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DEPARTMENT OF TRANSPORTATION

COAST GUARD

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CHRIS

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Response Methods

Handbook

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Important

The *Chemical Hazards Response Information System* (CHRIS) has been developed to provide timelv information essential for proper decision making bv responsible, trained Coast Guard personnel during emergencies involving the water transport of hazardous chemicals. It has now been made available to the public in its entirety. However, this is only one of several tools which should be used in evaluating chemical hazards. It is not, and is not intended to be, infallible. All attempts should be made to reference other sources of information in addition to this manual.

The information in this manual is subject to change.

DEPARTMENT OF TRANSPORTATION
UNITED STATES COAST GUARD

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COMDTINST M16465.14
20 JUN 1979

COMMANDANT INSTRUCTION M16465.14 (Old CG-446-4)

Subj: Response Methods Handbook of the Chemical Hazards Response Information System (CHRIS)

1. PURPOSE. CHRIS is an official publication of the U. S. Coast Guard and consists of the following four volumes:

COMDTINST M16465.11	A Condensed Guide to Chemical Hazards
COMDTINST M16465.12	Hazards Chemical Data
COMDTINST M16465.13	Hazards Assessment Handbook
COMDTINST M16465.14	Response Methods Handbook and Appendixes

This manual provides timely decision-making information for use by personnel involved in responding to and mitigating the effects of hazardous material discharges. It can be properly used only in conjunction with the other manuals of the Chemical Hazards Response Information System.

2. DIRECTIVES AFFECTED. This transmittal Instruction replaces the original Letter of Promulgation dated 26 April 1974.

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F. P. SCHUBERT
Acting Chief, Office of Marine Environment and Systems

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HOW TO USE THE RESPONSE METHODS HANDBOOK

In an Emergency

(The sequence of the following steps may be altered depending upon the magnitude of the incident and urgency of response)

- Confirm the identity of the chemical
- Determine that immediate responses, including rescue, notification, and precautionary measures have been taken at the scene of the incident—see the Condensed Guide to Chemical Hazards
- Develop on-scene information needed for further assessment and response including location, amount of chemical involved, weather, tides and currents and traffic – see the Hazard Assessment Handbook for Information Needs
- Refer to the Hazardous Chemical Data Manual for more detailed information on the chemical
- Assess the extent of the hazard presented using the Hazard Assessment Handbook
- Refer to Regional Contingency Plan Data Base for location of populated areas, facilities and property that may be threatened
- Use this Handbook
    - select potential response methods using Response Index, Table 4-1
    - evaluate applicability of potential response methods based on the conditions that prevail and availability of resources
    - carry out applicable *cautionary* responses
    - carry out applicable *corrective* responses

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6.0 CORRECTIVE RESPONSE METHODS (Continued)

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RECORD OF CHANGES

Identification of Amendment	Date Entered	By whom entered (Signature; rank, grade or rate; name of command)
Change 1	entered with second printing	
Change 2 (COMDTINSTNOTE 16465,11 SEP'78)	entered with second printing	
Change 3	entered with second printing	

1.0 THE CHEMICAL HAZARDS RESPONSE INFORMATION SYSTEM (CHRIS)

1.1 PURPOSE AND SCOPE

The Chemical Hazards 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, and a hazard-assessment computer system (HACS). The four manuals contain chemical data, hazard-assessment methods, and response guides. Regional data are included in the Coastal Regional Contingency Plans. Elements of the Coast Guard headquarters staff operate the hazard-assessment computer system and provide technical assistance on request by field personnel during emergencies. In addition, they are responsible for periodic update and maintenance of CHRIS.

A brief description of each component of CHRIS and its relation to ~~this~~ manual – the Response Method Handbook – is provided below.

1.2 A CONDENSED GUIDE TO CHEMICAL HAZARDS

The Condensed Guide to Chemical Hazards, 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 chemicals. 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.

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.

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

This manual, 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. Its general content is described on the next page.

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 and can be particularly important in the use of this manual, the Response Methods Handbook.

1.7 HAZARD-ASSESSMENT COMPUTER SYSTEM (HACS)

The Hazard-Assessment Computer System (HACS) is the computerized counterpart of the Hazard-Assessment Handbook and enables specialists utilizing the computer at Coast Guard Headquarters to obtain very detailed hazard evaluations quickly when requested by OSC personnel.

2.0 GENERAL CONTENT OF THE RESPONSE METHODS HANDBOOK

This manual of the Chemical Hazard Response Information System (CHRIS) has been developed to present current information and assist on-scene coordinators (OSC) on techniques, equipment, and systems that are available to combat and minimize the damage that can be expected when a hazardous chemical is discharged into navigable waters.

The handbook describes the content and use of CHRIS and discusses the causes of accidental discharges of hazardous chemicals. It provides a quick reference guide to the selection of response methods and describes these methods in detail. The handbook is also complemented by an appendix containing a review of the state-of-the-art response equipment and systems and a comprehensive catalogue of response equipment.*

In this handbook response methods are divided into two categories: cautionary and corrective. Cautionary responses, which should be promptly applied to preserve human and animal life, include restricting entry into the area affected by the discharge and use of the water polluted by the discharge, as well as evacuation of threatened areas. Corrective responses include methods of stopping or reducing a further discharge of the chemical, containment procedures, and methods of collection, recovery, and treatment. Methods of cleaning an affected shoreline and treatment of an exposed waterfront are also described.

The U.S. Coast Guard expects to continually expand facilities and equipment available for response to a hazardous chemical incident. It is important, however, that *all* U.S. Coast Guard personnel become familiar with the types and use of existing response equipment, so that any individual can be pressed into response service in the event of a hazardous chemical incident that threatens life and property. In most hazardous chemical incidents Coast Guard personnel will be responsible for directing and coordinating the response action of various governmental agencies, private industry, and contractual cleanup agencies. At the time of an incident, it is not appropriate that an individual attempt to gain response knowledge while a response is under way. The objective of this manual, therefore, is to guide Coast Guard and other personnel (in advance of a chemical discharge) in the action necessary to control the situation and to minimize loss of life and environmental damage.

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*Should USCG personnel develop or obtain information on new pollution response equipment, they are to forward the information to the Commandant (G-WEP).

3.0 CAUSES OF HAZARDOUS CHEMICAL DISCHARGES

There are two types of hazardous chemical discharges into navigable waters accidental and intentional. Each is described below.

- *Accidental Chemical Discharges* Chemical incidents occur accidentally when chemicals are transported, transferred, stored, and processed in bulk quantity. Some of the major problems are discussed in Sections 3.1 through 3.4. CHRIS was developed to respond to such accidental discharges.

- *Intentional Discharges* – The sources of such discharges are numerous; however, they predominantly originate in industrial facilities which, with governmental permission, discharge pretreated effluents through an outfall or a series of outfalls into a public waterway. Polluting discharges can also occur when waste oil and other materials are intentionally discharged into an available storm drain from which it rapidly enters a public watercourse. A study conducted for and within one state revealed that as much as 1,800,000 gallons of waste oil are unaccountably disposed of annually. On this basis a "major" intentional polluting discharge has been a common, often nightly, occurrence in our major cities. Where specific problems resulting from intentional discharges require action, the cautionary or corrective response methods cited in this handbook may be applied when appropriate.

3.1 HAZARDOUS CHEMICAL TRANSPORTATION PROBLEMS

The economics of bulk chemical transportation are such that as much material as practical must be transported at one time, or that a variety of chemicals must be transported in separate compartments of a single vessel to obtain a full-cargo condition. The draft of marine transportation craft is continually increasing, while channel depth conditions remain largely static due to bedrock or rock outcropping conditions that are now evident in most U.S. coastal and internal navigable channels. Groundings, beachings, and bottom impacts with rock outcroppings are becoming frequent occurrences. Fortunately, such incidents do not always result in the release of a chemical discharge, although USCG accident statistics indicate that chemical incidents do, on a regular basis, occur from bottom impacts. Efforts are under way to decrease such incidents by stricter regulatory requirements and improved vessel design and construction.

The federal requirements (CFR-31.10-20) for underwater hull examination of barges currently (with specified exceptions prior to July 1, 1975) specify the following drydocking frequency:

- Steel hull tank vessels
    - At intervals not to exceed 24 months if operated in salt water an aggregate of more than 12 months in a 24-month period.
    - At intervals not to exceed 36 months if operated in salt water less than an aggregate of 6 months in any 12-month period.
    - If tank vessel operates in salt water an aggregate of more than 6 months in any 12-month period, it shall be drydocked or hauled out within 12 months of the end of such 12-month period or within 36 months of its last drydocking or hauling out, whichever comes first.
    - If tank barges that operate in salt water an aggregate of less than 1 month in any 12-month period, the previous two requirements shall be met except that under same circumstances internal inspections may be accepted.
- Wood hull tank vessels
    - At intervals not to exceed 48 months.

Unless the barge owner voluntarily drydocks and inspects his vessel more frequently, underwater hull damage or deterioration might go undetected for several years, or at least until cargo leakage occurs.

Railroad tank car derailing, pumping, and collisions can also result in the release of chemical cargoes while in transit. Such incidents frequently terminate with the release of chemicals into public waterways. Tank car overfills due to operator inattention and the lack of high liquid-level audible alarms represent other causes of chemical incidents.

Automotive tank trucks involved in collisons and chemical overfills have contributed to chemical incidents. In many cases, such instances result in the escape of the chemical discharge into public waterways. Marine chemical incidents have also taken place when tank truck operators have pulled away from their loading platforms before disconnecting their fill line. The resulting pipeline damage releases the liquid, under transfer, until the master flow control valve on the bulk storage tank can be manually closed.

3.2 HAZARDOUS CHEMICAL TRANSFER PROBLEMS

A large percentage of the reported chemical discharges is related to transfer systems between vessels and at terminals. A common mode of accidental discharge is the failure of flexible hose lines. Considerable amounts of the chemical being transferred may be discharged before the flow can be shut off. In many cases, manual master control valves are located remotely from the loading unloading dock so that considerable time may elapse before the discharge can be stopped. Also transfer is often conducted with the deck of the pier or wharf at a much higher elevation than the loading unloading vessel. This requires the barge-crew to ascend dock ladders and travel some distance to alert the terminal personnel.

Hoselines should be hydrostatically tested periodically. Failure to replace and remove damaged or worn hose lines from the dock area can result in the use of defective systems with a subsequent likelihood of significant discharges of hazardous chemicals into the water body.

Another cause of accidental discharge is the failure to secure dockside transfer pump controls, either by locking the control box or removing a fuse, resulting in an inadvertent pump activation when transfer lines have not been made up. Similarly, failure to lock and secure the terminal valve wheels at dockside has been a repeated cause of chemical incidents.

Accidental discharges are also caused by unintentional overfilling of marine storage compartments. This, more often than not, results from a miscalculation of capacity and or the inattention of the operating personnel either ashore or afloat. The use of audible, high liquid-level alarms and automatic pump shut-off controls can greatly reduce such incidents; however many facilities are still operated without them.

Other contributing causes of discharges involve failure to blank the terminal flange of transfer pipelines and failure to use and empty drip containers which should be positioned under pipeline connections.

Discharges during transfer are often aggravated by a lack of communication between the crew of the transferring vessel and the terminal dockman. Also, lack of communication between a tanker or barge deck and engine room crew, and quite frequently the terminal personnel, has resulted in pump activation before the transfer manifold and hose line connection has been fully made.

3.3 HAZARDOUS CHEMICAL BULK STORAGE PROBLEMS

Chemical discharges of considerable magnitude have occurred with the complete failure of bulk chemical storage tanks. Chemicals are stored in all types of containers, including wooden vats. Very few containers are subjected to regular integrity testing, and only a few are protected by a diked enclosure or secondary means of containment. Faulty design and manufacture, inferior welding, and foundation failures have resulted in the release of the entire contents of some bulk storage tanks, even when new. Older tanks have failed from chemical reaction and internal corrosion either localized or in the form of scattered rust pits. The undetected deterioration and ultimate failure of partially and completely buried storage tanks also develops the potential for the accidental release of stored chemicals.

Most chemical discharges, such as tank overfill and overflow, occur, however, because of human failure. Inattention or failure to close a water draw valve when draining off bottom condensation from a bulk storage tank has also caused chemical incidents. When there is a complete lack of a secondary means of containment, such as an earthen-diked enclosure or a concrete retaining wall, the overfill or drained release can enter the nearest watercourse. Even when a secondary means of containment is provided, entry of the chemical into a waterway has occurred because of the failure of plant personnel to close and secure rainwater drainage valves. In most cases, these are provided as manually operated devices which control the drainage that passes through the dike or retaining wall.

Chemical incidents have also occurred due to lax plant security, lack of complete security fencing, and failure to lock or otherwise secure the master flow control valve on bulk storage tanks. In such cases, vandalism has often been defined as the cause of chemical discharges.

3.4 HAZARDOUS CHEMICAL PROCESSING PROBLEMS

Once a hazardous chemical is in production, a number of potential accidental discharge situations develop. The most frequent situation involves froth and boilover of the chemicals in a process reactor or container. Such discharges tend to cascade down the process vessel into floor drains, many of which lead directly into an outfall which empties into a waterway.

Production pipeline failures are common; such lines interconnect process vessels and storage and are frequently exposed to physical impact from moving vehicles, and thermal shock from chemicals under process at both high and low temperatures. Chemical materials also escape from pipelines resting on wooden or poorly constructed pipeline supports. In such cases the supports deteriorate and the pipeline becomes stressed and ultimately fails.

Shock loading of in-plant production lines has also contributed to line failure and liquid release. Such incidents occur in long runs of pipeline when the storage tank flow control valve is opened too quickly, permitting a slug of chemical material to run through the line to impact and fracture the next closed valve in the line.

Buried pipelines, many of which are 30 or more years old, have had undetected leaks for lengthy periods. Some plants protect these buried pipelines with sacrificial cathodic systems to protect the exterior metal from corrosion; in others the pipelines are run in exposed trenches that permit frequent examination. Unfortunately, many are buried and receive little care.

4.0 Response Methods Selection

4.0 SELECTION OF RESPONSE METHOD

To Select Response Methods

- Identify the chemical by name
- Use Response Index (Table 4-1) to determine applicable *cautionary* and *corrective* responses (as explained below)
- Review *special precautions* reference numbers listed in last column of Response Index refer to precautions – cited on last page of the Index
- For quick reference to downwind travel of hazardous gases or vapors, see Table 5-1 and 5-2, pages 5-4 through 5-6.

(Brief descriptions of response methods are presented immediately following the Response Index, Table 4-1)

4.1 CAUTIONARY AND CORRECTIVE RESPONSE INDEX (TABLE 4-1)

The purpose of the Cautionary and Corrective Response Index (Table 4-1) is to help the OSC, or his staff, to select an appropriate response for each of the chemicals contained in the CHRIS. It is impossible, however, to establish hard and fast rules for response actions since the terrain, water conditions, and even blending of one or more chemical materials can quickly change the situation to require the application of a combination of response actions. On this basis, the Index serves only as a guide and the appropriate applied response action for a given situation remains the direct responsibility of the OSC.

Response actions are divided into two groups:

1) Cautionary Response

Of prime importance is the preservation of human life and health followed by the minimization of property damage and the protection of the natural environment. Cautionary response actions, when applicable, should receive immediate attention and action. Once the name of the discharged chemical is known, it should be located in the first column of the Index. In the first six columns to the right of the name of the chemical, one or more "X's" or "?'s" will appear. The "X's" designate cautionary response actions that should be promptly introduced, if warranted by the amount of chemical discharged. The "?'s" indicate that the response may or may not be appropriate, depending upon the circumstances of the spill and the characteristics of the chemical, and that the Hazardous Chemical Data Manual should be accessed for further information.

In brackets under the title for each response action are listed Response Manual pages that provide a detailed description of the selected response action. A series of key reference numbers are also provided in the index for additional informational purposes. These numbers range from 1 to 22 and provide pertinent data on the chemical with regard to personal protection and the effects generated by the chemical following release. Lists of definitions of responses and key reference numbers follow Table 4-1.

2) Corrective Response

To select a corrective response action the name of the chemical is first located in the Index. Wherever an "X" appears in a corrective response column, the defined action should be given consideration as a means of containing or otherwise controlling the polluting discharge. Wherever a "?" appears, the Hazardous Chemical Data Manual should be accessed to determine the conditions under which the response may or may not be appropriate. (Question marks indicate that there is some unusual flammability or toxicity hazard associated with the chemical, or that its behavior upon release is sensitive to, and therefore dependent upon, environmental conditions.) As with cautionary response selection, the page number given under the suggested corrective response action refers the user to the manual page that provides details on the selected action. The numbers in the reference key column again define personal protection and the effects generated by the spilled chemical.

TABLE 4-1

CAUTIONARY AND CORRECTIVE RESPONSE INDEX*

	Cautionary Response							Corrective Response											
										Collection Systems† (Tab 6.3)			Chemical & Physical Treatment Systems (Tab 6.4)						
	Restrict Access (p. 5-11)	Restrict Ignition (p. 5-12)	Evacuate (p. 5-13)	Restrict Human Use (p. 5-14)	Restrict Farm Use (p. 5-15)	Restrict Industrial Use (p. 5-15)	Dilute and Disperse**	Stop Discharge (Tab 6.1) (p. 6-3)	Contain (Tab 6.2) (p. 6-9)	Skim (p. 6-38)	Pump (p. 6-42)	Dredge (p. 6-43)	Burn (p. 6-56)	Neutralize (p. 6-60)	Absorption (p. 6-71)	Other Treatments (p. 6-83)	Clean Shore Line (Tab 6.5) (p. 6-97)	Salvage Waterfowl (Tab 6.6) (p. 6-101)	Reference Key To Special Precautions/Information (Page 4-21)
Acetaldehyde	X	X	X	X			X	This response applies to all chemicals								State of the art not so well developed			1.2
Acetic acid						X	X												1,2
Acetic anhydride						X	X												1,2
Acetone	X	X					X						X						1,3,4
Acetone cyanohydrin	X		X	X	X	X	X		X	X								X	1,2,5,12,19
Acetonitrile	X	X		X		X	X												1,2
Acetophenone				X					X	X	X						X	X	2,9
Acetylacetone				X			X												1,2,3
Acetyl bromide	X		X	X		X	X							X					1,2,5,8,11,18
Acetyl chloride	X	X	X			X	X							X					1,2,3,5,8,11,18
Acetylene	X	X	X										X						1,4,6,20
Acetyl peroxide solution	X	X	X		X	X					X	X							2,7,9,12,21
Acridine	X				X				X	X		X							1,2,3
Acrolein	X	X	X	X	X	X	X												1,2,5,6
Acrylamide	X			X	X	X													1,2
Acrylic acid	X			X		X	X												1,2,12
Acrylonitrile	X	X	X	X	X	X	X		X	X							X	X	1,2,5,12,19
Adipic acid	X	X		X															1,2,3
Adiponitrile				X					X	X							X	X	12
Aldrin	X			X	X	X			X	X		X			X		X	X	1,2,9,12
Alkyl benzene sulfonic acids	X						X							X					2,18
Allyl alcohol	X	X		X			X												1,2,3,5,12

*The numbers in parentheses are page reference numbers.

**Dilute and disperse only when other corrective methods cannot be used.

†For recovery methods, see page 6-43.

