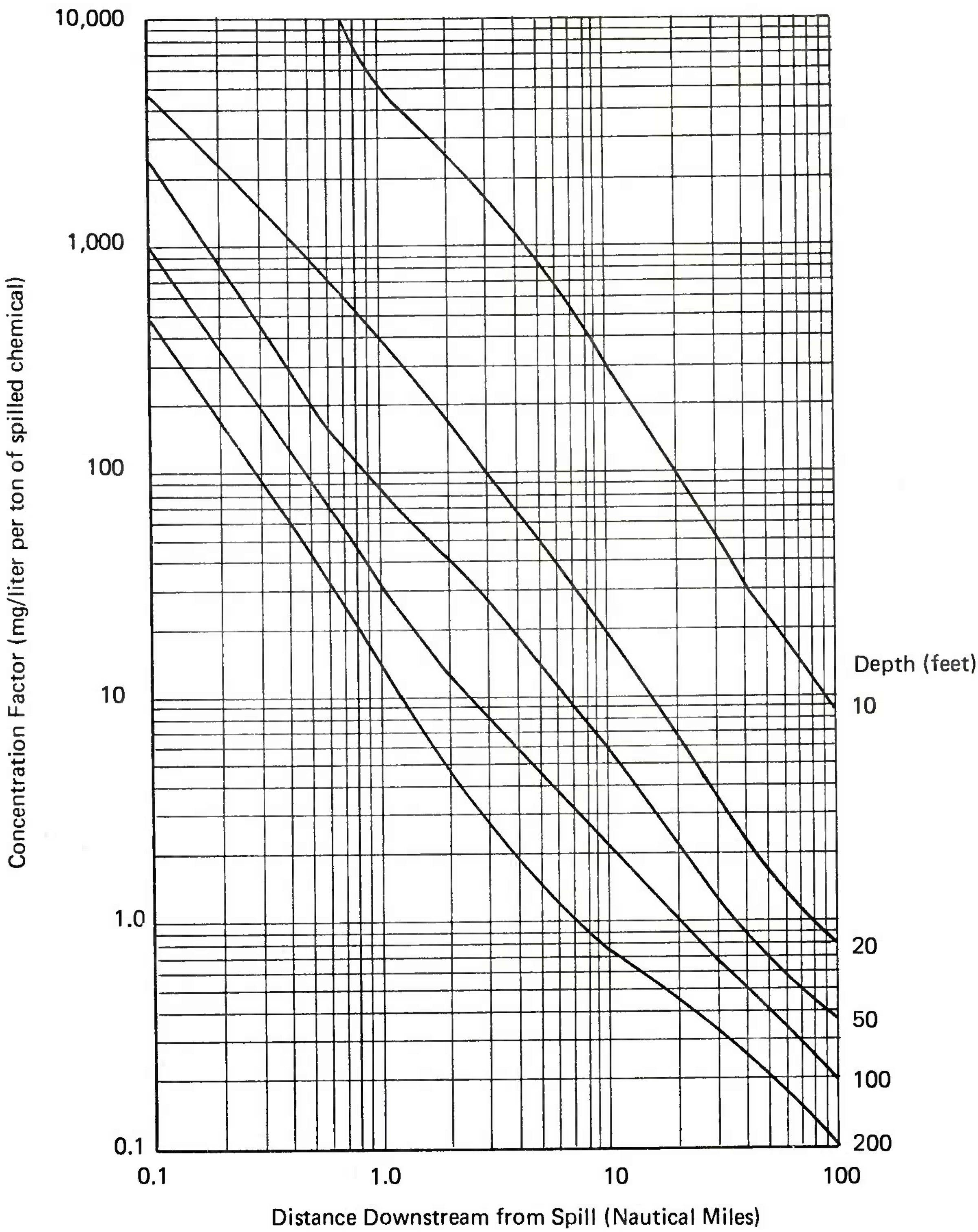


FIGURE P6 CONCENTRATION FACTOR FOR SOLUBLE CHEMICAL IN A FLOWING STREAM (WIDTH 1200 TO 1800 FEET)

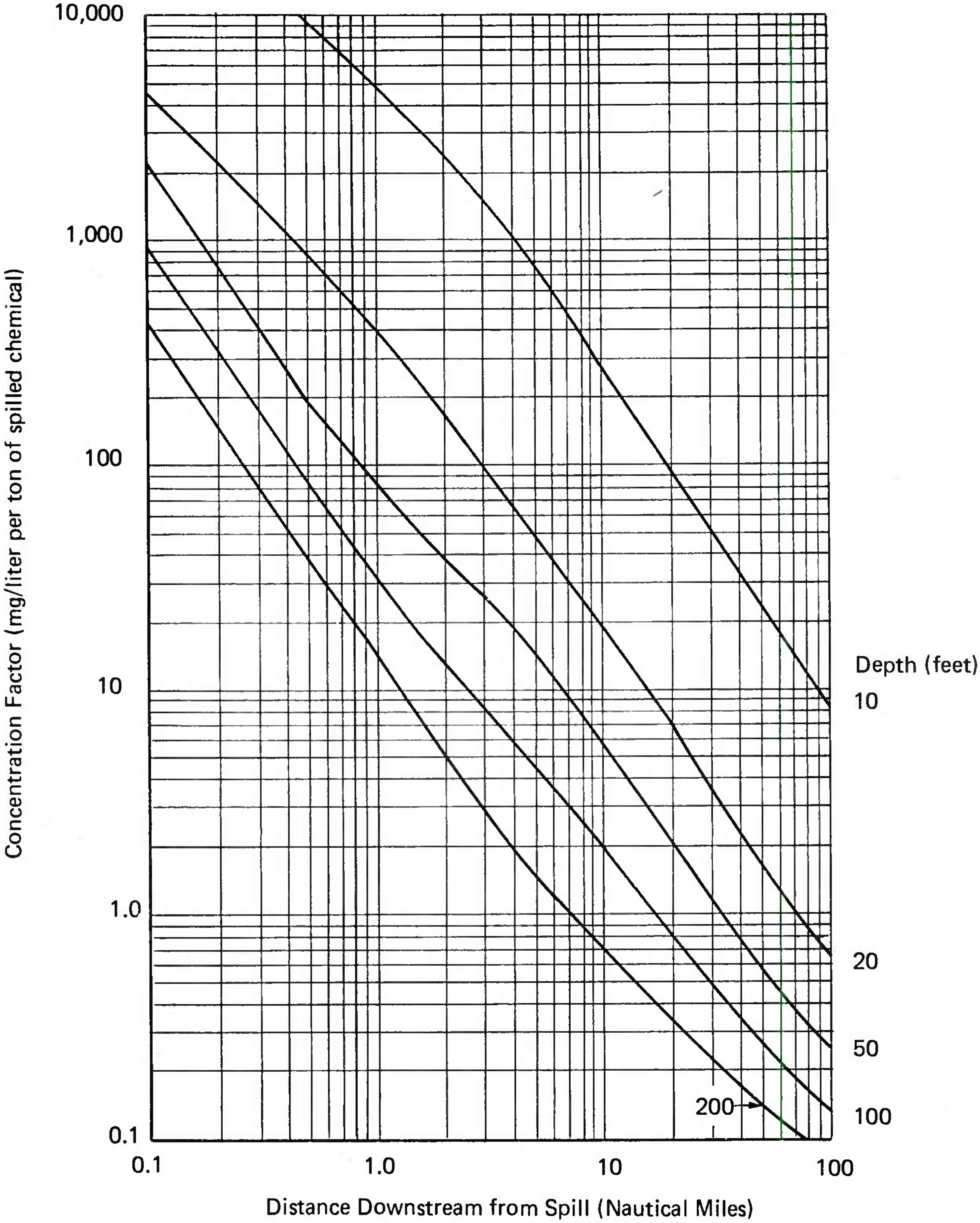


FIGURE P7 CONCENTRATION FACTOR FOR SOLUBLE CHEMICAL IN A FLOWING STREAM (WIDTH 1800 TO 2200 FEET)

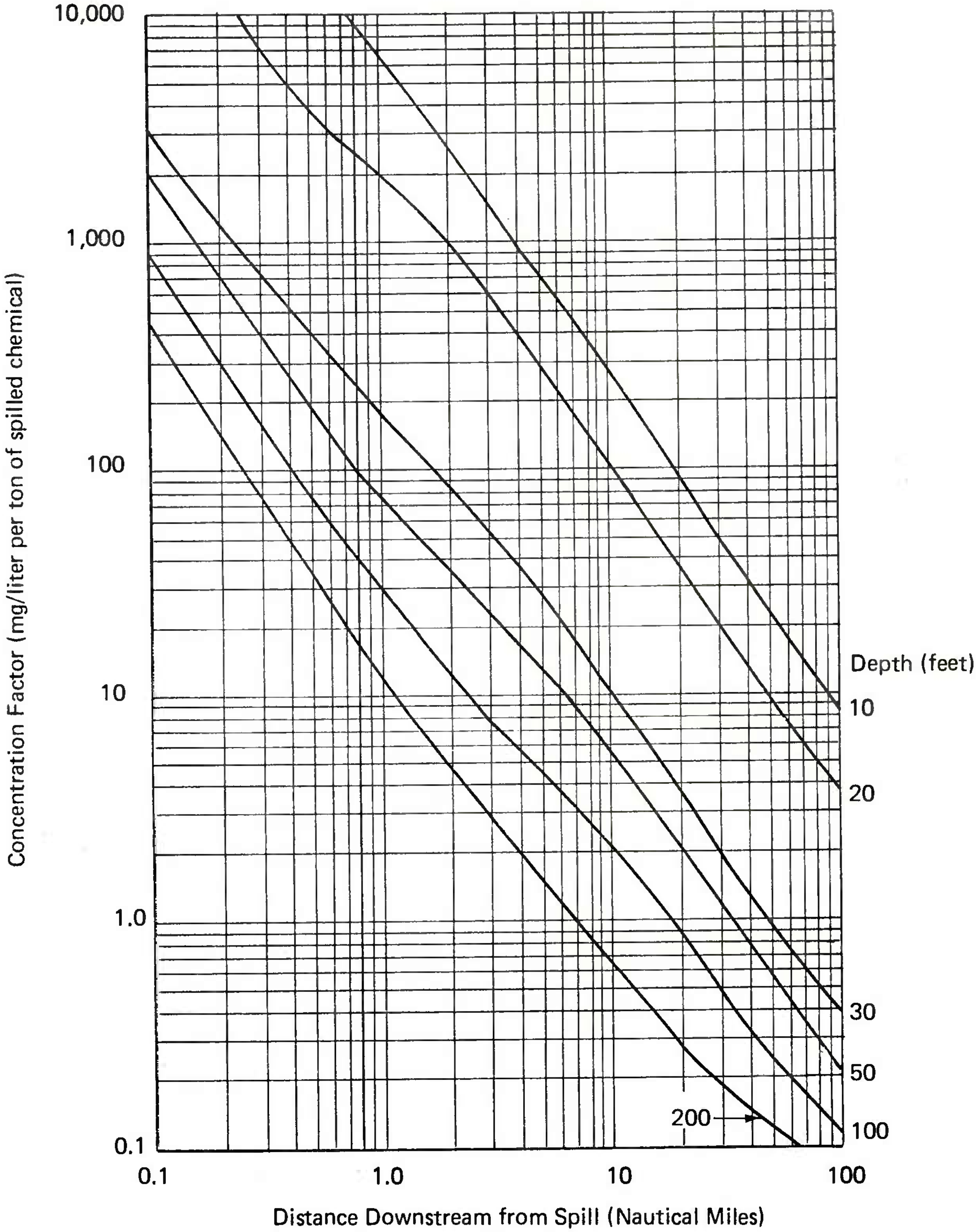


FIGURE P8 CONCENTRATION FACTOR FOR SOLUBLE CHEMICAL IN A FLOWING STREAM (WIDTH 2200 TO 2800 FEET)

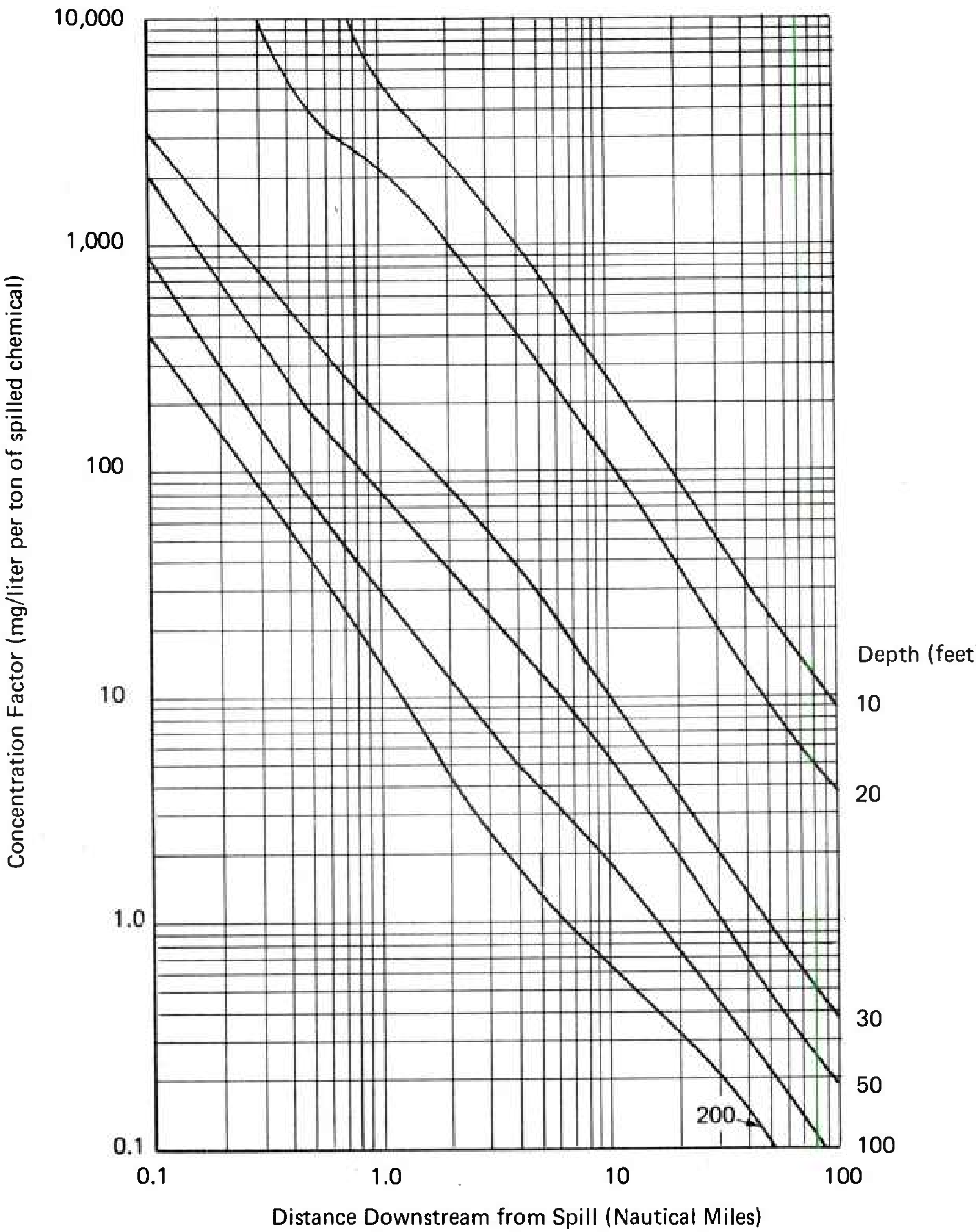


FIGURE P9 CONCENTRATION FACTOR FOR SOLUBLE CHEMICAL IN A FLOWING STREAM (WIDTH 2800 TO 3400 FEET)

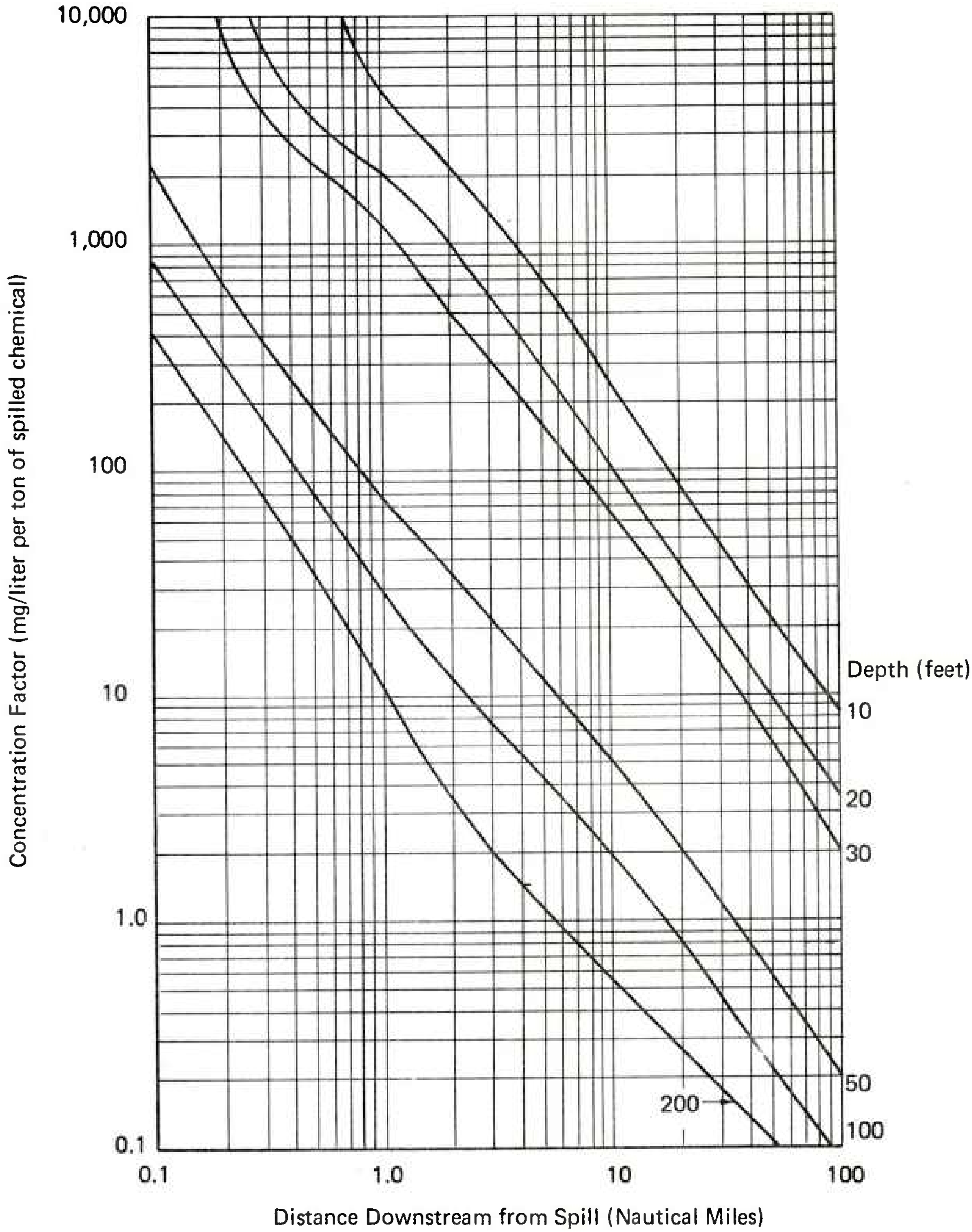


FIGURE P10 CONCENTRATION FACTOR FOR SOLUBLE CHEMICAL IN A FLOWING STREAM (WIDTH GREATER THAN 3400 FEET)

FIGURES FOR CALCULATION PROCEDURE R

Hazard calculation procedure R may be used to determine the amount of chemical which evaporates when a soluble, volatile liquid spills on a flowing stream. It can also provide an estimate of the distance downstream over which this evaporation will occur.

Forty-one figures are presented for use with this procedure.

Figures R1 and R2 give the hydraulic radius of the waterway as a function of its mean depth and width.

Figures R3 through R36 give the evaporation factor as a function of the hydraulic radius and amount spilled. Each of the figures is for a separate chemical.

Figures R37 through R41 give the maximum downstream extent of flammability and toxic vapor cloud hazard as a function of the hydraulic radius and tons spilled for various ranges of molecular weight.

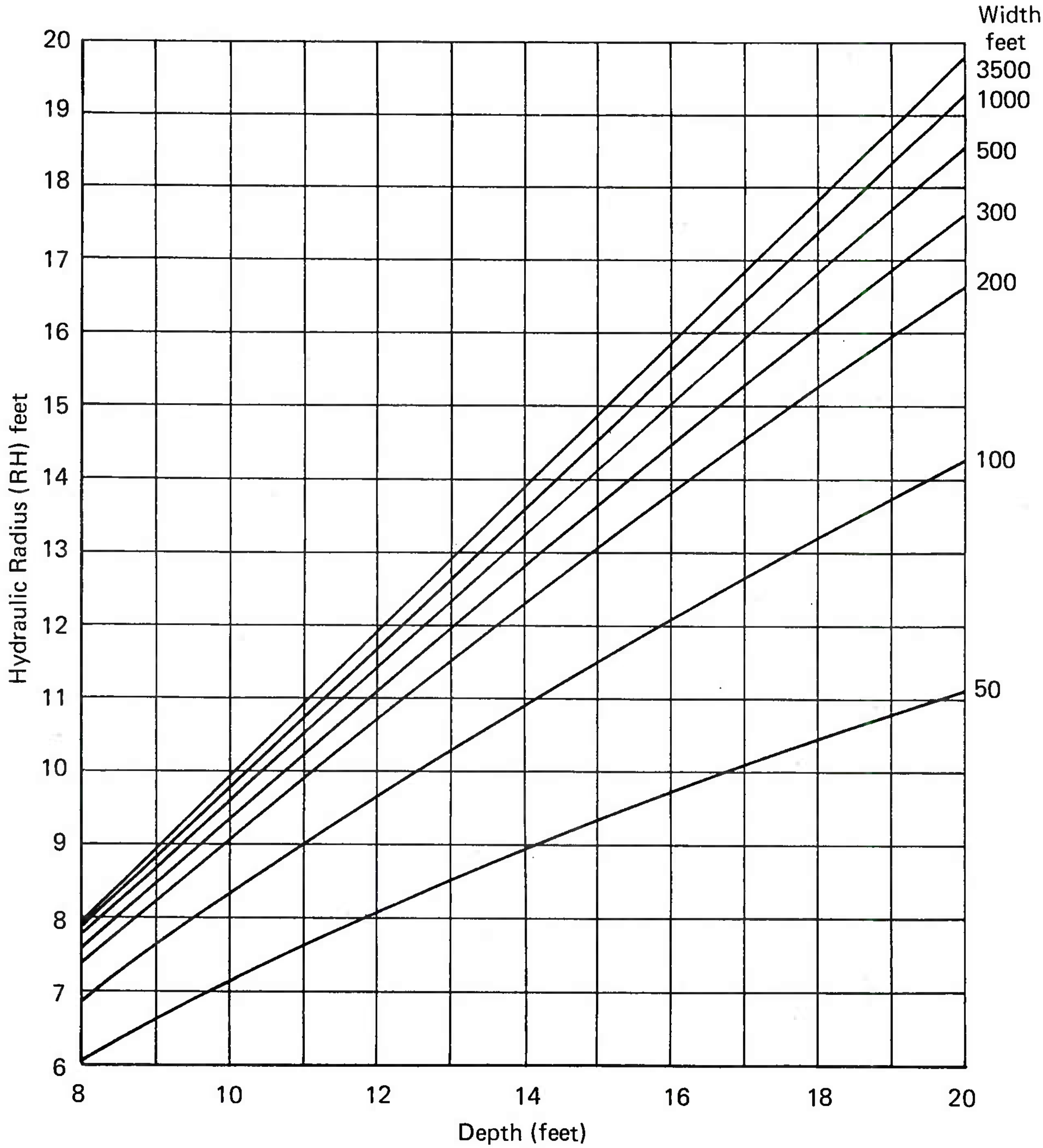


FIGURE R1 HYDRAULIC RADIUS FOR SPILLS OF WATER-SOLUBLE CHEMICALS

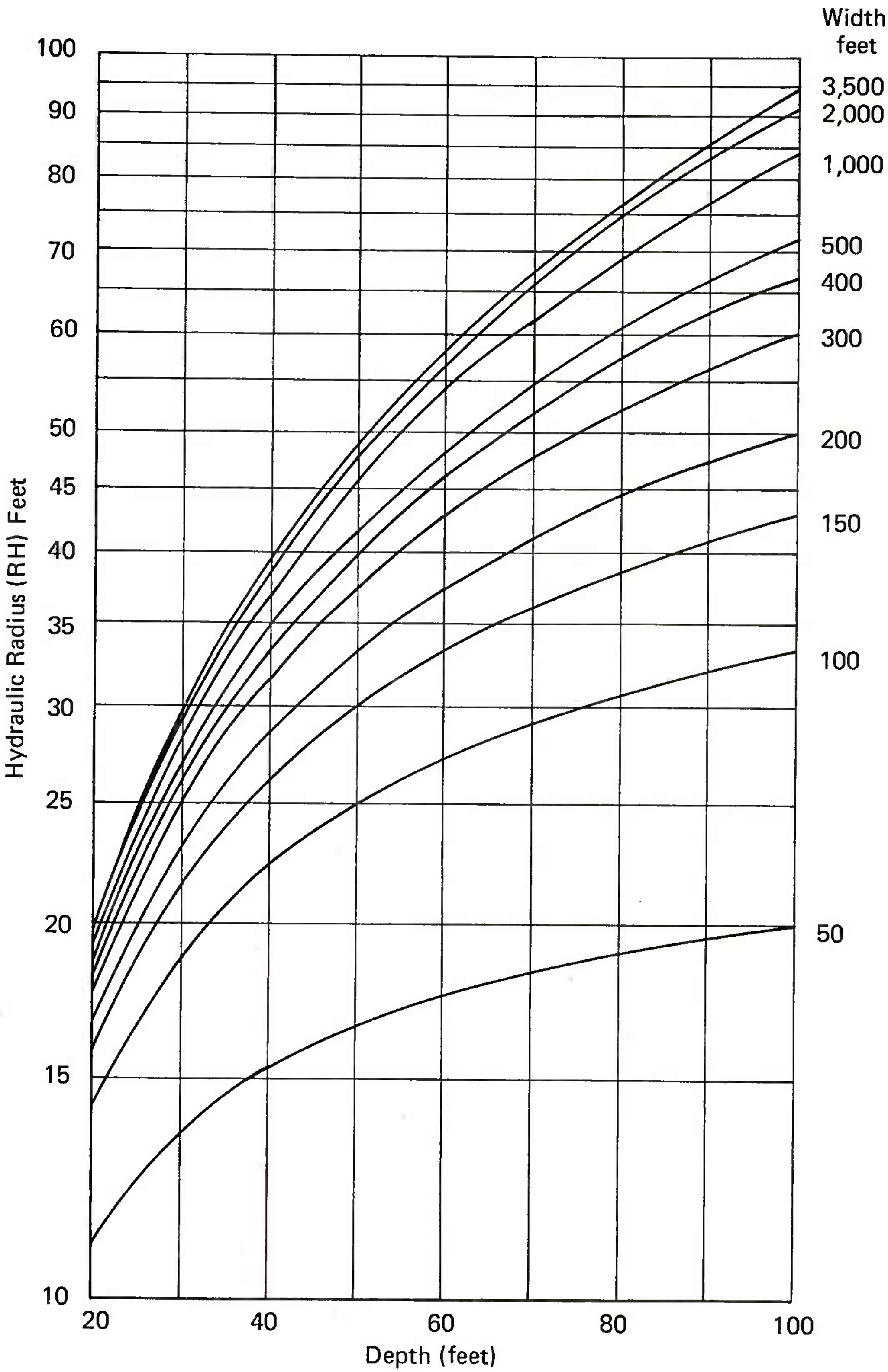


FIGURE R2 HYDRAULIC RADIUS FOR SPILLS OF WATER-SOLUBLE CHEMICALS

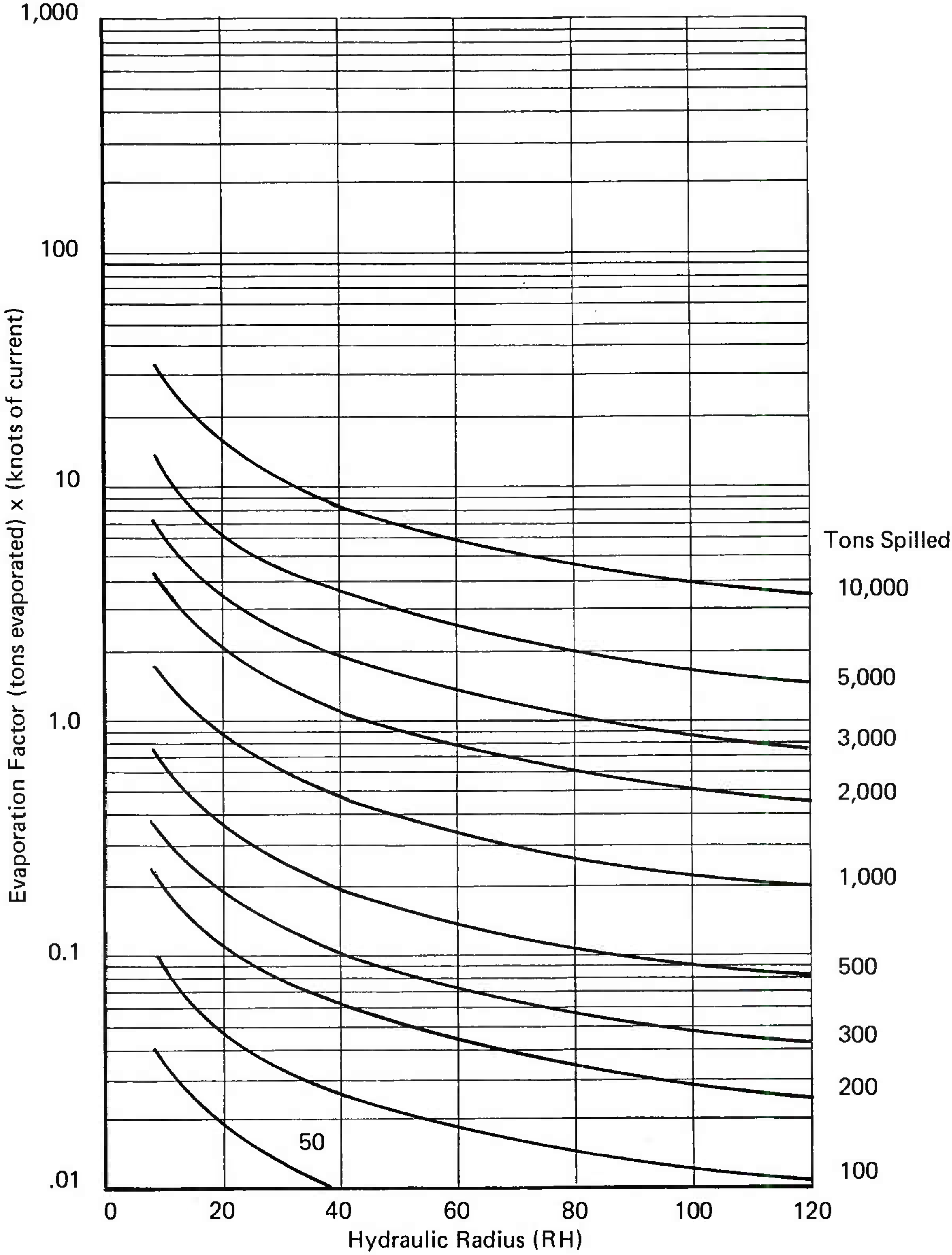


FIGURE R3 EVAPORATION FACTORS FOR SPILLS OF WATER-SOLUBLE CHEMICALS
Chemical: Acetone

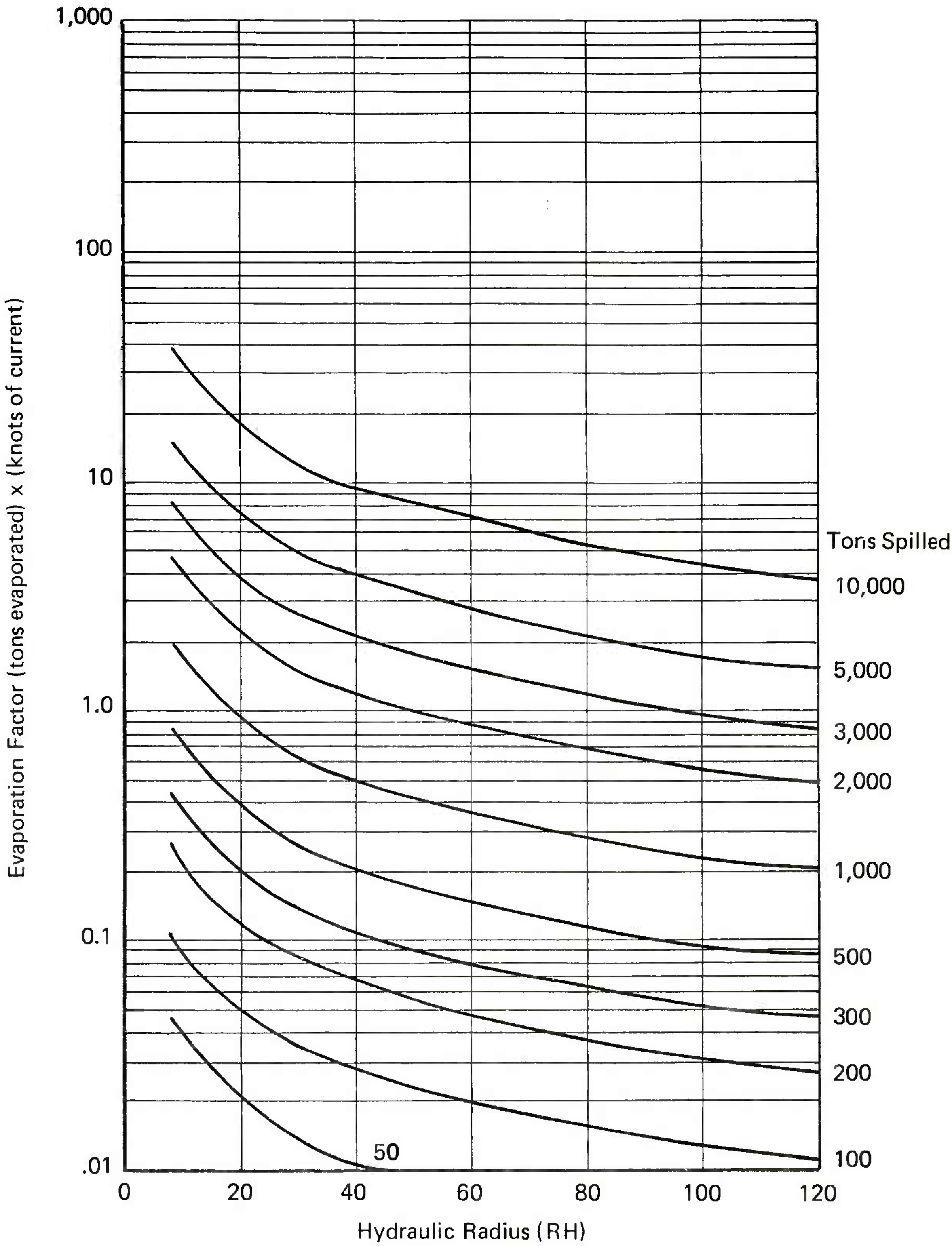


FIGURE R4 EVAPORATION FACTORS FOR SPILLS OF WATER-SOLUBLE CHEMICALS
Chemical: Acetonitrile

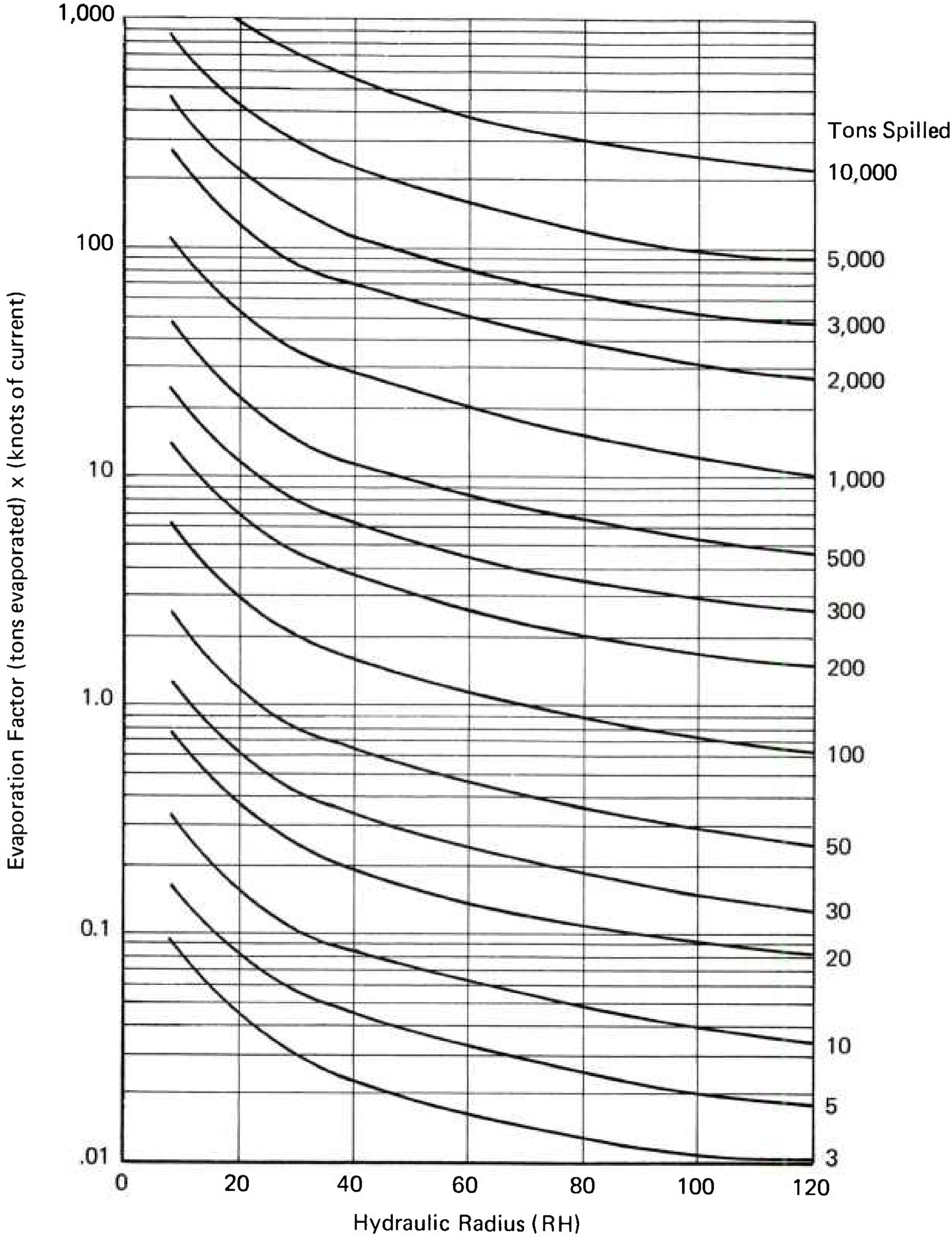


FIGURE R5 EVAPORATION FACTORS FOR SPILLS OF WATER-SOLUBLE CHEMICALS
Chemical: Acrolein

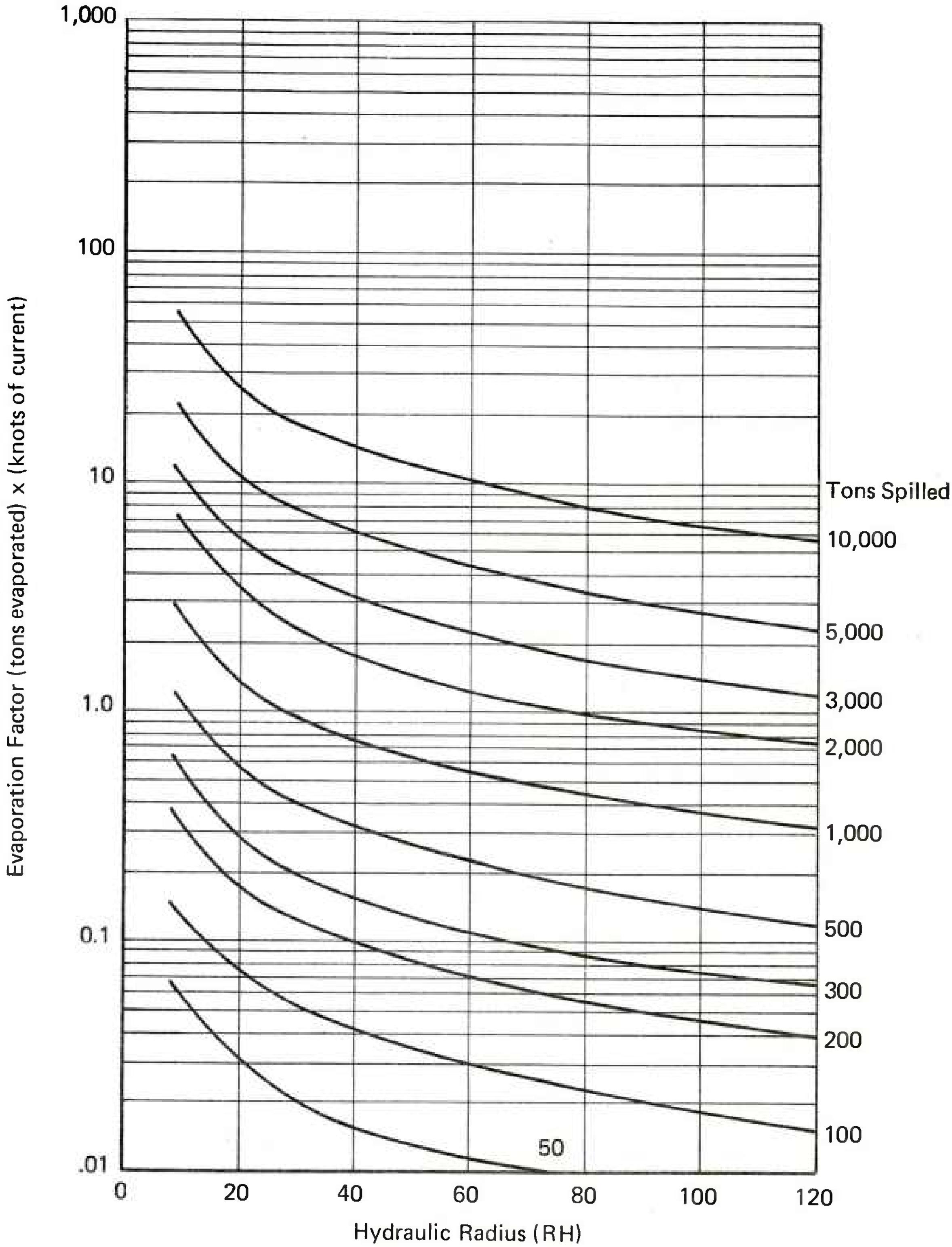


FIGURE R6 EVAPORATION FACTORS FOR SPILLS OF WATER-SOLUBLE CHEMICALS
Chemical: Acrylonitrile

Note: Use a molecular weight of 17 in subsequent calculations.

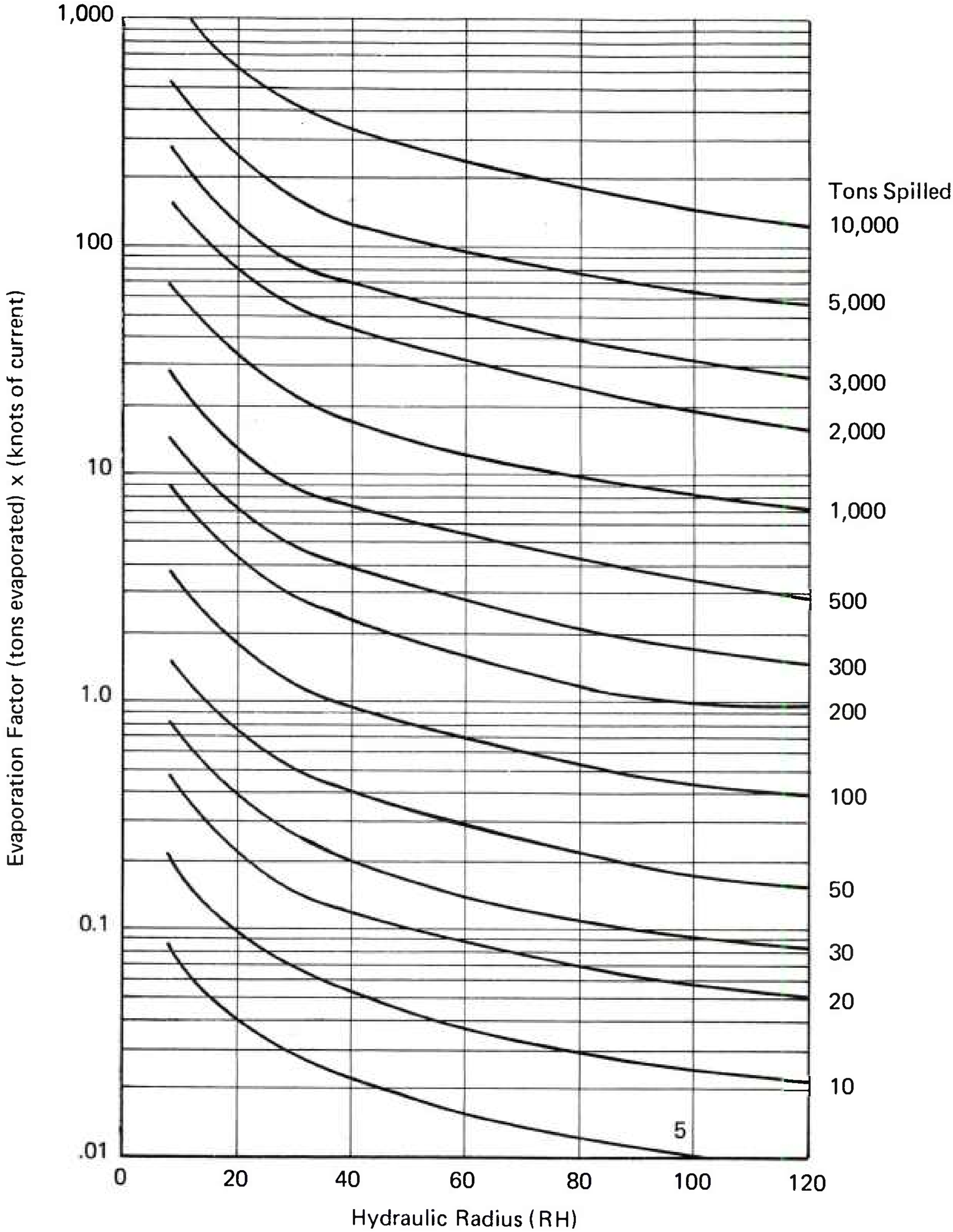


FIGURE R7 EVAPORATION FACTORS FOR SPILLS OF WATER-SOLUBLE CHEMICALS

Chemical: Ammonium Hydroxide (< 28% aqueous ammonia)

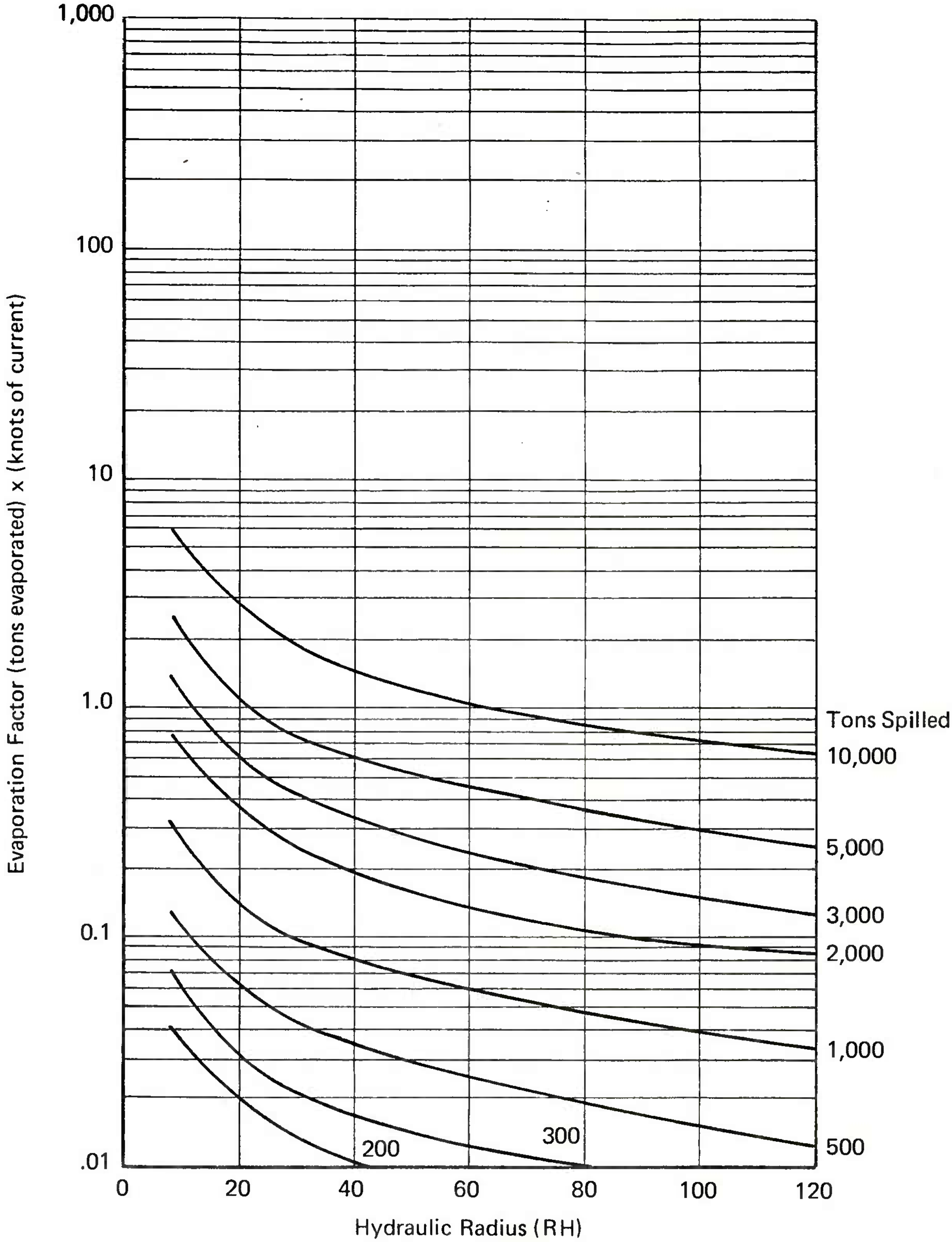


FIGURE R8 EVAPORATION FACTORS FOR SPILLS OF WATER-SOLUBLE CHEMICALS
Chemical: tert-Butyl Alcohol

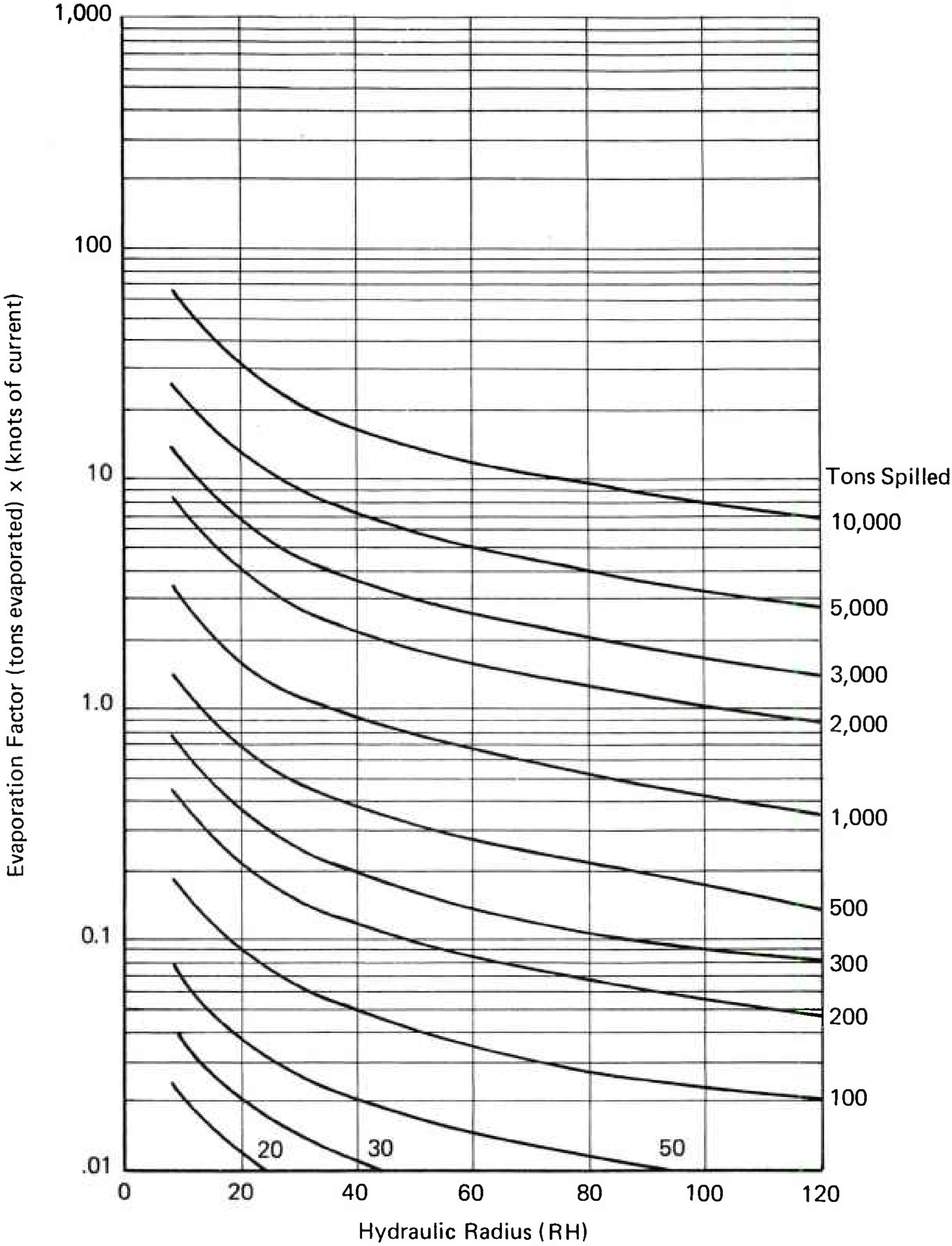


FIGURE R9 EVAPORATION FACTORS FOR SPILLS OF WATER-SOLUBLE CHEMICALS
Chemical: n–Butylamine

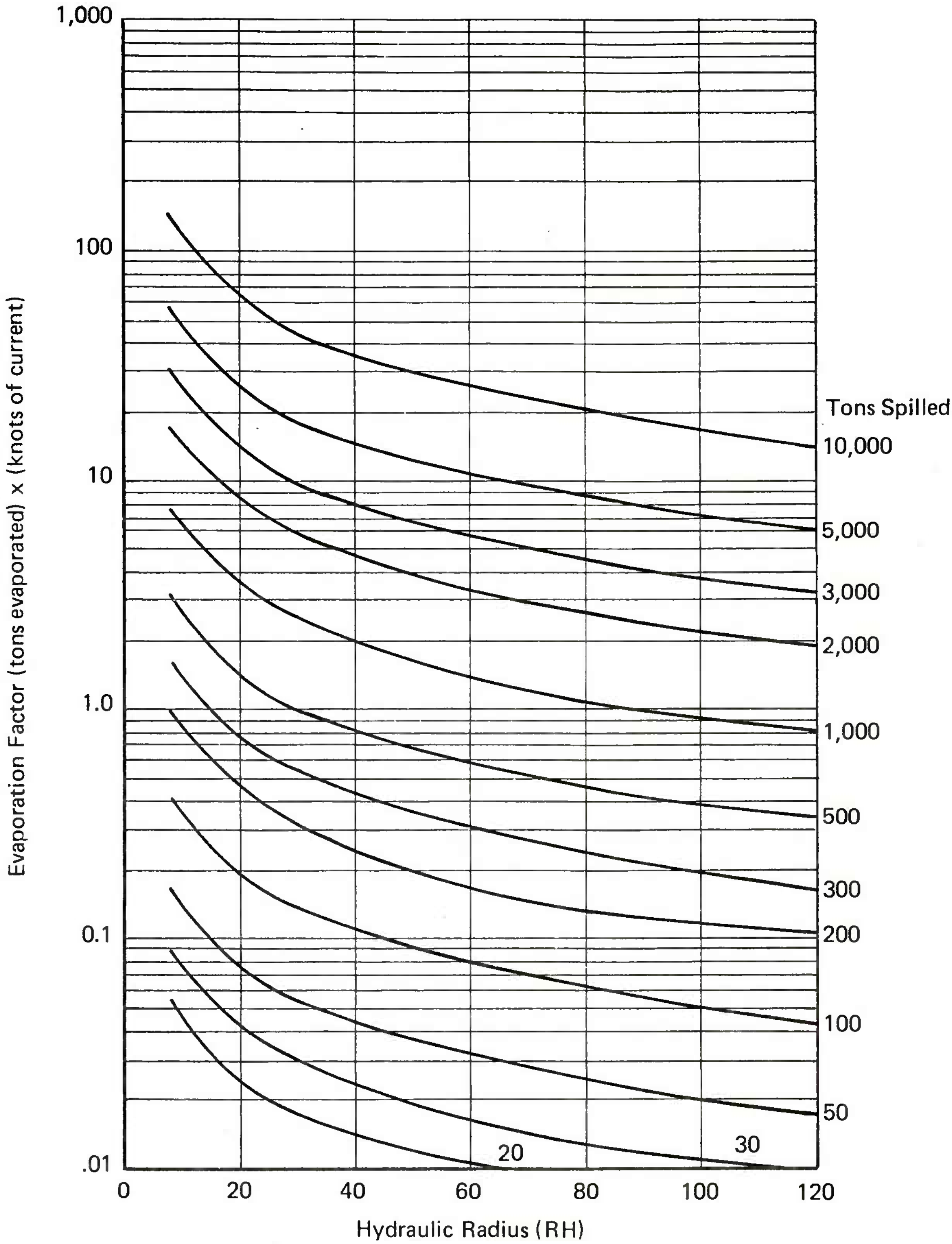


FIGURE R10 EVAPORATION FACTORS FOR SPILLS OF WATER-SOLUBLE CHEMICALS
Chemical: sec — Butylamine