TABLE 4-1 (Continued)

CAUTIONARY AND CORRECTIVE RESPONSE INDEX*

	Cautionary Response							Corrective Response												
										Collection Systems† (Tab 6.3)			Chemical & Physical Treatment Systems (Tab 6.4)						
	Restrict Access (p. 5-11)	Restrict Ignition (p. 5-12)	Evacuate (p. 5-13)	Restrict Human Use (p. 5-14)	Restrict Farm Use (p. 5-15)	Restrict Industrial Use (p. 5-15)	Dilute and Disperse***	Stop Discharge (Tab 6.1) (p. 6-3)	Contain (Tab 6.2) (p. 6-9)	Skim (p. 6-38)	Pump (p. 6-42)	Dredge (p. 6-43)	Burn (p. 6-56)	Neutralize (p. 6-60)	Absorption (p. 6-71)	Other Treatments (p. 6-83)	Clean Shore Line (Tab 6.5) (p. 6-97)	Salvage Waterfowl (Tab 6.6) (p. 6-101)	Reference Key To Special Precautions/Information (Page 4-21)
Allyl bromide	X	X			X	X		This response applies to all chemicals			X	X				State of the art not so well developed			1,2,9,12
Allyl chloride	X	X		X			X			X				X	X			X	1,2,5,12
Allyl chloroformate	X				X	X	X				X	X		X					1,2,3,8,12,18
Allyltrichlorosilane	X		X			X	X							X					1,2,3,5,8,11,12,18,21
Aluminum chloride				X		X													1,2,5,8,11,18
Aluminum fluoride												X							1,12
Aluminum nitrate	X	X				X	X												1,2
Aluminum sulfate																			1,2
Aminoethylethanolamine							X												2
Ammonia, anhydrous	X		X	X			X												1,2,5,11,20
Ammonium acetate							X												1,2
Ammonium benzoate							X												1,2
Ammonium bicarbonate						X	X												1,2
Ammonium bifluoride	X				X	X	X							X					1,2,18
Ammonium carbonate						X	X												1,2
Ammonium chloride					X		X												1,2
Ammonium citrate							X												1
Ammonium dichromate	X	X		X	X	X	X					X							1,2,3,7,8,12,21
Ammonium fluoride	X				X	X	X							X					1,2,18
Ammonium formate					X		X												1,2
Ammonium gluconate							X												1
Ammonium hydroxide**	X		X	X			X												1,2

*The numbers in parentheses are page reference numbers

**(<28% aqueous am.)

***Dilute and disperse only when other corrective methods cannot be used.

†For recovery methods, see page 6-43.

TABLE 4-1 (Continued)

CAUTIONARY AND CORRECTIVE RESPONSE INDEX*

	Cautionary Response							Corrective Response												
										(Tab 6.3) Collection Systems†			(Tab 6.4) Chemical & Physical Treatment Systems						
	Restrict Access (p. 5-11)	Restrict Ignition (p. 5-12)	Evacuate (p. 5-13)	Restrict Human Use (p. 5-14)	Restrict Farm Use (p. 5-15)	Restrict Industrial Use (p. 5-15)	Dilute and Disperse**	Stop Discharge (Tab 6.1) (p. 6-3)	Contain (Tab 6.2) (p. 6-9)	Skim (p. 6-38)	Pump (p. 6-42)	Dredge (p. 6-43)	Burn (p. 6-56)	Neutralize (p. 6-60)	Absorption (p. 6-71)	Other Treatments (p. 6-83)	Clean Shore Line (Tab 6.5) (p. 6-97)	Salvage Waterfowl (Tab 6.6) (p. 6-101)	Reference Key To Special Precautions/Information (Page 4-21)
Ammonium iodide					X		X	This response applies to all chemicals								State of the art not so well developed			1
Ammonium lactate							X												1
Ammonium lauryl sulfate							X												2
Ammonium molybdate	X			X	X														1,2
Ammonium nitrate	X	X		X		X	X												7,12
Ammonium nitrate-phosphate mixture	X	X				X	X												1,7,21
Ammonium nitrate-sulfate mixture	X	X				X	X												1,7,21
Ammonium nitrate-urea solution							X							X					2,21
Ammonium oleate							X												2
Ammonium oxalate	X			X	X														1,2
Ammonium pentaborate	X				X		X												1,2
Ammonium perchlorate	X	X		X		X	X												2,7
Ammonium persulfate	X	X			X	X	X												1,2,7,21
Ammonium phosphate	X					X	X												1,2
Ammonium silicofluoride	X			X	X	X	X												1,2
Ammonium stearate							X												3,12
Ammonium sulfamate				X	X		X												1,2
Ammonium sulfate							X												
Ammonium sulfide	X	X	X	X	X	X													1,2,5,6,8,12
Ammonium sulfite							X												1,2

*The numbers in parentheses are page reference numbers.

**Dilute and disperse only when other corrective methods cannot be used.

†For recovery methods, see page 6-43.

TABLE 4-1 (Continued)

CAUTIONARY AND CORRECTIVE RESPONSE INDEX*

	Cautionary Response							Corrective Response											
										Collection Systems† (Tab 6.3)			Chemical & Physical Treatment Systems (Tab 6.4)						
	Restrict Access (p. 5-11)	Restrict Ignition (p. 5-12)	Evacuate (p. 5-13)	Restrict Human Use (p. 5-14)	Restrict Farm Use (p. 5-15)	Restrict Industrial Use (p. 5-15)	Dilute and Disperse**	Stop Discharge (Tab 6.1) (p. 6-3)	Contain (Tab 6.2) (p. 6-9)	Skim (p. 6-38)	Pump (p. 6-42)	Dredge (p. 6-43)	Burn (p. 6-56)	Neutralize (p. 6-60)	Absorption (p. 6-71)	Other Treatments (p. 6-83)	Clean Shore Line (Tab 6.5) (p. 6-97)	Salvage Waterfowl (Tab 6.6) (p. 6-101)	Reference Key To Special Precautions/Information (Page 4-21)
Ammonium tartrate							X	This response applies to all chemicals								State of the art not so well developed			1,2
Ammonium thiocyanate	X			X	X		X												1,2
Ammonium thiosulfate	X			X			X												1,2
Amyl acetate	X	X				X			X	X								X	1,2
iso-Amyl nitrite	X	X	X		X	X			?	?					?				1,2,3,5,6,8,12,19
n-Amyl alcohol	X	X				X	X			X					X		X	X	1,3
n Amyl chloride	X	X				X			?	?					?		X	X	12
n-Amyl mercaptan	X	X				X			?	?					?		X	X	12
n-Amyl methyl ketone						X			X	X			X		X		X	X	2,4,14,19
n-Amyl nitrate	X	X			X	X			?	?	X	X			?		X		1,2,12,21
n-Amyltrichlorosilane	X		X			X	X							X					1,2,8,11,12,18,21
Aniline	X			X	X	X	X		X	X	X	X						X	1,2,12,19
Anisoyl chloride	X				X	X	X				X								1,2,8,18
Anthracene									X	X		X							1
Antimony pentachloride	X		X	X	X	X	X				X			X					1,2,8,18
Antimony pentafluoride	X		X	X	X	X	X							X					1,2,5,8,11,18
Antimony potassium tartrate	X			X	X		X												1,2
Antimony trichloride	X		X	X	X	X	X							X					1,2,5,8,11,18
Antimony trifluoride				X	X		X												2
Antimony trioxide	X											X							1,2
Arsenic acid	X			X	X	X						X		X					1,2,18
Arsenic disulfide	X			X	X	X						X							1,2

*The numbers in parentheses are page reference numbers.

**Dilute and disperse only when other corrective methods cannot be used.

†For recovery methods, see page 6-43.

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TABLE 4-1

CAUTIONARY AND CORRECTIVE RESPONSE INDEX*

	Cautionary Response						Corrective Response													
										Collection Systems† (Tab 6.3)			Chemical & Physical Treatment Systems (Tab 6.4)							
	Restrict Access (p. 5-11)	Restrict Ignition (p. 5-12)	Evacuate (p. 5-13)	Restrict Human Use (p. 5-14)	Restrict Farm Use (p. 5-15)	Restrict Industrial Use (p. 5-15)	Dilute and Disperse**	Stop Discharge (Tab 6.1) (p. 6-3)	Contain (Tab 6.2) (p. 6-9)	Skim (p. 6-38)	Pump (p. 6-42)	Dredge (p. 6-43)	Burn (p. 6-56)	Neutralize (p. 6-60)	Absorption (p. 6-71)	Other Treatments (p. 6-83)	Clean Shore Line (Tab 6.5) (p. 6-97)	Salvage Waterfowl (Tab 6.6) (p. 6-101)	Reference Key To Special Precautions/Information (Page 4-21)
Arsenic trichloride	X		X	X	X	X	X	This response applies to all chemicals						X		State of the art not so well developed			1,2,5,8,18
Arsenic trioxide	X			X	X	X						X							1,2
Arsenic trisulfide	X			X	X	X						X							1,2
Asphalt, ARF									X	X		X					X	X	9
Asphalt, ASP									X	X		X					X	X	9
Asphalt, ASR									X	X		X					X	X	9
Atrazine	X					X			X	X		X							1,2,17
Azinphosmethyl	X			X	X				X	X		X							1,2
Barium carbonate				X					X			X					X		9
Barium chlorate	X	X	X	X	X		X					X							1,2,7
Barium nitrate	X	X		X	X		X					X							1,2,7
Barium perchlorate	X	X	X	X	X		X					X							1,2,7
Barium permanganate	X	X		X	X		X					X							1,2,7
Barium peroxide	X	X		X	X							X							1,2,7,8
Benzaldehyde	X			X					X	X	X	X					X	X	1,2
Benzene	X	X		X		X			X	X			X					X	1,2,4,15
Benzene hexachloride	X			X	X				X			X			X		X		1,2
Benzene phosphorus dichloride	X		X			X	X							X					1,2,5,8,11,12,18
Benzene phosphorus thiodichloride	X				X	X	X				X			X					1,2,8,12,18
Benzoic acid									X			X							
Benzonitrile	X			X	X				X	X	X	X			X				1,2
Benzophenone									X	X		X							2

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TABLE 4-1

CAUTIONARY AND CORRECTIVE RESPONSE INDEX*

	Cautionary Response							Corrective Response												
										(Tab 6.3) Collection Systems†			(Tab 6.4) Chemical & Physical Treatment Systems						
	Restrict Access (p. 5-11)	Restrict Ignition (p. 5-12)	Evacuate (p. 5-13)	Restrict Human Use (p. 5-14)	Restrict Farm Use (p. 5-15)	Restrict Industrial Use (p. 5-15)	Dilute and Disperse**	Stop Discharge (Tab 6.1) (p. 6-3)	Contain (Tab 6.2) (p. 6-9)	Skim (p. 6-38)	Pump (p. 6-42)	Dredge (p. 6-43)	Burn (p. 6-56)	Neutralize (p. 6-60)	Absorption (p. 6-71)	Other Treatments (p. 6-83)	Clean Shore Line (Tab 6.5) (p. 6-97)	Salvage Waterfowl (Tab 6.6) (p. 6-101)	Reference Key To Special Precautions/Information (Page 4-21)
Benzoyl chloride	X			X		X	X	This response applies to all chemicals	X							State of the art not so well developed			1,2,5,11,12,18
Benzyl alcohol	X			X	X		X												1,2
Benzylamine	X			X	X	X	X												1,2,8
Benzyl bromide	X				X	X					X			X					1,2,8,12,18
Benzyl n-butyl phthalate											X								9
Benzyl chloride	X				X	X					X			X					1,2,8,12,18
Benzyl chloroformate	X				X	X					X			X					1,2,8,12,18
Benzyldimethyloctadecylammonium chloride	X			X	X		X												2
Benzyltrimethylammonium chloride	X			X	X		X												2
Beryllium chloride	X			X	X	X								X					1,2,8,11,18,21
Beryllium fluoride	X			X	X	X								X					1,2,8,11,18,21
Beryllium, metallic	X	X										X							1,2,21
Beryllium nitrate	X	X		X	X	X								X					1,2,18,21
Beryllium oxide	X	X		X	X							X							1,2,21
Beryllium sulfate	X			X	X	X													1,2,21
Bismuth oxychloride												X							1,2
Bisphenol A				X					X			X							2
Bisphenol A diglycidyl ether					X	X					X	X							2,9
Boiler compound, liquid	X					X	X							X					2,8

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TABLE 4-1

CAUTIONARY AND CORRECTIVE RESPONSE INDEX*

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										(Tab 6.3) Collection Systems†				(Tab 6.4) Chemical & Physical Treatment Systems					
	Restrict Access (p. 5-11)	Restrict Ignition (p. 5-12)	Evacuate (p. 5-13)	Restrict Human Use (p. 5-14)	Restrict Farm Use (p. 5-15)	Restrict Industrial Use (p. 5-15)	Dilute and Disperse**	Stop Discharge (Tab 6.1) (p. 6-3)	Contain (Tab 6.2) (p. 6-9)	Skim (p. 6-38)	Pump (p. 6-42)	Dredge (p. 6-43)	Burn (p. 6-56)	Neutralize (p. 6-60)	Absorption (p. 6-71)	Other Treatments (p. 6-83)	Clean Shore Line (Tab 6.5) (p. 6-97)	Salvage Waterfowl (Tab 6.6) (p. 6-101)	Reference Key To Special Precautions/Information (Page 4-21)
Boric acid				X	X			This response applies to all chemicals								State of the art not so well developed			2
Boron tribromide	X		X	X	X	X	X							X					1,2,5,8,11,18
Boron trichloride	X		X			X	X							X					1,2,5,8,11,18,20
Bromine	X		X	X	X	X	X				X	X			X				1,2,5,8
Bromine pentafluoride	X		X			X	X							X					1,2,5,7,8,11,18,20,21
Bromine trifluoride	X		X			X	X							X					1,2,5,7,8,11,18
Bromobenzene					X						X								2,3,9,12
Brucine	X			X	X				X	X		X							1,2
Butadiene, inhibited	X	X	X			X				X			X					X	1,2,4,6,20
Butane	X	X	X			X							X						1,2,4,6,20
1,4-Butanediol				X	X		X												2
1,4-Butenediol				X	X		X												2
n-Butyl acetate	X	X					X		X	X							X	X	1,2,19
sec-Butyl acetate	X	X							X	X							X	X	1,2,19
iso-Butyl acrylate	X	X		X					X	X							X	X	1,2
n-Butyl acrylate	X	X		X					X	X							X	X	1,2
n-Butyl alcohol	X	X					X												3
sec-Butyl alcohol	X	X					X												1,3
tert-Butyl alcohol	X	X					X												1,3
n-Butylamine	X	X	X	X	X	X	X												1,2,5,6
sec-Butylamine	X	X	X	X	X	X	X												1,2,5,6
tert-Butylamine	X	X	X	X	X	X	X												1,2,5,6

*The numbers in parentheses are page reference numbers.

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TABLE 4-1

CAUTIONARY AND CORRECTIVE RESPONSE INDEX*

	Cautionary Response							Corrective Response											
										Collection Systems† (Tab 6.3)				Chemical & Physical Treatment Systems (Tab 6.4)					
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Butylene	X	X	X					This response applies to all chemicals					X			State of the art not so well developed			1,2,4,20
Butylene oxide	X	X	X	X	X	X	X						X						1,2,3,4,5,6,14
tert-Butyl hydroperoxide	X	X		X		X	X		X	X								X	1,2,7
n-Butyl methacrylate									X	X			X		X		X	X	1,2,4,14
n-Butyl *mercaptan*	X	X	X			X			?	?					?		X		1,2,5,6,12
p-tert-Butylphenol	X			X	X				X	X		X					X		1,2
Butyltrichlorosilane	X		X			X	X							X					1,2,3,5,8,11,12,18,21
1,4-Butynediol				X	X		X												2
iso-Butyraldehyde	X	X		X			X		X	X								X	1,2
n-Butyraldehyde	X	X		X			X		X	X								X	1,2
n-Butyric acid	X			X	X	X	X												1,2,8
Cacodylic acid	X			X	X														1
Cadmium acetate	X			X	X		X												1,2
Cadmium bromide	X			X	X		X												1,2
Cadmium chloride				X	X							X			X				
Cadmium fluoborate	X			X	X		X												1,2
Cadmium nitrate	X	X		X	X	X	X												1,2,3,7
Cadmium oxide	X			X	X							X							1,2
Cadmium sulfate	X			X	X		X												1,2
Calcium arsenate	X			X	X	X						X							1,2
Calcium carbide	X	X	X	X			X												2,10,11
Calcium chlorate	X	X	X	X	X		X												1,2,7

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TABLE 4-1

CAUTIONARY AND CORRECTIVE RESPONSE INDEX*

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										(Tab 6.3) Collection Systems†			(Tab 6.4) Chemical & Physical Treatment Systems							
	Restrict Access (p. 5-11)	Restrict Ignition (p. 5-12)	Evacuate (p. 5-13)	Restrict Human Use (p. 5-14)	Restrict Farm Use (p. 5-15)	Restrict Industrial Use (p. 5-15)	Dilute and Disperse**	Stop Discharge (Tab 6.1) (p. 6-3)	Contain (Tab 6.2) (p. 6-9)	Skim (p. 6-38)	Pump (p. 6-42)	Dredge (p. 6-43)	Burn (p. 6-56)	Neutralize (p. 6-60)	Absorption (p. 6-71)	Other Treatments (p. 6-83)	Clean Shore Line (Tab 6.5) (p. 6-97)	Salvage Waterfowl (Tab 6.6) (p. 6-101)	Reference Key To Special Precautions/Information (Page 4-21)
Calcium chloride	X						X	This response applies to all chemicals								State of the art not so well developed			1,2
Calcium chromate	X			X	X		X												1,2
Calcium cyanide	X		X	X	X	X													1,2,5,21
Calcium fluoride				X					X			X							
Calcium hydroxide												X							
Calcium hypochlorite	X			X		X	X												1,2
Calcium, metallic	X	X	X				X					X							2,8,10,21
Calcium nitrate	X	X			X		X					X							7
Calcium oxide	X						X					X							2
Calcium peroxide	X	X					X					X							1,2,7
Calcium phosphate						X	X					X							1,2,22
Calcium phosphide	X	X	X																1,2,5,6,21
Calcium resinate	X	X				X			X	X		X							1,2,3
Camphene	X	X				X			X	X			X						2,4,15,17
Camphor oil				X					X	X	X				X		X	X	2,9
Caprolactam, liquid				X			X												12
Captan	X	X			X				X	X		X							1,2,3,12
Carbaryl				X	X							X					X		2,9
Carbolic oil	X		X	X	X	X	X				X								1,2,12
Carbon bisulfide	X	X	X	X	X	X					X								1,2,5,6,12
Carbon dioxide	X						X												1,2,20
Carbon monoxide	X	X	X										X						1,5,6,14,20,21

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TABLE 4-1 (Continued)

CAUTIONARY AND CORRECTIVE RESPONSE INDEX*

	Cautionary Response							Corrective Response												
										Collection Systems† (Tab 6.3)			Chemical & Physical Treatment Systems (Tab 6.4)							
	Restrict Access (p. 5-11)	Restrict Ignition (p. 5-12)	Evacuate (p. 5-13)	Restrict Human Use (p. 5-14)	Restrict Farm Use (p. 5-15)	Restrict Industrial Use (p. 5-15)	Dilute and Disperse**	Stop Discharge (Tab 6.1) (p. 6-3)	Contain (Tab 6.2) (p. 6-9)	Skim (p. 6-38)	Pump (p. 6-42)	Dredge (p. 6-43)	Burn (p. 6-56)	Neutralize (p. 6-60)	Absorption (p. 6-71)	Other Treatments (p. 6-83)	Clean Shore Line (Tab 6.5) (p. 6-97)	Salvage Waterfowl (Tab 6.6) (p. 6-101)	Reference Key To Special Precautions/Information (Page 4-21)
Carbon tetrachloride	X			X				This response applies to all chemicals	X		X	X				State of the art not so well developed			1,2,5
Carene	X	X				X			X	X			X		X		X	X	1,2,4,15
Catechol	X			X	X		X												1,2
Caustic potash solution	X			X	X	X	X												2,8
Caustic soda solution	X			X	X	X	X												2,8
Charcoal	X	X					X		X										3,21
Chlordane	X				X	X			X	X	?	?							1,2,9,12
Chlorine	X		X	X	X	X	X												1,2,5,8,11,20
Chlorine trifluoride	X		X	X	X	X								X					1,2,5,7,8,11,20,21
Chloroacetophenone	X		X		X	X	X		X	X		X							1,2,18
Chloroacetyl chloride	X		X			X	X							X					1,2,5,8,11,18
p-Chloroaniline	X			X	X				X	X		X							1,2
Chlorobenzene	X	X		X					X		X	X					X		1,2,12
Chloroform	X			X		X			X		X	X							1,2,12
Chlorohydrins (crude)	X			X			X												1,2,5,12
Chloromethyl methyl ether	X	X	X	X	X	X			?	?	X	X			?				1,2,3,5,6,8,10,12,18
Chloropicrin, liquid	X		X	X	X	X					X	X							1,2,5,8,21
Chlorosulfonic acid	X		X	X	X	X	X							X					1,2,5,8,11
4-Chloro-o-toluidine	X				X				X	X		X							1,2,12
Chromic anhydride	X			X	X	X	X												1,2,7
Chromyl chloride	X		X	X	X	X	X							X					1,2,5,7,8,11,18
Citric acid							X												1,2