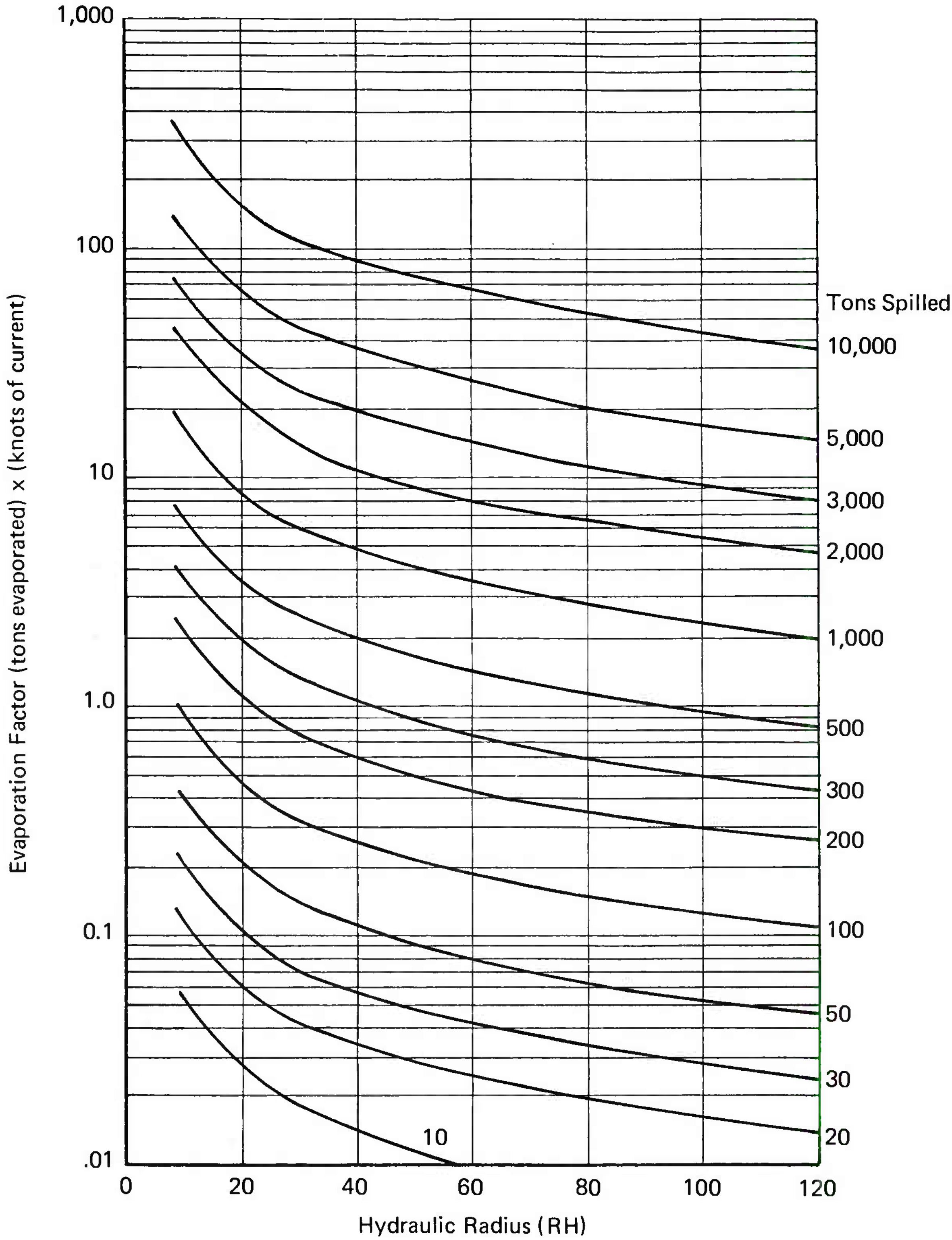


FIGURE R11 EVAPORATION FACTORS FOR SPILLS OF WATER-SOLUBLE CHEMICALS
Chemical: tert – Butylamine

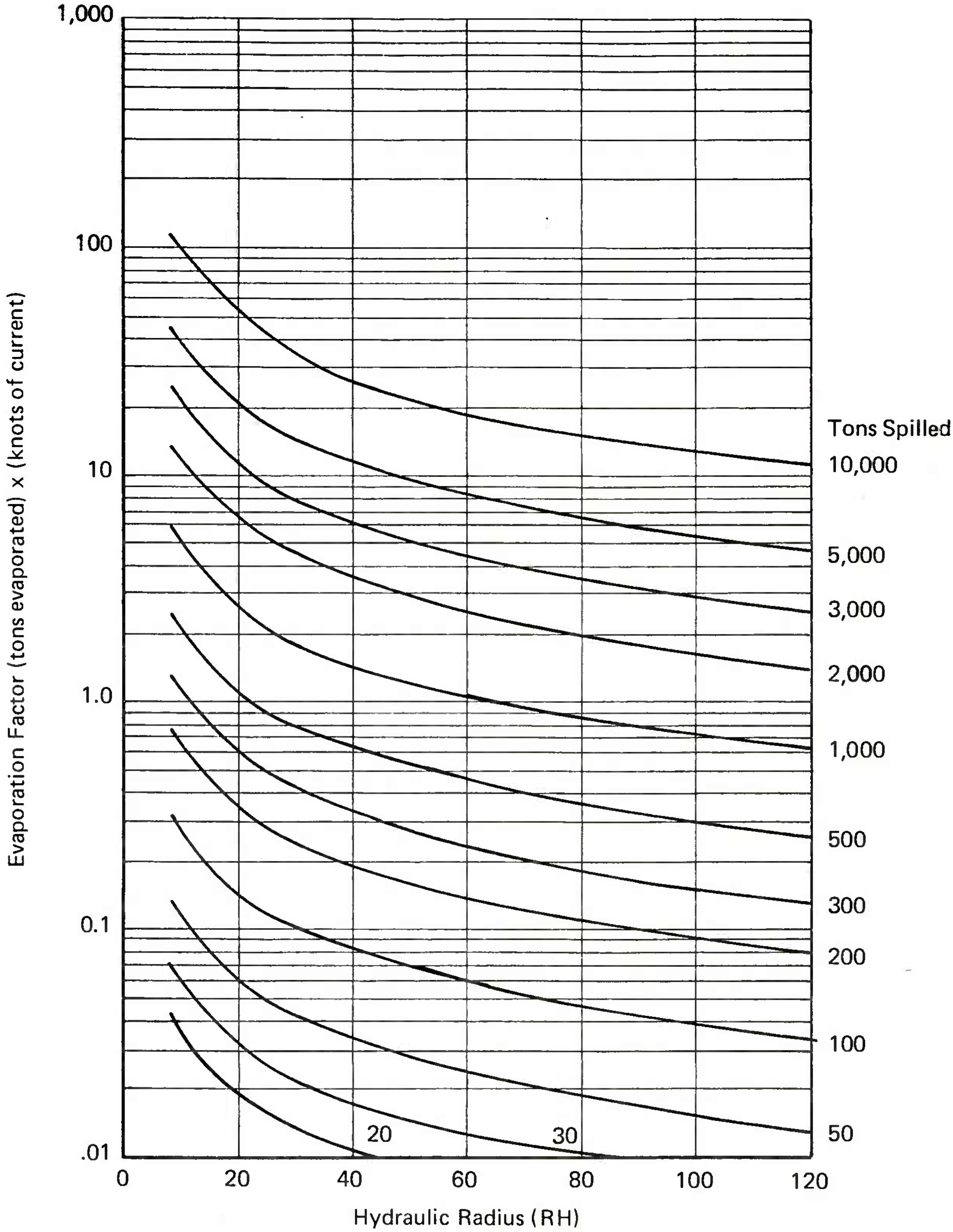


FIGURE R12 EVAPORATION FACTORS FOR SPILLS OF WATER-SOLUBLE CHEMICALS
Chemical: Butylene Oxide

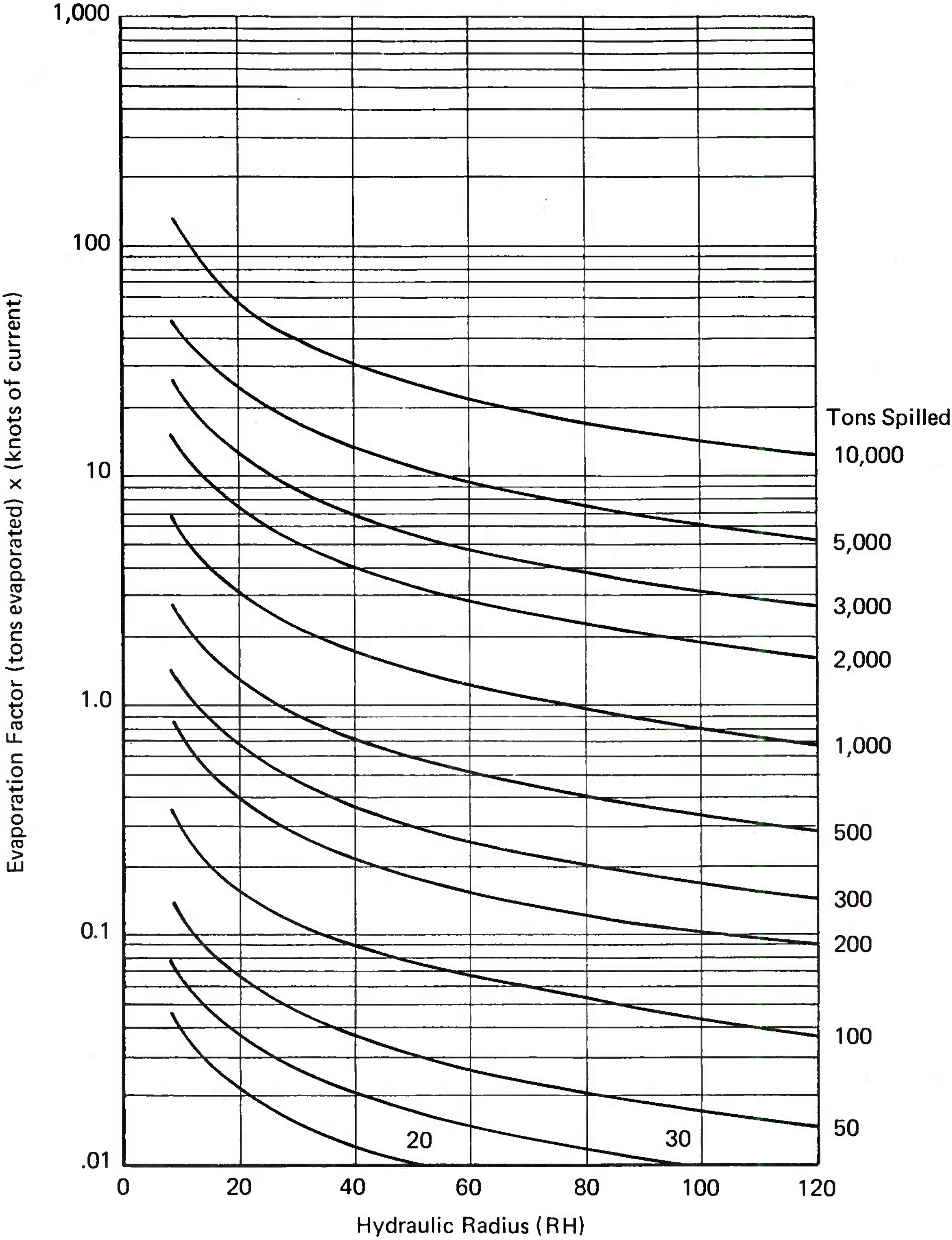


FIGURE R13 EVAPORATION FACTORS FOR SPILLS OF WATER-SOLUBLE CHEMICALS

Chemical: Diethylamine

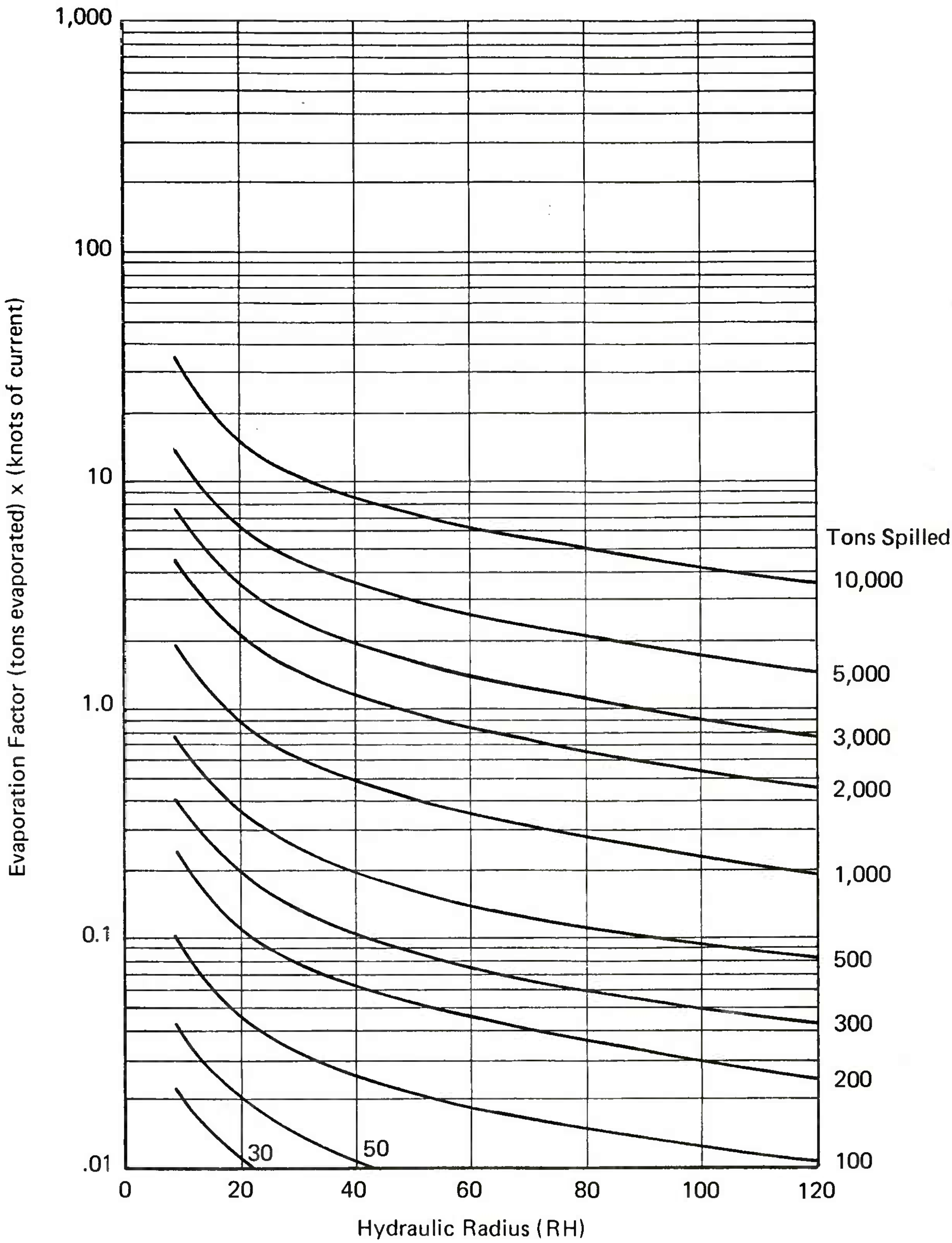


FIGURE R14 EVAPORATION FACTORS FOR SPILLS OF WATER-SOLUBLE CHEMICALS
Chemical: Diisopropylamine

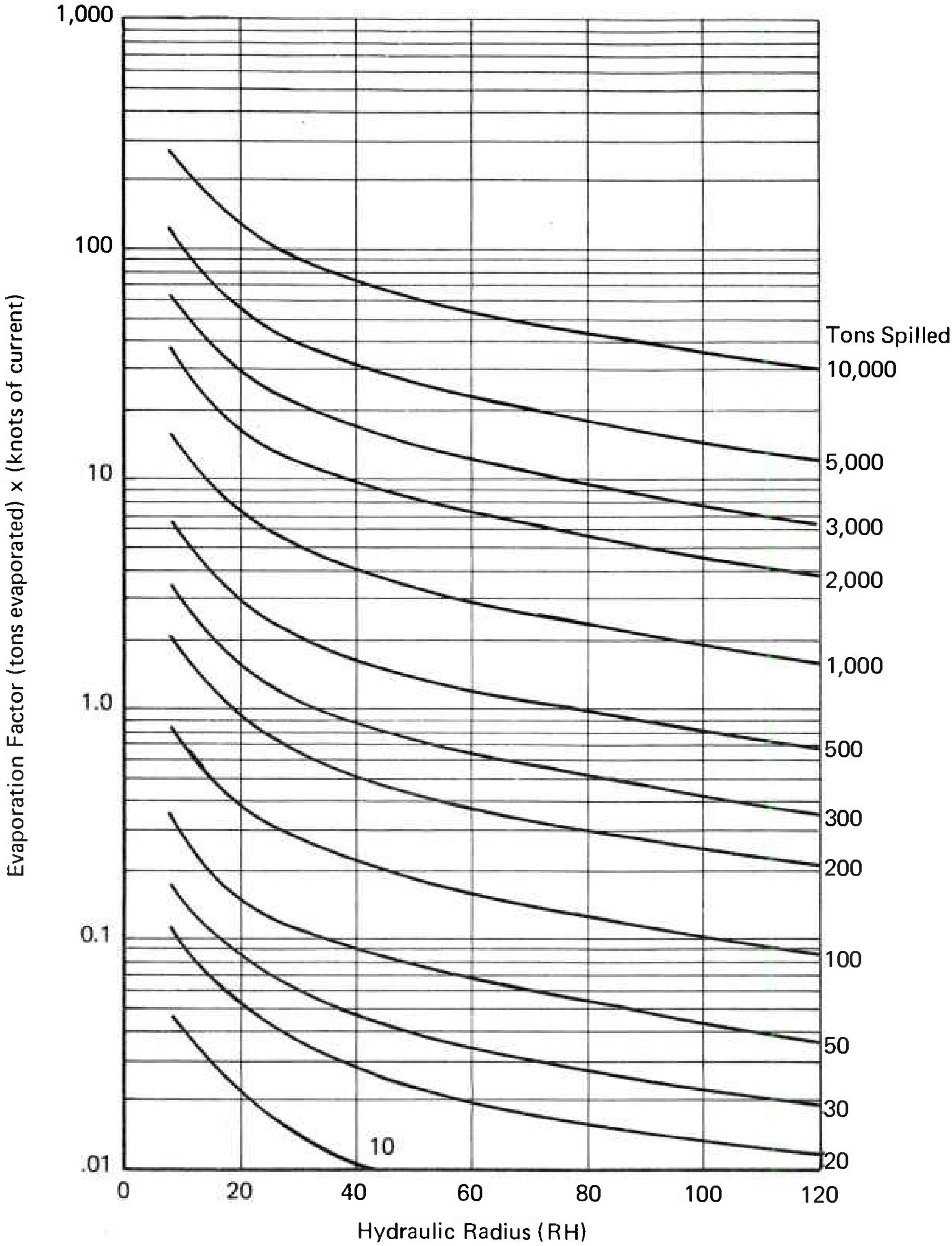


FIGURE R15 EVAPORATION FACTORS FOR SPILLS OF WATER-SOLUBLE CHEMICALS
Chemical: 1,1 — Dimethylhydrazine

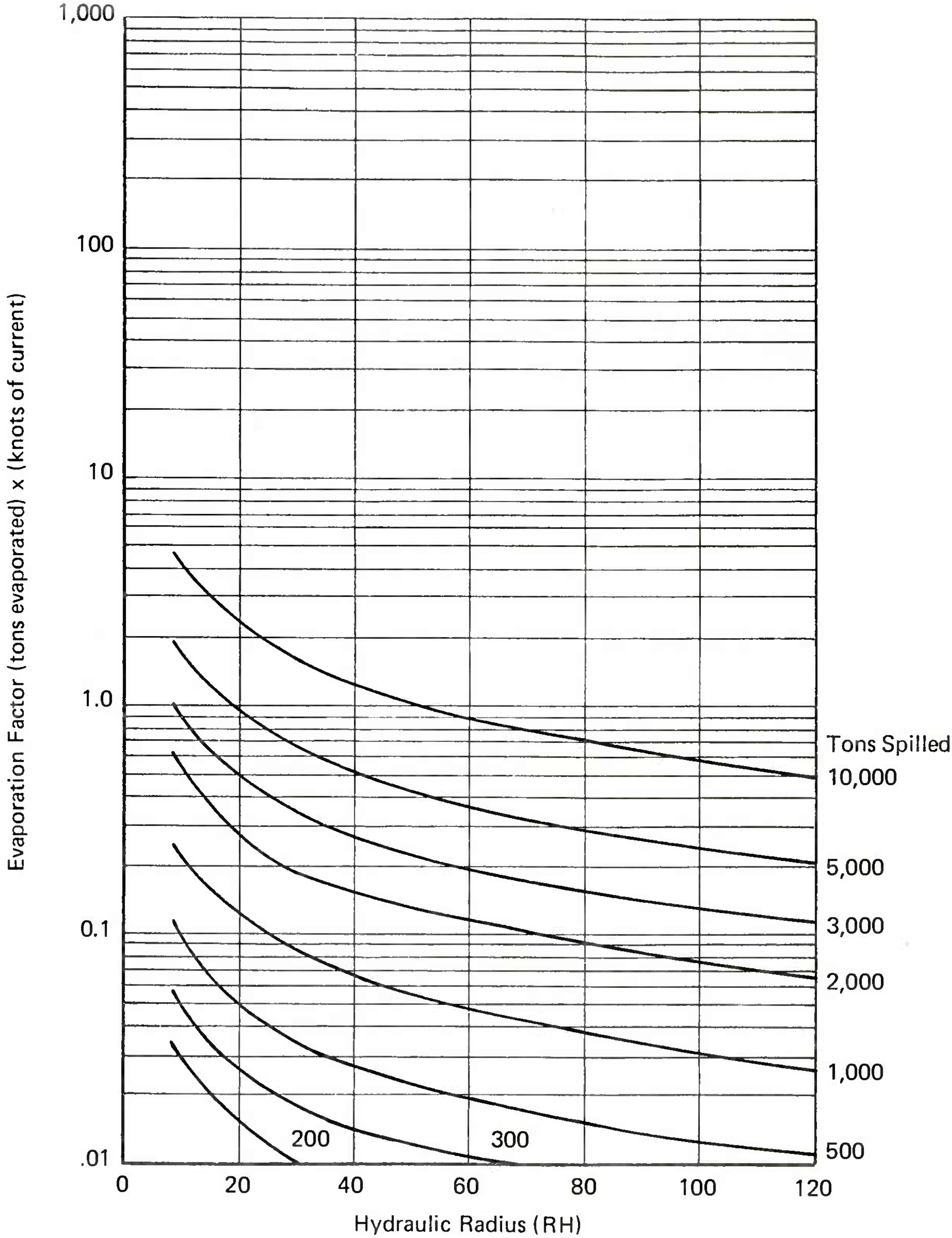


FIGURE R16 EVAPORATION FACTORS FOR SPILLS OF WATER-SOLUBLE CHEMICALS
Chemical: Ethyl Alcohol

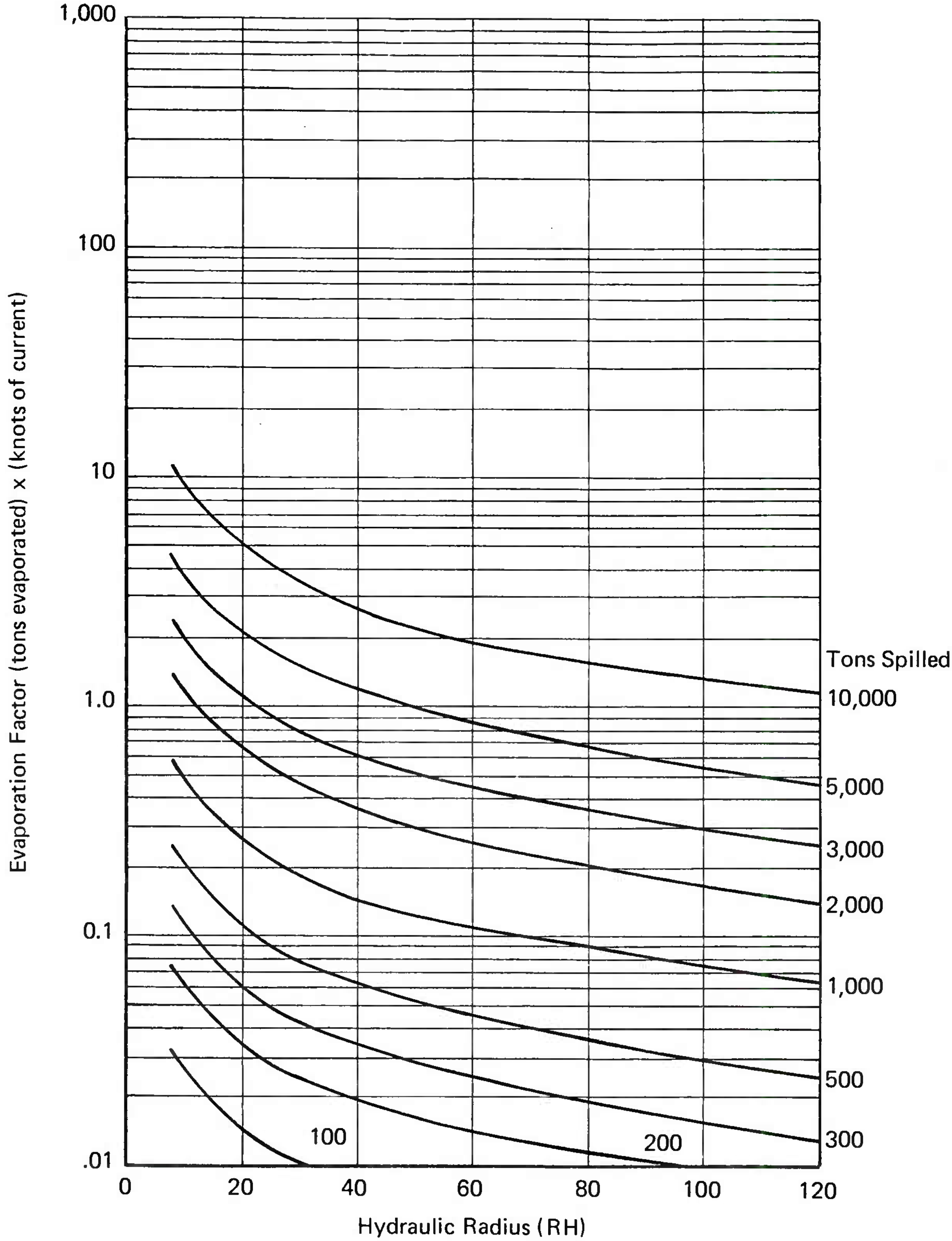


FIGURE R17 EVAPORATION FACTORS FOR SPILLS OF WATER-SOLUBLE CHEMICALS
Chemical: Ethylene Glycol Dimethyl Ether

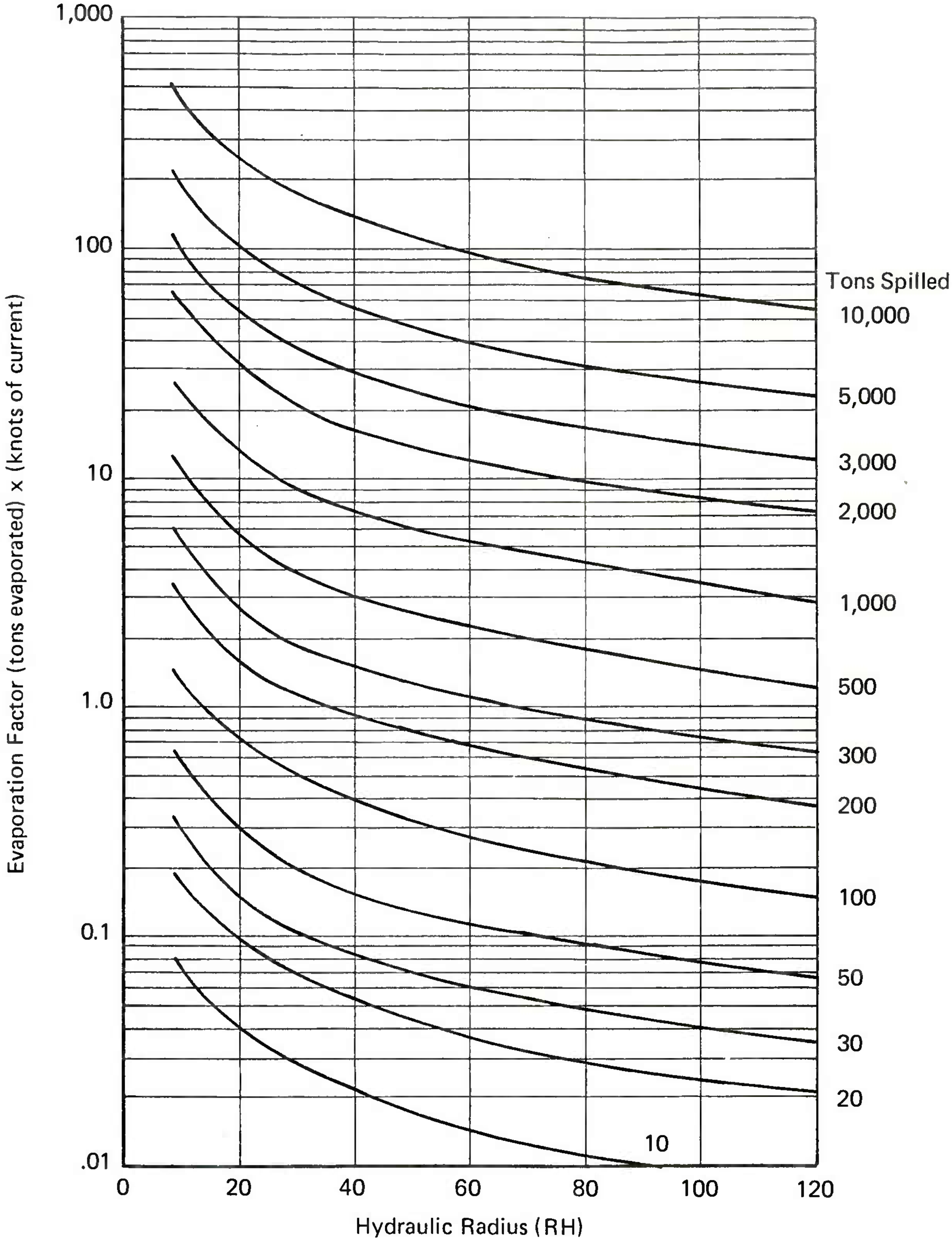


FIGURE R18 EVAPORATION FACTORS FOR SPILLS OF WATER-SOLUBLE CHEMICALS
Chemical: Ethyleneimine

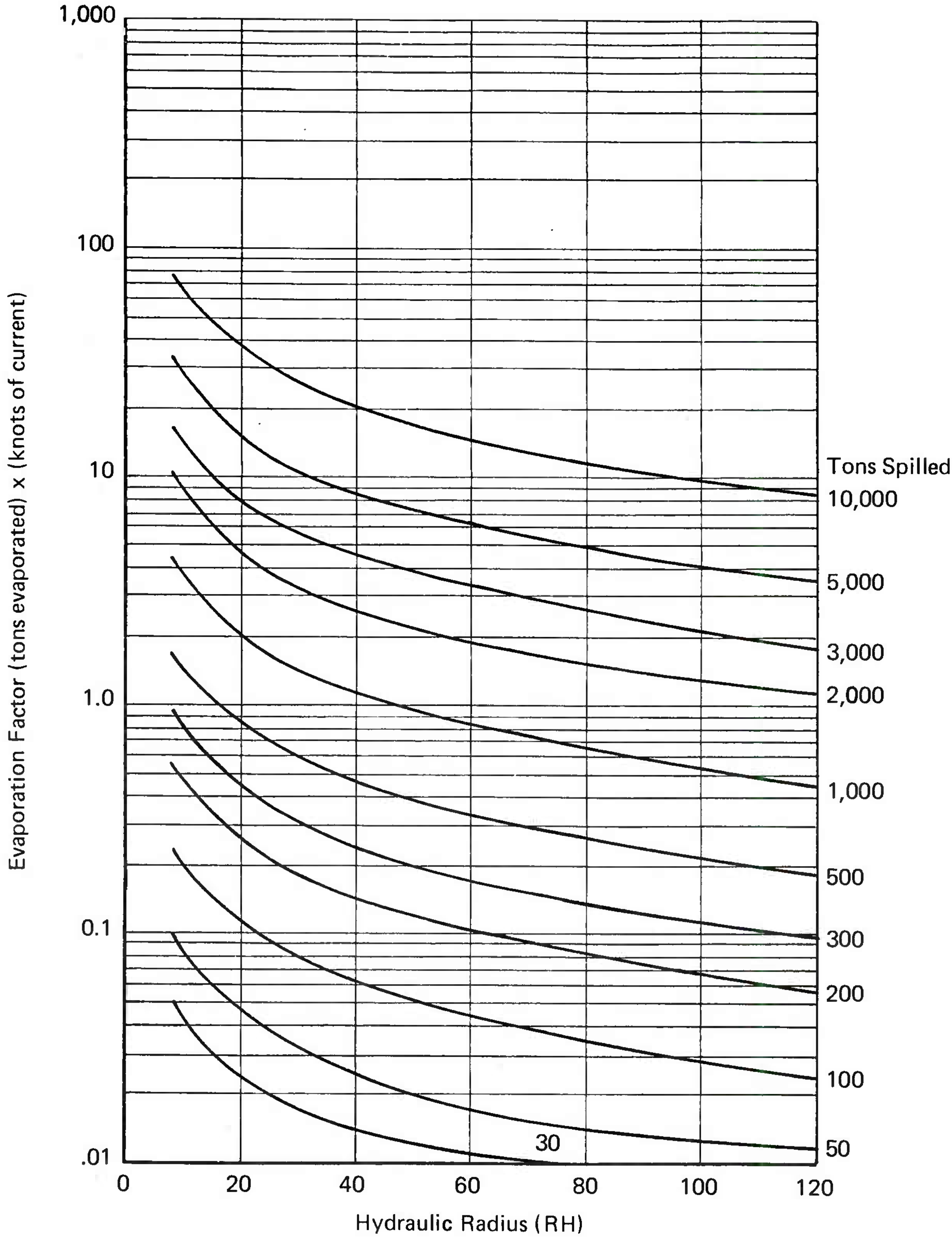


FIGURE R19 EVAPORATION FACTORS FOR SPILLS OF WATER-SOLUBLE CHEMICALS
Chemical: Ethyl Formate

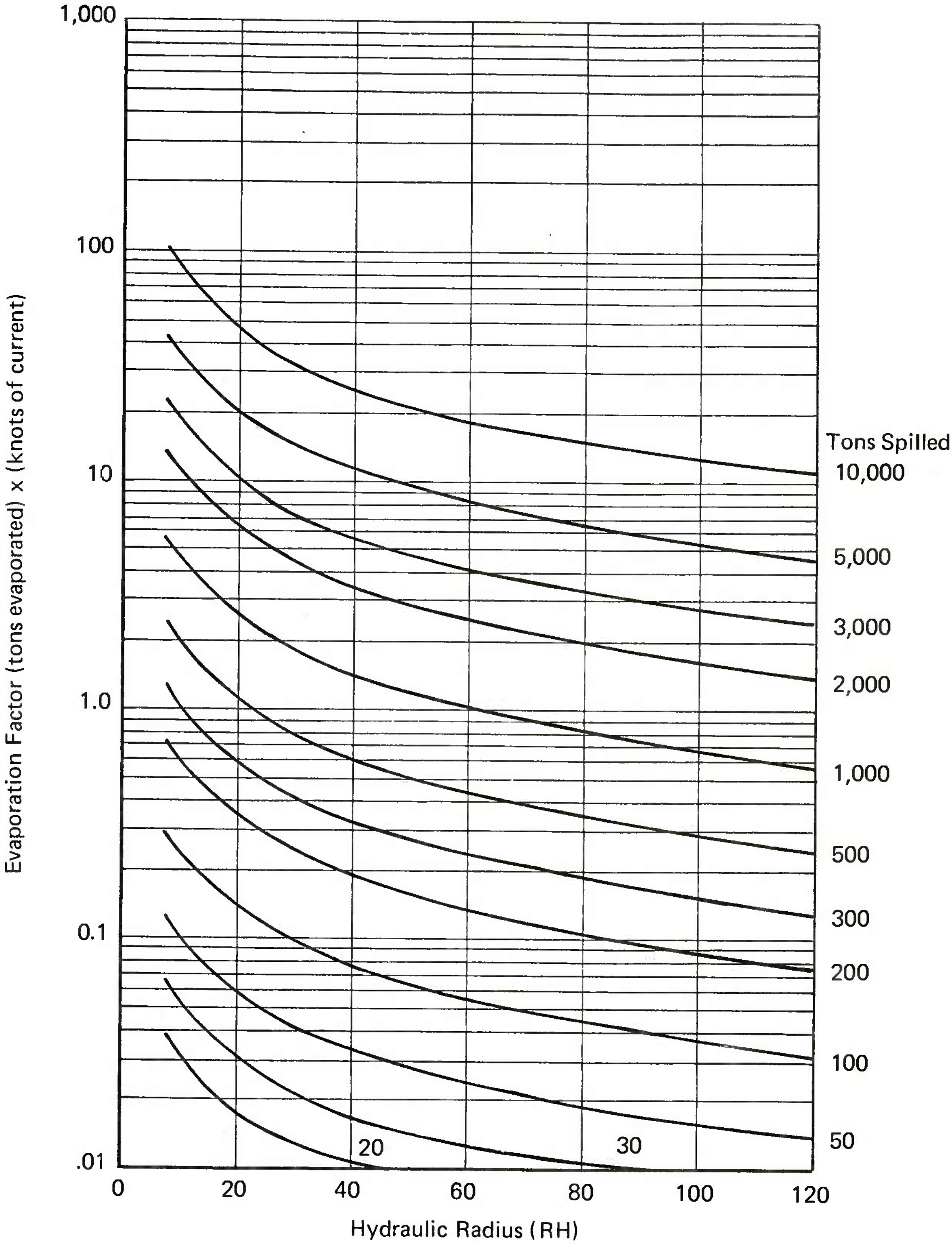


FIGURE R20 EVAPORATION FACTORS FOR SPILLS OF WATER-SOLUBLE CHEMICALS
Chemical: Isobutylamine

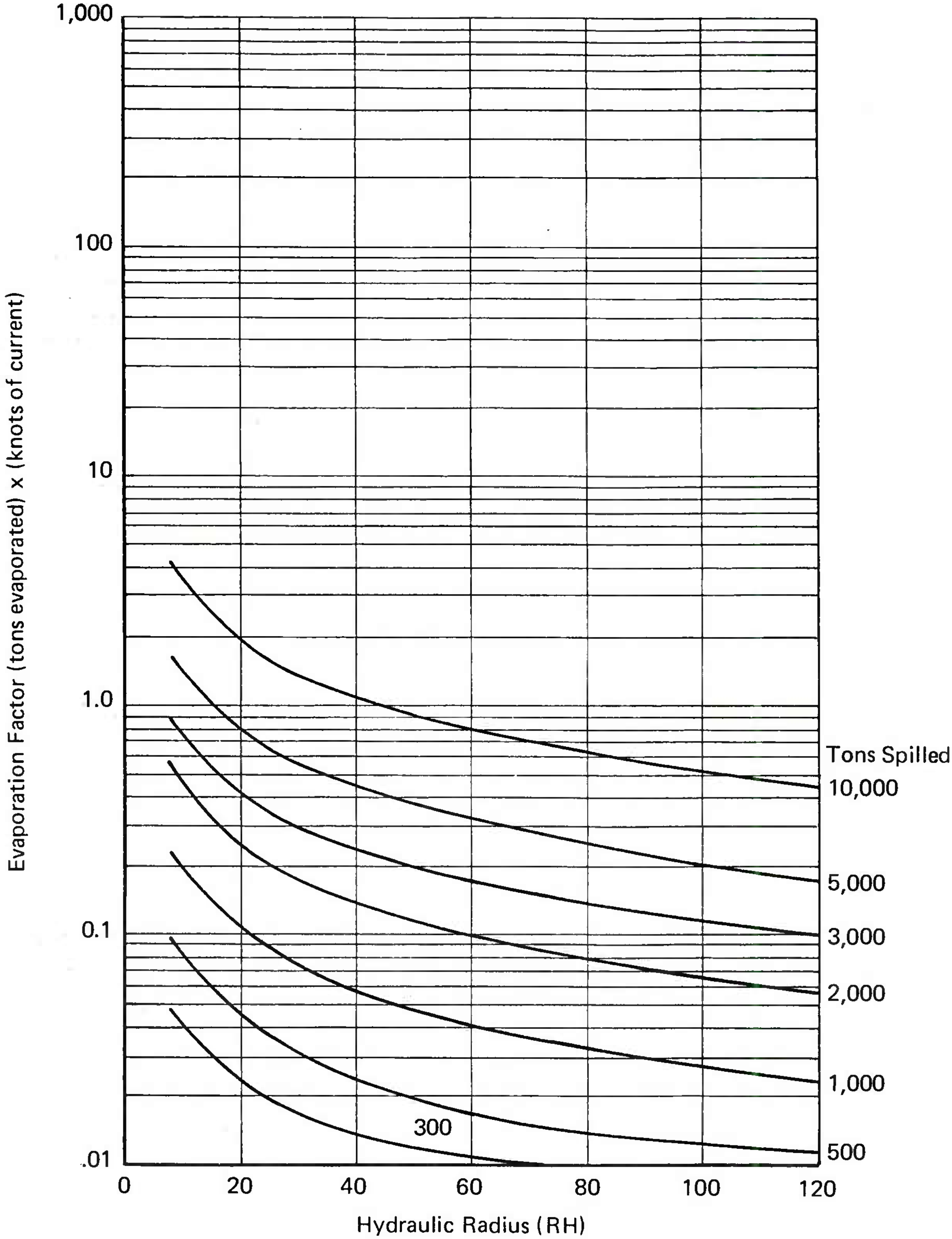


FIGURE R21 EVAPORATION FACTORS FOR SPILLS OF WATER-SOLUBLE CHEMICALS
Chemical: Isopropyl Alcohol

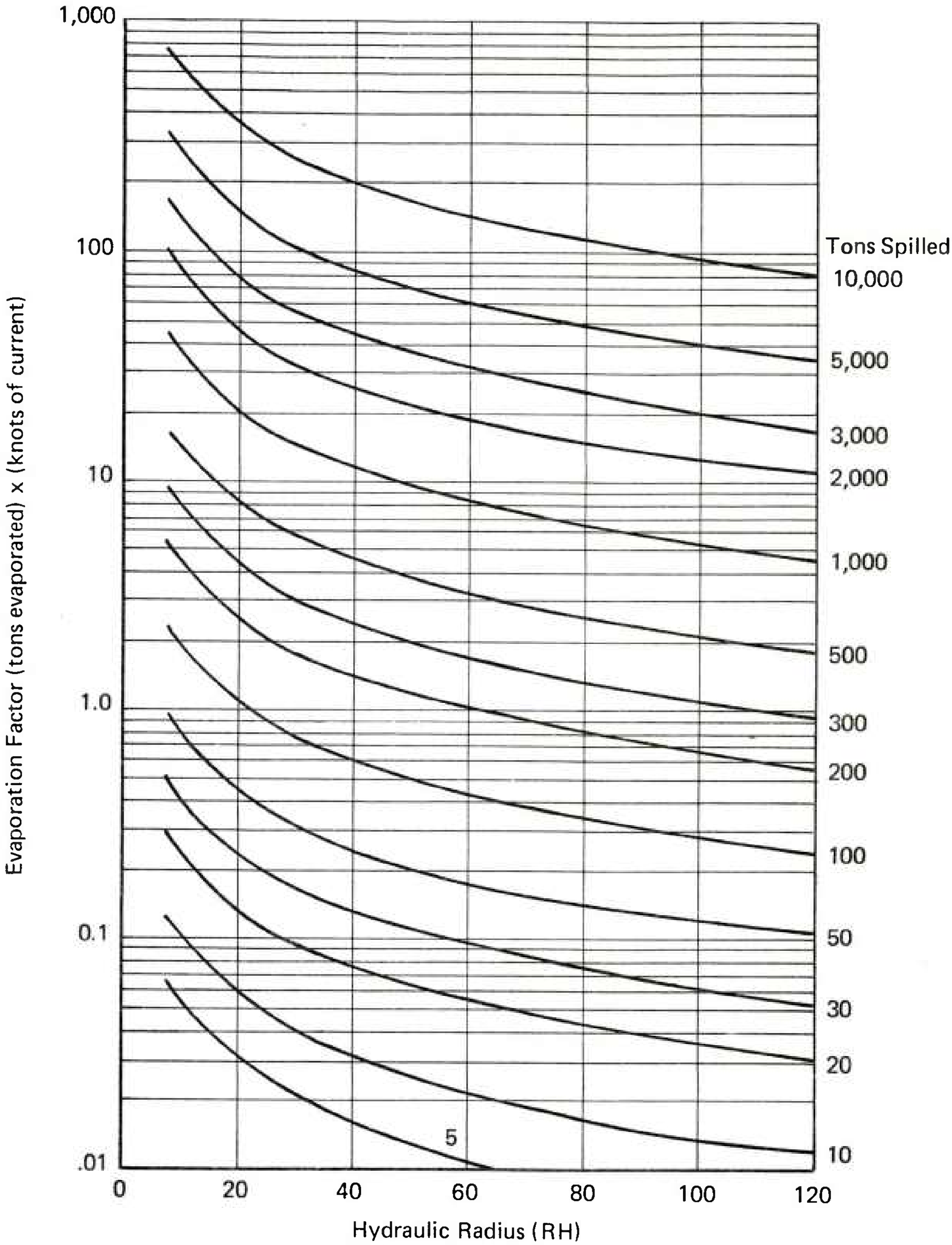


FIGURE R22 EVAPORATION FACTORS FOR SPILLS OF WATER-SOLUBLE CHEMICALS
Chemical: Isopropylamine

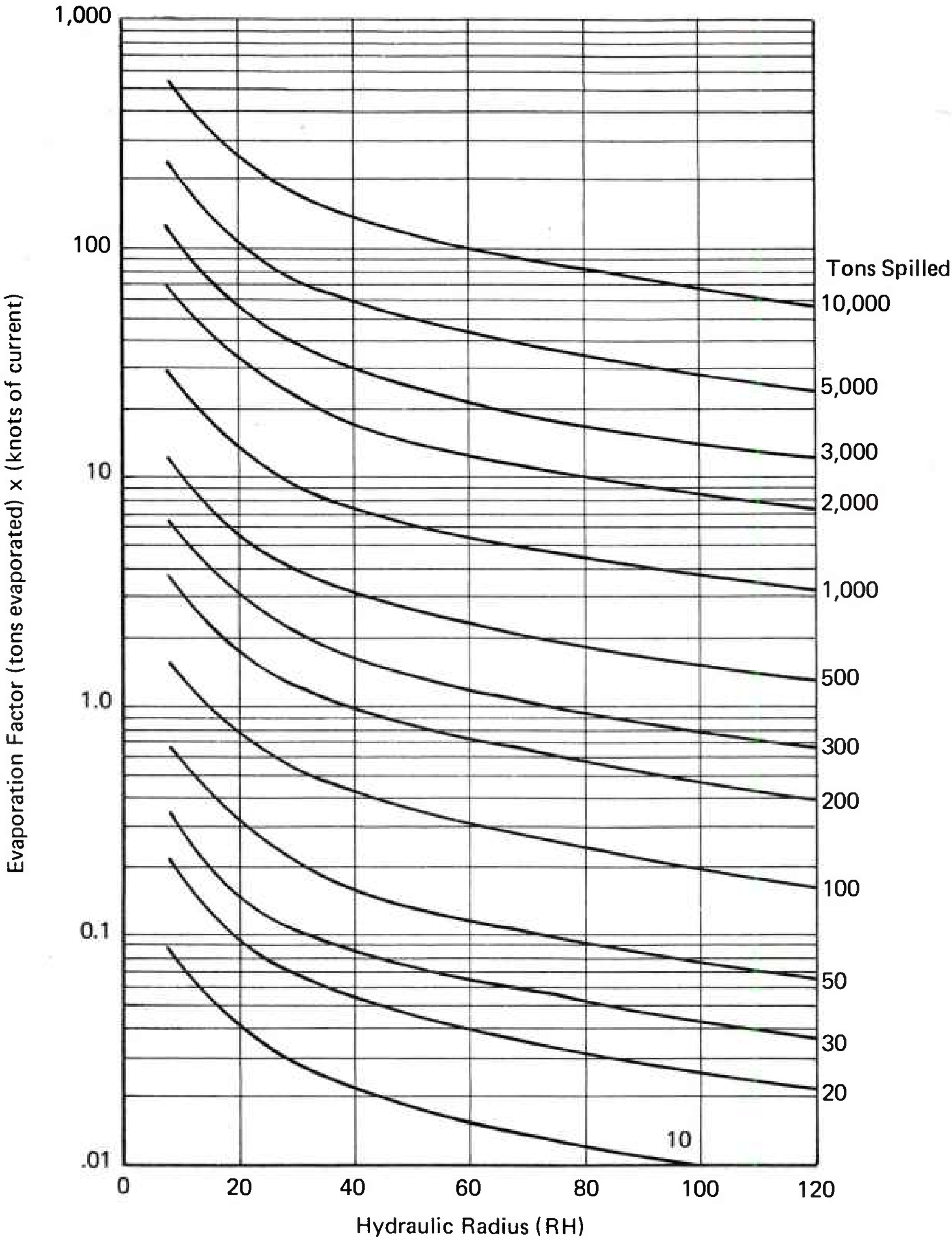


FIGURE R23 EVAPORATION FACTORS FOR SPILLS OF WATER-SOLUBLE CHEMICALS
Chemical: Isopropyl Mercaptan

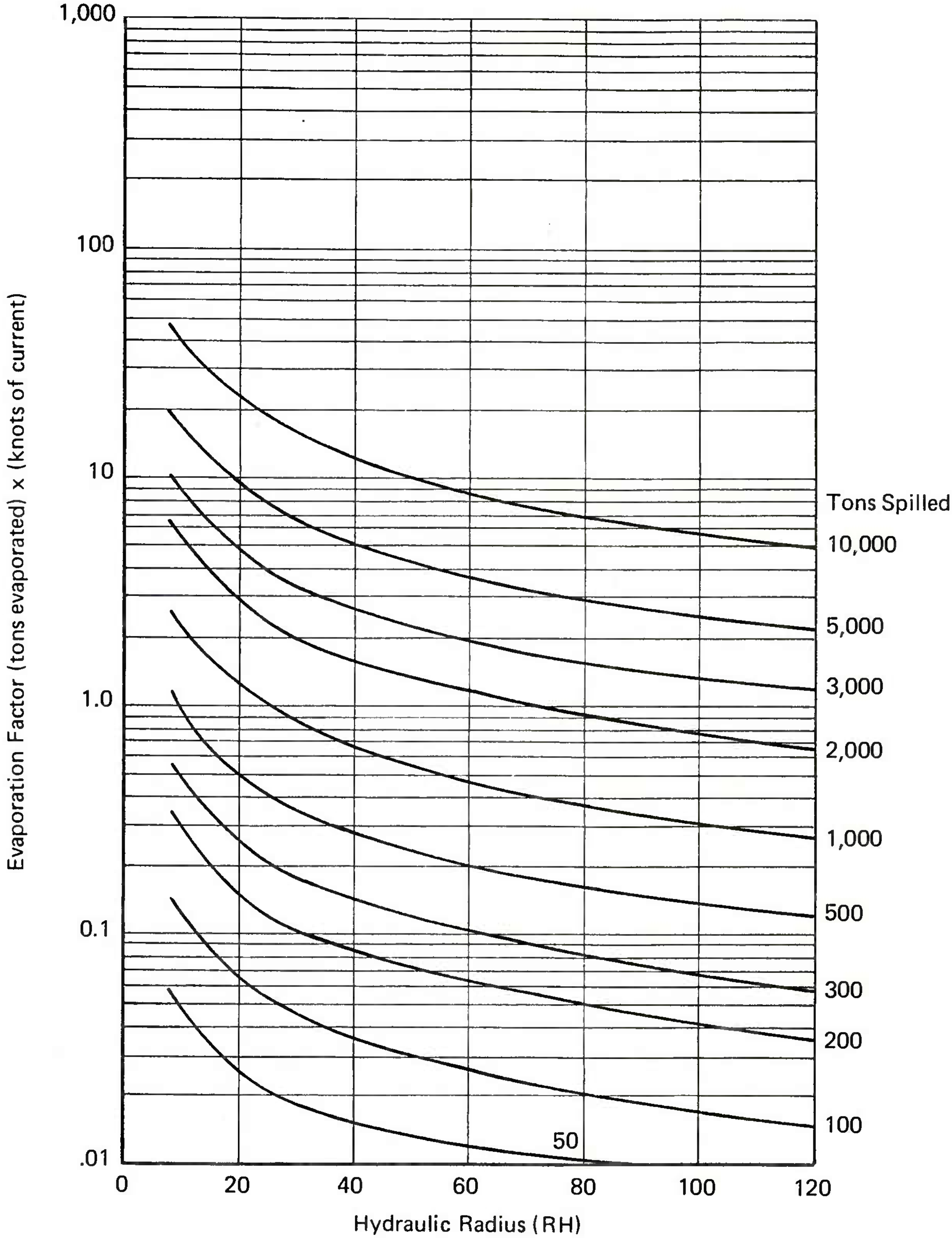


FIGURE R24 EVAPORATION FACTORS FOR SPILLS OF WATER-SOLUBLE CHEMICALS
Chemical: Methyl Acetate

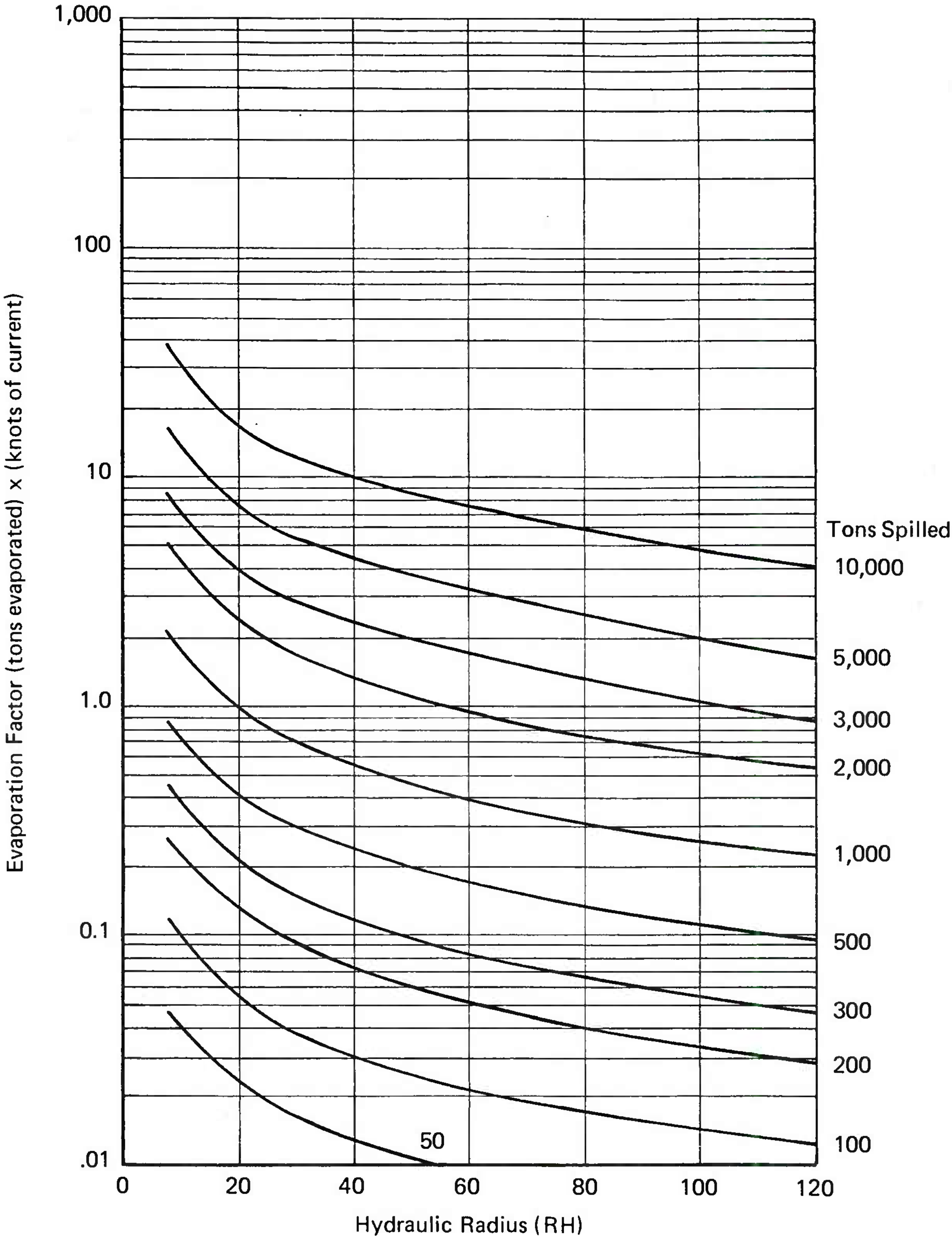


FIGURE R25 EVAPORATION FACTORS FOR SPILLS OF WATER-SOLUBLE CHEMICALS
Chemical: Methyl Alcohol