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CAUTIONARY AND CORRECTIVE RESPONSE INDEX*

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Cobalt acetate	X			X	X	X	X	This response applies to all chemicals								State of the art not so well developed			1,2
Cobalt chloride	X			X	X	X	X												1,2
Cobalt nitrate	X	X		X	X	X	X												1,2,7,21
Cobalt sulfate	X			X	X	X	X												1,2
Collodion	X	X	X			X			?	?							X	?	1,5,6,12
Copper acetate	X				X		X												1,2
Copper acetoarsenite	X			X	X							X							1,2,21
Copper arsenite	X			X	X							X							1,2,21
Copper bromide	X			X	X		X												1,2
Copper chloride	X				X	X	X												1,2
Copper cyanide	X			X	X	X						X							1,2
Copper fluoroborate	X			X	X		X												1,2
Copper iodide	X				X							X							1,2
Copper naphthenate						X			X	X	X	X	X		X		X	X	4,15
Copper nitrate	X	X			X	X	X												1,2,3,7
Copper oxalate					X							X							1,2
Copper sulfate				X	X		X					X							
Corn syrup							X												
Coumaphos	X			X	X				X	X		X							1,2
Creosote, coal tar	X				X	X			X	X	X	X			X		X		1,2,8,9
Cresols	X			X	X	X	X		X			X					X		1,2,12
Cresyl glycidyl ether	X				X	X			X	X	X				X		X		1,2

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Crotonaldehyde	X	X		X			X	This response applies to all chemicals								State of the art not so well developed	X		1,2
Cumene									X	X							X	X	2
Cumene hydroperoxide	X	X			X	X			X	X	X	X			X		X		1,2,3,8,12,21
Cupriethylenediamine solution	X			X	X	X	X							X					1,2,8
Cyanoacetic acid					X		X												1,2,12
Cyanogen	X	X	X	X	X	X	X												1,2,5,6,12,20
Cyanogen bromide	X		X	X	X	X	X												1,2,5,12
Cyanogen chloride	X		X	X	X	X	X												1,2,5,12,20
Cyclohexane	X	X		X		X			X	X			X				X	X	1,2,4
Cyclohexanol	X	X		X			X		X	X								X	2,19
Cyclohexanone				X			X		X	X								X	1,2,19
Cyclohexanone peroxide	X				X	X			X	X	X	X					X	X	2,7,9
Cyclohexenyltrichlorosilane	X		X			X	X							X					1,2,5,8,11,12,18,21
Cyclohexylamine				X	X		X		X	X								X	1,2,19
Cyclopentane	X	X	X			X	X		?	?			X				X	X	1,2,4,6,14
Cyclopropane	X	X	X										X						1,2,4,6,14,20
p-Cymene									X	X			X		X		X	X	1,2,4,15
2,4-D esters	X			X	X	X			X	X	X						X		2,12
Dalapon	X			X	X	X	X							X					1,2,8,18
DDD	X			X	X							X							1,2
DDT				X	X				X	X		X			X		X		2,9
Decaborane	X	X		X	X	X			X	X									1,2,3,10,12,17,19,21
Decahydronaphthalene									X	X			X		X		X	?	1,2,4,15

*The numbers in parentheses are page reference numbers

**Dilute and disperse only when other corrective methods cannot be used.

†For recovery methods, see page 6-43.

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TABLE 4-1

CAUTIONARY AND CORRECTIVE RESPONSE INDEX*

	Cautionary Response							Corrective Response	(Tab 6.3)				(Tab 6.4)						
										Collection Systems†				Chemical & Physical Treatment Systems					
	Restrict Access (p. 5-11)	Restrict Ignition (p. 5-12)	Evacuate (p. 5-13)	Restrict Human Use (p. 5-14)	Restrict Farm Use (p. 5-15)	Restrict Industrial Use (p. 5-15)	Dilute and Disperse**	Stop Discharge (Tab 6.1) (p. 6-3)	Contain (Tab 6.2) (p. 6-9)	Skim (p. 6-38)	Pump (p. 6-42)	Dredge (p. 6-43)	Burn (p. 6-56)	Neutralize (p. 6-60)	Absorption (p. 6-71)	Other Treatments (p. 6-83)	Clean Shore Line (Tab 6.5) (p. 6-97)	Salvage Waterfowl (Tab 6.6) (p. 6-101)	Reference Key To Special Precautions/Information (Page 4-21)
Decaldehyde								This response applies to all chemicals	X	X						State of the art not so well developed	X	X	2
1-Decene	X	X							X	X			X		X		X	X	2
n Decyl alcohol									X	X					X		X	X	
n-Decylbenzene						X			X	X					X		X	X	1,2
Demeton	X	X		X	X				X	X	X				X		X	X	1,2,12
Dextrose solution							X												
Diacetone alcohol				X			X												1,2
Di n amyl phthalate									X	X					X		X	X	none
Diazinon	X			X	X	X					X	X							1,2,3,9,12
Dibenzoyl peroxide	X	X		X	X							X							1,2,7
Di n butylamine	X			X		X			X	X					X		X		1,2,8,12,19
Di n butyl ether						X			?	?			X		?		X	X	2,4,14,19
Di n-butyl ketone						X			X	X					X		X	X	1,2
Dibutylphenol									X	X			X		X		X	X	2,4,15,17
Dibutyl phthalate											X	X					X		9
4,4-Dichloro-alpha trichloro-methylbenzhydrol	X	X		X	X	X			?	?		X			?		X		1,2,12
O Dichlorobenzene				X					X		X	X					X		2,12
p Dichlorobenzene				X		X			X		X	X					X		2,9,12
Di (p-chlorobenzoyl) peroxide	X	X	X			X			?	?		X							2,7,21
Dichlorobutene	X				X	X					X			X					1,2,8,9,12,18
Dichlorodifluoromethane	X																		1
1,2 Dichloroethylene	X	X	X			X					X								1,2,3,5,6,9,12
Dichloroethyl ether	X			X	X	X					X								1,2,12
Dichloromethane	X			X		X	X		X		X	X							1,2,12

*The numbers in parentheses are page reference numbers.

**Dilute and disperse only when other corrective methods cannot be used

†For recovery methods, see page 6-43.

TABLE 4-1 (Continued)

CAUTIONARY AND CORRECTIVE RESPONSE INDEX*

	Cautionary Response							Corrective Response												
										Collection Systems† (Tab 6.3)				Chemical & Physical Treatment Systems (Tab 6.4)						
	Restrict Access (p. 5-11)	Restrict Ignition (p. 5-12)	Evacuate (p. 5-13)	Restrict Human Use (p. 5-14)	Restrict Farm Use (p. 5-15)	Restrict Industrial Use (p. 5-15)	Dilute and Disperse**	Stop Discharge (Tab 6.1) (p. 6-3)	Contain (Tab 6.2) (p. 6-9)	Skim (p. 6-38)	Pump (p. 6-42)	Dredge (p. 6-43)	Burn (p. 6-56)	Neutralize (p. 6-60)	Absorption (p. 6-71)	Other Treatments (p. 6-83)	Clean Shore Line (Tab 6.5) (p. 6-97)	Salvage Waterfowl (Tab 6.6) (p. 6-101)	Reference Key To Special Precautions/Information (Page 4-21)
2,4-Dichlorophenol	X			X				This response applies to all chemicals	X		X					State of the art not so well developed			1,2,12
2,4-Dichlorophenoxy acetic acid	X			X	X				X	X		X							1,2
Dichloropropane	X	X		X							X	X							1,2,12
Dichloropropene	X	X		X							X	X							1,2,12
Dicyclopentadiene	X	X							X	X							X	X	2
Dieldrin	X			X	X	X			X	X		X					X		1,2,21
Diethanolamine				X			X												1,2
Diethylamine	X	X		X			X												1,2
Diethylbenzene									X	X			X				X	X	2,4,15
Diethyl carbonate	X	X		X					X	X							X	X	1,2
Diethylene glycol							X												
Diethylene glycol dimethyl ether				X			X												
Diethylene glycol monobutyl ether				X			X												none
Diethylene glycol monobutyl ether acetate	X						X		X	X					X				1,2,19
Diethylene glycol monoethyl ether				X			X												
Diethylene glycol monomethyl ether				X			X												
Diethylenetriamine				X			X												1,2
Diethyl phthalate											X	X							9
Di-(2-ethylhexyl) phosphoric acid	X					X			X	X				X	X		X		2,8,19
Diethylzinc	X	X	X																1,2,8,10,21

*The numbers in parentheses are page reference numbers.

**Dilute and disperse only when other corrective methods cannot be used.

†For recovery methods, see page 6-43.

TABLE 4-1 (Continued)

CAUTIONARY AND CORRECTIVE RESPONSE INDEX*

	Cautionary Response						Corrective Response													
										Collection Systems† (Tab 6.3)			Chemical & Physical Treatment Systems (Tab 6.4)							
	Restrict Access (p. 5-11)	Restrict Ignition (p. 5-12)	Evacuate (p. 5-13)	Restrict Human Use (p. 5-14)	Restrict Farm Use (p. 5-15)	Restrict Industrial Use (p. 5-15)	Dilute and Disperse**	Stop Discharge (Tab 6.1) (p. 6-3)	Contain (Tab 6.2) (p. 6-9)	Skim (p. 6-38)	Pump (p. 6-42)	Dredge (p. 6-43)	Burn (p. 6-56)	Neutralize (p. 6-60)	Absorption (p. 6-71)	Other Treatments (p. 6-83)	Clean Shore Line (Tab 6.5) (p. 6-97)	Salvage Waterfowl (Tab 6.6) (p. 6-101)	Reference Key To Special Precautions/Information (Page 4-21)
1-Difluoroethane	X	X	X					This response applies to all chemicals								State of the art not so well developed			1,2,6,12,20
Difluorophosphoric acid, anhydrous	X		X			X	X							X					1,2,5,8,11,18
Diheptyl phthalate									X	X	X	X			X		X	X	none
Diisobutylcarbinol				X					X	X								X	1,2
Diisobutylene	X	X								X								X	
Diisobutyl ketone	X					X			X	X			X		X		X	X	1,2,4,14,19
Diisodecyl phthalate									X	X					X		X	X	none
Diisopropanolamine				X			X												1,2
Diisopropylamine	X	X	X	X	X	X	X												1,2,5,6,8
Diisopropylbenzene hydroperoxide	X	X				X			?	?					?		X		1,2,7,12,21
Dimethylacetamide				X	X		X												2
Dimethylamine	X	X	X	X			X												1,2,3,20
Dimethylhexane dihydro peroxide, wet	X	X			X	X			?	?							X		2,3,7,21
Dimethyldichlorosilane	X	X	X			X	X							X					1,2,3,5,6,8,11,12,18,21
Dimethyl ether	X	X	X										X						1,2,4,5,6,14,20
Dimethylformamide	X			X			X												1,2
1,1 Dimethylhydrazine	X	X	X	X	X	X	X												1,2,5,12
Dimethylpolysiloxane									X	X	X		X		X		X	X	4,14,19
Dimethyl sulfate	X		X	X	X	X	X				X	X					X		1,2,8,12

*The numbers in parentheses are page reference numbers

**Dilute and disperse only when other corrective methods cannot be used

†For recovery methods, see page 6-43.

TABLE 4-1 (Continued)

CAUTIONARY AND CORRECTIVE RESPONSE INDEX*

	Cautionary Response							Corrective Response	(Tab 6.3) Collection Systems†				(Tab 6.4) Chemical & Physical Treatment Systems						
	Restrict Access (p. 5-11)	Restrict Ignition (p. 5-12)	Evacuate (p. 5-13)	Restrict Human Use (p. 5-14)	Restrict Farm Use (p. 5-15)	Restrict Industrial Use (p. 5-15)	Dilute and Disperse**	Stop Discharge (Tab 6.1) (p. 6-3)	Contain (Tab 6.2) (p. 6-9)	Skim (p. 6-38)	Pump (p. 6-42)	Dredge (p. 6-43)	Burn (p. 6-56)	Neutralize (p. 6-60)	Absorption (p. 6-71)	Other Treatments (p. 6-83)	Clean Shore Line (Tab 6.5) (p. 6-97)	Salvage Waterfowl (Tab 6.6) (p. 6-101)	Reference Key To Special Precautions/Information (Page 4-21)
Dimethyl sulfide	X	X	X	X		X	X	This response applies to all chemicals	?	?						State of the art not so well developed			1,2,5,6,12,19
Dimethyl sulfoxide				X			X												2,12
Dimethyl terephthalate					X				X	X		X							1,2
Dimethylzinc	X	X	X																1,2,6,8,10,21
2,4-Dinitroaniline	X		X	X					X			X							1,2,12
m-Dinitrobenzene	X	X		X	X				X	X		X							1,2,3,21
Dinitrocresols	X	X		X	X	X						X							1,2,8
2,4-Dinitrophenol	X			X					X			X							1,2,12
2,4-Dinitrotoluene	X	X		X	X				X	X		X							1,2,3,21
Dioctyl adipate									X	X							X	X	
Dioctyl phthalate									X	X							X	X	
Dioctyl sodium sulfosuccinate	X			X		X	X												1,2
1,4-Dioxane	X	X		X			X												1,2,3
Dipentene						X			X	X			X		X		X	X	2,4,15
Diphenylamine	X				X				X	X		X							1,2
Diphenyldichlorosilane	X					X	X							X					1,2,8,18
Diphenyl ether					X				X	X	X	X			X		X	X	2,9
Diphenylmethanediisocynate (MDI)	X			X	X							X							1,2,12
Di-n-propylamine	X	X		X		X	X		?	?									1,2,3,12,19
Dipropylene glycol							X												
Distillates: flashed feed stocks	X	X	X	X		X			X	X			X				X	X	1,2,4

*The numbers in parentheses are page reference numbers.

**Dilute and disperse only when other corrective methods cannot be used.

†For recovery methods, see page 6-43.

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TABLE 4-1 (Continued)

CAUTIONARY AND CORRECTIVE RESPONSE INDEX*

	Cautionary Response						Corrective Response												
										Collection Systems† (Tab 6.3)			Chemical & Physical Treatment Systems (Tab 6.4)						
	Restrict Access (p. 5-11)	Restrict Ignition (p. 5-12)	Evacuate (p. 5-13)	Restrict Human Use (p. 5-14)	Restrict Farm Use (p. 5-15)	Restrict Industrial Use (p. 5-15)	Dilute and Disperse**	Stop Discharge (Tab 6.1) (p. 6-3)	Contain (Tab 6.2) (p. 6-9)	Skim (p. 6-38)	Pump (p. 6-42)	Dredge (p. 6-43)	Burn (p. 6-56)	Neutralize (p. 6-60)	Absorption (p. 6-71)	Other Treatments (p. 6-83)	Clean Shore Line (Tab 6.5) (p. 6-97)	Salvage Waterfowl (Tab 6.6) (p. 6-101)	Reference Key To Special Precautions/Information (Page 4-21)
Distillates: straight run	X	X	X	X		X		This response applies to all chemicals	X	X			X			State of the art not so well developed	X	X	1,2,4
Dodecanol									X	X							X	X	2
Dodecene									X	X							X	X	
1-Dodecene				X					X	X							X	X	2
Dodecylbenzene									X	X					X		X	X	2
Dodecylbenzenesulfonic acid, calcium salt	X	X			X	X			X	X	X				X		X	X	1,2,12
Dodecylbenzenesulfonic acid, isopropylamine salt				X	X		X		?	?					?		?	?	2
Dodecylbenzenesulfonic acid, triethanolamine salt							X												2
Dodecyl sulfate, diethanolamine salt							X												2
Dodecyl sulfate, magnesium salt							X												2
Dodecyl sulfate, sodium salt	X						X												1,2
Dodecyl sulfate, triethanolamine salt	X						X												2
Dodecyltrichlorosilane	X					X	X							X					1,2,8,18,21
Dowtherm				X					X	X	X	X					X	X	2
Endrin	X			X	X				X	X		X							1,2,12
Epichlorohydrin	X			X			X												1,2,5,12

*The numbers in parentheses are page reference numbers.

**Dilute and disperse only when other corrective methods cannot be used

†For recovery methods, see *page 6-43*.

TABLE 4-1 (Continued)

CAUTIONARY AND CORRECTIVE RESPONSE INDEX*

	Cautionary Response							Corrective Response											
										Collection Systems† (Tab 6.3)			Chemical & Physical Treatment Systems (Tab 6.4)						
	Restrict Access (p. 5-11)	Restrict Ignition (p. 5-12)	Evacuate (p. 5-13)	Restrict Human Use (p. 5-14)	Restrict Farm Use (p. 5-15)	Restrict Industrial Use (p. 5-15)	Dilute and Disperse**	Stop Discharge (Tab 6.1) (p. 6-3)	Contain (Tab 6.2) (p. 6-9)	Skim (p. 6-38)	Pump (p. 6-42)	Dredge (p. 6-43)	Burn (p. 6-56)	Neutralize (p. 6-60)	Absorption (p. 6-71)	Other Treatments (p. 6-83)	Clean Shore Line (Tab 6.5) (p. 6-97)	Salvage Waterfowl (Tab 6.6) (p. 6-101)	Reference Key To Special Precautions/Information (Page 4-21)
Epoxidized vegetable oils								This response applies to all chemicals	X	X					X	State of the art not so well developed	X	X	
Ethane	X	X	X										X						2,4 14,20
Ethoxydihydropyran						X			?	?			X		X		X	X	2,4,14,19
Ethoxylated dodecanol							X												
Ethoxylated nonylphenol							X												2
Ethoxylated pentadecanol							X												
Ethoxylated tetradecanol							X												
Ethoxylated tridecanol				X			X												
Ethyl acetate	X	X		X			X		X	X								X	1,2
Ethyl acetoacetate				X	X		X												2,3
Ethyl acrylate	X	X		X			X		X	X								X	1,2,19
Ethyl alcohol	X	X					X												3
Ethylaluminum dichloride	X	X	X			X								X					1,2,3,5,6,8,10,11, 18,21
Ethylaluminum sesquichloride	X	X	X			X								X					1,2,3,5,6,8,10,11, 18,21
Ethylamine	X	X	X	X	X	X	X												1,2,5,6,8,12,20
Ethylbenzene	X	X		X					X	X							X	X	1,2,19
Ethyl butanol				X					X	X					X		X	X	2
Ethyl chloride	X	X	X	X															1,2
Ethyl chloroacetate	X				X	X					X	X							1,2,3,12
Ethyl chloroformate	X	X	X	X	X	X	X				X			X					1,2,3,8,12,18

*The numbers in parentheses are page reference numbers.

**Dilute and disperse only when other corrective methods cannot be used.

†For recovery methods, see page 6-43.