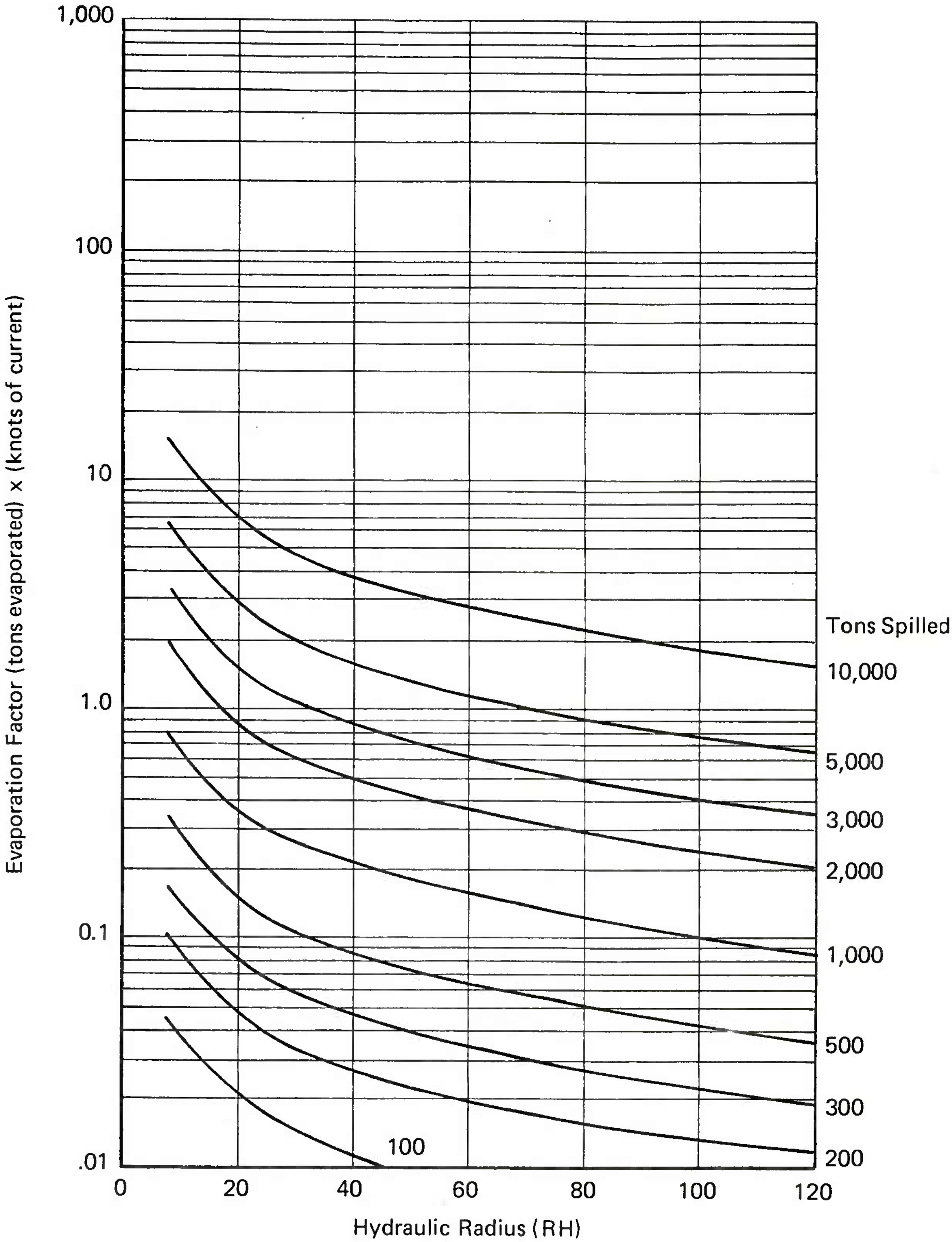


FIGURE R26 EVAPORATION FACTORS FOR SPILLS OF WATER-SOLUBLE CHEMICALS
Chemical: Methyl Ethyl Ketone

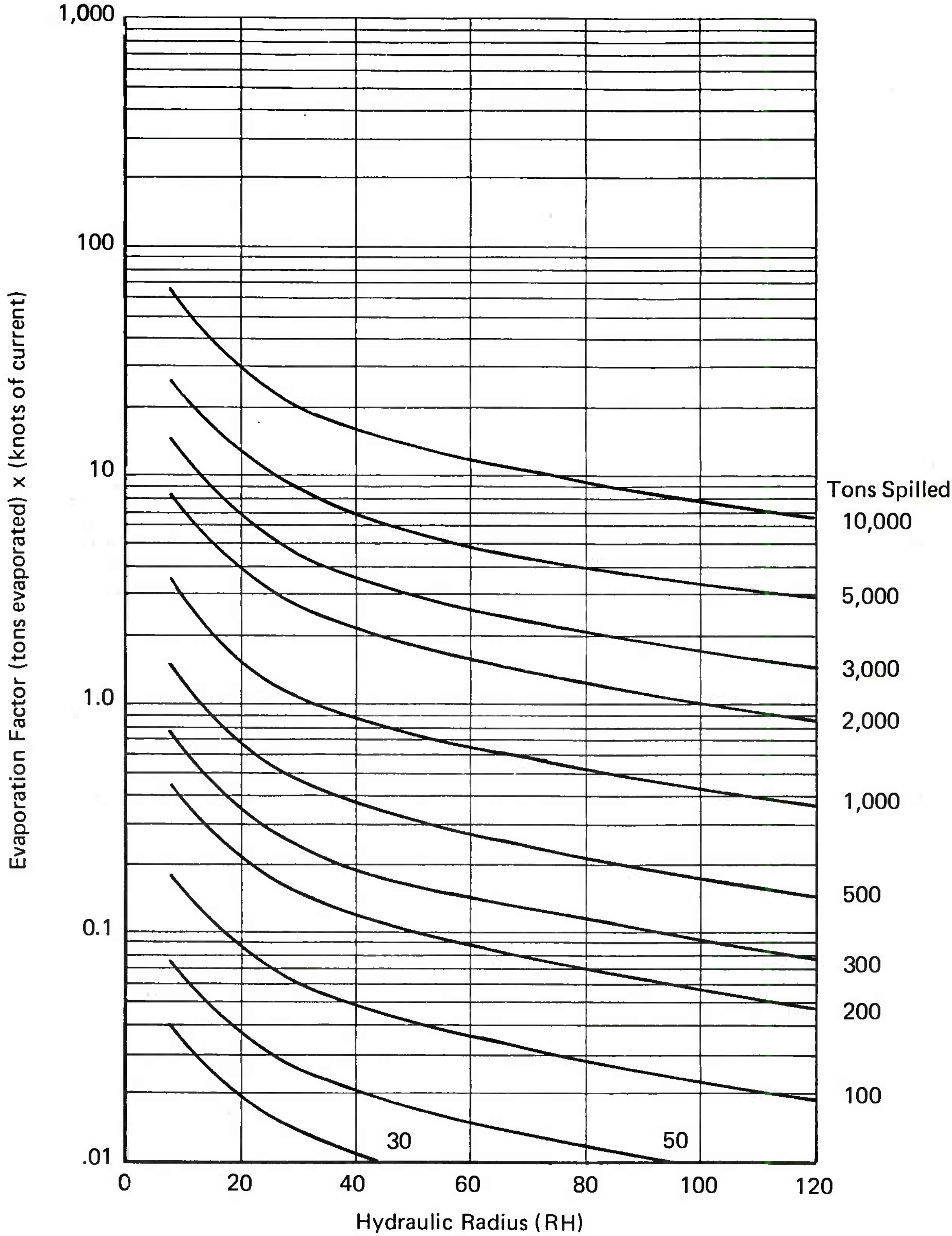


FIGURE R27 EVAPORATION FACTORS FOR SPILLS OF WATER-SOLUBLE CHEMICALS
Chemical: Methyl Formal

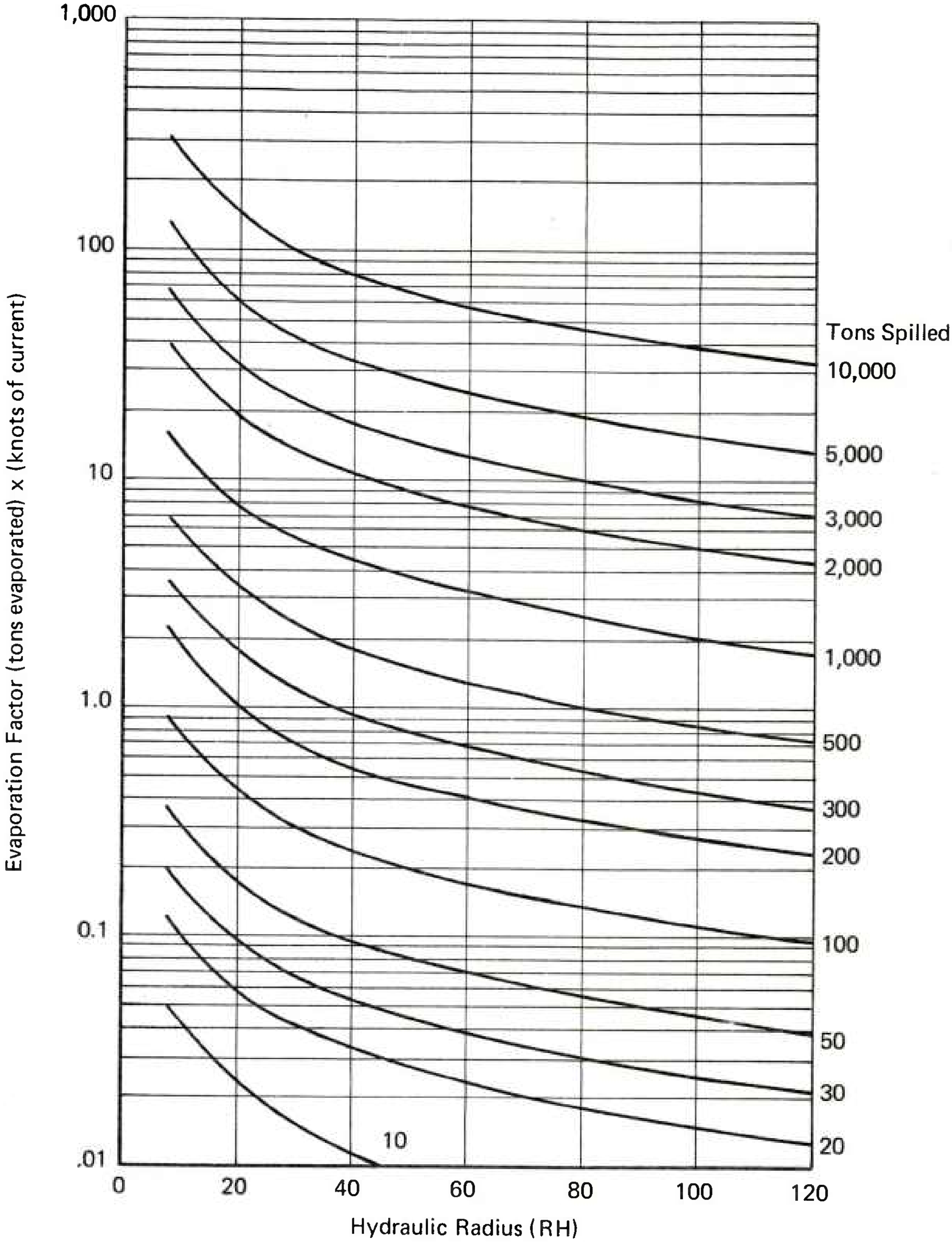


FIGURE R28 EVAPORATION FACTORS FOR SPILLS OF WATER-SOLUBLE CHEMICALS
Chemical: Methyl Formate

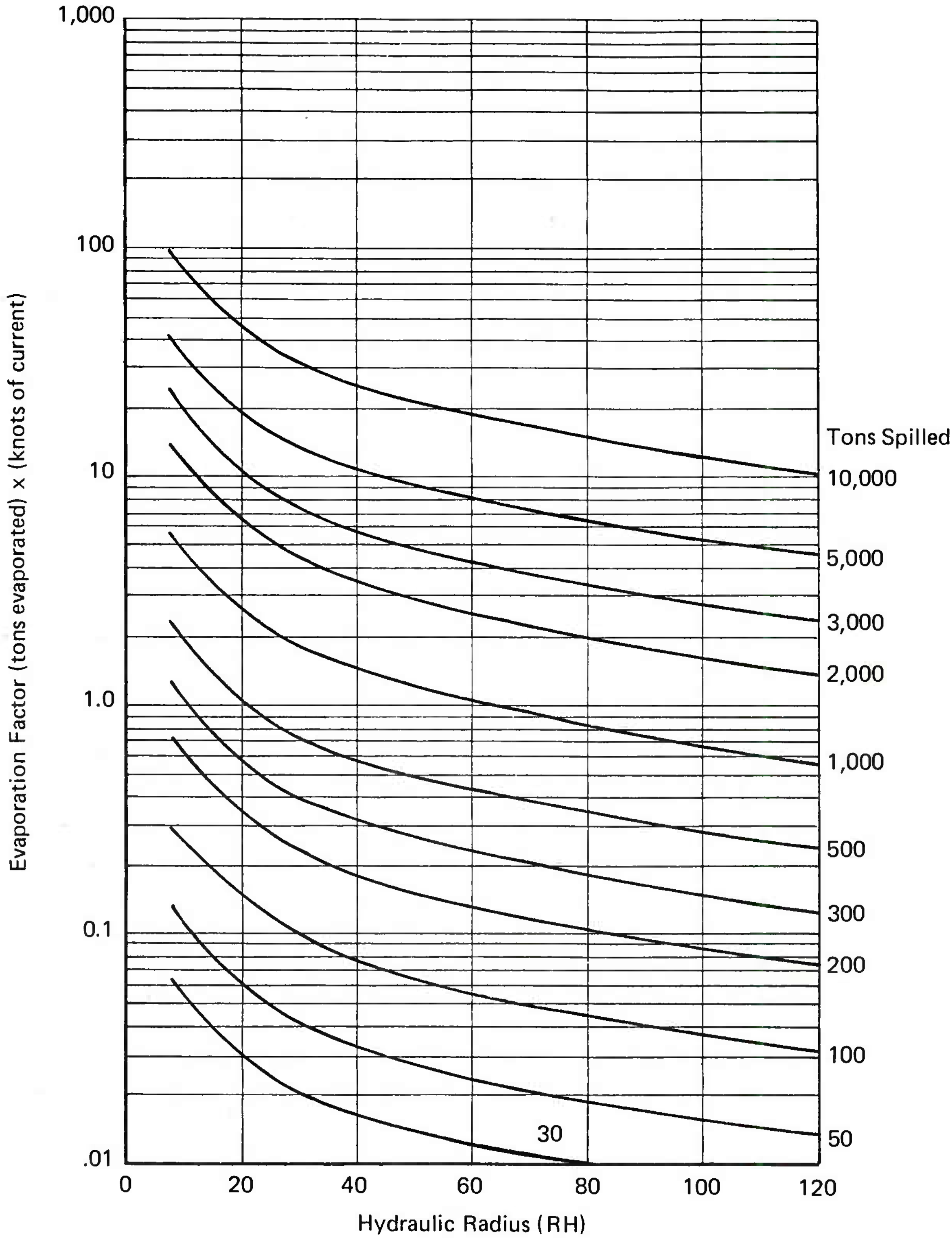


FIGURE R29 EVAPORATION FACTORS FOR SPILLS OF WATER-SOLUBLE CHEMICALS
Chemical: Methylhydrazine

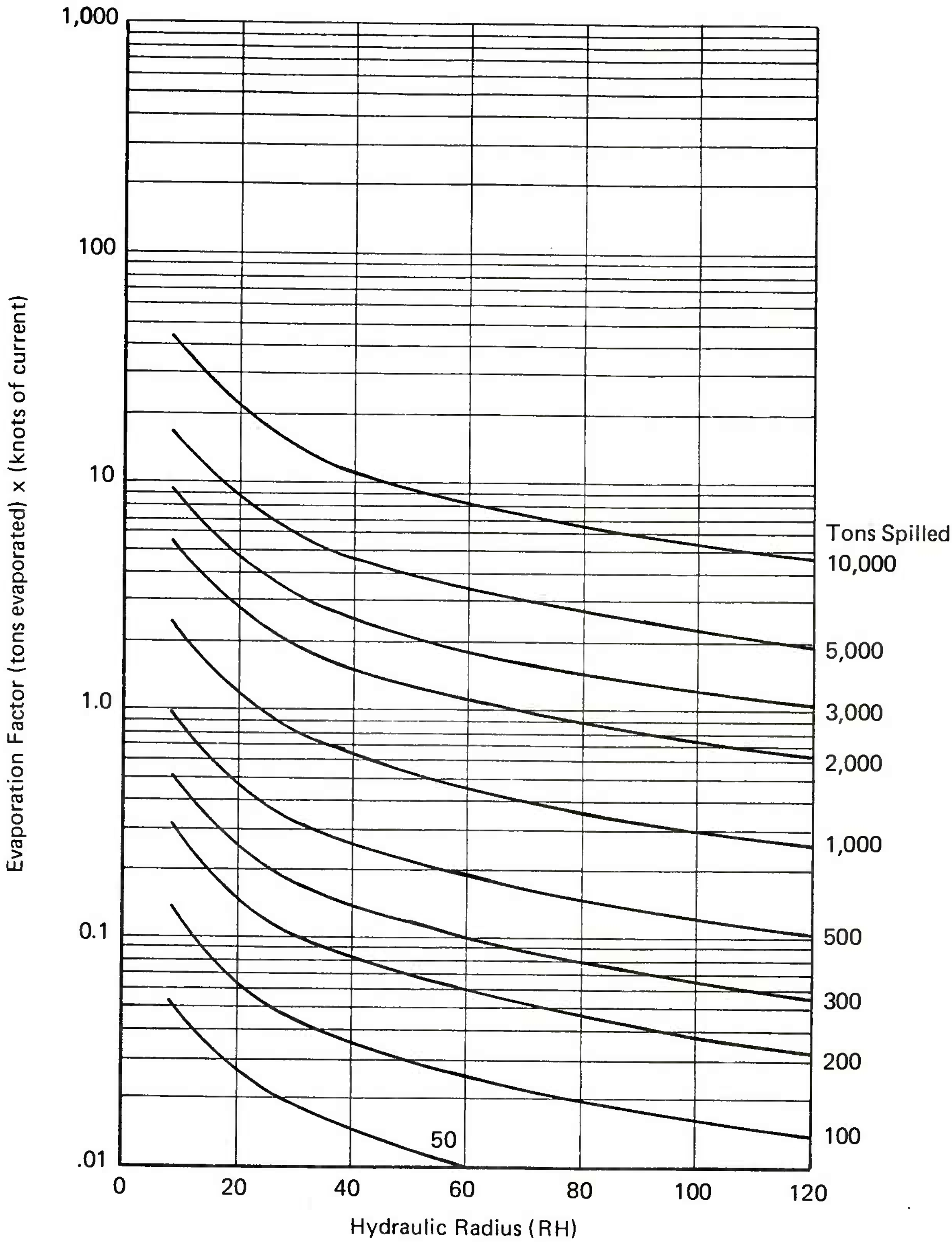


FIGURE R30 EVAPORATION FACTORS FOR SPILLS OF WATER-SOLUBLE CHEMICALS
Chemical: Methyl Vinyl Ketone

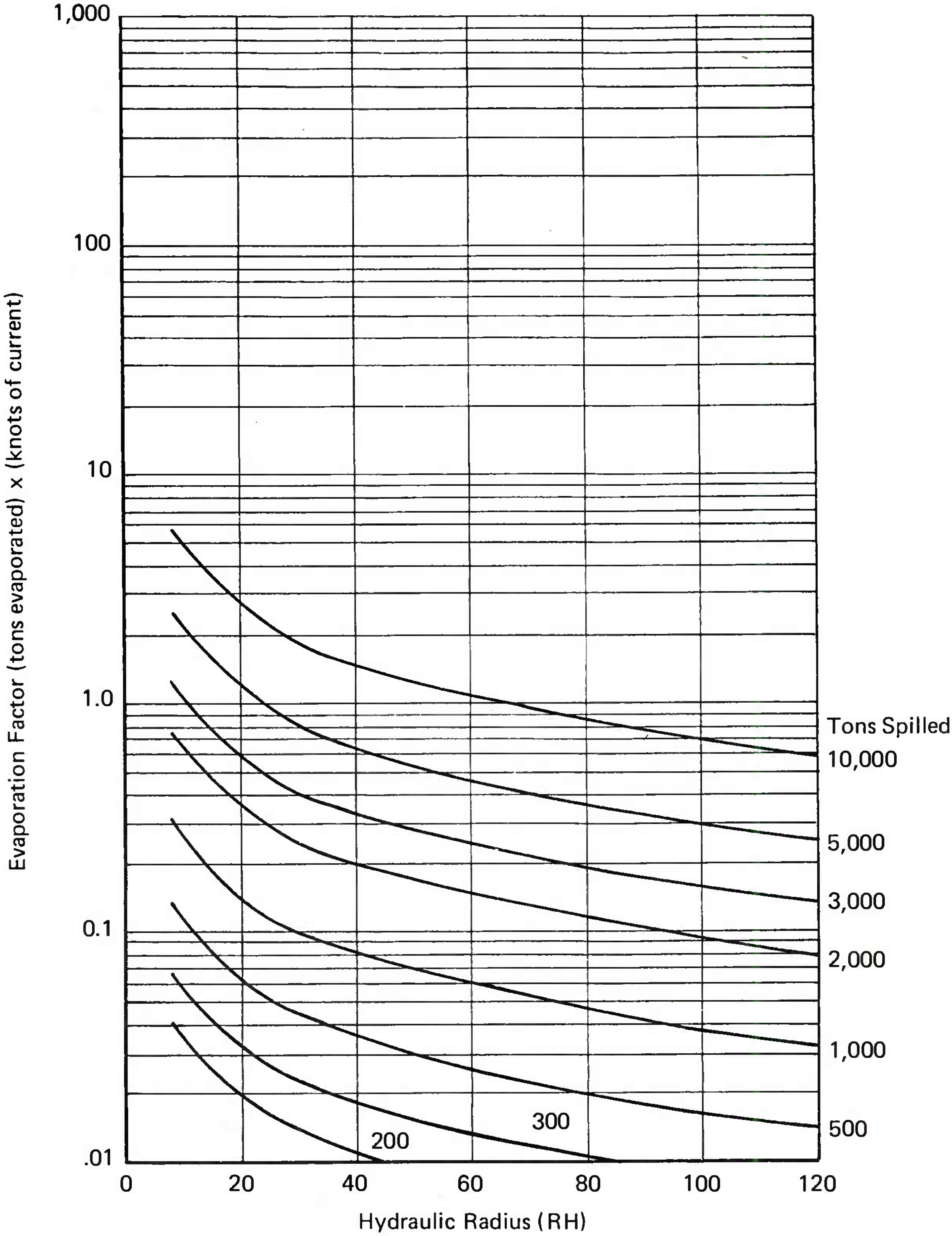


FIGURE R31 EVAPORATION FACTORS FOR SPILLS OF WATER-SOLUBLE CHEMICALS
Chemical: Nitromethane

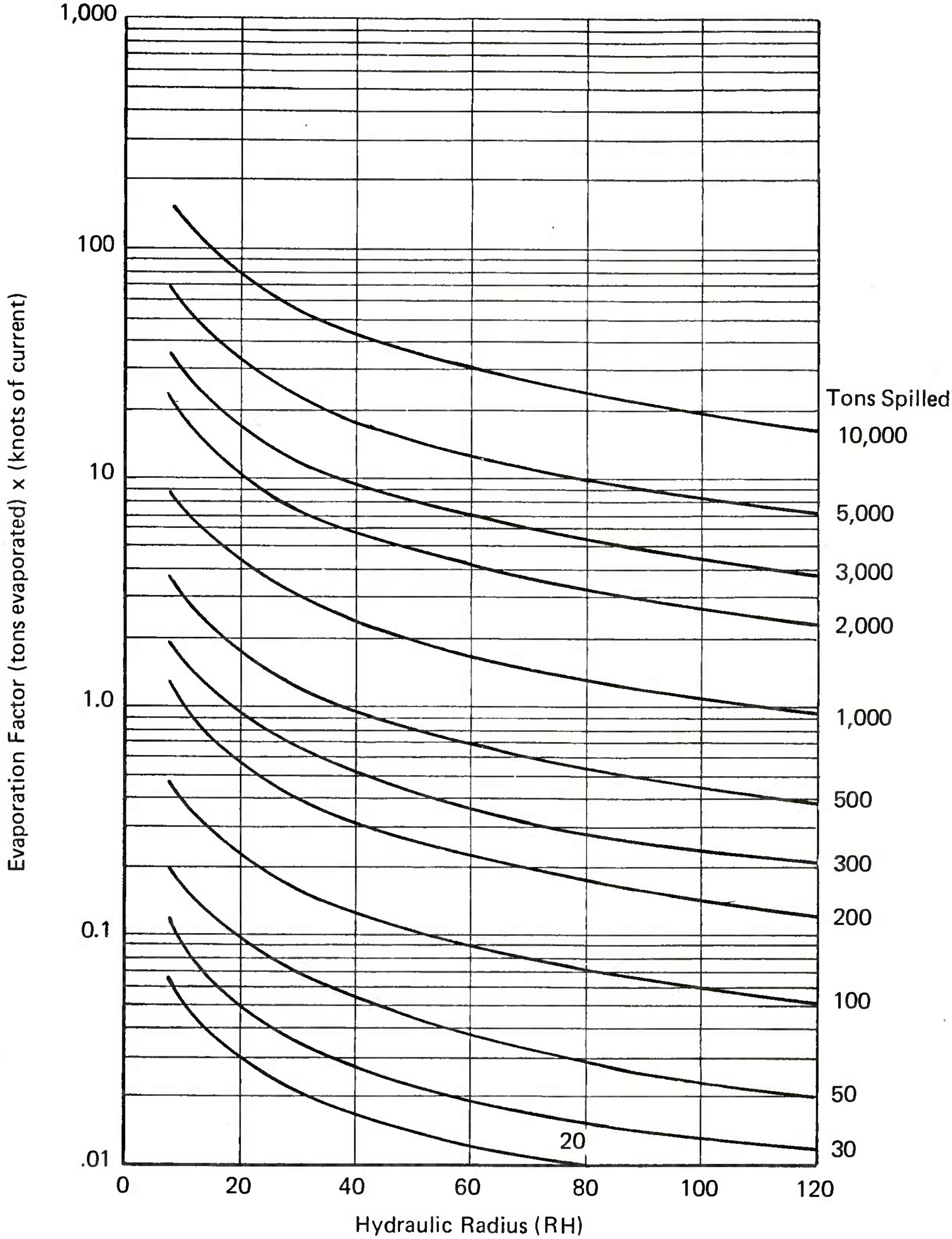


FIGURE R32 EVAPORATION FACTORS FOR SPILLS OF WATER-SOLUBLE CHEMICALS
Chemical: Propyleneimine

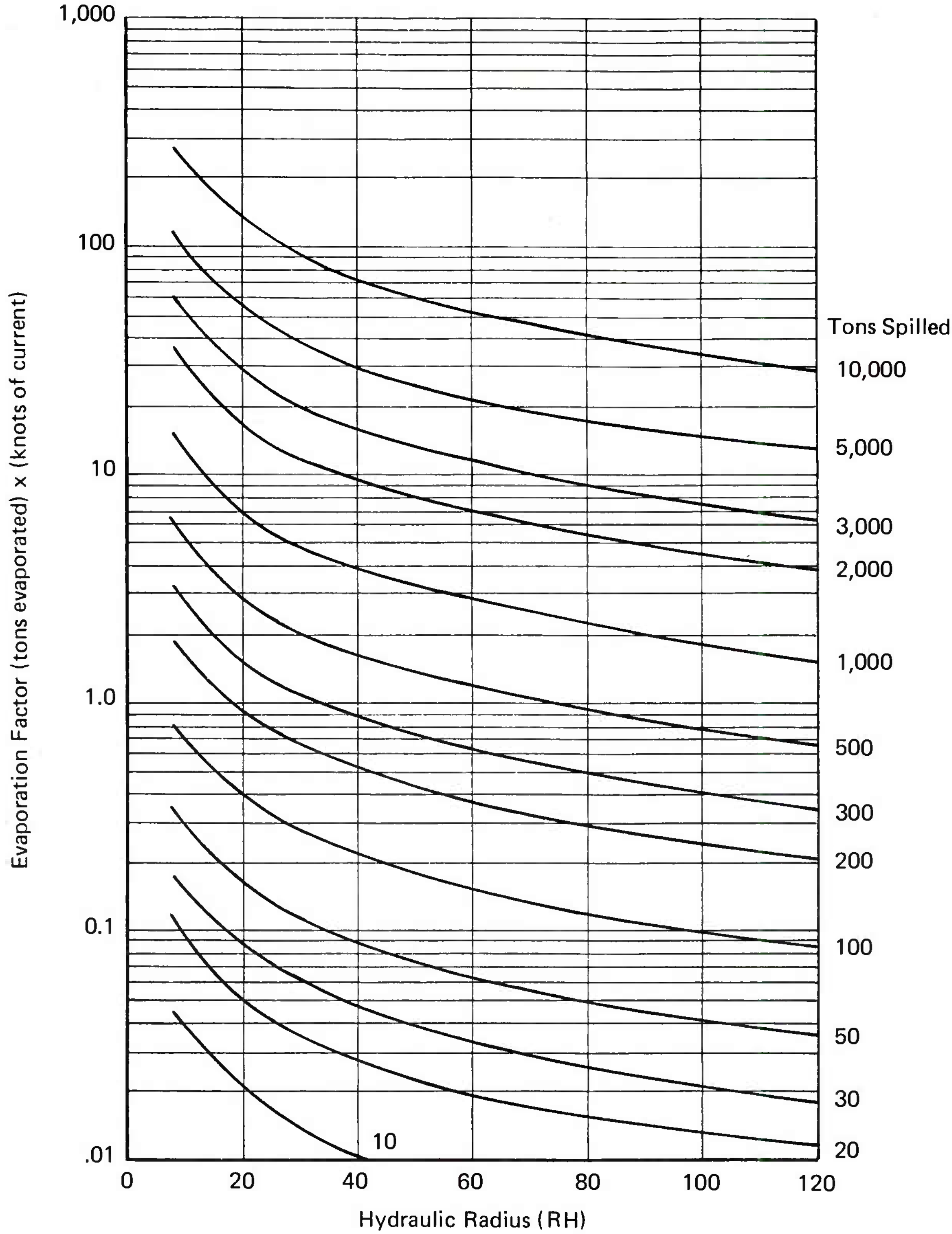


FIGURE R33 EVAPORATION FACTORS FOR SPILLS OF WATER-SOLUBLE CHEMICALS
Chemical: Propylene Oxide