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TABLE 4-1 (Continued)

CAUTIONARY AND CORRECTIVE RESPONSE INDEX*

	Cautionary Response						Corrective Response												
										Collection Systems† (Tab 6.3)			Chemical & Physical Treatment Systems (Tab 6.4)						
	Restrict Access (p. 5-11)	Restrict Ignition (p. 5-12)	Evacuate (p. 5-13)	Restrict Human Use (p. 5-14)	Restrict Farm Use (p. 5-15)	Restrict Industrial Use (p. 5-15)	Dilute and Disperse**	Stop Discharge (Tab 6.1) (p. 6-3)	Contain (Tab 6.2) (p. 6-9)	Skim (p. 6-38)	Pump (p. 6-42)	Dredge (p. 6-43)	Burn (p. 6-56)	Neutralize (p. 6-60)	Absorption (p. 6-71)	Other Treatments (p. 6-83)	Clean Shore Line (Tab 6.5) (p. 6-97)	Salvage Waterfowl (Tab 6.6) (p. 6-101)	Reference Key To Special Precautions/Information (Page 4-21)
Ethyldichlorosilane	X	X	X			X	X	This response applies to all chemicals						X		State of the art not so well developed			1,2,3,5,6,8,11,12, 18,21
Ethylene	X	X	X										X						1,2,4,6,20
Ethylene chlorohydrin	X			X	X		X												1,2,12
Ethylene cyanohydrin				X		X	X												2,12
Ethylenediamine	X	X		X	X		X												1,2
Ethylenediamine tetracetic acid									X	X								X	2,17
Ethylene dibromide	X			X							X	X							1,2,12
Ethylene dichloride	X	X		X							X	X							1,2,12
Ethylene glycol							X												
Ethylene glycol diacetate				X			X												none
Ethylene glycol diethyl ether				X	X	X	X		?	?			X		?				3,4,14,19
Ethylene glycol dimethyl ether							X												1
Ethylene glycol monobutyl ether				X			X												2
Ethylene glycol monobutyl ether acetate	X			X	X		X		X	X			X		X				1,2,4,14,19
Ethylene glycol monoethyl ether				X			X												2
Ethylene glycol monoethyl ether acetate				X			X												2
Ethylene glycol monomethyl ether				X			X												2

*The numbers in parentheses are page reference numbers.

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†*For recovery methods, see page 6-43.*

TABLE 4-1 (Continued)

CAUTIONARY AND CORRECTIVE RESPONSE INDEX*

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										Collection Systems† (Tab 6.3)			Chemical & Physical Treatment Systems (Tab 6.4)						
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Ethyl formate	X	X	X	X	X	X	X	This response applies to all chemicals								State of the art not so well developed			1,2,3,5,6
Ethylhexaldehyde	X	X			X	X			?	?			X				X		2,4,7,8,14,21
2-Ethylhexyl acrylate, inhibited	X								X	X			X		X		X	X	1,2,4,14,19
Ethyl lactate	X			X	X		X												1,2
Ethyleneimine	X	X	X	X	X		X												1,2,5
Ethylene oxide	X	X	X				X												1,2,6,20
Ethyl ether	X	X	X			X	X												1,2,4,6,14
2-Ethyl hexanol				X					X	X					X		X	X	2
Ethyl hexyl tallate									X	X	X						X	X	9
Ethylidenenorbornene	X	X				X			?	?			X		X		X	X	1,2,4,14
Ethyl mercaptan	X	X	X	X		X	X		?	?									1,2,5,6,12,19
Ethyl methacrylate	X	X		X		X			?	?			X		X		X		1,2,4,6,14,21
Ethyl nitrite	X	X	X																1,2,5,6,12
Ethylphenyldichlorosilane	X					X	X							X					1,2,8,11,18,21
Ethyl phosphonothioic dichloride, anhydrous	X					X	X				X			X					1,2,8,18
Ethyl phosphorodichloridate	X					X	X				X			X					1,2,8,18
2-Ethyl-3-propylacrolein				X		X	X		X	X							X	X	2
Ethyl silicate	X					X	X						X						1,2,3,4,14
Ethyltrichlorosilane	X	X	X			X	X							X					1,2,3,5,8,11,12,18,21
Ferric ammonium citrate							X												1,2

*The numbers in parentheses are page reference numbers.

**Dilute and disperse only when other corrective methods cannot be used.

†For recovery methods, see page 6-43.

TABLE 4-1 (Continued)

CAUTIONARY AND CORRECTIVE RESPONSE INDEX*

	Cautionary Response							Corrective Response											
										Collection Systems† (Tab 6.3)			Chemical & Physical Treatment Systems (Tab 6.4)						
	Restrict Access (p. 5-11)	Restrict Ignition (p. 5-12)	Evacuate (p. 5-13)	Restrict Human Use (p. 5-14)	Restrict Farm Use (p. 5-15)	Restrict Industrial Use (p. 5-15)	Dilute and Disperse**	Stop Discharge (Tab 6.1) (p. 6-3)	Contain (Tab 6.2) (p. 6-9)	Skim (p. 6-38)	Pump (p. 6-42)	Dredge (p. 6-43)	Burn (p. 6-56)	Neutralize (p. 6-60)	Absorption (p. 6-71)	Other Treatments (p. 6-83)	Clean Shore Line (Tab 6.5) (p. 6-97)	Salvage Waterfowl (Tab 6.6) (p. 6-101)	Reference Key To Special Precautions/Information (Page 4-21)
Ferric ammonium oxalate	X			X	X		X	This response applies to all chemicals								State of the art not so well developed			1,2,8
Ferric chloride						X	X												1,2
Ferric glycerophosphate							X												1,2
Ferric nitrate	X	X				X	X												1,2,3,7
Ferric sulfate						X	X												1,2
Ferrous ammonium sulfate							X												1,2
Ferrous chloride						X	X												1,2
Ferrous chloride				X		X	X												2
Ferrous fluoroborate	X				X							X							1,2
Ferrous oxalate				X			X					X							
Fluorine	X		X	X	X	X	X												1,2,5,8,20
Fluosilicic acid	X					X	X							X					1,2,8,18
Fluosulfonic acid	X		X			X	X							X					1,2,5,8,11,18
Formaldehyde solution	X			X	X		X												1,2
Formic acid	X						X							X					1,2,8
Fumaric acid							X												1,2
Furfural	X			X	X		X				X								1,2
Furfuryl alcohol	X			X	X		X												1,2
Gallic acid					X		X					X							1,2
Gas oil: cracked									X	X			X		X		X	X	2

*The numbers in parentheses are page reference numbers.

**Dilute and disperse only when other corrective methods cannot be used.

†For recovery methods, see page 6-43.

TABLE 4-1 (Continued)

CAUTIONARY AND CORRECTIVE RESPONSE INDEX*

	Cautionary Response							Corrective Response												
										Collection Systems† (Tab 6.3)			Chemical & Physical Treatment Systems (Tab 6.4)						
	Restrict Access (p. 5-11)	Restrict Ignition (p. 5-12)	Evacuate (p. 5-13)	Restrict Human Use (p. 5-14)	Restrict Farm Use (p. 5-15)	Restrict Industrial Use (p. 5-15)	Dilute and Disperse**	Stop Discharge (Tab 6.1) (p. 6-3)	Contain (Tab 6.2) (p. 6-9)	Skim (p. 6-38)	Pump (p. 6-42)	Dredge (p. 6-43)	Burn (p. 6-56)	Neutralize (p. 6-60)	Absorption (p. 6-71)	Other Treatments (p. 6-83)	Clean Shore Line (Tab 6.5) (p. 6-97)	Salvage Waterfowl (Tab 6.6) (p. 6-101)	Reference Key To Special Precautions/Information (Page 4-21)
Gasoline: automotive, aviation, casinghead, polymer, and straight run	X	X	X			X		This response applies to all chemicals	X	X			X			State of the art not so well developed		X	1,2,4,15
Gasoline blend stocks: alkylates	X	X	X			X			X	X			X					X	1,2,4,15
Gasoline blend stocks: reformates	X	X	X			X			X	X			X					X	1,2,4,15
Glutaraldehyde solution	X			X	X		X												2
Glycerine							X												
Glycidyl methacrylate				X					X		X						X		2,9
Glyoxal, 40% solution				X	X	X	X												2
Heptachlor	X			X	X	X			X	X		X							1,2,21
Heptane	X	X	X			X			X	X			X					X	1,2,4,15
Heptanol		X							X	X					X		X	X	
1-Heptene	X	X	X			X			X	X			X					X	1,2,4,15
Hexachlorocyclopentadiene	X				X	X					X								1,2,8
Hexadecyl sulfate, sodium salt							X												2
Hexadecyltrimethylammonium chloride	X	X		X	X	X	X												2
n-Hexaldehyde	X	X				X			?	?			X		X		X		2,4,6,14
Hexamethylenediamine	X			X	X		X												2
Hexamethyleneimine	X	X		X	X	X	X												1,2,3,5,8,12
Hexamethylenetetramine				X			X					X							2
Hexane	X	X	X			X			X	X			X					X	1,2,4,15

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*The numbers in parentheses are page reference numbers.

**Dilute and disperse only when other corrective methods cannot be used.

†For recovery methods, see page 6-43.

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TABLE 4-1 (Continued)

CAUTIONARY AND CORRECTIVE RESPONSE INDEX*

	Cautionary Response							Corrective Response											
										Collection Systems† (Tab 6.3)				Chemical & Physical Treatment Systems (Tab 6.4)					
	Restrict Access (p. 5-11)	Restrict Ignition (p. 5-12)	Evacuate (p. 5-13)	Restrict Human Use (p. 5-14)	Restrict Farm Use (p. 5-15)	Restrict Industrial Use (p. 5-15)	Dilute and Disperse**	Stop Discharge (Tab 6.1) (p. 6-3)	Contain (Tab 6.2) (p. 6-9)	Skim (p. 6-38)	Pump (p. 6-42)	Dredge (p. 6-43)	Burn (p. 6-56)	Neutralize (p. 6-60)	Absorption (p. 6-71)	Other Treatments (p. 6-83)	Clean Shore Line (Tab 6.5) (p. 6-97)	Salvage Waterfowl (Tab 6.6) (p. 6-101)	Reference Key To Special Precautions/Information (Page 4-71)
Hexanol				X				This response applies to all chemicals	X	X					X	State of the art not so well developed	X	X	
1-Hexene	X	X		X					X	X			X					X	1,2,4,15
Hexylene glycol							X												
Hydrazine	X	X	X	X	X	X	X								X				1,2,5,6
Hydrochloric acid	X		X	X	X	X	X							X					1,2,8
Hydrofluoric acid	X		X	X	X	X	X							X					1,2,8,20
Hydrogen bromide	X		X			X	X							X					1,2,5,8,18,20
Hydrogen chloride	X		X	X	X	X	X							X					1,2,5,8,11,20
Hydrogen cyanide	X	X	X	X	X	X	X												1,2,5,11,20
Hydrogen fluoride	X		X	X	X	X	X							X					1,2,5,8,11
Hydrogen peroxide	X		X	X		X	X												1,2,7
Hydrogen sulfide	X	X	X	X	X	X	X												1,5,20
Hydroquinone	X			X	X		X												1,2
2-Hydroxyethyl acrylate inhibited	X			X	X		X												1,2,8
Hydroxylamine sulfate	X			X	X	X	X												1,2
Hydroxypropyl acrylate	X			X			X												1,2,8,21
Hydroxypropyl methacrylate	X			X			X												1,2,8,21
Isoamyl alcohol							X		X	X								X	1,19
Isobutane	X	X	X			X							X						1,4,6,14,20
Isobutyl acetate	X	X							X	X							X	X	1,2
Isobutyl alcohol	X	X		X			X		X	X								X	1,2,3

*The numbers in parentheses are page reference numbers.

**Dilute and disperse only when other corrective methods cannot be used.

†For recovery methods, see page 6-43.

TABLE 4-1 (*Continued*)

CAUTIONARY AND CORRECTIVE RESPONSE INDEX*

	Cautionary Response							Corrective Response											
										Collection Systems† (Tab 6.3)			Chemical & Physical Treatment Systems (Tab 6.4)						
	Restrict Access (p. 5-11)	Restrict Ignition (p. 5-12)	Evacuate (p. 5-13)	Restrict Human Use (p. 5-14)	Restrict Farm Use (p. 5-15)	Restrict Industrial Use (p. 5-15)	Dilute and Disperse**	Stop Discharge (Tab 6.1) (p. 6-3)	Contain (Tab 6.2) (p. 6-9)	Skim (p. 6-38)	Pump (p. 6-42)	Dredge (p. 6-43)	Burn (p. 6-56)	Neutralize (p. 6-60)	Absorption (p. 6-71)	Other Treatments (p. 6-83)	Clean Shore Line (Tab 6.5) (p. 6-97)	Salvage Waterfowl (Tab 6.6) (p. 6-101)	Reference Key To Special Precautions/Information (Page 4-21)
Isobutylamine	X	X	X	X	X	X	X	This response applies to all chemicals								State of the art not so well developed			1,2,5,6,8
Isobutylene	X	X	X										X						1,2,4,6,20
Isobutyric acid	X				X	X	X												1,2
Isobutyronitrile	X	X	X			X			?	?					?		X		1,2,5,6,12
Isodecaldehyde									X	X							X	X	2
Isodecyl acrylate, inhibited									X	X					X		X	X	2,19
Isodecyl alcohol									X	X					X		X	X	2
Isohexane	X	X	X			X			X	X			X					X	1,2,4,15
Isooctaldehyde									X	X							X	X	
Isooctyl alcohol				X					X	X					X		X	X	2
Isopentane	X	X	X			X			X	X			X					X	1,2,4
Isophorone	X								X	X					X		X		1,2,19
Isophthalic acid												X							1,2
Isoprene	X	X	X			X			X	X								X	1,2
Isopropyl acetate	X	X		X			X		X	X								X	1,2
Isopropyl alcohol	X	X					X												1
Isopropylamine	X	X	X	X	X	X	X												1,2,5,6,12
Isopropyl ether	X	X	X			X	X		?	?			X		?				1,2,4,5,6,14,19
Isopropyl mercaptan	X	X	X	X	X	X	X												1,2,5,6,12
Isopropyl percarbonate	X	X			X	X			?	?									2,3,12,21
Isovaleraldehyde	X	X	X		X	X			?	?			X		?		X	X	1,2,4,5,6,14

*The numbers in parentheses are page reference numbers.

**Dilute and disperse only when other corrective methods cannot be used.

†For recovery methods, see page 6-43.

TABLE 4-1 (Continued)

CAUTIONARY AND CORRECTIVE RESPONSE INDEX*

	Cautionary Response							Corrective Response												
										Collection Systems† (Tab 6.3)			Chemical & Physical Treatment Systems (Tab 6.4)						
	Restrict Access (p. 5-11)	Restrict Ignition (p. 5-12)	Evacuate (p. 5-13)	Restrict Human Use (p. 5-14)	Restrict Farm Use (p. 5-15)	Restrict Industrial Use (p. 5-15)	Dilute and Disperse**	Stop Discharge (Tab 6.1) (p. 6-3)	Contain (Tab 6.2) (p. 6-9)	Skim (p. 6-38)	Pump (p. 6-42)	Dredge (p. 6-43)	Burn (p. 6-56)	Neutralize (p. 6-60)	Absorption (p. 6-71)	Other Treatments (p. 6-83)	Clean Shore Line (Tab 6.5) (p. 6-97)	Salvage Waterfowl (Tab 6.6) (p. 6-101)	Reference Key To Special Precautions/Information (Page 4-21)
Jet Fuels: JP-1 (kerosene), JP-3, JP-4, JP-5 (heavy kerosene)	X	X						This response applies to all chemicals	X	X			X			State of the art not so well developed	X	X	1,2,4,15
Kerosene	X	X							X	X			X				X	X	2,4,15
Lactic acid	X						X												1,2
Latex, liquid synthetic				X		X	X										X		
Lauroyl peroxide	X	X	X		X	X			X	X							X		2,7,17,21
Lauryl mercaptan	X			X					X	X							X	X	1,2,12
Lead acetate	X			X	X	X													1,2
Lead arsenate				X	X							X					X		2
Lead fluoride	X			X	X							X							1,2
Lead fluoroborate	X			X	X	X	X												1,2,8
Lead iodide	X			X	X							X							1,2
Lead nitrate	X	X		X	X	X	X												1,2,7
Lead tetraacetate	X	X		X	X	X	X												1,2,3,7,8
Lead thiocyanate	X			X	X							X							1,2
Linear alcohols**									X	X							X	X	
Liquefied natural gas	X	X	X										X						1,2,4,6,14,20
Liquefied petroleum gas	X	X	X										X						1,2,4,6,14,20
Litharge	X			X	X							X							1
Lithium aluminum hydride	X	X	X	X	X	X	X												2,6,10,11
Lithium hydride	X	X	X				X							X					1,2,3,5,6,7,8,10, 11,16,21

*The numbers in parentheses are page reference numbers.

**Dilute and disperse only when other corrective methods cannot be used.

†For recovery methods, see page 6-43.

TABLE 4-1 (Continued)

CAUTIONARY AND CORRECTIVE RESPONSE INDEX*

	Cautionary Response							Corrective Response											
										Collection Systems† (Tab 6.3)			Chemical & Physical Treatment Systems (Tab 6.4)						
	Restrict Access (p. 5-11)	Restrict Ignition (p. 5-12)	Evacuate (p. 5-13)	Restrict Human Use (p. 5-14)	Restrict Farm Use (p. 5-15)	Restrict Industrial Use (p. 5-15)	Dilute and Disperse**	Stop Discharge (Tab 6.1) (p. 6-3)	Contain (Tab 6.2) (p. 6-9)	Skim (p. 6-38)	Pump (p. 6-42)	Dredge (p. 6-43)	Burn (p. 6-56)	Neutralize (p. 6-60)	Absorption (p. 6-71)	Other Treatments (p. 6-83)	Clean Shore Line (Tab 6.5) (p. 6-97)	Salvage Waterfowl (Tab 6.6) (p. 6-101)	Reference Key To Special Precautions/Information (Page 4-21)
Lithium, metallic	X	X	X				X	This response applies to all chemicals						X		State of the art not so well developed			1,2,3,5,6,7,8,10, 11,16,21
Magnesium		X										X							21
Magnesium perchlorate	X	X	X		X	X	X												1,2,7,21
Malathion	X			X	X	X			X		X				X		X		1,2,9,12
Maleic acid							X												1,2
Maleic anhydride							X					X							1,2
Maleic hydrazide	X			X	X				X	X		X							1,2
Mercuric acetate	X			X	X														1,2
Mercuric ammonium chloride	X			X	X							X							1,2
Mercuric chloride	X			X	X	X													1,2,21
Mercuric cyanide	X			X	X	X													1,2,21
Mercuric iodide	X			X	X	X						X							1,2,21
Mercuric nitrate	X	X		X	X	X													1,2,3,7,21
Mercuric oxide	X			X	X							X							1,2,21
Mercuric sulfide	X			X	X							X							1,2,21
Mercurous chloride	X			X	X							X							1,2,21
Mercurous nitrate	X	X		X	X	X						X							1,2,3,7,21
Mercury									X		X	X		X					2,13
Mesityl oxide	X	X		X	X	X	X		?	?			X		?				1,2,3,4,8,14,19
Methallyl chloride	X	X	X			X			?	?					?				1,2,5,6,12,19
Methane	X	X	X										X						1,2,4,6,14,20

*The numbers in parentheses are page reference numbers.

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†For recovery methods, see page 6-43.