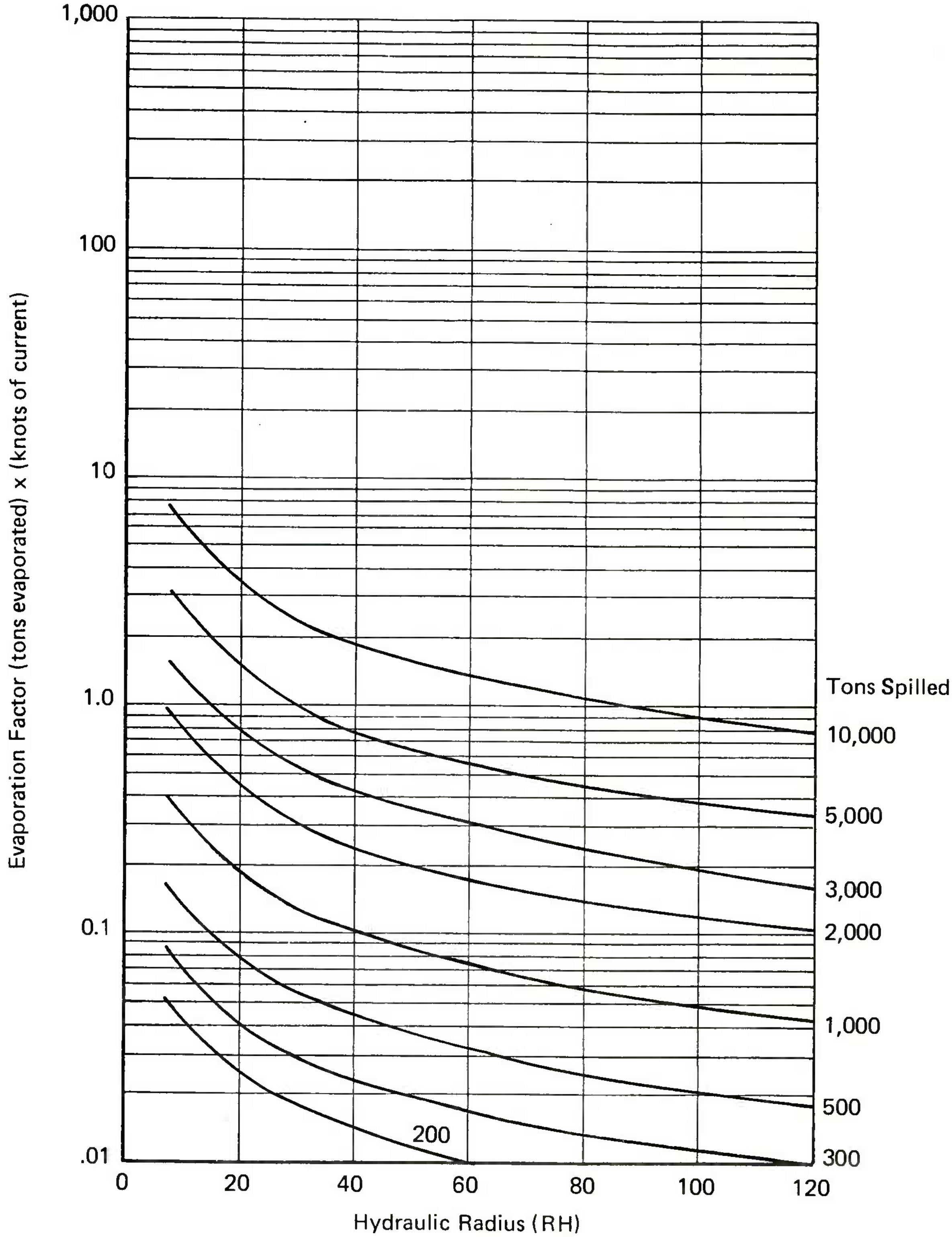


FIGURE R34 EVAPORATION FACTORS FOR SPILLS OF WATER-SOLUBLE CHEMICALS
Chemical: Pyridine

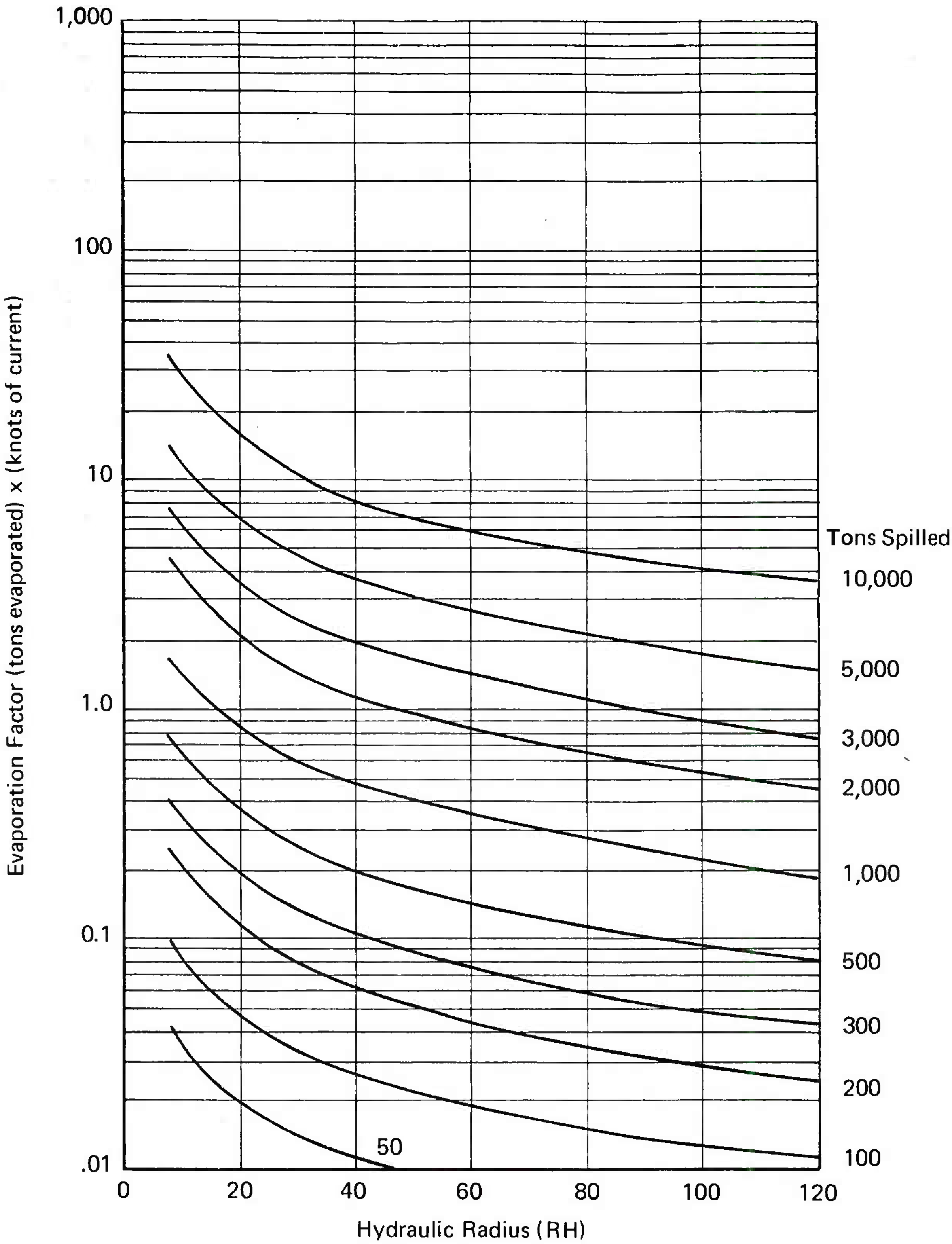


FIGURE R35 EVAPORATION FACTORS FOR SPILLS OF WATER-SOLUBLE CHEMICALS
Chemical: Tetrahydrofuran

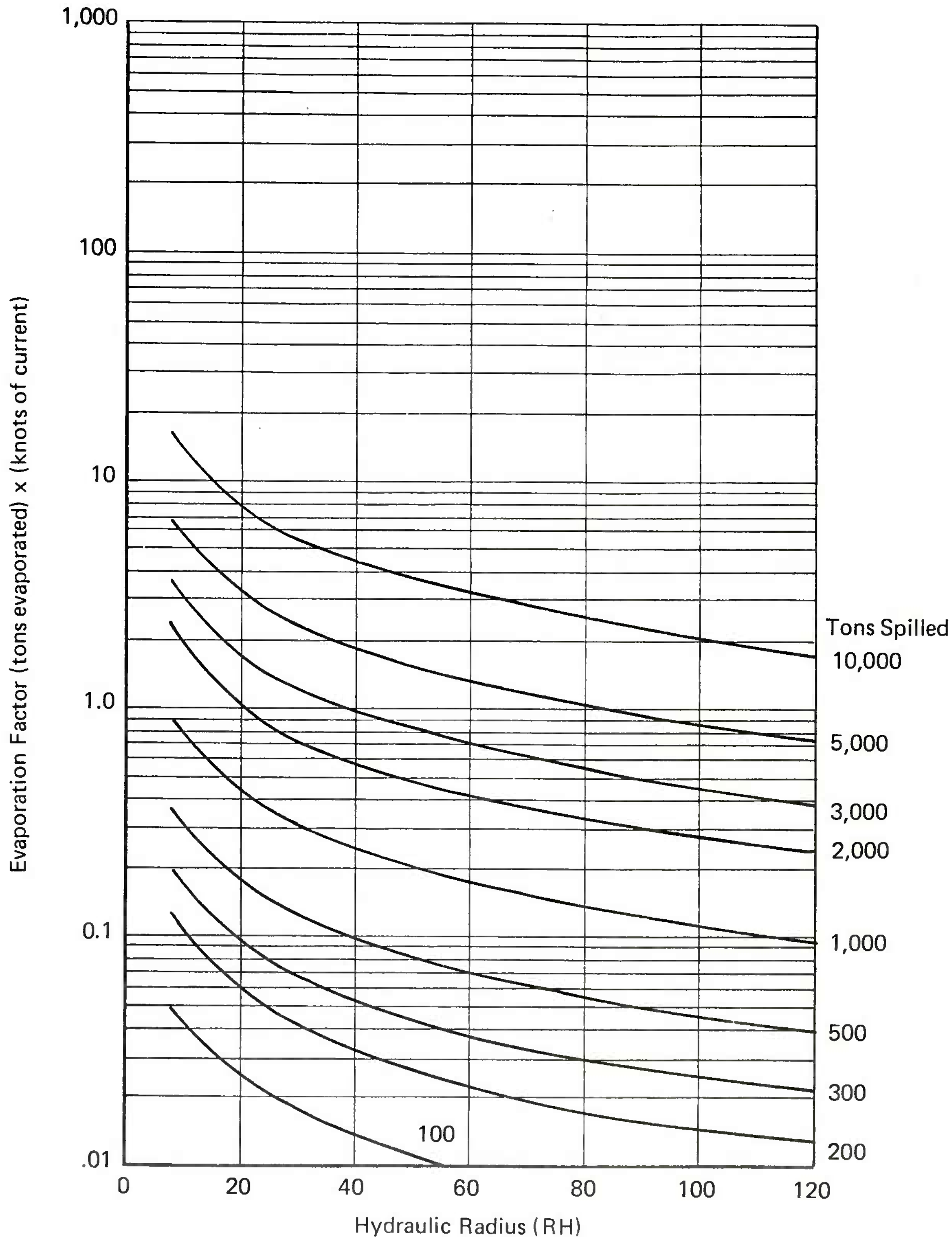


FIGURE R36 EVAPORATION FACTORS FOR SPILLS OF WATER-SOLUBLE CHEMICALS
Chemical: Triethylamine

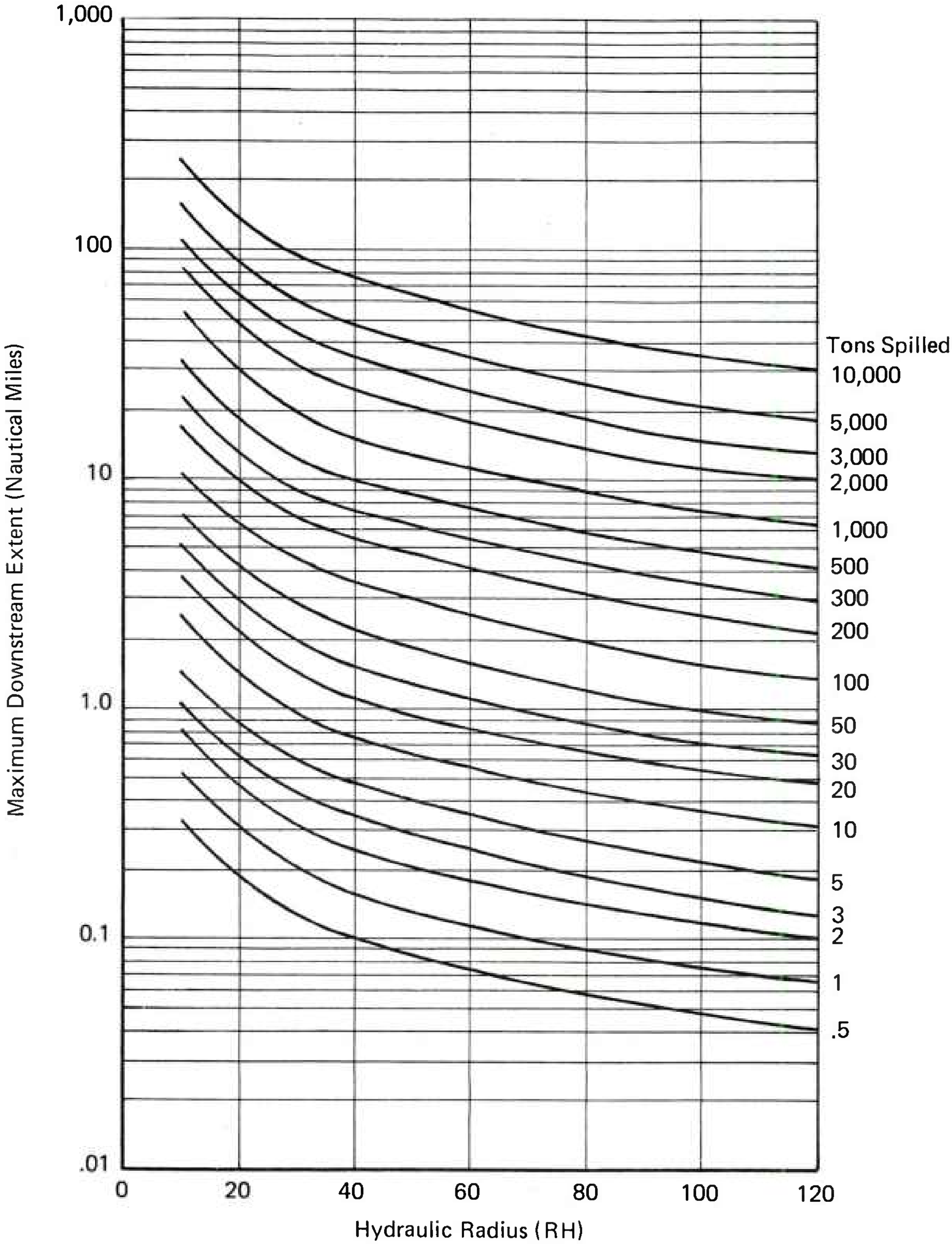


FIGURE R37 MAXIMUM DOWNSTREAM EXTENT OF FLAMMABILITY AND TOXIC VAPOR CLOUD HAZARD
Molecular Weight: <30

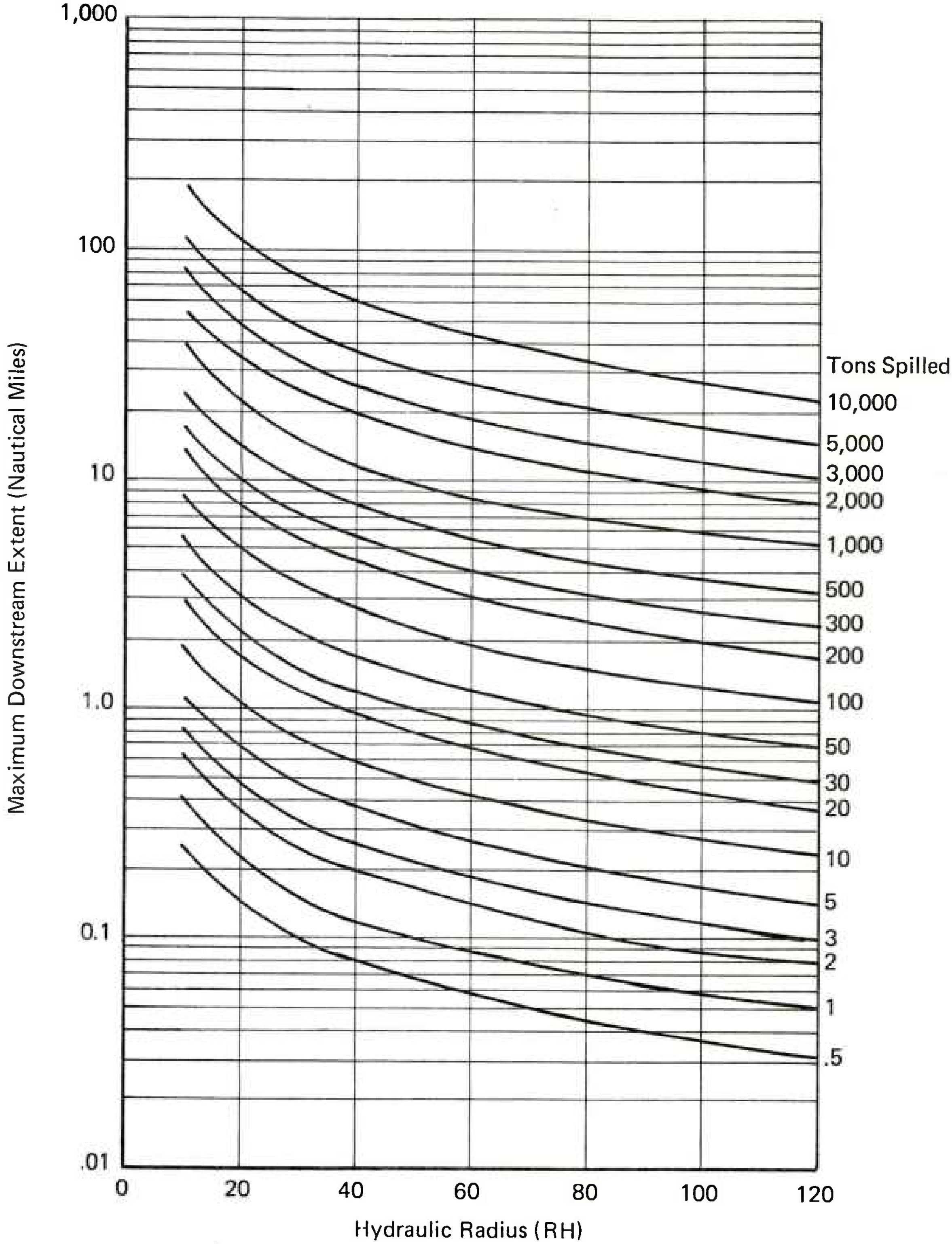


FIGURE R38 MAXIMUM DOWNSTREAM EXTENT OF FLAMMABILITY AND TOXIC VAPOR CLOUD HAZARD
Molecular Weight: 30–50

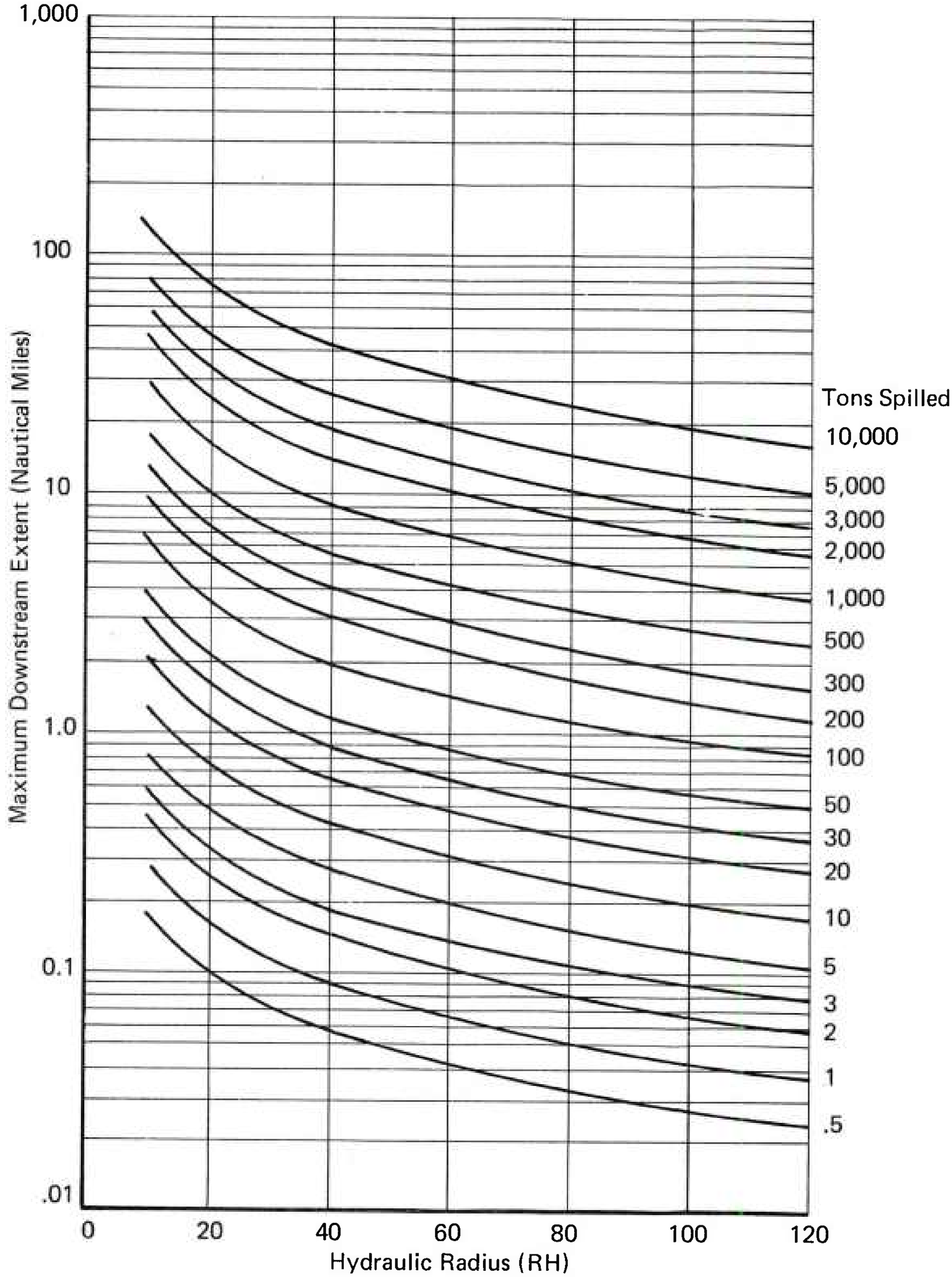


FIGURE R39 MAXIMUM DOWNSTREAM EXTENT OF FLAMMABILITY AND TOXIC VAPOR CLOUD HAZARD
Molecular Weight: 50–70

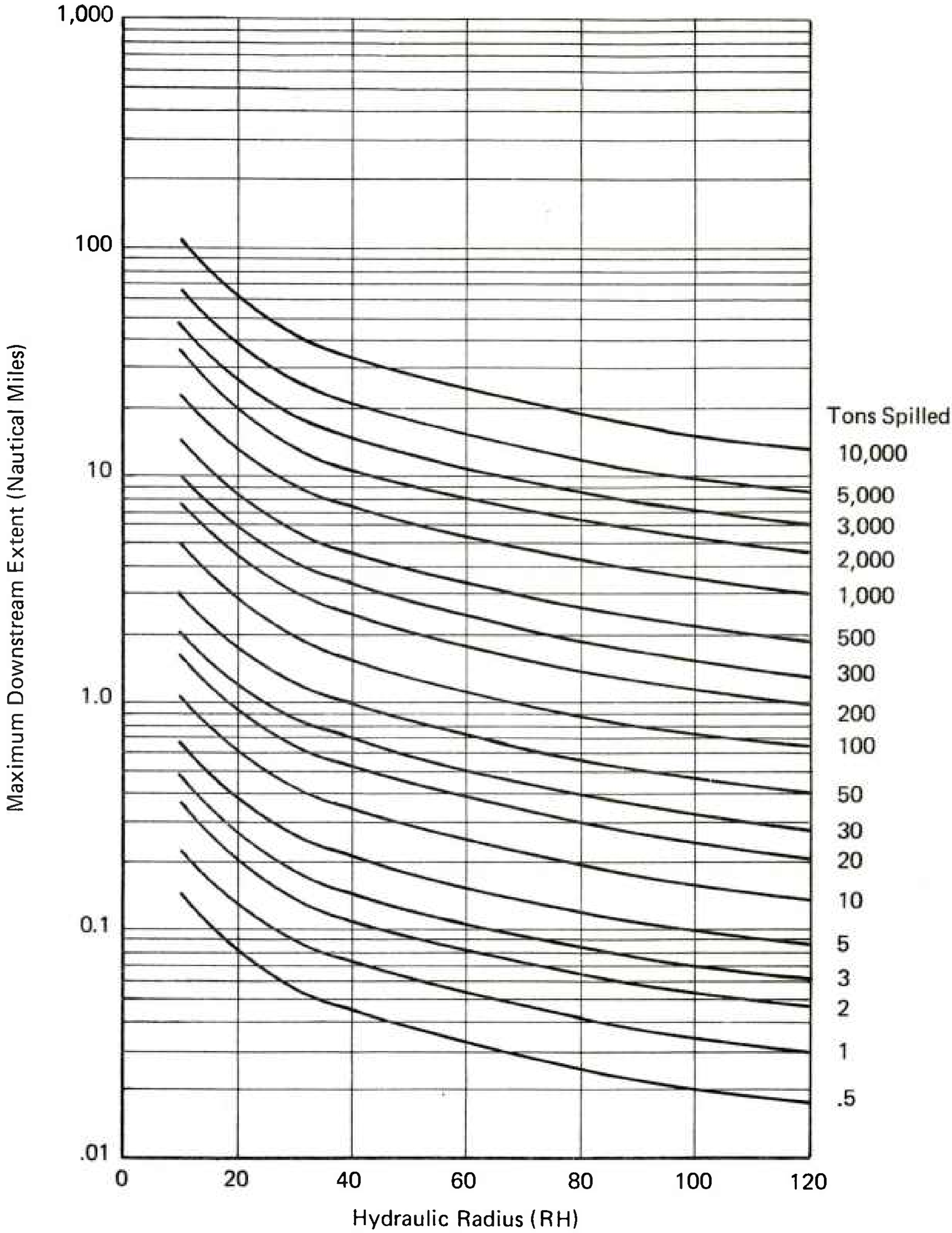


FIGURE R40 MAXIMUM DOWNSTREAM EXTENT OF FLAMMABILITY AND TOXIC VAPOR CLOUD HAZARD
Molecular Weight: 70–90

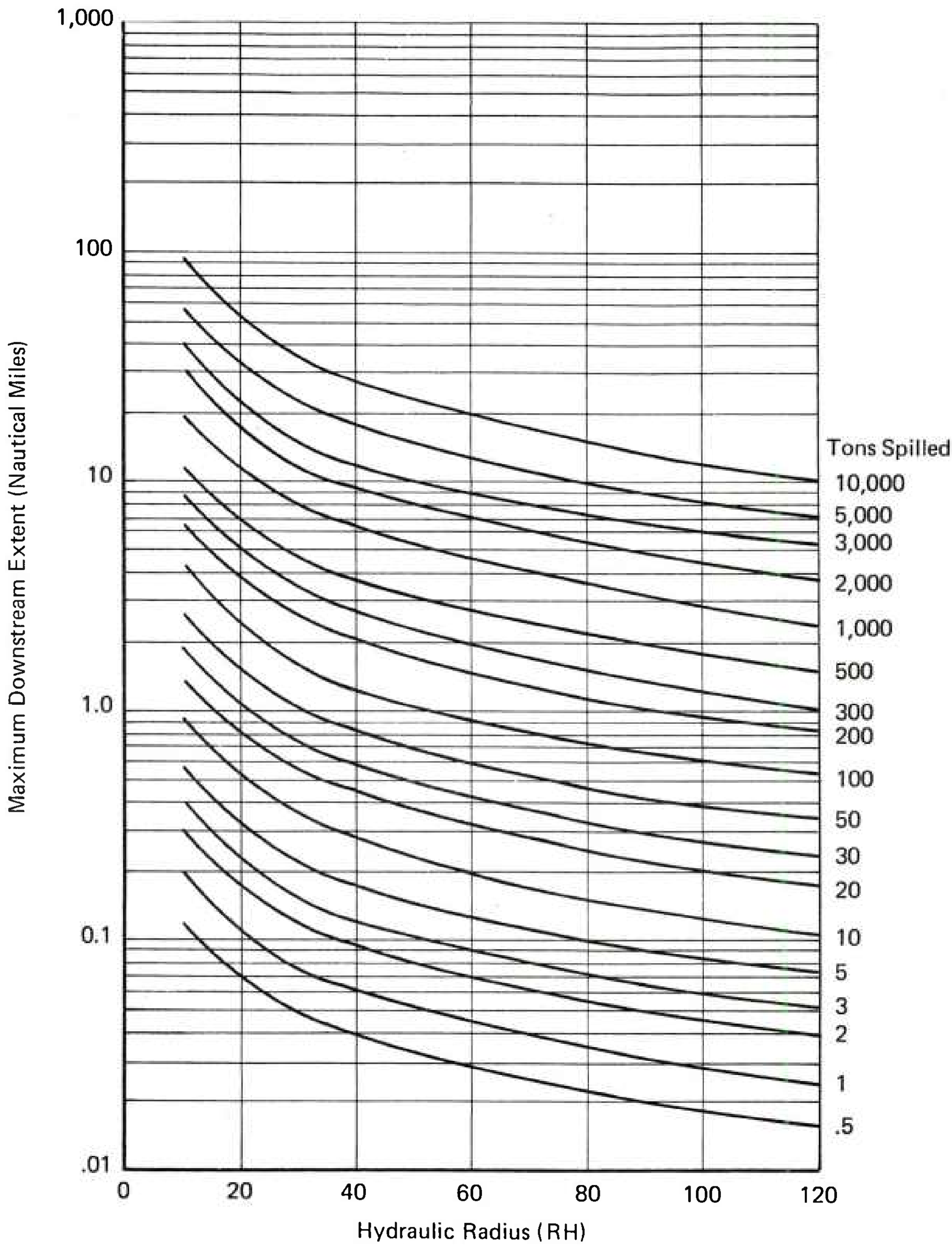


FIGURE R41 MAXIMUM DOWNSTREAM EXTENT OF FLAMMABILITY AND TOXIC VAPOR CLOUD HAZARD
Molecular Weight: >90

FIGURES FOR CALCULATION PROCEDURE T

Hazard calculation procedure T may be used to determine the radius of the pool formed when a lighter-than-water, insoluble, non-volatile liquid with a boiling point greater than ambient spills on water.

One table and one figure are presented for use with this procedure.

Table T-1 gives the calculation parameters R,T; and F and the maximum radius the pool can spread to as a function of the amount spilled and the specific gravity of the chemical.

Figure T1 gives the non-dimensional pool radius r/R (radius of the pool at desired time, in feet/calculation parameter R) as a function of the non-dimensional time ratio t/T (time at which radius is desired in seconds/calculation parameter T) and calculation parameter F. Note that if the constant F line to be consulted starts to the right of the value of t/T, the dashed line should be used instead. If the radius predicted is greater than the maximum radius given in the table, then the table value is to be used.

TABLE T-1

CALCULATION PARAMETERS AND MAXIMUM POOL RADIUS FOR SPREADING POOL ASSESSMENT

Amount Spilled (tons)	Specific Gravity	R (ft)	T (sec)	F	Max. Radius* (ft)
0.1	0.9	1.53	0.689	62.	59.
0.1	0.8	1.59	0.497	82.	62.
0.1	0.7	1.66	0.415	98.	67.
0.1	0.6	1.75	0.368	113.	72.
0.1	0.5	1.86	0.340	127.	79.
0.1	0.4	2.00	0.322	143.	88.
0.1	0.3	2.20	0.313	161.	102.
0.1	0.2	2.52	0.313	184.	125.
0.2	0.9	1.92	0.773	71.	83.
0.2	0.8	2.00	0.557	95.	88.
0.2	0.7	2.09	0.465	113.	94.
0.2	0.6	2.20	0.414	130.	102.
0.2	0.5	2.34	0.381	147.	112.
0.2	0.4	2.52	0.361	165.	125.
0.2	0.3	2.78	0.351	186.	144.
0.2	0.2	3.18	0.351	212.	176.
0.3	0.9	2.20	0.827	77.	102.
0.3	0.8	2.29	0.596	103.	108.
0.3	0.7	2.40	0.498	123.	115.
0.3	0.6	2.52	0.442	142.	125.
0.3	0.5	2.68	0.408	160.	137.
0.3	0.4	2.89	0.386	179.	153.
0.3	0.3	3.18	0.375	202.	176.
0.3	0.2	3.64	0.376	231.	216.
0.5	0.9	2.61	0.901	86.	131.
0.5	0.8	2.72	0.649	114.	139.
0.5	0.7	2.84	0.542	137.	149.
0.5	0.6	2.99	0.482	158.	161.
0.5	0.5	3.18	0.444	178.	176.
0.5	0.4	3.42	0.421	200.	197.
0.5	0.3	3.77	0.409	225.	228.
0.5	0.2	4.31	0.409	257.	279.
1	0.9	3.29	1.011	99.	185.
1	0.8	3.42	0.729	132.	197.
1	0.7	3.58	0.608	158.	210.
1	0.6	3.77	0.541	182.	227.
1	0.5	4.00	0.498	205.	249.

*Use Table V.1 for chemicals whose hazard assessment code includes letter V.

TABLE T-1 (Continued)

Amount Spilled (tons)	Specific Gravity	R (ft)	T (sec)	F	Max. Radius* (ft)
1	0.4	4.31	0.472	230.	278.
1	0.3	4.75	0.459	259.	322.
1	0.2	5.43	0.459	296.	394.
2	0.9	4.15	1.135	114.	262.
2	0.8	4.31	0.818	152.	278.
2	0.7	4.51	0.683	182.	298.
2	0.6	4.75	0.607	210	322.
2	0.5	5.04	0.559	237.	352.
2	0.4	5.43	0.530	266.	394.
2	0.3	5.98	0.515	299.	455.
2	0.2	6.84	0.515	342.	557.
3	0.9	4.75	1.214	125.	322.
3	0.8	4.94	0.875	166.	341.
3	0.7	5.16	0.731	198.	365.
3	0.6	5.43	0.649	228	394.
3	0.5	5.77	0.599	258.	432.
3	0.4	6.22	0.567	289.	483.
3	0.3	6.84	0.551	326.	557.
3	0.2	7.84	0.551	373.	683.
5	0.9	5.62	1.322	139.	415.
5	0.8	5.85	0.953	184.	440.
5	0.7	6.12	0.796	221.	471.
5	0.6	6.44	0.707	254.	509.
5	0.5	6.84	0.652	287.	557.
5	0.4	7.37	0.618	322.	623.
5	0.3	8.12	0.600	362.	720.
5	0.2	9.29	0.600	414.	881.
10	0.9	7.09	1.484	160.	587.
10	0.8	7.37	1.070	213.	623.
10	0.7	7.71	0.893	255.	666.
10	0.6	8.12	0.794	294.	720.
10	0.5	8.62	0.732	332.	788.
10	0.4	9.29	0.693	372.	881.
10	0.3	10.22	0.673	419.	1018.
10	0.2	11.70	0.674	479.	1247.
20	0.9	8.93	1.666	185.	831.
20	0.8	9.29	1.201	246.	881.

*Use Table V.1 for chemicals whose hazard assessment code includes letter V.

TABLE T-1 (Continued)

Amount Spilled Tons	Specific Gravity	R ft	T sec	F	Max Radius * ft
20	0.7	9.71	1.003	295.	942.
20	0.6	10.22	0.891	339.	1018.
20	0.5	10.87	0.821	383.	1115.
20	0.4	11.70	0.778	430.	1247.
20	0.3	12.88	0.756	484.	1440.
20	0.2	14.75	0.756	553.	1763.
30	0.9	10.22	1.782	202.	1018.
30	0.8	10.63	1.285	268.	1080.
30	0.7	11.12	1.073	321.	1154.
30	0.6	11.70	0.953	369.	1247.
30	0.5	12.44	0.879	417.	1366.
30	0.4	13.40	0.833	468.	1527.
30	0.3	14.75	0.809	526.	1763.
30	0.2	16.88	0.809	602.	2160.
50	0.9	12.12	1.941	224.	1314.
50	0.8	12.61	1.399	298.	1394.
50	0.7	13.18	1.168	357.	1490.
50	0.6	13.88	1.038	411.	1610.
50	0.5	14.75	0.957	464.	1763.
50	0.4	15.89	0.907	520.	1972.
50	0.3	17.48	0.881	586.	2277.
50	0.2	20.01	0.881	670.	2789.
100	0.9	15.27	2.178	259.	1859.
100	0.8	15.89	1.571	345.	1972.
100	0.7	16.61	1.311	413.	2108.
100	0.6	17.48	1.165	475.	2277.
100	0.5	18.58	1.074	536.	2494.
100	0.4	20.01	1.018	601.	2789.
100	0.3	22.03	0.988	677.	3220.
100	0.2	25.22	0.989	774.	3944.
200	0.9	19.24	2.445	299.	2629.
200	0.8	20.01	1.763	398.	2789.
200	0.7	20.93	1.472	477.	2981.
200	0.6	22.03	1.308	548.	3220.
200	0.5	23.41	1.206	619.	3527.
200	0.4	25.22	1.142	695.	3944.
200	0.3	27.75	1.110	782.	4554.
200	0.2	31.77	1.110	894.	5578.
300	0.9	22.03	2.616	326.	3220.
300	0.8	22.91	1.886	433.	3415.
300	0.7	23.95	1.575	519.	3651.
300	0.6	25.22	1.399	597.	3944.
300	0.5	26.80	1.290	674.	4320.
300	0.4	28.87	1.222	756.	4830.
300	0.3	31.77	1.187	851.	5578.

*Use Table V1 for chemicals whose hazard assessment code includes letter V.

TABLE T-1 (Continued)

Amount Spilled Tons	Specific Gravity	R ft	T sec	F	Max Radius* ft
300	0.2	36.37	1.188	973.	6831.
500	0.9	26.12	2.849	363.	4157.
500	0.8	27.16	2.054	482.	4409.
500	0.7	28.40	1.715	577.	4714.
500	0.6	29.90	1.524	664.	5092.
500	0.5	31.77	1.405	750.	5578.
500	0.4	34.22	1.331	841.	6236.
500	0.3	37.67	1.293	946.	7201.
500	0.2	43.12	1.294	1083.	8819.
1,000	0.9	32.91	3.198	419.	5879.
1,000	0.8	34.22	2.306	557.	6236.
1,000	0.7	35.78	1.925	667.	6667.
1,000	0.6	37.67	1.710	767.	7201.
1,000	0.5	40.03	1.577	866.	7888.
1,000	0.4	43.12	1.494	972.	8819.
1,000	0.3	47.46	1.451	1093.	10184.
1,000	0.2	54.33	1.452	1251.	12472.
2,000	0.9	41.46	3.589	484.	8315.
2,000	0.8	43.12	2.588	644.	8819.
2,000	0.7	45.08	2.161	770.	9428.
2,000	0.6	47.46	1.920	886.	10184.
2,000	0.5	50.43	1.770	1001.	11156.
2,000	0.4	54.33	1.677	1123.	12472.
2,000	0.3	59.80	1.629	1263.	14402.
2,000	0.2	68.45	1.630	1445.	17639.
3,000	0.9	47.46	3.840	527.	10184.
3,000	0.8	49.36	2.769	700.	10801.
3,000	0.7	51.61	2.312	838.	11547.
3,000	0.6	54.33	2.054	964.	12472.
3,000	0.5	57.73	1.894	1089.	13663.
3,000	0.4	62.19	1.794	1222.	15276.
3,000	0.3	68.45	1.743	1375.	17639.
3,000	0.2	78.35	1.744	1573.	21603.
5,000	0.9	56.27	4.181	586.	13147.
5,000	0.8	58.52	3.015	779.	13945.
5,000	0.7	61.19	2.517	933.	14907.
5,000	0.6	64.41	2.237	1073.	16102.
5,000	0.5	68.45	2.062	1212.	17639.
5,000	0.4	73.73	1.954	1359.	19721.
5,000	0.3	81.15	1.898	1529.	22772.
5,000	0.2	92.90	1.899	1749.	27890.
10,000	0.9	70.90	4.694	677.	18593.
10,000	0.8	73.73	3.385	900.	19721.
10,000	0.7	77.09	2.826	1078.	21083.
10,000	0.6	81.15	2.511	1240.	22772.

*Use Table V1 for chemicals whose hazard assessment code includes letter V.

TABLE T.1 (Continued)

Amount Spilled Tons	Specific Gravity	R ft	T sec	F	Max Radius* ft
10,000	0.5	86.24	2.315	1400.	24945.
10,000	0.4	92.90	2.193	1570.	27890.
10,000	0.3	102.25	2.130	1767.	32204.
10,000	0.2	117.05	2.132	2021.	39442.
30,000	0.9	102.25	5.637	851.	32204.
30,000	0.8	106.34	4.065	1132.	34158.
30,000	0.7	111.18	3.393	1355.	36516.
30,000	0.6	117.05	3.015	1558.	39442.
30,000	0.5	124.38	2.780	1760.	43207.
30,000	0.4	133.98	2.634	1974.	48307.
30,000	0.3	147.47	2.558	2221.	55780.
30,000	0.2	168.81	2.560	2541.	68316.
50,000	0.9	121.23	6.138	947.	41576.
50,000	0.8	126.08	4.426	1259.	44098.
50,000	0.7	131.82	3.695	1507.	47143.
50,000	0.6	138.77	3.283	1733.	50920.
50,000	0.5	147.47	3.027	1958.	55780.
50,000	0.4	158.86	2.868	2196.	62364.
50,000	0.3	174.84	2.786	2471.	72012.
50,000	0.2	200.15	2.788	2827.	88196.
100,000	0.9	152.74	6.889	1094.	58797.
100,000	0.8	158.86	4.968	1454.	62364.
100,000	0.7	166.09	4.148	1741.	66670.
100,000	0.6	174.84	3.685	2003.	72012.
100,000	0.5	185.80	3.398	2262.	78885.
100,000	0.4	200.15	3.219	2537.	88196.
100,000	0.3	220.29	3.127	2855.	101840.
100,000	0.2	252.17	3.129	3266.	124728.

Time Conversion Table

Conversion Factors:

1 minute	= 60 seconds
1 hour	= 3600
1 day	= 86,400
1 week	= 604,800

Table of Equivalent Times:

1 hour	= 3600 seconds
2 hours	= 7200
3 hours	= 10,800
4 hours	= 14,400
8 hours	= 28,800
12 hours	= 43,200
1 day	= 86,400
1 week	= 604,800
2 weeks	= 1,209,600

*Use Table V1 for chemicals whose hazard assessment code includes letter V.

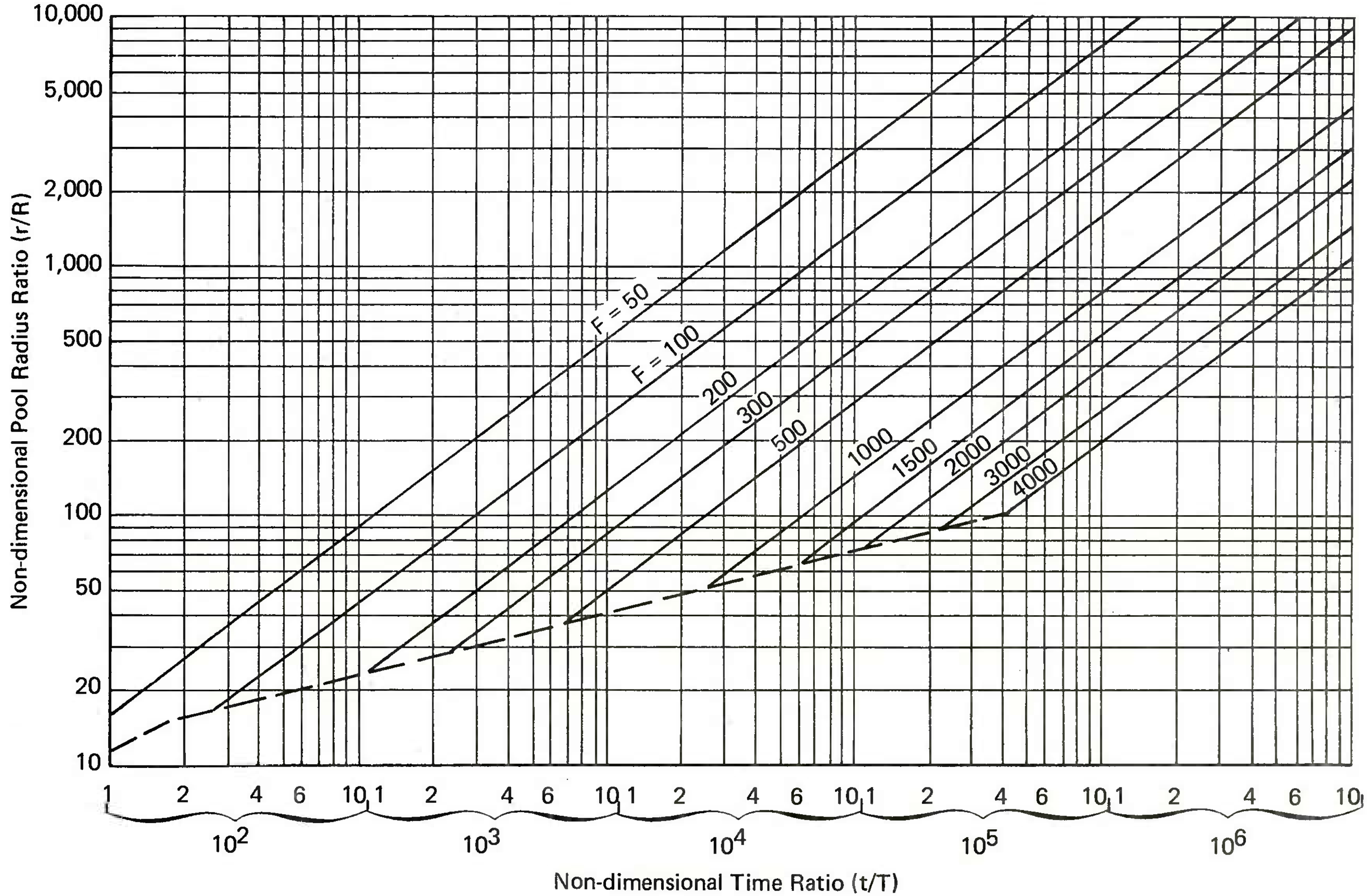


FIGURE T1 DETERMINATION OF NON-DIMENSIONAL POOL RADIUS RATIO (r/R)

FIGURES FOR CALCULATION PROCEDURE V

Hazard calculation procedure V may be used to determine the radius of the pool formed when a lighter-than-water, insoluble, volatile liquid with a boiling point greater than ambient spills on water. It can also be used to determine how long it will take for the entire pool of the chemical to evaporate.

Two tables are presented for use with this procedure.

Table V-1 gives the maximum pool radii for various spill amounts of the chemicals listed.

Table V-2 gives the time it will take for various amounts of these chemicals to evaporate completely.

TABLE V.1

MAXIMUM RADIUS OF POOL FOR VARIOUS SPILL AMOUNTS†
(Radius in Feet)

Chemical Name	Spill Amounts (tons)**														
	0-.1	.1-.5	.5-1	1-5	5-10	10-30	30-60	60-125	125-250	250-500	500-1000	1000-2000	2000-4000	4000-8000	Over 8000
Allyl chloride	35	50	70	110	140	190	240	290	350	450	610	810	1050	1400	1750
iso-Amyl nitrite	85	130	180	300	370	490	650	830	970	1300	1600	1950	2400	2900	3350
Benzene	45	65	85	140	180	240	300	360	460	600	800	1050	1400	1850	2250
n-Butyl mercaptan	50	75	100	170	210	280	360	440	520	690	930	1200	1600	2150	2650
Chloromethyl methyl ether*	35	50	70	110	150	200	260	320	410	500	600	710	920	1200	1500
Collodion	Mixture of nitrocellulose and ethyl ether, usually. See ethyl ether below.														
Cyclohexane	45	70	95	150	190	250	320	380	500	660	880	1150	1550	2050	2500
Cyclopropane	30	45	60	95	120	180	250	330	440	590	770	1000	1350	1750	2200
Diisobutylene*	55	80	110	180	220	290	370	440	570	750	990	1300	1750	2300	2800
Dimethyl sulfide	30	45	60	95	110	160	220	290	390	510	680	890	1150	1550	1900
Distillates — flashed feed stocks*	55	80	110	180	220	290	370	440	560	740	980	1300	1700	2250	2750
Distillates — straight run*	55	80	110	180	220	290	370	440	560	740	980	1300	1700	2250	2750
Ethyl ether*	30	40	50	85	120	170	240	310	420	560	740	970	1300	1700	2100
Ethyl mercaptan	30	40	55	85	110	160	220	290	390	510	670	890	1150	1550	1900
Gasolines — automotive*	55	80	110	180	210	280	350	430	570	760	1000	1300	1750	2300	2850
Gasolines — aviation*	55	80	110	180	210	280	350	430	570	760	1000	1300	1750	2300	2850
Gasolines — casing head*	30	40	55	85	110	170	230	310	410	540	710	950	1250	1650	2050
Gasolines — polymer*	55	80	110	180	210	280	350	430	570	760	1000	1300	1750	2300	2850
Gasolines — straight run*	55	80	110	180	210	280	350	430	570	760	1000	1300	1750	2300	2850
Gasoline blending stocks — alkylates*	55	80	110	180	210	280	350	430	570	760	1000	1300	1750	2300	2850
Gasoline blending stocks — reformates*	55	80	110	180	210	280	350	430	570	760	1000	1300	1750	2300	2850
Heptane	50	75	110	170	200	270	330	420	560	740	980	1300	1700	2250	2750
1-Heptene	50	75	110	170	210	280	340	420	560	740	980	1300	1700	2250	2750
Hexane	40	60	80	130	150	210	280	380	510	670	880	1150	1550	2050	2500
1-Hexene	40	55	75	120	140	200	270	370	490	640	850	1150	1500	1950	2450
Isobutyronitrile*	70	100	130	220	280	380	480	620	750	890	1100	1500	1950	2600	3200
Isohexane	35	50	70	110	130	200	270	360	480	640	840	1100	1500	1950	2400

TABLE V.1 (Continued)

	Spill Amounts (tons)**														
	0 -.1	.1-.5	.5-1	1-5	5-10	10-30	30-60	60-125	125-250	250-500	500-1000	1000-2000	2000-4000	4000-8000	Over 8000
Isopentane	25	40	50	85	120	170	240	320	420	550	730	960	1250	1700	2050
Isoprene	30	40	55	85	120	170	240	310	420	550	730	950	1250	1700	2050
Isopropyl acetate	45	65	95	150	190	250	320	380	480	630	840	1100	1450	1950	2400
Isopropyl ether	35	55	70	110	130	200	270	360	480	640	850	1100	1500	1950	2400
Isovaleraldehyde	45	70	95	150	190	250	310	400	530	700	930	1250	1650	2150	2650
Methallyl chloride*	40	55	80	130	160	220	270	340	410	550	720	960	1250	1700	2050
Methyl acrylate	40	60	85	140	170	240	310	380	470	560	710	930	1250	1650	2000
Methylcyclopentane	40	60	80	130	150	200	280	370	490	650	870	1150	1500	2000	2450
Methyl isopropenyl ketone	50	75	110	170	210	290	370	450	540	700	930	1250	1650	2150	2650
Methyl methacrylate	50	75	110	170	210	300	380	480	600	740	890	1050	1350	1800	2250
Naphtha — coal tar*	110	160	220	360	440	600	780	980	1200	1500	1900	2300	2800	3300	3900
Naphtha — VM&P*	30	40	60	90	110	160	230	300	400	530	700	910	1200	1600	2000
Neohexane	30	45	60	90	130	190	260	350	460	600	800	1050	1400	1850	2300
Pentaborane*	45	60	85	140	160	220	310	410	550	730	960	1300	1700	2250	2750
Pentane	30	45	60	90	120	180	250	330	440	580	750	1000	1350	1750	2150
1-Pentene	25	35	50	85	110	150	200	270	370	490	640	850	1150	1500	1850
Petroleum naphtha*	110	170	230	360	440	600	780	1000	1150	1500	1950	2300	2900	3350	4050
n-Propyl mercaptan	35	50	65	110	120	180	260	340	450	600	800	1050	1400	1850	2250
Vinyl acetate	40	55	80	130	160	220	280	330	410	540	710	940	1250	1650	2000

† Pool radii are a strong function of temperature. This table is based on a chemical/water temperature of 68°F (20°C). Lower temperatures are likely to result in greater pool sizes; higher temperature may result in smaller pools.

* One or more chemical property data items necessary for pool size estimates were unavailable for these substances. Table values shown are based on rough estimates of values for these data.

** One ton = 2000 lb.

TABLE V.2

TIME FOR COMPLETE EVAPORATION OF VARIOUS SPILL AMOUNTS†

(hours:minutes)

Chemical Name	Spill Amounts (tons)** 0-.1	.1-.5	.5-1	1-5	5-10	10-30	30-60	60-125	125-250	250-500	500-1000	1000-2000	2000-4000	4000-8000	Over 8000
Allyl chloride	0:02	0:03	0:04	0:07	0:10	0:15	0:20	0:26	0:32	0:34	0:47	0:57	1:08	1:21	1:34
iso-Amyl nitrite	0:06	0:10	0:16	0:31	0:41	1:00	1:28	2:01	2:30	3:40	4:53	6:20	8:27	10:40	12:31
Benzene	0:03	0:04	0:07	0:13	0:17	0:25	0:34	0:44	0:54	1:05	1:19	1:34	1:57	2:25	2:45
n-Butyl mercaptan	0:04	0:06	0:09	0:18	0:23	0:35	0:48	1:02	1:11	1:30	1:54	2:17	2:48	3:24	3:55
Chloromethyl methyl ether*	0:02	0:03	0:05	0:10	0:14	0:21	0:30	0:39	0:54	1:10	1:30	1:53	2:16	2:45	3:08
Collodion	Mixture of nitrocellulose and ethyl ether, usually. See ethyl ether below.														
Cyclohexane	0:02	0:04	0:06	0:11	0:15	0:21	0:29	0:37	0:46	0:54	1:07	1:21	1:39	2:02	2:21
Cyclopropane	0:02	0:03	0:05	0:09	0:10	0:13	0:16	0:19	0:22	0:28	0:33	0:39	0:50	0:55	1:09
Diisobutylene*	0:03	0:05	0:07	0:14	0:18	0:26	0:36	0:45	0:55	1:07	1:21	1:38	2:00	2:25	2:47
Dimethyl sulfide	0:02	0:03	0:05	0:08	0:10	0:13	0:16	0:19	0:23	0:27	0:33	0:39	0:44	0:57	1:06
Distillates — flashed feedstocks*	0:03	0:05	0:07	0:14	0:17	0:26	0:35	0:45	0:55	1:07	1:21	1:38	1:59	2:24	2:45
Distillates — straight run*	0:03	0:05	0:07	0:14	0:17	0:26	0:35	0:45	0:55	1:07	1:21	1:38	1:59	2:24	2:45
Ethyl ether*	0:02	0:03	0:04	0:06	0:07	0:09	0:11	0:13	0:17	0:20	0:25	0:30	0:36	0:43	0:49
Ethyl mercaptan	0:02	0:03	0:04	0:08	0:09	0:11	0:14	0:17	0:20	0:24	0:29	0:35	0:40	0:51	0:59
Gasolines — automotive*	0:03	0:05	0:07	0:13	0:17	0:25	0:34	0:42	0:50	1:01	1:14	1:30	1:49	2:12	2:32
Gasolines — aviation*	0:03	0:05	0:07	0:13	0:17	0:25	0:34	0:42	0:51	1:02	1:15	1:30	1:49	2:12	2:32
Gasolines — casinghead*	0:01	0:02	0:03	0:05	0:06	0:07	0:09	0:11	0:14	0:16	0:19	0:24	0:29	0:33	0:39
Gasolines — polymer*	0:03	0:05	0:07	0:13	0:17	0:25	0:33	0:41	0:50	1:00	1:14	1:29	1:48	2:10	2:30
Gasolines — straight run*	0:03	0:05	0:07	0:13	0:17	0:25	0:33	0:41	0:50	1:00	1:14	1:29	1:48	2:10	2:30
Gasoline blending stocks — alkylates*	0:03	0:05	0:07	0:13	0:17	0:25	0:33	0:41	0:50	1:00	1:14	1:29	1:48	2:10	2:30
Gasoline blending stocks — reformates*	0:03	0:05	0:07	0:13	0:17	0:25	0:33	0:41	0:50	1:00	1:14	1:29	1:48	2:10	2:30
Heptane	0:03	0:05	0:08	0:15	0:19	0:28	0:36	0:45	0:54	1:06	1:20	1:37	1:57	2:22	2:40
1-Heptene	0:03	0:04	0:07	0:13	0:16	0:24	0:32	0:40	0:49	0:59	1:11	1:26	1:45	2:07	2:26
Hexane	0:02	0:03	0:05	0:09	0:11	0:15	0:18	0:23	0:28	0:34	0:41	0:49	1:00	1:13	1:25
1-Hexene	0:02	0:03	0:04	0:08	0:10	0:13	0:17	0:21	0:25	0:31	0:37	0:45	0:55	1:07	1:17
Isobutyronitrile*	0:05	0:08	0:12	0:24	0:33	0:50	1:07	1:34	2:02	2:32	3:09	3:58	4:49	5:50	6:45
Isohexane	0:02	0:03	0:05	0:08	0:09	0:12	0:15	0:18	0:22	0:27	0:33	0:40	0:49	1:00	1:09
Isopentane	0:01	0:02	0:03	0:04	0:05	0:06	0:08	0:09	0:11	0:13	0:16	1:19	0:23	0:28	0:33
Isoprene	0:01	0:02	0:03	0:06	0:07	0:08	0:10	0:12	0:14	0:17	0:21	0:23	0:30	0:36	0:42

TABLE V.2 (Continued)

Chemical Name	Spill Amounts (tons)** 0-.1	.1-.5	.5-1	1-5	5-10	10-30	30-60	60-125	125-250	250-500	500-1000	1000-2000	2000-4000	4000-8000	Over 8000
Isopropyl acetate	0:03	0:05	0:08	0:15	0:20	0:30	0:41	0:53	1:05	1:18	1:35	1:55	2:19	2:49	3:15
Isopropyl ether	0:02	0:04	0:06	0:10	0:12	0:16	0:20	0:25	0:30	0:37	0:45	0:54	1:06	1:21	1:34
Isovaleraldehyde	0:03	0:05	0:08	0:16	0:20	0:30	0:39	0:48	0:58	1:11	1:26	1:44	2:07	2:35	2:58
Methallyl chloride*	0:02	0:04	0:06	0:12	0:16	0:24	0:32	0:43	0:53	1:05	1:20	1:36	1:59	2:25	2:48
Methyl acrylate	0:03	0:04	0:07	0:14	0:18	0:28	0:39	0:52	1:08	1:27	1:46	2:09	2:38	3:11	3:40
Methylcyclopentane	0:02	0:04	0:06	0:11	0:14	0:19	0:24	0:30	0:37	0:45	0:54	1:06	1:21	1:39	1:54
Methyl isopropenyl ketone	0:04	0:06	0:09	0:18	0:24	0:36	0:50	1:06	1:22	1:40	2:02	2:28	3:00	3:37	4:13
Methyl methacrylate	0:03	0:05	0:08	0:15	0:20	0:31	0:44	0:59	1:19	1:44	2:15	2:50	3:27	4:09	4:49
Naphtha — coal tar*	0:08	0:12	0:19	0:37	0:48	1:14	1:44	2:21	3:09	4:13	5:36	7:16	9:33	11:49	13:53
Naphtha — VM&P*	0:02	0:03	0:04	0:07	0:08	0:10	0:12	0:15	0:18	0:22	0:27	0:30	0:37	0:47	0:54
Neohexane	0:02	0:03	0:04	0:06	0:07	0:09	0:11	0:14	0:17	0:20	0:25	0:30	0:37	0:44	0:51
Pentaborane*	0:02	0:04	0:06	0:11	0:13	0:18	0:23	0:27	0:34	0:42	0:50	1:01	1:15	1:31	1:46
Pentane	0:01	0:02	0:03	0:05	0:06	0:07	0:09	0:11	0:13	0:16	0:19	0:24	0:29	0:34	0:39
1-Pentene	0:01	0:02	0:03	0:05	0:06	0:08	0:09	0:11	0:14	0:16	0:20	0:23	0:28	0:34	0:39
Petroleum naphtha*	0:07	0:12	0:19	0:35	0:45	1:08	1:37	2:17	2:47	3:56	5:26	6:51	9:15	11:21	13:00
n-Propyl mercaptan	0:03	0:05	0:07	0:14	0:17	0:22	0:28	0:34	0:40	0:50	1:03	1:15	1:32	1:51	2:07
Vinyl acetate	0:03	0:04	0:06	0:12	0:16	0:25	0:34	0:44	0:56	1:07	1:25	1:38	1:55	2:21	2:41

† Evaporation times are a strong function of temperature. This table is based on a chemical/water temperature of 68°F (20°C). Lower temperatures require greater times; higher temperatures require shorter times for complete evaporation.