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TABLE 4-1 (Continued)

CAUTIONARY AND CORRECTIVE RESPONSE INDEX*

	Cautionary Response							Corrective Response											
										Collection Systems† (Tab 6.3)				Chemical & Physical Treatment Systems (Tab 6.4)						
	Restrict Access (p. 5-11)	Restrict Ignition (p. 5-12)	Evacuate (p. 5-13)	Restrict Human Use (p. 5-14)	Restrict Farm Use (p. 5-15)	Restrict Industrial Use (p. 5-15)	Dilute and Disperse**	Stop Discharge (Tab 6.1) (p. 6-3)	Contain (Tab 6.2) (p. 6-9)	Skim (p. 6-38)	Pump (p. 6-42)	Dredge (p. 6-43)	Burn (p. 6-56)	Neutralize (p. 6-60)	Absorption (p. 6-71)	Other Treatments (p. 6-83)	Clean Shore Line (Tab 6.5) (p. 6-97)	Salvage Waterfowl (Tab 6.6) (p. 6-101)	Reference Key To Special Precautions/Information (Page 4-21)
Methanearsonic acid, sodium salts				X		X		This response applies to all chemicals				X				State of the art not so well developed			2,12
Methoxychlor	X			X	X				X	X		X							1,2
Methyl acetate	X	X	X	X	X	X	X												1,2,3,5,6
Methylacetylene-propadiene mixture	X	X	X										X						2,4,6,14,20
Methyl acrylate	X	X	X	X	X		X			X							X	X	1,2
Methyl alcohol	X	X					X												1,2,3
Methylamine	X	X	X	X	X	X	X												1,2,3,5,6,8,12,20
Methyl amyl acetate									X	X							X	X	2
Methyl amyl alcohol				X			X		X	X					X		X	X	1,2,19
n-Methylaniline	X			X	X	X			?	?	?	?			?		X		1,2,9
Methyl bromide	X		X	X			X												1,2,5,12,20
Methyl chloride	X	X	X	X			X												1,2,5,12,20
Methyl chloroformate	X	X	X	X	X	X	X				X			X					1,2,3,8,12,18
Methylcyclopentadienylmanganese tricarbonyl	X			X	X	X					X								1,2
Methylcyclopentane	X	X	X			X			?	?			X		?		X	?	1,2,4,6,14
Methyldichlorosilane	X	X	X			X	X							X					1,2,3,5,6,8,11,12,18,21
Methyl ethyl ketone	X	X		X			X												1,2
Methylethylpyridine	X			X					X	X					X		X	X	1,2

*The numbers in parentheses are page reference numbers.

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†For recovery methods, see page 6-43.

TABLE 4-1 (Continued)

CAUTIONARY AND CORRECTIVE RESPONSE INDEX*

	Cautionary Response							Corrective Response											
										(Tab 6.3) Collection Systems†				(Tab 6.4) Chemical & Physical Treatment Systems					
	Restrict Access (p. 5-11)	Restrict Ignition (p. 5-12)	Evacuate (p. 5-13)	Restrict Human Use (p. 5-14)	Restrict Farm Use (p. 5-15)	Restrict Industrial Use (p. 5-15)	Dilute and Disperse**	Stop Discharge (Tab 6.1) (p. 6-3)	Contain (Tab 6.2) (p. 6-9)	Skim (p. 6-38)	Pump (p. 6-42)	Dredge (p. 6-43)	Burn (p. 6-56)	Neutralize (p. 6-60)	Absorption (p. 6-71)	Other Treatments (p. 6-83)	Clean Shore Line (Tab 6.5) (p. 6-97)	Salvage Waterfowl (Tab 6.6) (p. 6-101)	Reference Key To Special Precautions/Information (Page 4-21)
Methyl formate	X	X	X	X		X	X	This response applies to all chemicals								State of the art not so well developed			1,2,3,5,6,12
Methyl formate	X	X	X	X		X	X												1,2,3,5,6
Methylhydrazine	X	X	X	X	X	X	X												1,2,3,5,6,8,21
Methyl isobutyl carbinol				X			X		X	X							X	X	1,2,19
Methyl isobutyl ketone				X			X		X	X							X	X	1,2,19
Methyl isopropenyl ketone, inhibited	X	X	X	X		X			?	?			X		?		X		1,2,4,6,14,21
Methyl mercaptan	X	X	X	X		X	X						X						1,2,3,4,5,6,20
Methyl methacrylate	X	X	X	X	X		X		X	X					X		X	X	1,2
Methyl n-butyl ketone	X	X		X		X			?	?			X		?		X	X	1,2,4,14,19
Methyl parathion	X		X	X	X	X					X	X					X		1,2,9,12
Methyl phosphonothioic dichloride (anhyd)	X		X			X	X							X					1,2,3,5,8,11,12,18
1-Methylpyrrolidone				X			X												2
alpha-Methylstyrene	X					X			X	X			X		X		X		1,2,4,15,19
Methyltrichlorosilane	X	X	X			X	X							X					1,2,3,5,6,8,11,12, 18,21
Methyl vinyl ketone	X	X	X	X	X	X	X												1,2,3,5,6,8,21
Molybdic trioxide												X							none
Monochloroacetic acid	X					X	X												1,2,8,18
Monochlorodifluoromethane	X		X				X												1,2,12,20
Monoethanolamine				X			X												2
Monoisopropanolamine				X			X												2

*The numbers in parentheses are page reference numbers

**Dilute and disperse only when other corrective methods cannot be used

†For recovery methods, see page 6 43

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TABLE 4 1 (Continued)

CAUTIONARY AND CORRECTIVE RESPONSE INDEX*

	Cautionary Response							Corrective Response											
										(Tab 6.3) Collection Systems†			(Tab 6.4) Chemical & Physical Treatment Systems						
	Restrict Access (p. 5-11)	Restrict Ignition (p. 5-12)	Evacuate (p. 5-13)	Restrict Human Use (p. 5-14)	Restrict Farm Use (p. 5-15)	Restrict Industrial Use (p. 5-15)	Dilute and Disperse**	Stop Discharge (Tab 6.1) (p. 6-3)	Contain (Tab 6.2) (p. 6-9)	Skim (p. 6-38)	Pump (p. 6-42)	Dredge (p. 6-43)	Burn (p. 6-56)	Neutralize (p. 6-60)	Absorption (p. 6-71)	Other Treatments (p. 6-83)	Clean Shore Line (Tab 6.5) (p. 6-97)	Salvage Waterfowl (Tab 6.6) (p. 6-101)	Reference Key To Special Precautions/Information (Page 4-21)
Morpholine				X			X	This response applies to all chemicals								State of the art not so well developed			1,2
Motor fuel anti knock compounds																			1,2,5,12
containing lead alkyls	X		X	X	X	X					X								1,2
Nabam	X			X	X	X													
Naphtha coal tar, solvent, stoddard solvent, VM & P (75% Naphtha)	X	X		X	X	X			X	X			X				X	X	1,2,4,15
Naphthalene, molten	X									X		X					X	X	1,2,9
Naphthenic acids									X	X					X		X	X	2
1 Naphthylamine	X			X	X	X			X	X		X			X		X		1,2,21
Neohexane	X	X	X			X	X		?	?			X		?				1,4,6,14
Nickel acetate					X		X												1,2
Nickel ammonium sulfate					X		X												1,2
Nickel bromide					X		X												1,2
Nickel carbonyl	X	X	X	X	X	X					X	X							1,2,3,5,6,8,9 12,21
Nickel chloride					X		X												1,2
Nickel cyanide	X			X	X							X							1,2
Nickel fluoroborate				X	X		X												2
Nickel formate				X	X		X												1,2
Nickel nitrate	X	X			X	X	X												1,2,7
Nickel sulfate				X			X					X							
Nicotine	X			X	X	X													1,2,12

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*The numbers in parentheses are page reference numbers

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†For recovery methods, see page 6 43

TABLE 4-1 (Continued)

CAUTIONARY AND CORRECTIVE RESPONSE INDEX*

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									Collection Systems† (Tab 6.3)				Chemical & Physical Treatment Systems (Tab 6.4)						
	Restrict Access (p. 5-11)	Restrict Ignition (p. 5-12)	Evacuate (p. 5-13)	Restrict Human Use (p. 5-14)	Restrict Farm Use (p. 5-15)	Restrict Industrial Use (p. 5-15)	Dilute and Disperse**	Stop Discharge (Tab 6.1) (p. 6-3)	Contain (Tab 6.2) (p. 6-9)	Skim (p. 6-38)	Pump (p. 6-42)	Dredge (p. 6-43)	Burn (p. 6-56)	Neutralize (p. 6-60)	Absorption (p. 6-71)	Other Treatments (p. 6-83)	Clean Shore Line (Tab 6.5) (p. 6-97)	Salvage Waterfowl (Tab 6.6) (p. 6-101)	Reference Key To Special Precautions/Information (Page 4-21)
Nicotine sulfate	X			X	X			This response applies to all chemicals								State of the art not so well developed			1,2
Nitralin	X			X	X				X	X		X							1,2,21
Nitric acid	X		X	X	X	X	X							X					1,2,5,7,8
Nitric oxide	X	X	X			X								X					1,2,8,18,20,21
Nitrilotriacetic acid & salts				?			X					?							2
2-*Nitroaniline*	X			X	X	X			?	?		X							1,2,21
4-Nitroaniline	X			X	X	X			?	?		X							1,2,21
Nitrobenzene	X			X	X	X					X	X							2,12
Nitroethane	X	X		X		X	X		?	?	?				?				1,2,3,12,19,22
Nitrogen, liquefied	X																		2,20
Nitrogen tetroxide	X		X	X	X	X	X												1,2,5,8,20
Nitromethane	X	X		X			X												1,3
2-Nitrophenol	X	X		X	X	X						X							1,2,21
4-Nitrophenol	X	X		X	X	X						X							1,2,21
2-Nitropropane	X	X				X	X		?	?	?				?		X	X	1,2,12,19,22
Nitrosyl chloride	X		X	X	X	X	X							X					1,2,5,8,20
Nitrous oxide	X	X	X																1,2,20
Nonane	X	X				X			?	?			X		?		X	X	1,2,4,14
Nonanol									X	X					X		X	X	
Nonene	X	X							X	X			X				X	X	1,2,4
1-Nonene	X	X							X	X			X				X	X	1,2,4

*The numbers in parentheses are page reference numbers.

**Dilute and disperse only when other corrective methods cannot be used.

†For recovery methods, see page 6-43.

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TABLE 4-1 (Continued)

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	Cautionary Response							Corrective Response											
										Collection Systems† (Tab 6.3)			Chemical & Physical Treatment Systems (Tab 6.4)						
	Restrict Access (p. 5-11)	Restrict Ignition (p. 5-12)	Evacuate (p. 5-13)	Restrict Human Use (p. 5-14)	Restrict Farm Use (p. 5-15)	Restrict Industrial Use (p. 5-15)	Dilute and Disperse**	Stop Discharge (Tab 6.1) (p. 6-3)	Contain (Tab 6.2) (p. 6-9)	Skim (p. 6-38)	Pump (p. 6-42)	Dredge (p. 6-43)	Burn (p. 6-56)	Neutralize (p. 6-60)	Absorption (p. 6-71)	Other Treatments (p. 6-83)	Clean Shore Line (Tab 6.5) (p. 6-97)	Salvage Waterfowl (Tab 6.6) (p. 6-101)	Reference Key To Special Precautions/Information (Page 4-21)
Nonylphenol				X				This response applies to all chemicals	X	X					X	State of the art not so well developed	X	X	2
Octane	X	X				X			?	?			X		?		X	X	1,2,4,14
Octanol									X	X					X		X	X	2
1-Octene	X	X							X	X			X				X	X	1,2,4
Octyl epoxy tallate	X								X	X					X		X		2
Oils, clarified: crude, diesel	X	X							X	X			X		X		X	X	1,2,4,15
Oils, coal tar	X	X							X	X			X		X		X	X	1,2,4,15
Oils, edible: castor, cottonseed, fish, olive, peanut, soya bean, vegetable									X	X					X		X	X	
Oils, edible: coconut									X	X					X		X	X	none
Oils, edible: lard									X	X					X		X	X	none
Oils, edible: palm									X	X					X		X	X	none
Oils, edible: safflower									X	X					X		X	X	none
Oils, edible: tucum									X	X					X		X	X	2
Oils, fuel: No. 1 (kerosene), 1D,2D,3,4,5&6	X	X							X	X			X		X		X	X	2,4,15
Oils, lubricating									X	X					X		X	X	2
Oils, mineral									X	X					X		X	X	2
Oils, mineral seal									X	X			X		X		X	X	2,4,15
Oils, miscellaneous: absorption	X	X							X	X			X		X		X	X	2,4,15

*The numbers in parentheses are page reference numbers.
**Dilute and disperse only when other corrective methods cannot be used
†For recovery methods, see page 6 43.

TABLE 4-1 (Continued)

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										Collection Systems† (Tab 6.3)			Chemical & Physical Treatment Systems (Tab 6.4)						
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Oils, miscellaneous: croton	X							This response applies to all chemicals	X	X					X	State of the art not so well developed	X	X	2
Oils, miscellaneous: linseed									X	X							X	X	2
Oils, miscellaneous: turbine									X	X							X	X	2
Oils, motor									X	X					X		X	X	2
Oils, neatsfoot									X	X			X		X		X	X	2,4,15
Oils, penetrating									X	X			X		X		X	X	2,4,15
Oils, range	X	X							X	X			X		X		X	X	2,4,15
Oils, resin									X	X							X	X	2
Oils, road									X	X		X					X	X	2,9
Oils rosin									X	X							X	X	2
Oils, sperm									X	X			X		X		X	X	2,4,15
Oils, spindle									X	X			X		X		X	X	2,4,15
Oils, spray									X	X			X		X		X	X	2,4,15
Oils, tall									X	X					X		X	X	2
Oils, tanner's									X	X					X		X	X	2
Oils, transformer									X	X					X		X	X	2
Oleic acid									X	X					X		X	X	2
Oleic acid, potassium salt							X												1
Oleic acid, sodium salt							X												1
Oleum	X		X	X	X	X	X						X						1,2,8,11,18
Oxalic acid	X			X	X		X					X	X						1,2

*The numbers in parentheses are page reference numbers.

**Dilute and disperse only when other corrective methods cannot be used

†For recovery methods, see page 6-43.

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TABLE 4-1 (Continued)

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	Cautionary Response							Corrective Response												
										(Tab 6.3) Collection Systems†			Chemical & Physical Treatment Systems (Tab 6.4)						
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Oxygen, liquefied	X	X	X					This response applies to all chemicals								State of the art not so well developed			1,2,6,7,20,21
Paraformaldehyde				X	X		X					X							1,2
Parathion, liquid	X			X	X	X					X	X							1,2
Pentaborane	X	X	X		X	X	X										X		1,2,3,6,10,21
Pentachlorophenol	X			X	X							X							1,2
Pentadecanol									X	X							X	X	2,19
Pentaerythritol																			none
Pentane	X	X	X	X		X			X	X			X					X	1,4
1-Pentene	X	X	X	X		X			X	X			X					X	1,4
Peracetic acid	X	X		X	X	X	X												1,2,6,7,8,21
Perchloric acid	X	X	X		X	X	X							X					1,2,7,8,18,21
Perchloromethyl mercaptan	X		X		X	X					X			X					1,2,8,18
Petrolatum									X	X					X		X	X	
Petroleum naphtha	X	X		X		X			X	X			X		X		X	X	2,4,15
Phenol	X		X	X	X	X	X				X	X							1,2,12,19
Phenyldichloroarsine, liquid	X			X	X	X					X			X					1,2,8,12,18
Phenylhydrazine hydrochloride	X			X	X	X	X												1,2
Phosgene	X		X	X	X	X	X												1,2,5,11,20
Phosphoric acid	X						X							X					2,8
Phosphorus oxychloride	X		X	X	X	X	X							X					1,2,5,11,18
Phosphorus pentasulfide	X	X	X	X	X	X	X							X					1,2,5,11,18

*The numbers in parentheses are page reference numbers

**Dilute and disperse only when other corrective methods cannot be used

†For recovery methods, see page 6 43

TABLE 4-1 (Continued)

CAUTIONARY AND CORRECTIVE RESPONSE INDEX*

	Cautionary Response						Corrective Response												
									Collection Systems† (Tab 6.3)			Chemical & Physical Treatment Systems (Tab 6.4)							
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Phosphorus, red	X	X						This response applies to all chemicals				X				State of the art not so well developed			2,12
Phosphorus tribromide	X		X			X	X							X					1,2,5,8,11,18
Phosphorus trichloride	X		X	X	X	X	X							X					1,2,5,11,18
Phosphorus, white	X	X	X	X								X							1,2,5,12
Phthalic anhydride									X			X							2
Piperazine	X			X	X	X	X												1,2
Polybutene									X	X					X		X	X	
Polychlorinated biphenyl				X	X				X		X	X					X		2
Polymethylene polyphenyl isocyanate	X			X	X	X					X						X		1,2
Polyphosphoric acid	X						X							X					2,8
Polypropylene									X	X							X		17
Polypropylene glycol				X					X	X	X				X		X	X	22
Polypropylene glycol methyl ether							X												2
Potassium arsenate	X			X	X		X												1,21
Potassium binoxalate	X			X	X		X					X							1,2
Potassium chlorate	X	X		X	X	X	X												1,2,7,21
Potassium chromate	X	X		X	X	X	X												1,2,7,8,21
Potassium cyanide	X			X	X	X	X												1,2,5
Potassium dichloro-s-triazinetrione	X	X		X	X	X	X												1,2,7,21
Potassium dichromate	X			X	X	X	X					X							1,2,7
Potassium hydroxide	X						X												1,2,8

*The numbers in parentheses are page reference numbers.

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†For recovery methods, see *page 6-43*.

TABLE 4-1 (Continued)

CAUTIONARY AND CORRECTIVE RESPONSE INDEX*

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										Collection Systems† (Tab 6.3)			Chemical & Physical Treatment Systems (Tab 6.4)						
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Potassium iodide				X			X	This response applies to all chemicals				X				State of the art not so well developed			
Potassium, metallic	X	X					X							X					2,6,7,8,10,11, 16,21
Potassium permanganate				X			X					X							2,7,16
Potassium peroxide	X	X	X				X							X					1,2,7,8,11,21
Potassium oxalate	X			X	X		X												1,2
Propane	X	X	X										X						1,2,4,6,14,20
beta-Propiolactone	X		X	X	X	X													1,2,12,21
Propionaldehyde	X	X		X			X			X								X	1,2
Propionic acid	X						X												1,2
Propionic anhydride	X						X		X	X	X		X				X		1,2,4,8,14,19
Propylene	X	X	X										X						1,2,4,6,14,20
Propylene butylene polymer				X					X	X							X	X	1,2,4,6,14,20
Propylene glycol							X												
Propylene glycol methyl ether							X												1
Propylene oxide	X	X	X				X												1,2,3
Propylene tetramer									X	X							X	X	2
Propyleneimine, inhibited	X	X	X	X	X	X	X												1,2,5,6,8,12
n-Propyl acetate	X	X		X						X								X	1,2
n-Propyl alcohol	X	X					X						X						1,3
n-Propyl mercaptan	X	X	X			X			?	?							X		1,2,5,6,12
Pyridine	X	X	X	X			X												1,2,3,5

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*The numbers in parentheses are page reference numbers.

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TABLE 4-1 (Continued)

CAUTIONARY AND CORRECTIVE RESPONSE INDEX*

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Pyrogallic acid	X			X	X		X	This response applies to all chemicals								State of the art not so well developed			1,2
Quinoline	X				X	X			?	?	?						X		1,2,22
Resorcinol	X			X	X		X												1,2
Salicylic acid	X				X	X			X	X		X							1,2,17,21
Selenium dioxide	X			X	X	X	X												1,2
Selenium trioxide	X			X	X	X	X							X					1,2,8,11,18
Silicon tetrachloride	X		X			X	X							X					1,2,5,11,18
Silver acetate	X			X	X	X	X					X							1,2
Silver carbonate	X				X							X							1,2
Silver fluoride	X			X	X	X	X					X							1,2
Silver iodate					X							X							1,2
Silver nitrate				X	X		X										X		
Silver oxide					X							X							1,2,21
Silver sulfate	X			X	X	X						X							1,2
Sodium	X	X	X				X												2,6,10,12,16
Sodium alkylbenzenesulfonates							X												
Sodium alkyl sulfates							X												
Sodium amide	X	X					X												1,2,5,8,11
Sodium arsenate	X			X	X	X	?												1,2,21
Sodium arsenite	X			X	X	X	X												1,2,21
Sodium azide	X			X	X	X	X												1,2,21
Sodium bisulfite							X					X							2

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TABLE 4-1 (Continued)

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Sodium borate					X		X	This response applies to all chemicals								State of the art not so well developed			2
Sodium borohydride	X	X					X												1,2,6,10
Sodium cacodylate	X			X	X	X	X												1,2
Sodium chlorate				X	X	X	X					X							2,7
Sodium chromate	X	X		X	X	X	X												1,2,7,8,21
Sodium cyanide	X			X	X		X					X							1,2,5
Sodium dichloro-s-triazinetrione	X	X		X	X	X	X												1,2,7
Sodium dichromate	X			X	X	X	X					X							1,2,7
Sodium ferrocyanide				X			X					X							2
Sodium fluoride				X	X		X					X							2
Sodium hydride	X	X	X				X												2,6,10,11
Sodium hydrosulfite solution	X			X	X	X	X												1,2,8
Sodium hydroxide	X			X	X	X	X												2,8
Sodium hypochlorite, aqueous							X												2
Sodium methylate	X	X					X						X	X					1,2,3,4,8,11,14
Sodium nitrite	X	X		X	X	X	X												1,2,7
Sodium oxalate	X			X	X	X	X												1,2
Sodium phosphate	X						X					?							1,2
Sodium silicate							X												
Sodium silicofluoride	X			X	X		?					X							1,2
Sodium sulfide	X			X	X	X	X					X							1,2,12
Sodium sulfite							X					X							2
Sodium thiocyanate	X			X	X		X												1,2

*The numbers in parentheses are page reference numbers

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TABLE 4-1 (Continued)

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Sorbitol							X	This response applies to all chemicals								State of the art not so well developed			2
Stearic acid									X	X							X	X	17
Styrene	X	X		X		X			X	X							X	X	1,2
Sucrose							X												none
Sulfolane				X			X				X								2,12
Sulfuric acid	X						X							X					2,8
Sulfuric acid, spent	X			X			X							X					2,12
Sulfur dioxide	X		X	X	X	X	X												1,2,5,8,11,20
Sulfur (liquid)		X							X			X							2,12
Sulfur monochloride	X		X	X	X	X	X							X					1,2,5,8,11,18
Sulfuryl chloride	X		X	X		X	X							X					1,2,5,8,11,18
Tallow									X	X					X		X	X	
Tallow fatty alcohol									X	X					X		X		17
Tannic acid							X												1,2
Tetrabutyl titanate	X						X												1,2
Tetrachloroethane	X				X	X					X								1,2
Tetrachloroethylene				X		X			X		X						X		1,2
Tetradecanol									X	X							X	X	2,17
1-Tetradecene									X	X					X		X	X	
Tetradecylbenzene									X	X					X		X	X	2
Tetraethyl dithiopyrophosphate	X			X	X	X					X						X		1,2
Tetraethylene glycol							X												none

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CAUTIONARY AND CORRECTIVE RESPONSE INDEX*

	Cautionary Response						Corrective Response												
										Collection Systems† (Tab 6.3)			Chemical & Physical Treatment Systems (Tab 6.4)						
	Restrict Access (p. 5-11)	Restrict Ignition (p. 5-12)	Evacuate (p. 5-13)	Restrict Human Use (p. 5-14)	Restrict Farm Use (p. 5-15)	Restrict Industrial Use (p. 5-15)	Dilute and Disperse**	Stop Discharge (Tab 6.1) (p. 6-3)	Contain (Tab 6.2) (p. 6-9)	Skim (p. 6-38)	Pump (p. 6-42)	Dredge (p. 6-43)	Burn (p. 6-56)	Neutralize (p. 6-60)	Absorption (p. 6-71)	Other Treatments (p. 6-83)	Clean Shore Line (Tab 6.5) (p. 6-97)	Salvage Waterfowl (Tab 6.6) (p. 6-101)	Reference Key To Special Precautions/Information (Page 4-21)
Tetraethylenepentamine	X			X	X		X	This response applies to all chemicals								State of the art not so well developed			1,2
Tetraethyl lead	X		X	X	X	X					X								1,2,5,12
Tetraethyl pyrophosphate	X			X	X	X													1,2
Tetrafluoroethylene, inhibited	X	X	X																1,6,12,20
Tetrahydrofuran	X	X					X												1,2
Tetrahydronaphthalene				X					X	X					X		X	X	2
Tetramethyl lead	X		X	X	X	X					X								1,2,5,12
Thiophosgene	X		X	X	X	X	X				X			X					1,2,5,8,10,12,18
Thiram	X			X	X							X							1,2
Thorium nitrate	X	X	X	X	X	X								X					1,2,3,7,18,21
Titanium tetrachloride	X		X				X							X					1,2,8,11,18
Toluene	X	X		X					X	X			X				X	X	1,2,4,15
Toluene 2,4-Diisocyanate	X			X	X						X								1,2,12
p-Toluenesulfonic acid	X				X	X	X							X					1,2,8,18
o-Toluidine	X	X		X	X	X			?	?	?				?		?		1,2,12,19
Toxaphene	X			X	X		X		X			X						X	2,12
Trichloroethane	X								X		X								1,2,12
Trichloroethylene	X			X	X				X		X								1,2,12
Trichlorofluoromethane	X								X		X								1,2,12
Trichlorophenol					X				X			X							2
2,4,5-Trichlorophenoxyacetic acid	X			X	X	X			X	X		X							1,2,17
Trichlorosilane	X	X	X			X	X							X					1,2,3,5,6,8,11, 12,18,21

*The numbers in parentheses are page reference numbers.

**Dilute and disperse only when other corrective methods cannot be used.

†For recovery methods, see page 6-43.

TABLE 4-1 (Continued)

CAUTIONARY AND CORRECTIVE RESPONSE INDEX*

	Cautionary Response							Corrective Response											
										Collection Systems† (Tab 6.3)			Chemical & Physical Treatment Systems (Tab 6.4)						
	Restrict Access (p. 5-11)	Restrict Ignition (p. 5-12)	Evacuate (p. 5-13)	Restrict Human Use (p. 5-14)	Restrict Farm Use (p. 5-15)	Restrict Industrial Use (p. 5-15)	Dilute and Disperse**	Stop Discharge (Tab 6.1) (p. 6-3)	Contain (Tab 6.2) (p. 6-9)	Skim (p. 6-38)	Pump (p. 6-42)	Dredge (p. 6-43)	Burn (p. 6-56)	Neutralize (p. 6-60)	Absorption (p. 6-71)	Other Treatments (p. 6-83)	Clean Shore Line (Tab 6.5) (p. 6-97)	Salvage Waterfowl (Tab 6.6) (p. 6-101)	Reference Key To Special Precautions/Information (Page 4-21)
Trichloro-s-triazinetrione	X	X		X	X	X	X	This response applies to all chemicals						X		State of the art not so well developed			1,2,3,7,8
Tricresyl phosphate					X				X		X								2
Tridecanol									X	X							X	X	
1-Tridecene									X	X					X		X	X	
Triethanolamine							X												2,12
Triethylamine	X	X		X			X												1,2
Triethylbenzene									X	X					X		X	X	2
Triethylene glycol							X												
Triethylenetetramine	X			X			X		X	X								X	19
Trifluralin	X			X		X			X	X		X							none
Trifluorochloroethylene	X	X	X																1,2,5,6,12,20,21
Trimethylamine	X	X	X				X												1,2,5,20
Tripropylene glycol							X												none
Tris(aziridinyl) phosphine oxide	X			X	X	X	X												1,2,21
Triethylaluminum	X	X	X				X												1,2,5,6,8,10,15,21
Turpentine	X	X							X	X					X		X	X	1,2
Undecanol									X	X					X		X	X	
1-Undecene									X	X					X		X	X	2
n-Undecylbenzene									X	X					X		X	X	2
Uranyl acetate	X			X	X	X	X												1,2
Uranyl nitrate	X	X	X	X	X	X	X							X					1,2,3,7,18,21
Uranyl sulfate	X			X	X	X	X												1,2

*The numbers in parentheses are page reference numbers.

**Dilute and disperse only when other corrective methods cannot be used

†For recovery methods, see page 6-43.

TABLE 4-1 (Continued)

CAUTIONARY AND CORRECTIVE RESPONSE INDEX*

	Cautionary Response							Corrective Response												
										Collection Systems† (T.b 6.3)			Chemical & Physical Treatment Systems (Tab 6.4)						
	Restrict Access (p. 5-11)	Restrict Ignition (p. 5-12)	Evacuate (p. 5-13)	Restrict Human Use (p. 5-14)	Restrict Farm Use (p. 5-15)	Restrict Industrial Use (p. 5-15)	Dilute and Disperse**	Stop Discharge (Tab 6.1) (p. 6-3)	Contain (Tab 6.2) (p. 6-9)	Skim (p. 6-38)	Pump (p. 6-42)	Dredge (p. 6-43)	Burn (p. 6-56)	Neutralize (p. 6-60)	Absorption (p. 6-71)	Other Treatments (p. 6-83)	Clean Shore Line (Tab 6.5) (p. 6-97)	Salvage Waterfowl (Tab 6.6) (p. 6-101)	Reference Key To Special Precautions/Information (Page 4-21)
Urea							X	This response applies to all chemicals				X				State of the art not so well developed			
Urea peroxide	X	X					X												1,2,3,7,21
Valeraldehyde	X	X					X		X	X							X	X	1,2
Vanadium oxytrichloride	X			X	X	X	X							X					1,2,5,8,11,18
Vanadium pentoxide	X				X							X							1,2
Vanadyl sulfate	X			X	X		X												1,2
Vinyl acetate	X	X	X	X			X			X							X	X	1,2
Vinyl chloride	X	X	X	X			X												1,2,12,20
Vinyl fluoride, inhibited	X	X	X																1,2,6,12,20
Vinylidenechloride, inhibited	X	X		X							X	X							1,2,12
Vinyl methyl ether, inhibited	X	X	X			X							X						1,2,4,5,6,14,20
Vinyltrichlorosilane	X	X	X			X	X							X					1,2,3,5,8,11,12,16,21
Vinyltoluene				X			X		X	X								X	2
Waxes: carnauba									X	X							X	X	2,17
Waxes: paraffin									X	X							X	X	2,17
m-Xylene	X	X		X	X				X	X			X				X	X	1,2,4,15
o-Xylene	X	X		X	X				X	X			X				X	X	1,2,4,15
p-Xylene	X	X		X	X				X	X			X				X	X	1,2,4,15
Xylenol	X				X	X			X	X	X	X			X		X		1,2
Zinc acetate							X												1,2
Zinc ammonium chloride							X												1,2

*The numbers in parentheses are page reference numbers.

**Dilute and disperse only when other corrective methods cannot be used

†For recovery methods, see page 6-43.

TABLE 4.1 (Continued)

CAUTIONARY AND CORRECTIVE RESPONSE INDEX*

	Cautionary Response							Corrective Response												
										Collection Systems† (Tab 6.3)			Chemical & Physical Treatment Systems (Tab 6.4)							
	Restrict Access (p. 5-11)	Restrict Ignition (p. 5-12)	Evacuate (p. 5-13)	Restrict Human Use (p. 5-14)	Restrict Farm Use (p. 5-15)	Restrict Industrial Use (p. 5-15)	Dilute and Disperse**	Stop Discharge (Tab 6.1) (p. 6-3)	Contain (Tab 6.2) (p. 6-9)	Skim (p. 6-38)	Pump (p. 6-42)	Dredge (p. 6-43)	Burn (p. 6-56)	Neutralize (p. 6-60)	Absorption (p. 6-71)	Other Treatments (p. 6-83)	Clean Shore Line (Tab 6.5) (p. 6-97)	Salvage Waterfowl (Tab 6.6) (p. 6-101)	Reference Key To Special Precautions/Information (Page 4-21)
Zinc arsenate	X			X	X	X		This response applies to all chemicals				X				State of the art not so well developed			1,2,21
Zinc borate	X											X							1,2
Zinc bromide				X	X		X												1,2
Zinc chloride				X	X		X								X				1,2
Zinc chromate	X			X	X							X							1,2
Zinc dialkyldithiophosphate	X				X						X	X							1,2
Zinc fluoroborate				X	X	X	X												2
Zinc nitrate						X	X												1,2,7
Zinc phenolsulfonate				X	X		X												1,2
Zinc phosphide	X		?	X	X	X						?							1,2,5,10,21
Zinc silicofluoride	X			X	X	X	X												1,2,21
Zinc sulfate							X												1,2
Zirconium acetate				X	X		X												2
Zirconium nitrate				X	X	X	X												1,2
Zirconium oxychloride				X	X		X												1,2
Zirconium sulfate				X	X		X												1,2

*The numbers in parentheses are page reference numbers.

**Dilute and disperse only when other corrective methods cannot be used

†For recovery methods, see page 6 43.

change 1

REFERENCE KEY TO RESPONSE INDEX

1. Avoid inhalation. Vapors or dust are irritating or toxic.

2. Avoid direct contact. Contact with skin or eyes can cause irritation or burns.

3. No ignition hazard once material is dissolved, reacted, or covered with water.

4. Burning may be prohibited by anti-air pollution laws and regulations.

5. Poisonous gas or vapor danger. Substance is highly volatile.

6. Flammable or explosive gas or vapor danger. Substance is highly volatile.

7. Powerful oxidant – explosion and/or fire hazard in the presence of organic matter.

8. Highly corrosive, particularly to eyes and skin.

9. Sorbs strongly on bottom sediments. Substance is not at all soluble or reactive.

10. Reacts with water to form explosive or flammable gas or vapor.

11. Water reactive compound which reacts vigorously or violently. Disperse or neutralize contaminated waters after reaction subsides.

12. Burning not recommended; fire difficult to control and/or poisonous gas is formed.

13. Cover with organic sulfur-containing compounds or free sulfur

14. Clean burning.

15. Sooty burning.

16. DO NOT ADD water to chemical. AFTER the chemical has reacted with water, the resulting alkaline solution can be diluted

17. Floating solid.

18. Strong acid formed in water.

19. First try to contain and skim, THEN dilute and disperse what has dissolved *in* water.

20. Chemical shipped as gas or liquefied compressed gas, depending on atmospheric conditions, a large portion of the hazard will be dissipated with no action necessary.

21. Has unusual fire or toxicity hazards. See the hazardous chemical data sheets for chemical.

22. May float or sink as insoluble substance or dissolve like miscible substance. See the hazardous chemical data sheets for chemical

RESPONSE DEFINITIONS

A CAUTIONARY RESPONSES

1. *Restrict Access* This response is invoked when appreciable danger arises from a flammable or toxic spill, and the general public (spectators) should be kept from the spill area. Access is restricted if ignition is considered possible (restrict ignition), or if evacuation is recommended.

2. *Restrict Ignition* This response is invoked when chemicals are involved which develop flammable vapors.

3. *Evacuate* This response is invoked when there is a very real danger that a highly flammable or toxic spill may spread, or develop a detrimental reaction with water. This category includes flammable chemicals and extremely toxic chemicals, e.g., poisonous gases.

4. *Restrict Human Use* – This response is invoked when mostly soluble substances or those which are exceptionally toxic are involved in a spill. The primary danger is that of ingesting the chemicals in drinking water.

5. *Restrict Farm Use* This response is invoked when a toxic chemical contaminant is spilled in water used for irrigation or animals.

6. *Restrict Industrial Use* This response is invoked when the spill contains chemicals which could corrode machinery, *or* if the possibility of ignition from highly flammable organics is developed. Those chemicals which upon heating could release poisonous gases could also cause this response to be invoked; as could those which might form an insulating film on internal boiler surfaces.

B CORRECTIVE RESPONSES

It is possible that several responses may be appropriate for a particular chemical spill. On site conditions will dictate which responses are required. Also, a chemical could exist in more than one physical form and thus require several ameliorative responses. *In cases where multiple responses are checked, "dilute and disperse" should be the last response implemented.*

1. *Dilute and Disperse* This response is invoked to handle spills primarily involving dissolved species which are dangerous in a concentrated state. The situation can be ameliorated by water jets, propellors, or similar means of agitation spreading and mixing.

2. *Contain* This response is invoked to contain spills involving insoluble species which form surface slicks. Slicks having vapors of very low flammability may be contained near ships, piers, etc but highly flammable materials should only be confined in areas which are remote from ignition sources. Explosion proof equipment should be employed. Corrosivity with respect to materials should *also be considered.*

3. *Skim* This response is invoked to handle insoluble species which float and form surface slicks. Corrosivity with respect to hoses and pump should be considered.

4. *Pump* This response is invoked to handle insoluble species which sink (particularly liquids or finely divided solids), but which may be pumped directly from the spill. Again, corrosivity should be considered.

RESPONSE DEFINITIONS (Continued)

5 *Dredge* This response is invoked to handle insoluble species which sink (solids and some liquids).

6. *Burn* This response is invoked to handle highly flammable floating chemicals. Even though there is an ignition danger, the "contain" category is checked. Containment may have to be accomplished by air barriers, herders, or expendable booms since few booms are fire-resistant.

7. *Neutralize* This response is invoked to handle acids, bases, oxidants, or reductants. Calcium hypochlorite or caustic soda is often used in neutralization. This response action is largely confined to still or confined non-flowing waters.

8. *Absorption* This response is invoked to handle chemical species which can be absorbed or adsorbed. These species which form surface slicks (float) and include: oil-like chemicals, solvents, toxic compounds (e.g., pesticides and halogenated hydrocarbons). Treatment by ion exchange is also possible for miscible chemicals. Materials for sorption include hay, paper, styrofoam, plastic, glass beads, charcoal and ion exchange resins.

9. *Other Treatments* This response is invoked to handle oils and other floating materials by specialized methods. These treatments include the use of emulsifiers, dispersants, sinking agents, coagulants and flocculants. Biological degradation is also included in this category.

10. *Clean Shore Line* This reponse is invoked to handle insolubles (especially oils) with high surface tensions.

11. *Salvage Waterfowl* This response is invoked when it is deemed feasible to salvage waterfowl that have been exposed to an oil discharge.

5.0 Cautionary Response
Methods

5.0 CAUTIONARY RESPONSE METHODS

To Apply Cautionary Response

First	be sure that hazardous nature, precautions, and first aid are understood
Second	rescue exposed or threatened personnel and take appropriate action to prevent accident from getting worse
Third	select applicable response methods using Response Index (Table 4-1)
Fourth	apply cautionary responses (utilize CHRIS, and the Regional Contingency Plan Data Base where applicable)

- For volatile chemicals.

  - refer to Tables 5-1 and 5-2 to determine the maximum distances over which the hazardous gases may be harmful. Refer to Table 5-3 for time of arrival and duration of *harmful* gas clouds.

- Small or slow discharges

  apply cautionary responses to immediate area within several hundred feet or away from movement of the chemical in the water

- Large discharges occurring quickly

  apply cautionary responses over large distances. For gases this *generally* has to be done before the vapors reach a given area (see Harmful Distance Tables 5-1 and 5-2, and their descriptions, and the Hazard Assessment Handbook)

- Restrict access and evacuate

  - downwind for volatile chemicals that are either flammable or toxic
  - downstream or in path of moving fluid for chemicals that float or mix with water

- Restrict ignition

  downwind for flammable gases

  downstream or in path of moving fluid for flammable chemicals that float

- Restrict water use

  downstream or in path of moving fluid for harmful chemicals that float or mix with water

Checklist of Agencies to be Contacted, Depending upon Requirements of Cautionary Response

- Applicable Coast Guard Units COTP, District Headquarters, Search and Rescue, Strike Team, USCG Auxiliary
- Environmental Protection Agency
- Industry response teams
- Port Authority
- Municipalities with water intakes
- Industries with water intakes
- Agricultural units with water intakes
- Municipal emergency services Fire and Police
- Local health authorities
- Corps of Engineers for control of dams and locks
- Railroads
- Airports
- County and State emergency services - Fire and Police
- Yacht and boat associations
- Civil Defense
- Radio and television stations

5.1 MAXIMUM DISTANCES OVER WHICH HAZARDOUS GASES MAY BE HARMFUL (Tables 5-1 and 5-2)

Because of the *urgency* of the response to the downwind travel of toxic or flammable gases over populated areas, estimates of the *maximum* distances over which the gases may conceivably be harmful are given in Tables 5-1 and 5-2. In these tables the distances tend to be overestimated for reasons of safety and simplicity. When time is available and more accurate estimates are needed, use the Hazard Assessment Handbook. Assistance may also be obtained from USCG Headquarters.