* One or more chemical property data items necessary for evaporation time estimates were unavailable for these substances. Table values shown are based on rough estimates of values for these data.

** One ton = 2000 lb.

FIGURES FOR CALCULATION PROCEDURE X

Hazard calculation procedure X may be used to determine the sinking velocity of a heavier-than-water liquid with a boiling point greater than ambient when it spills on water.

One figure is presented for use with this procedure.

Figure X1 gives the sinking velocity as a function of the surface tension and specific gravity of the chemical.

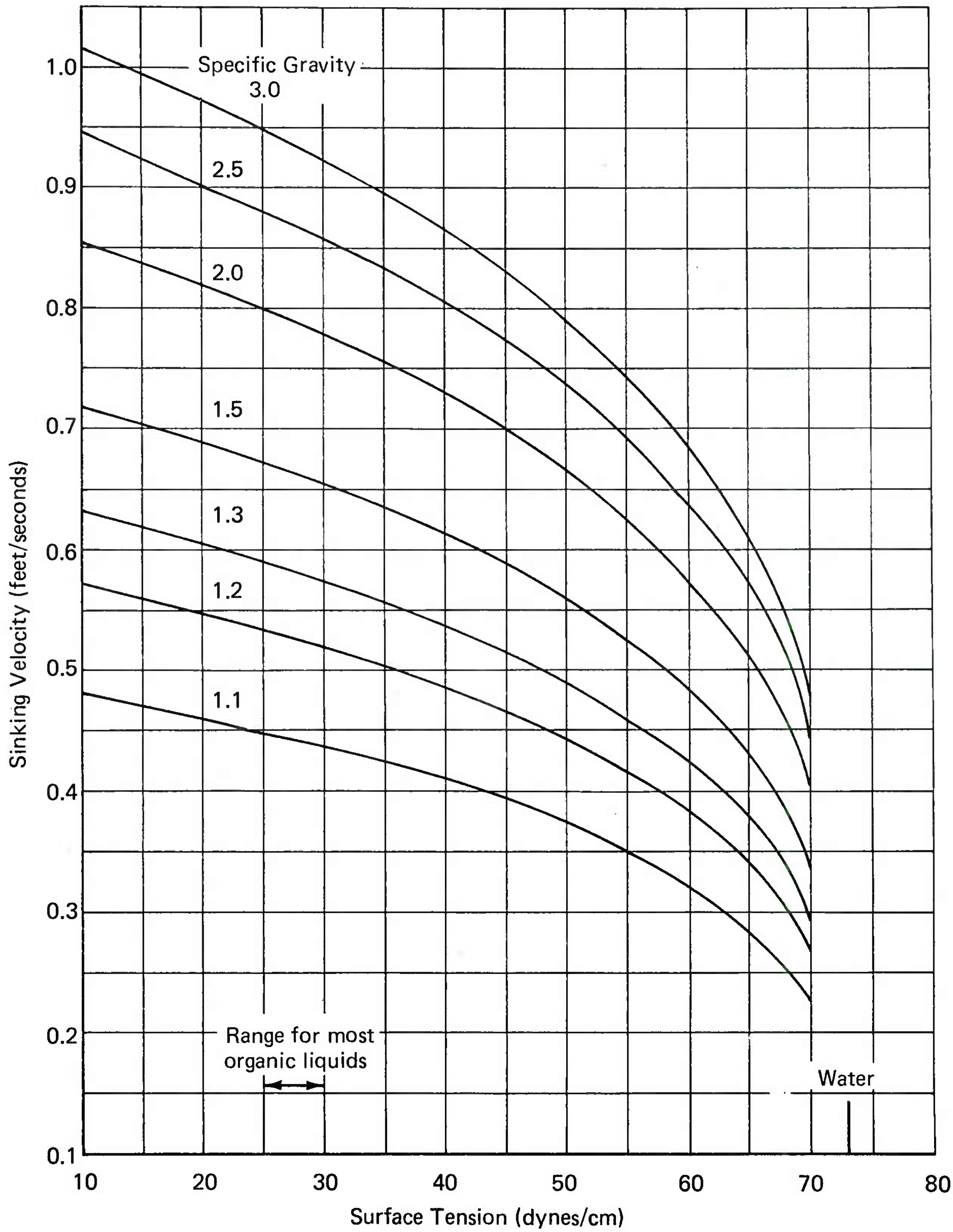


FIGURE X1 SINKING VELOCITY FOR LIQUIDS IN WATER

FIGURES FOR CALCULATION PROCEDURE RR

Hazard calculation procedure RR may be used to determine the reaction products of solid chemicals (which react with water) and water.

One table is presented for use with this procedure.

Table RR-1 lists, for each of the chemicals included, their reaction products with water and the weight fraction of the spill amount which will be converted to each product. For example, if one ton of calcium carbide is spilled on water, 0.40 ton of acetylene and 1.16 tons of calcium hydroxide will be formed.

TABLE RR.1[†]

SOLID CHEMICALS WHICH REACT WITH WATER

Reactant Compound	Products	Pertinent Code	Weight Fraction of Spill	Remarks
Aluminum chloride	Aluminum hydroxide	(no code)	$\leq$.59	Reacts violently. Reaction is not stoichiometric
	Hydrochloric acid	AP	$\leq$.82	
	Hydrogen chloride	AC		
Antimony trichloride	Antimonous acid	(no code)	.76	Reacts vigorously
	Hydrochloric acid	AP	.48	
	Hydrogen chloride	AC		
Beryllium chloride	Beryllium oxide	II	.31	Reacts vigorously with heat evolution
	Hydrochloric acid	AP	.91	
	Hydrogen chloride	AC		
Calcium carbide	Acetylene	ABC	.40	Reacts vigorously. Acetylene may spontaneously ignite.
	Calcium hydroxide	II	1.16	
Calcium, metallic	Calcium hydroxide	II	1.85	Reaction not violent. Hydrogen may ignite
	Hydrogen	ABC	.05	
Calcium oxide	Calcium hydroxide	II	1.32	Heat may ignite combustibles. Swells during reaction

TABLE RR.1[†] (Continued)

Reactant Compound	Products	Pertinent Code	Weight Fraction of Spill	Remarks
Calcium peroxide	Calcium hydroxide	II	1.03	Reacts *very slowly*
	Oxygen	AI	.22	
Calcium phosphide	Calcium hydroxide	II	1.22	Reacts vigorously. Phosphine is a poisonous, spontaneously flammable gas.
	Phosphine	(no code)	.37	
Chloroacetophenone	Hydrochloric acid	AP	.24	Reacts *slowly.*
	Hydroxyacetophenone	(no code)	.88	
Decaborane	Boric acid	SS-II	5.05	Reacts *slowly.*
	Hydrogen	ABC	.36	
Lead tetraacetate	Acetic acid	APQ	.54	Reaction not violent.
	Lead dioxide	(no code)	.54	
Lithium aluminum hydride	Aluminum hydroxide	(no code)	2.06	Reacts violently.
	Hydrogen	ABC	.21	
	Lithium hydroxide	(no code)	.63	
Lithium hydride	Hydrogen	ABC	.25	Reacts violently. Ignition may occur.
	Lithium hydroxide	(no code)	3.01	

TABLE RR.1† (Continued)

Reactant Compound	Products	Pertinent Code	Weight Fraction of Spill	Remarks
Lithium, metallic	Hydrogen	ABC	.29	Reacts violently. Ignition usually occurs.
	Lithium hydroxide	(no code)	3.45	
Maleic anhydride	Maleic acid	SS	1.18	Reaction with cold water slow. Hot water may cause frothing.
Paraformaldehyde	Formaldehyde	APQ	1.00	
Phosphorus, white	Phosphoric acid (in water)	AP	1.58	Ignites spontaneously in air.
Phosphorus pentasulfide	Hydrogen sulfide	ABC	.76	
	Phosphoric acid	AP	.88	
Potassium, metallic	Hydrogen	ABC	.026	Reacts violently.
	Caustic potash solution	AP	1.44	
Potassium peroxide	Oxygen	AI	.073	Reacts violently with heat evolution.
	Caustic potash solution	AP	1.02	
Selenium trioxide	Selenic acid	(no code)	1.14	Reacts vigorously.
Sodium	Hydrogen	ABC	.043	Reacts violently. Fire often occurs.
	Caustic potash solution	AP	1.74	

TABLE RR.1† (Continued)

Reactant Compound	Products	Pertinent Code	Weight Fraction of Spill	Remarks
Sodium amide	Ammonia	ABC	.36	Reacts violently. Frequently bursts into flames.
	Caustic soda solution	AP	1.03	
Sodium borohydride	Boric acid	SS-II	<1.63	Boric acid and sodium hydroxide may form sodium borate solution.
	Hydrogen	ABC	.21	
	Caustic soda solution	AP	<1.06	
Sodium hydride	Hydrogen	ABC	.08	Vigorous reaction. Hydrogen ignition is infrequent.
	Caustic soda solution	AP	1.66	

†Notes for Table RR.1

1) The *pertinent* hazard assessment codes of this table were especially chosen to best reflect the hazards from the products of reaction. They may or may not be the same as those found for these chemicals in CG-446-2.

2) The products of reaction for aluminum chloride, antimony trichloride, and beryllium chloride include both hydrochloric acid and hydrogen chloride. Since it cannot be estimated how much hydrogen chloride vapor or acid mist will enter the atmosphere, or how much will mix with the water, a single "weight fraction of spill" has been given which shows the total of the two possible products. The user must decide how to apportion the weight fraction between the two products. As a general guideline, it can only be said that the slower the reaction is, the more that will mix with water, and vice versa.

3) The products of reaction and their weight fractions were estimated by assuming that all of the reactant compound reacts with water before it itself poses a hazard to the environment. When the reaction is slow, however, this assumption may not be true. Depending upon the circumstances, for slow-reacting substances, the user may wish to assume that some portion of the initially spilled chemical does not react and to utilize the hazard assessment code for the unreacted chemical also to determine hazards.

4) The hazard assessment code "B" should not be utilized for a product of reaction unless the reaction takes place *within* a punctured tank or other container.

5) "No code" indicates that the chemical is not contained in CHRIS. It should not be interpreted as signifying that the substance is non-hazardous.

7.0 ACCURACY OF THE HAZARD ASSESSMENT

7.0 ACCURACY OF THE HAZARD ASSESSMENT

The certainty with which a hazard assessment can be made utilizing this handbook is limited by:

1 The on-scene information that is available.

2. The accuracy with which the chemical properties are known

3. The ability of the assessment models to predict real, physical phenomena.

The certainty with which on-scene information can be collected cannot be determined, since it depends largely on the circumstances surrounding an accident and the quality of personnel collecting the information. Information will only be accurate if care is taken in collecting the on-scene information (answering the primary questions) and transmitting it to Base without error.

The calculation procedures presented in this manual are each based upon several simplifying assumptions. These assumptions were necessary in order that the procedures be simple and the mathematical problems tractable. In most cases where the use of a simplifying assumption introduced substantial uncertainties in a hazard evaluation calculation, appropriate changes were incorporated so that the hazard evaluation itself was conservative from a safety point of view.

If the on-scene information is determined accurately, a hazard assessment utilizing this handbook and the Hazardous Chemical Data Manual can be made with answers obtained accurate within a factor of 2, for those cases involving hazard to life. Assessments of water pollution hazards, however, are characterized by larger uncertainties, and are only expected to be accurate within a factor of 10.

8.0 USE OF THE HAZARD-ASSESSMENT COMPUTER SYSTEM (HACS)

8.0 USE OF THE HAZARD-ASSESSMENT COMPUTER SYSTEM (HACS)

The Hazard-Assessment Computer System (HACS) is the computerized counterpart of the Hazard-Assessment Handbook and enables trained specialists utilizing the computer at headquarters to obtain very detailed hazard evaluations quickly when requested by OSC personnel.

The on-scene information which is essential for any level of hazard assessment by HACS is obtained by answering the "primary questions" given in Section 3.2 of this manual. The additional information which will allow a more refined and accurate assessment utilizing HACS is collected by answering the "secondary questions" given in Section 3.3.

Once the "primary questions" have been answered by OSC personnel, the information obtained should be transmitted to headquarters personnel. If time permits, and attempts at answering the "secondary questions" are successful, this information should also be forwarded.

APPENDIX

APPENDIX A

USEFUL CONVERSION FACTORS

In the process of using the Hazard-Assessment Handbook, on-scene information may have to be calculated to more desirable units. This appendix provides useful factors for converting one set of units to another. A more detailed conversion table is given in the Hazardous Chemical Data Manual.

USEFUL CONVERSION FACTORS

To Convert	To	Multiply By
Length		
inches	millimeters	25.4
inches	feet	0.0833
feet	inches	12
feet	meters	0.3048
feet	yards	0.333
feet	miles	1.894×10^{-4}
yards	feet	3.0
yards	miles	5.682×10^{-4}
miles	feet	5280
miles	yard	1760
miles	meters	1609.3
meters	feet	3.281
meters	yards	1.094
meters	miles	6.214×10^{-4}
nautical miles	miles	1.15
miles	nautical miles	0.869
Area		
sq. inches	sq. cm.	6.452
sq. inches	sq. feet	6.944×10^{-3}
sq. feet	sq. inches	144
sq. feet	sq. meters	0.290×10^{-2}
sq. meters	sq. feet	10.76
Volume		
cu. inches	cu. cm.	16.387
cu. inches	cu. feet	5.787×10^{-4}
cu. feet	cu. inches	1728
cu. feet	cu. meters	2.832×10^{-2}
cu. meters	cu. feet	35.31
U.S. gallon	cu. feet	0.1337
U.S. gallon	cu. meters	3.785×10^{-3}
U.S. gallon	imperial gallon	0.833
imperial gallon	U.S. gallon	1.201
barrel	U.S. gallon	42
U.S. gallon	barrel	0.0238

Time		
seconds	minutes	1.667×10^{-2}
seconds	hours	2.778×10^{-4}
seconds	days	1.157×10^{-5}
minutes	seconds	60
minutes	hours	1.667×10^{-2}
minutes	days	6.944×10^{-4}
hours	seconds	3600
hours	minutes	60
hours	days	4.167×10^{-2}
Mass		
pound	kilogram	0.4536
pound	ton	5.0×10^{-4}
kilogram	pound	2.205
tonne	kilogram	1000
tons	pounds	2000
Energy		
calorie	Btu	252.0
calorie	Joule	4.187
Btu	calorie	3.969×10^{-3}
Btu	Joule	1055.0
Joule	calorie	0.2388
Joule	Btu	9.479×10^{-4}
Velocity		
feet per second	meters per second	0.3048
miles per hour	feet per second	1.467
miles per hour	meters per second	0.4470
meters per second	feet per second	3.281
meters per second	miles per hour	2.237
knots	meters per second	0.5144
knots	miles per hour	1.1501
knots	feet per second	1.688
Density		
lb/ft^3	g/cm^3	0.01602
gm/cm^3	lb/ft^3	62.42
Pressure		
psi	kN/m^2	6.895
atm	kN/m^2	101.325
bar	kN/m^2	10^2
in. water	kN/m^2	0.2491
in. mercury	kN/m^2	3.386
torr	kN/m^2	0.1333
psi	atm	0.0680
atm	psi	14.696
kN/m^2	psi	0.1450
kN/m^2	atm	9.869×10^{-3}
Viscosity		
centipoise	lb/ft-sec	6.720×10^{-4}

lb/ft-sec	centipoise	1.488×10^{-3}
centipoise	poise	10^{-2}
centipoise	N s/m^2	10^{-3}
N s/m^2	centipoise	10^{3}
Thermal Conductivity		
Btu/hr-ft-°F	W/mK	1.7307
Kcal/hr-m-°C	W/mK	1.163
Btu/hr-ft-°F	kcal/hr-m-°C	1.488
kcal/hr-m-°C	Btu/hr-ft-°F	0.6720
W/mK	Btu/hr-ft-°F	0.5778
Heat Capacity		
Btu/lb-°F	cal/g-°C	1.0
cal/g-°C	Btu/lb-°F	1.0
Btu/lb-°F	J/g-°C	4.187
J/g-°C	Btu/lb-°F	0.2388
Temperature		
°K	°R	1.8
°R	°K	0.556
°C	°F	first multiply by 1.8 and then add 32.
°F	°C	first subtract 32 and then multiply by 0.556
°C	°K	+273.2
°F	°R	+459.8
Concentration in Water		
mg/m^3	gm/cm^3	10^{-9}
gm/cm^3	mg/m^3	10^{9}
mg/liter	parts per million (ppm)	1

<u>Volume to Weight Conversions</u>

Gallons liquid to tons:

Weight in Tons = (0.0042)(Specific gravity of liquid)(No. of Gallons)

Cubic feet liquid to tons:

Weight in Tons = (0.0312)(Specific gravity of liquid)(No. of Cubic feet liquid)

Cubic feet gas to tons:

$$\text{Weight in Tons} = \frac{\text{(Cu ft gas)(Molecular weight)}}{718{,}000}$$

Note: For the specific gravity and molecular weight of the substance, find its data sheet in CG-446-2, Hazardous Chemical Data. Molecular weight is data item 13.2. Specific gravity is data item 1[illegible]

APPENDIX B

EXPLANATION OF TERMS

In the process of using the Hazard Assessment Handbook, certain terms may be encountered which may not be familiar to or understood by the user. Those of the terms which are not defined at the time of their use or are not self-explanatory are listed and explained below.

Ambient temperature – the temperature of the air or the water before the spill or discharge of the chemical occurred.

Critical depth – the depth in water at which, because of the hydrostatic pressure, the boiling point of a chemical will equal the ambient water temperature. At greater depths, the chemical will not boil, regardless of its normal boiling point.

Current drift – a nautical term meaning stream (current) velocity, i.e., the speed at which the body of water moves.

Current set – a nautical term meaning current direction, i.e., the direction in which a moving body of water travels.

Dispersion – the manner in which a concentrated mass of a material "spreads out" through another material, e.g., the way in which a gas or vapor cloud "spreads outs" and becomes less concentrated as it mixes with air, or the manner in which an amount of a concentrated liquid will "spread out" and become diluted as it moves downstream in a flowing stream.

Fire-protective clothing – clothing which provides some protection to the heat or radiation given off by a fire. There are many types of this clothing. The kind referred to in this manual is that which provides the barest minimum protection. Trained personnel can safely approach fires more closely when wearing the best types.

Flame angle – the angle, measured from the vertical, that a flame will take in wind. The higher the wind speed, the more the flame will "bend over" and the greater the flame angle will be.

Flame height – the height of the flame that forms over a pool of burning liquid.

Hazard extent – the downwind or downstream distance a flammable or toxic concentration of a chemical will travel to before becoming too dilute to present a significant hazard. One or more hazard extents may be combined to partially or fully define the shape and size of the hazard zone.

Hazard zone – the area encompassing all areas which at some time after a spill or discharge occurs may be subjected to a toxic or flammable concentration of the chemical involved.

Hydraulic radius (RH) – a term combining the width and depth of a stream into a single value. Given by the expression:

$$RH = \frac{\text{Width x Depth}}{\text{Width + 2 x Depth}}$$

Immiscible chemical – one which does not mix with water.

Insoluble chemical – one which does not mix readily with water.

Low(er) Flammability Limit (LFL) – the lowest volume concentration in air of a substance which represents a flammable mixture. The value is sometimes referred to as the "lower explosive limit."

Low(er) Toxicity Limit (TLV) – the highest concentration of a substance in air that most people can breathe for 5 consecutive 8-hour work days without adverse effect. For the sake of being conservative in matters involving life or death, it is this concentration which is used for determining maximum downwind extents of vapor cloud toxicity hazard. Use of short-term inhalation limits might give more realistic answers, but the desired safety factors would not be included.

Maximum pool radius – the maximum radius to which a pool of chemical spilled on water will spread.

Miscible chemical – one which mixes readily with water.

Safe separation distance for people – the distance from the fire at which the thermal radiation level is such (450 Btu/hr ft^2) that unprotected personnel would be burned after long-term exposure.

Safe separation distance for people in fire-protective clothing – the distance from the fire at which the thermal radiation level is such (1500 Btu/hr ft^2) that unprotected personnel would virtually be instantly burned.

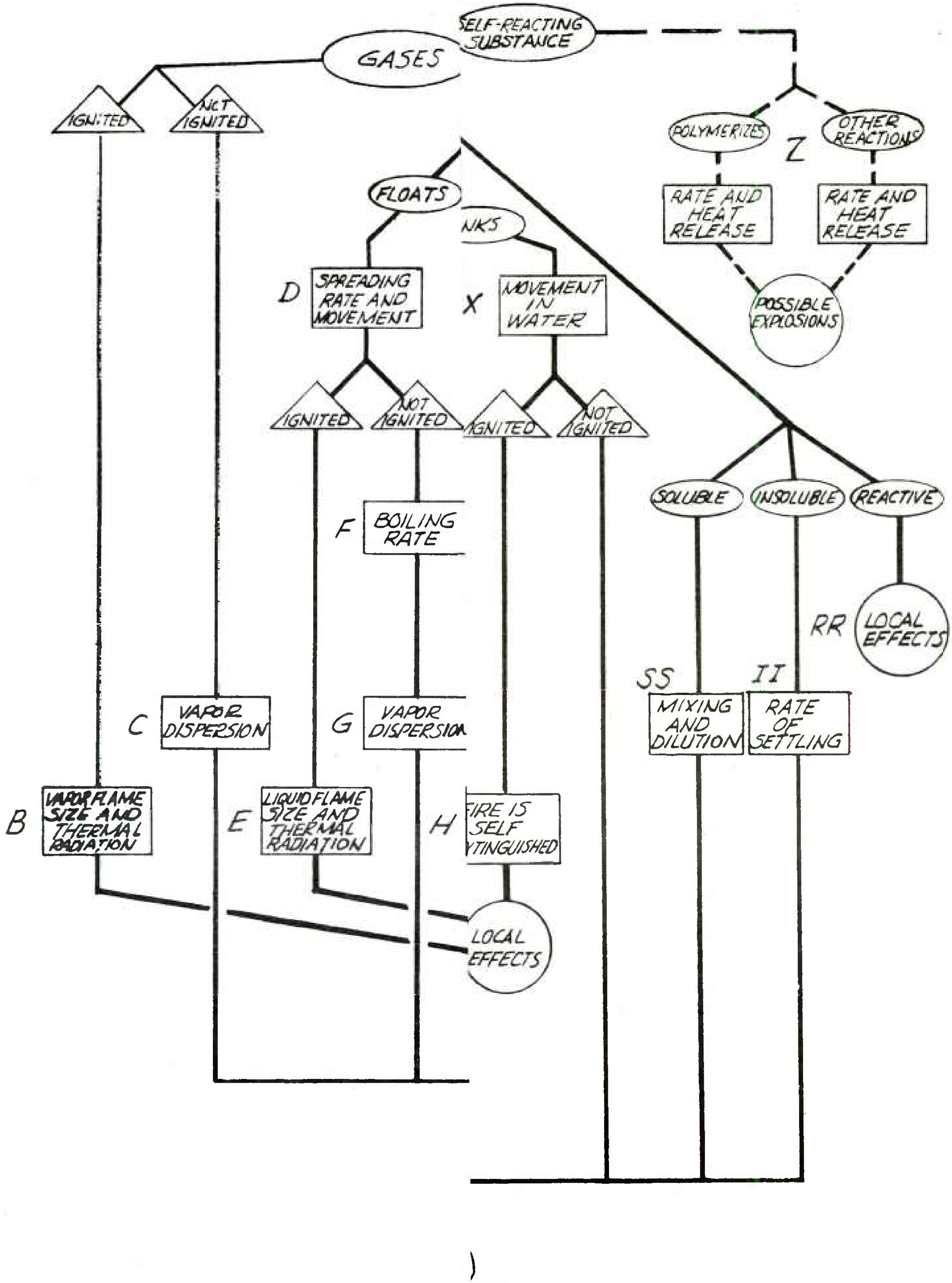
Safe separation distance for wooden structures – the distance from the fire at which the thermal radiation is such (10,000 Btu/hr ft^2) that wooden structures will eventually ignite.

Soluble chemical – one which mixes readily with water.

Tidal period – the time between two consecutive high tides or two low tides.

APPENDIX C

FOLD-OUT HAZARD ASSESSMENT TREE


SELF-REACTING SUBSTANCE
GASES
IGNITED
NOT IGNITED
FLOATS
NKS
POLYMERIZES
OTHER REACTIONS
Z
RATE AND HEAT RELEASE
RATE AND HEAT RELEASE
POSSIBLE EXPLOSIONS
D
SPREADING RATE AND MOVEMENT
X
MOVEMENT IN WATER
IGNITED
NOT IGNITED
IGNITED
NOT IGNITED
SOLUBLE
INSOLUBLE
REACTIVE
F
BOILING RATE
RR
LOCAL EFFECTS
SS
II
C
VAPOR DISPERSION
G
VAPOR DISPERSION
MIXING AND DILUTION
RATE OF SETTLING
B
VAPOR FLAME SIZE AND THERMAL RADIATION
E
LIQUID FLAME SIZE AND THERMAL RADIATION
H
FIRE IS SELF EXTINGUISHED
LOCAL EFFECTS

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3.0 Information Needs	13 (RB)	Original
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	23	Change 2
	24-25	Original
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	73	Change 1
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	79	Change 2
	81-85	Change 1
	87	Original
	89	Change 1

SUBJECT MATTER	PAGE NUMBER	AMENDMENT
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APQRS	115-119	Change 1
	121-123	Original
	125-131	Change 1
ATUVW	133	Original
	135	Change 2
	137-149	Original
	151	Change 2
	153-155	Original
AXY	157	Original
	159	Change 2
	161	Original
AZ	163	Original
II	165	Original
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SS	171	Original
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	177-179 (RB)	Change 1
Procedure D	181 (RB)	Change 1
	183-184	Change 1
Procedure E	185 (RB)	Change 1
	187-211 (RB)	Change 1
Procedure G	213 (RB)	Change 1
	215-221 (RB)	Change 1
Procedure I	223 (RB)	Change 1
	225 (RB)	Change 1
Procedure K	227 (RB)	Change 1
	229-230a (RB)	Change 1
Procedure O	231 (RB)	Change 1
	233 a-n	Change 1
	234	Change 2
Procedure P	235 (RB)	Change 1
	237-246	Change 1
Procedure R	247 (RB)	Change 1
	249-263 (a-t)	Change 1

SUBJECT MATTER	PAGE NUMBER	AMENDMENT
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	285 (RB)	Change 1
Procedure RR	287 (RB)	Change 1
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	290c (RB)	Change 2
7.0 Accuracy of the Hazard Assessment	291 (RB)	Original
	293 (RB)	Change 2
	295 (RB)	Change 1
8.0 Use of the Hazard Assessment Computer System (HACS)	297 (RB)	Change 2
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	LEP-5 (RB)	Change 2