Before applying Tables 5-1 and 5-2, consider the following:

1. All chemicals in CHRIS that are extremely volatile (become gaseous) are included in these tables. Some of these chemicals are not allowed to be shipped in bulk by water transport.

2. Chemicals that may create hazardous vapors, but have a low volatility (boiling point higher than ambient) are *not* included in these tables. (Use the Hazard Assessment Handbook to estimate distances for these chemicals.)

3. The distances given for toxic gases are based on the maximum distances over which the concentration of the gas in air may exceed the threshold limit value (TLV), which is the tolerable concentration for an 8-hour day, 5 days per week. Since the duration of the gaseous cloud tends to be of the order of minutes for the rapid discharges that have been assumed, the harmful distances may be *much less* than those given in Table 5-1.

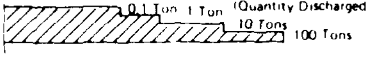
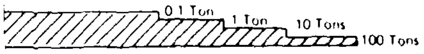
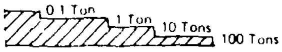
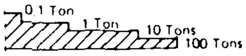
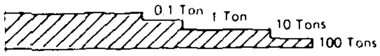
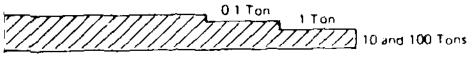
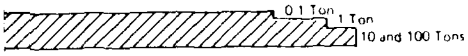
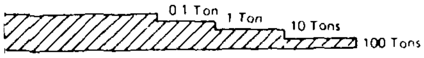
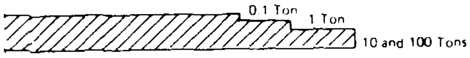
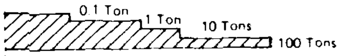
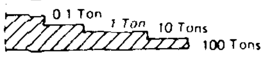
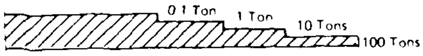
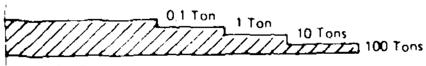
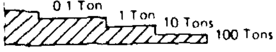
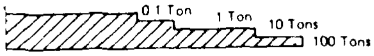
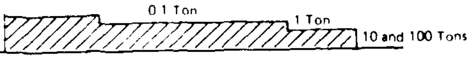
4. Data in both tables have been estimated for weather conditions (low turbulence) that give maximum harmful distances. The distances will be *less* when the atmosphere is windy and turbulent.

5. The data in both tables are based on the assumption that the quantities discharged are released into the water instantaneously (very rapidly). If these quantities are discharged over extended periods of time, the harmful distances will be much less than those given in the tables.

6. Flammable vapor clouds will *not* generally travel beyond the point where they become ignited.

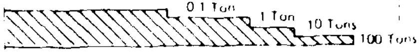
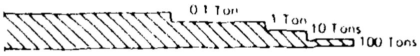
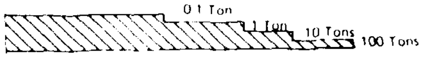
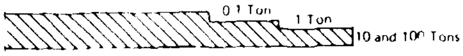
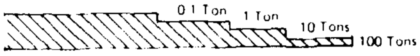
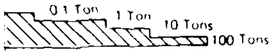
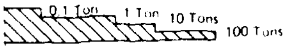
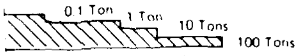
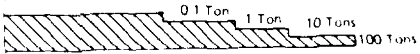
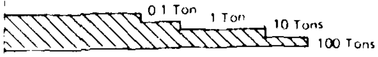
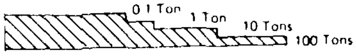
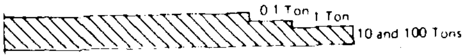
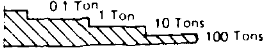
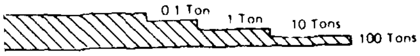
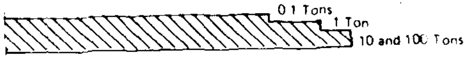
A more detailed discussion of the maximum harmful distances is presented immediately following Tables 5-1 and 5-2.

TABLE 5-1(a)
TOXIC GASES
MAXIMUM DOWNWIND DISTANCE OVER WHICH GASES MAY BE HARMFUL*†

Chemical Name and Code** ↓		Maximum Distances → Distance in Feet: 600–3000, 3000–6000, 6000–30,000, 30,000–60,000, 60,000–300,000, 300,000
Acetaldehyde	AAD	
Acetylene	ACE	Simple Asphyxiant
Ammonia, Anhydrous	AMA	
Boron Trichloride	BRT	Unknown Toxic Level
Butadiene, Inhibited	BDI	
Butane	BUT	Simple Asphyxiant
Butylene	BTN	Unknown Toxic Level (Low Toxicity)
Carbon Dioxide	CDO	
Carbon Monoxide	CMO	
Chlorine	CLX	
Chlorine Trifluoride	CTF	
Cyanogen	CYG	
Cyanogen Chloride	CCL	
Cyclopropane	CPR	
Dichlorodifluoromethane	DCF	
1, 1 - Difluoroethane	DFE	Unknown Toxic Level
Dimethylamine	DMA	
Dimethyl Ether	DIM	Unknown Toxic Level
Ethane	ETH	Simple Asphyxiant
Ethylamine	EAM	
Ethyl Chloride	ECL	
Ethylene	ETL	Simple Asphyxiant
Ethylene Oxide	EOX	
Ethyl Nitrite	ETN	Unknown Toxic Level
Fluorine	FXX	

*Hazard calculated assuming worst case weather conditions (steady low wind) and instantaneous discharge
†See Table 5-3 for time of arrival and duration of cloud
**See Condensed Guide to Chemical Hazards

TABLE 5-1(a) (Continued)

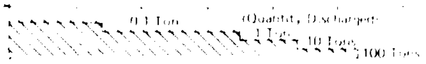
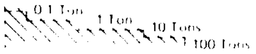
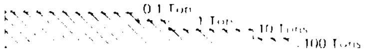
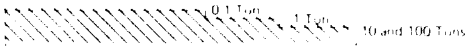
Maximum Distances → Chemical Name and Code** ↓		Distance in Feet* 600–3000† / 3000–6000† / 6000–30,000† / 30,000–60,000† / 60,000–300,000† / >300,000 (Quantity Discharged)
Hydrogen Bromide	HBR	 0.1 Ton 1 Ton 10 Tons 100 Tons
Hydrogen Chloride	HDC	 0.1 Ton 1 Ton 10 Tons 100 Tons
Hydrogen Cyanide	HCN	 0.1 Ton 1 Ton 10 Tons 100 Tons
Hydrogen Fluoride	HFX	 0.1 Ton 1 Ton 10 and 100 Tons
Hydrogen, Liquefied	HXX	Simple Asphyxiant
Hydrogen Sulfide	HDS	 0.1 Ton 1 Ton 10 Tons 100 Tons
Isobutane	IBT	Unknown Toxic Level (Low Toxicity)
Isobutylene	IBL	 0.1 Ton 1 Ton 10 Tons 100 Tons
Liquefied Natural Gas	LNG	Unknown Toxic Level (Low Toxicity)
Liquefied Petroleum Gas	LPG	 0.1 Ton 1 Ton 10 Tons 100 Tons
Methane	MTH	Simple Asphyxiant
Methylacetylene Propadiene Mixture	MAP	 0.1 Ton 1 Ton 10 Tons 100 Tons
Methylamine	MTA	 0.1 Ton 1 Ton 10 Tons 100 Tons
Methyl Bromide	MTB	 0.1 Ton 1 Ton 10 Tons 100 Tons
Methyl Chloride	MTC	 0.1 Ton 1 Ton 10 Tons 100 Tons
Methyl Mercaptan	MMC	 0.1 Ton 1 Ton 10 and 100 Tons
Monochlorodifluoromethane	MCF	 0.1 Ton 1 Ton 10 Tons 100 Tons
Nitric Oxide	NTX	 0.1 Ton 1 Ton 10 Tons 100 Tons
Nitrogen, Liquefied	NXX	Simple Asphyxiant
Nitrogen Tetroxide	NOX	 0.1 Tons 1 Ton 10 Tons 100 Tons
Nitrous Oxide	NTO	Simple Asphyxiant
Phosgene	PHG	 0.1 Tons 1 Ton 10 and 100 Tons
Propane	PRP	Simple Asphyxiant
Propylene	PPL	Simple Asphyxiant

*Hazard calculated assuming worst case weather conditions (steady low wind) and instantaneous discharge

†See Table 5-3 for time of arrival and duration of cloud

**See Condensed Guide to Chemical Hazards

TABLE 5 1(a) (Continued)

Maximum Distances Chemical Name and Code** ↓	→	Distance in Feet 600 3000 · 3000 6000 · 6000 30 000 · 30 000 60 000 · 60 000 300 000 · 300 000
Sulfur Dioxide	SFD	
Tetrafluoroethylene Inhibited	TFE	Unknown Toxic Level
Trichlorofluoromethane	TCF	
Trifluorochloroethylene	TFC	
Trimethylamine	TMA	Unknown Toxic Level
Vinyl Chloride	VCM	
Vinyl Fluoride Inhibited	VFI	Unknown Toxic Level
Vinyl Methyl Ether Inhibited	VME	Unknown Toxic Level

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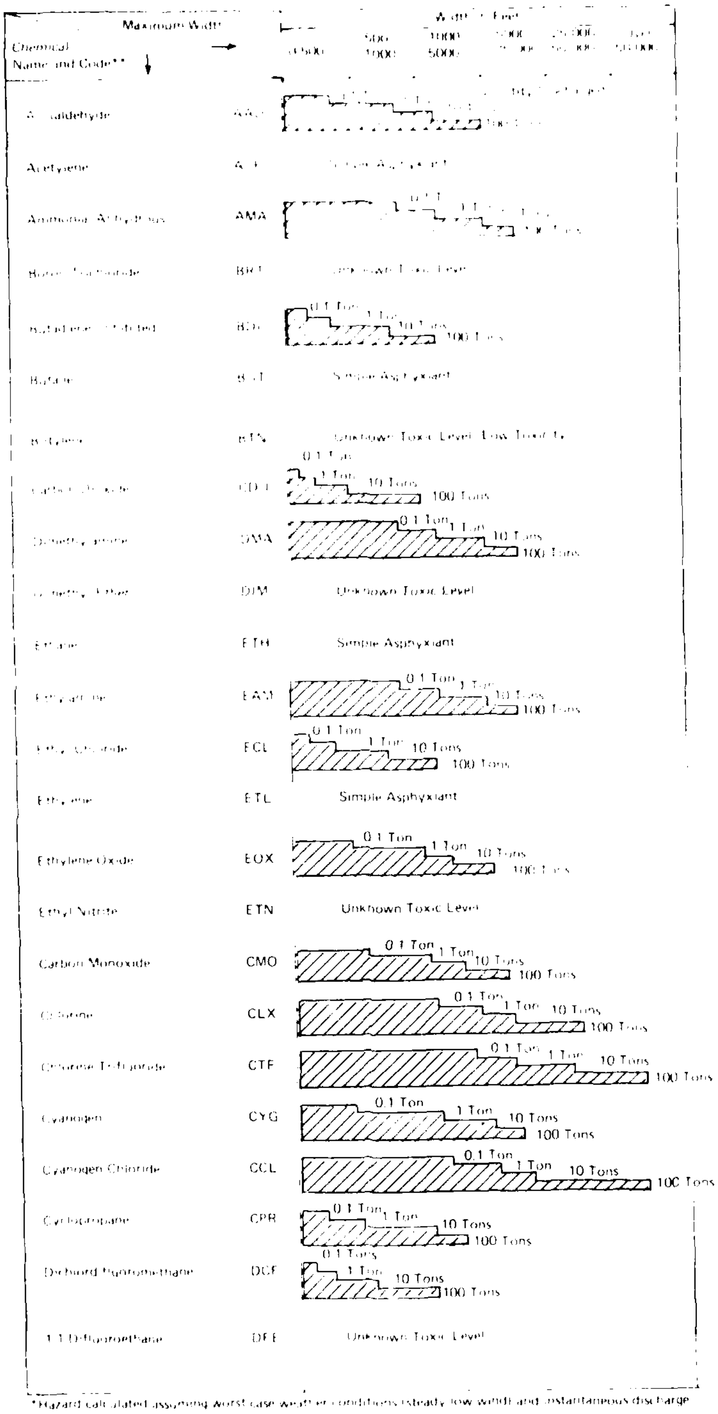
*Hazards evaluated [illegible] worst case weather conditions (steady low winds) and instantaneous discharge (see Table 5 [illegible])

**See Condensed Guide to Chemical Hazards

Change 3

TABLE 5-1b
TOXIC GASES
MAXIMUM WIDTH OF THE CLOUD WHICH MAY BE HARMFUL*†



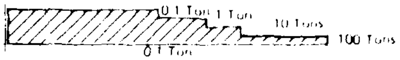
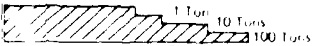
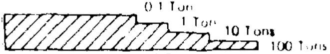
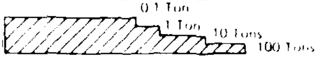
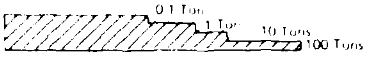
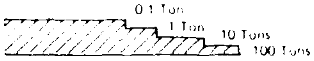
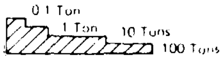
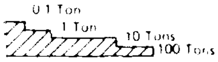
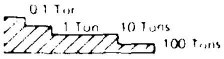
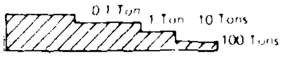
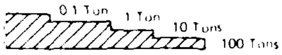
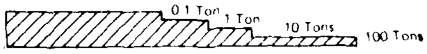
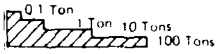
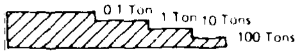
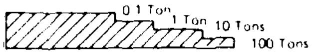
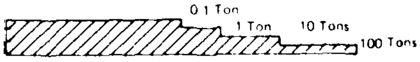
Chemical Name	Code	Maximum Width
Acetaldehyde	AAD	0.1 Ton, 1 Ton, 10 Tons, 100 Tons
Acetylene	ACE	Simple Asphyxiant
Ammonia, Anhydrous	AMA	0.1 Ton, 1 Ton, 10 Tons, 100 Tons
Boron Trichloride	BRT	Unknown Toxic Level
Butadiene, Inhibited	BDI	0.1 Ton, 1 Ton, 10 Tons, 100 Tons
Butane	BUT	Simple Asphyxiant
Butylene	BTN	Unknown Toxic Level Low Toxicity
Carbon Dioxide	CDO	0.1 Ton, 1 Ton, 10 Tons, 100 Tons
Dimethylamine	DMA	0.1 Ton, 1 Ton, 10 Tons, 100 Tons
Dimethyl Ether	DIM	Unknown Toxic Level
Ethane	ETH	Simple Asphyxiant
Ethylamine	EAM	0.1 Ton, 1 Ton, 10 Tons, 100 Tons
Ethyl Chloride	ECL	0.1 Ton, 1 Ton, 10 Tons, 100 Tons
Ethylene	ETL	Simple Asphyxiant
Ethylene Oxide	EOX	0.1 Ton, 1 Ton, 10 Tons, 100 Tons
Ethyl Nitrite	ETN	Unknown Toxic Level
Carbon Monoxide	CMO	0.1 Ton, 1 Ton, 10 Tons, 100 Tons
Chlorine	CLX	0.1 Ton, 1 Ton, 10 Tons, 100 Tons
Chlorine Trifluoride	CTF	0.1 Ton, 1 Ton, 10 Tons, 100 Tons
Cyanogen	CYG	0.1 Ton, 1 Ton, 10 Tons, 100 Tons
Cyanogen Chloride	CCL	0.1 Ton, 1 Ton, 10 Tons, 100 Tons
Cyclopropane	CPR	0.1 Ton, 1 Ton, 10 Tons, 100 Tons
Dichlorodifluoromethane	DCF	0.1 Tons, 1 Ton, 10 Tons, 100 Tons
1,1-Difluoroethane	DFE	Unknown Toxic Level

*Hazard calculated assuming worst case weather conditions (steady low wind) and instantaneous discharge

†See Table 5-3 for time of arrival and duration of cloud

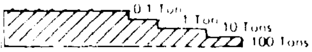
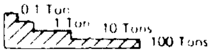
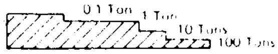
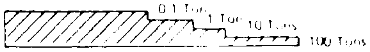
**See Condensed Guide to Chemical Hazards

TABLE 5-1(b) (Continued)

Chemical Name and Code**		Maximum Width — Width in Feet: 0-500 · 500-1000 · 1000-5000 · 5000-25,000 · 25,000-50,000 · Over 50,000
Fluorine	FXX	
Hydrogen Bromide	HBR	
Hydrogen Chloride	HDC	
Hydrogen Cyanide	HCN	
Hydrogen Fluoride	HFX	
Hydrogen, Liquefied	HXX	Simple Asphyxiant
Hydrogen Sulfide	HDS	
Isobutane	IBT	Unknown Toxic Level (Low Toxicity)
Isobutylene	IBL	
Liquid Natural Gas	LNG	Unknown Toxic Level (Low Toxicity)
Liquid Petroleum Gas	LPG	
Methane	MTH	Simple Asphyxiant
Methylacetylene Propadiene Mixture	MAP	
Methylamine	MTA	
Methyl Bromide	MTB	
Methyl Chloride	MTC	
Methyl Mercaptan	MMC	
Monochlorodifluoromethane	MCF	
Nitric Oxide	NTX	
Nitrogen, Liquefied	NXX	Simple Asphyxiant
Nitrogen Tetroxide	NOX	
Nitrous Oxide	NTO	Simple Asphyxiant
Phosgene	PHG	
Propane	PRP	Simple Asphyxiant

*Hazard calculated assuming worst case weather conditions (steady low wind) and instantaneous discharge
†See Table 5-3 for time of arrival and duration of cloud
**See Condensed Guide to Chemical Hazards

TABLE 5 1(b) (Continued)

Maximum Width → Chemical Name and Code** ↓		Width in Feet 0 500	500 1000	1000 5000	5000 25 000	25 000 50 000	Over 50 000
Propylene	PPL	Simple Asphyxiant					
Sulfur Dioxide	SFD						
Tetrafluoroethylene Inhibited	TFE	Unknown Toxic Level					
Trichlorofluoromethane	TCF						
Trifluorochloroethylene	TFC						
Trimethylamine	TMA	Unknown Toxic Level					
Vinyl Chloride	VCM						
Vinyl Fluoride Inhibited	VFI	Unknown Toxic Level					
Vinyl Methyl Ether Inhibited	VME	Unknown Toxic Level					

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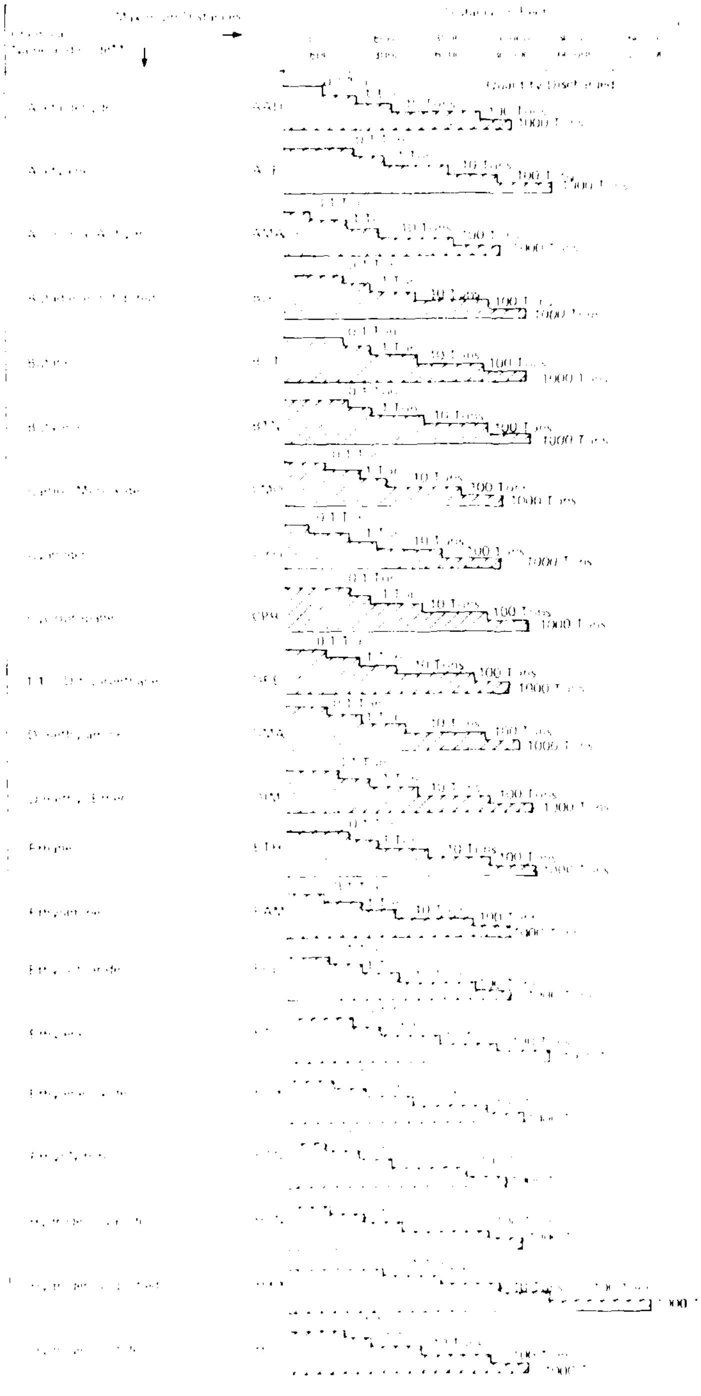
*Hazard calculated assuming worst case weather conditions (steady low wind) and instantaneous discharge

*See Table 5 3 for time of arrival and duration of cloud

**See Condensed Guide to Chemical Hazards

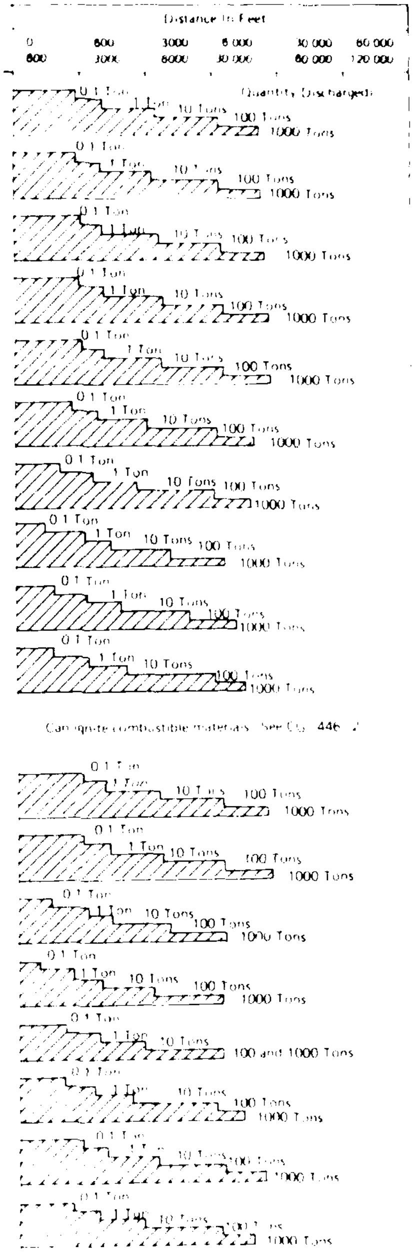
TABLE 5-2(a)
FLAMMABLE GASES
MAXIMUM DOWNWIND DISTANCES OVER WHICH GASES MAY IGNITE*†



[illegible]

TABLE 5 2(a) (Continued)

Chemical Name and Code**		Maximum Distances → Distance In Feet
Isobutane	IBT	
Isobutylene	IBL	
Liquefied Natural Gas	LNG	
Liquefied Petroleum Gas	LPG	
Methane	MTH	
Methylacetylene Propadiene Mixture	MAP	
Methylamine	MTA	
Methyl Bromide	MTB	
Methyl Chloride	MTC	
Methyl Mercaptan	MMC	
Oxygen, Liquefied	OXY	Can ignite combustible materials (See CG 446-2)
Propane	PRP	
Propylene	PPL	
Tetrafluoroethylene, inhibited	TFE	
Trifluorochloroethylene	TFC	
Trimethylamine	TMA	
Vinyl Chloride	VCM	
Vinyl Fluoride, inhibited	VFI	
Vinyl Methyl Ether, inhibited	VME	



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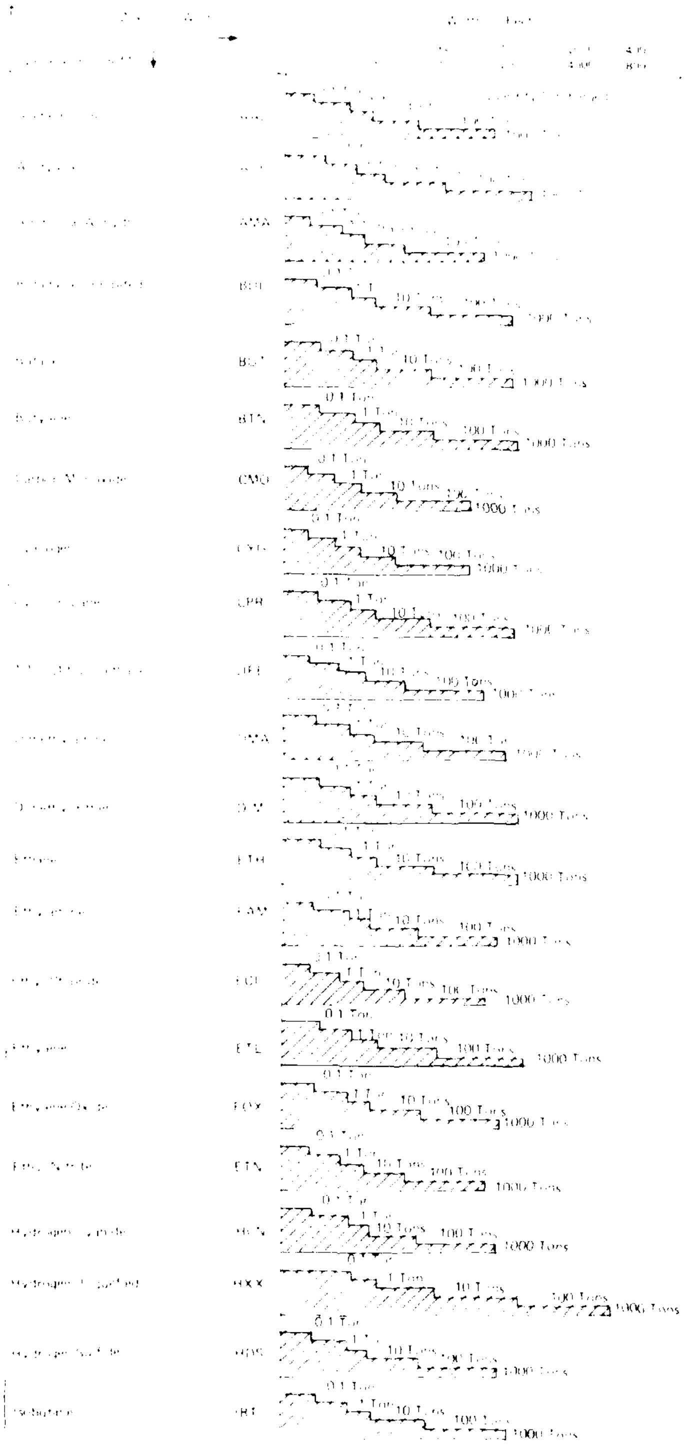
*Hazard zones calculated assuming worst case weather conditions (steady low wind) and instantaneous discharge
(see Table [illegible])
**See [illegible]

TABLE 5-2.6
FLAMMABLE GASES
MAXIMUM WIDTH OF THE CLOUD THAT IS FLAMMABLE*†



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*Hazard calculated assuming worst case weather conditions (steady low wind) and instantaneous discharge

†See Table 5- for time of arrival and duration of cloud

**See Condensed Guide to Chemical Hazards

Change 3

TABLE 5-2b — Continued

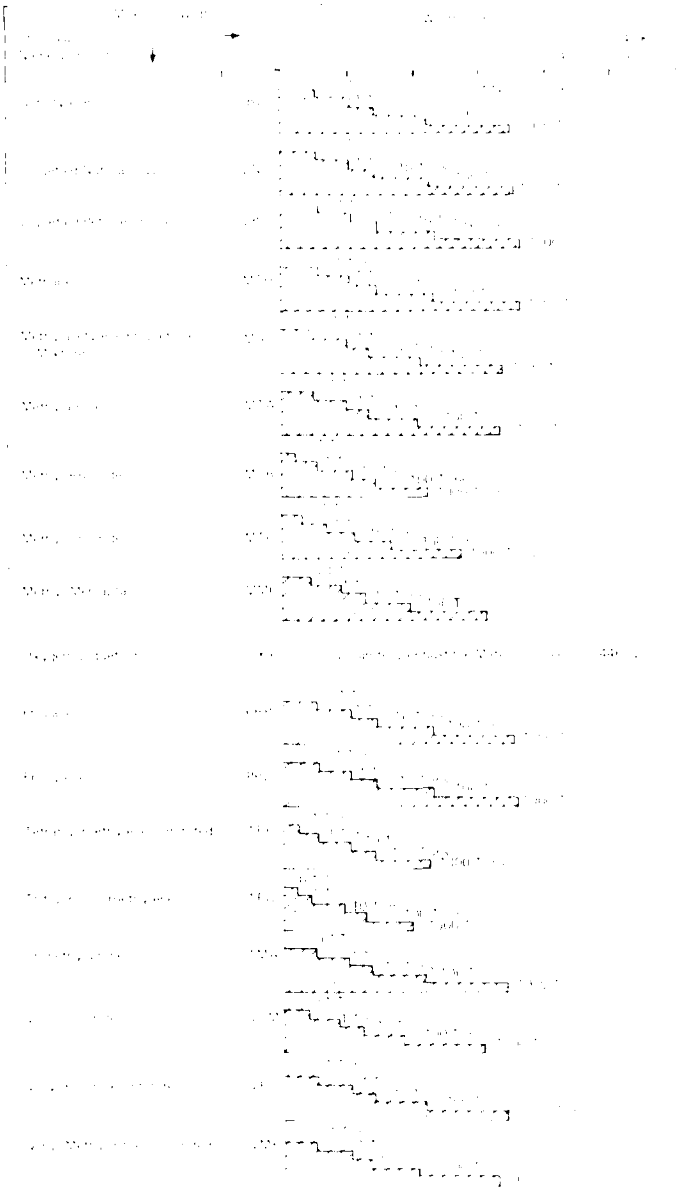

TABLE 5-3

TIME OF ARRIVAL AND DURATION OF HARMFUL GAS CLOUD*

$$\text{Time of arrival (min. after spill)} \cong \frac{60 \times \text{Distance Downwind (n.m.)}}{\text{Wind Speed (knots)}}$$

$$\text{Maximum duration (min)} \cong \frac{\text{Max. Width (ft)}}{\text{Wind Speed (knots)} \times 100}$$

*These formulas only apply to very rapid ("instantaneous") discharges. The maximum duration for a discharge that occurs over an *extended* period of time will tend to be the same time that is involved in the discharge of the chemical.

The method of estimating the time of arrival and duration can, as an approximation, be applied to any point downwind along the line of travel of the gas cloud.

5.2 DESCRIPTION OF TABLES 5-1, 5-2, AND 5-3

The chemicals listed in Tables 5-1 and 5-2 are all chemicals which have boiling points close to or below normal air and water temperatures. They are transported either as gases or liquids in pressurized containers, or as liquids at very cold temperatures. When they are discharged, they will quickly form a toxic and/or flammable vapor cloud which has the *potential* of traveling considerable downwind distances before becoming diluted (with air) to concentrations below hazardous levels. Tables 5-1 and 5-2 deal with the maximum distances over which toxic and flammable gases, respectively, may be harmful. Table 5-3 deals with the time of arrival and duration of harmful gas clouds.

By no means is it intended to imply that chemicals not on the list cannot or will not also present similar or worse hazards over large areas. There are many chemicals which have boiling points only slightly above normal air and water temperatures and which therefore, are volatile. Floating pools of such materials on water will evaporate slowly as they travel downstream with the current, exposing nearby populated areas in the downwind direction to hazardous vapors. These chemicals are *not* included in Tables 5-1 and 5-2.

Factors that should be considered in utilizing the tables include the following:

1. The distances given in Tables 5-1 and 5-2 were estimated using currently available, but not fully proven, analytical methods. The concentrations of the hazardous gases at any point along the line of travel (including the maximum distance) will fluctuate with time. The distances given in the table correspond to the maximum distances over which the *average* concentration may be harmful (i.e., toxic or flammable). Since the distances were calculated using the Hazard Assessment Handbook, a more complete exposition of the methods can be found in the report entitled, *Assessment Models in Support of the Hazard Assessment Handbook* (may be obtained from National Technical Information Service, AD 776617).

2. Table 5-1 gives harmful distances based upon the threshold unit value (TLV) concentration for each chemical. These values may be found in the Hazardous Chemical Data Manual. The TLV is the limiting concentration deemed to be tolerable during a continuous exposure for 8 hours each day of a five-day work week. Since higher concentrations may not cause injury when exposure times are short, as they may be for the gas cloud from an accidental

discharge, the distances estimated in Table 5-1 may be excessive. The TLV is used in the interest of safety and because there is a lack of approved data on maximum concentrations for short-term durations.

3. Estimates of distances in Tables 5-1 and 5-2 are based on the assumption that the weather conditions provide poor mixing of the gas with air and result in the greatest distances over which they would remain harmful. Weather "Condition F," as used in the Hazard Assessment Handbook, was employed throughout. This condition (F) is characteristic of a weather inversion and is associated with low turbulence; and, *hence, poor mixing of the vaper* and air.

4. Both Tables 5-1 and 5-2 are based on the assumption that the land or water over which the gas cloud will travel is flat and that there is nothing in the travel path, such as rough terrain, buildings, and trees which might promote mixing of the gas with air. Increased mixing would tend to reduce the maximum harmful distances.

5. All three tables are based on the assumption that the quantity of each chemical discharged is released instantaneously (within a few minutes). Although discharges may conceivably occur at a sufficiently rapid rate to make this assumption valid, many others will occur over much longer periods of time. For prolonged discharges the maximum distances will be significantly less than those given in Tables 5-1 and 5-2. The duration of the gas cloud, however, may also be prolonged.

6. In Table 5-2 it is assumed that the flammable vapor cloud is not ignited. In many cases it will be ignited in the immediate vicinity of the discharge and under these circumstances the unignited cloud will not travel very far. Also, if it enters a populated area, it may ignite quite soon due to the presence of many man-made ignition sources. Once ignited, the flame will propagate through the cloud and its downwind progress will generally be halted.

5.3 EVALUATING THE INCIDENT BEFORE RESPONDING

Cautionary responses being required before corrective responses require an alert and prudent evaluation of the pending or actual chemical discharge. A very careful assessment of the incident must be made within a time interval appropriate to the occasion. Great care must be taken to identify the chemical, determine its hazardous nature, and understand how it may act on being discharged. The handbook, A Condensed Guide to Chemical Hazards, should be reviewed before taking almost any action. Specific chemical data may be found in the Hazardous Chemical Data Manual.

For all cautionary responses, knowledge of the potential area over which harmful effects may occur can be critical. A quick reference to maximum distances for toxic and flammable gas clouds is given in the preceding tables; however, the Hazard Assessment Handbook should be employed for most discharges, including those of gaseous chemicals.

In assessing the hazard it should be remembered that the extent to which chemicals disperse in the water (for those that mix with water) or in the air is dependent upon the quantity or rate of discharge and the turbulence of the fluid with which they mix. Soluble chemicals will become diluted more rapidly so that they no longer provide an immediate health hazard if discharged into a turbulent stream than in a calm body of water. Gases will disperse more quickly in the air under gusty wind conditions than when the air is relatively still.

The time of travel of discharged chemicals will be determined by the velocity of the medium (either air or water) in which they are dispersed. Chemicals that float will move at the velocity of the surface water with some effect by wind. Those that mix with water will move with the tide or current and gases that are formed will travel at the velocity of the prevailing wind.

Naturally, a great responsibility is placed on the On-Scene Coordinator to determine the extent of cautionary response warranted in a given situation. Actions required to respond to the accidental discharge of one 55-gal. drum of benzene are obviously not the same as those required for handling a 10,000-bbl discharge of the same material. Correct information about a discharge must be secured as rapidly as possible to avoid the massive disruption of community life resulting from an overresponse to a minor discharge of a hazardous material. Conversely, an inadequate response to a major discharge could result in a catastrophe. If the extent of the danger cannot be readily determined, it would appear better to err on the safe side than to expose large areas to the threat of dangerous vapors or badly contaminated water supplies. Such decisions can be made only on the spot and must be left to the judgment of the On-Scene Coordinator.

5.4 RESTRICT ACCESS

5.4.1 Access to Waterways

When relatively small quantities are discharged or the discharge is at a low rate, restricting access primarily applies to the waterway or surrounding body of water and nearby shore areas. People, boats, ships and land vehicles should be prevented from entering the threatened zone by communications and means of physical blockage that are available at the site of the discharge. These include radio communication, signals, loud hailers and interference by USCG craft where necessary. Control of locks and aid of harbormasters may also be required. When necessary, and when appropriate the local Port Authority should be requested to restrain ship departures and divert incoming ship traffic. The Regional Contingency Plan Data Base should provide a ready source of people and agencies that can provide assistance.

Problems can be anticipated with small craft that lack marine radio communication systems. In this case, restriction of access could only be accomplished by the use of picket and patrol craft continually patrolling a safe boundary line. To relieve USCG personnel and vessels for other duties, it may be advisable to solicit the aid of local yacht clubs, the USCG Auxiliary, and the U.S. Power Squadrons.

5.4.2 Access to Land Areas and Air

For large discharges and particularly those that may create hazardous vapors, immediate action should be taken to alert regulatory authorities (state and local Fire and Police Departments) to the extent of boundaries of restricted land access so that traffic diversion can be initiated and detour routes established. It may also be necessary to support available police forces with additional personnel. USCG forces may be more readily available than military reserve units which generally require a gubernational order for activation (National Guard), and can take as long as 10 hours for full assembly. The USCG Reserve is undergoing special training to aid during pollution emergencies, and their response to past spill incidents has been accomplished in a minimum of time.

For large discharges, and when appropriate, radio and television stations should be alerted to the boundaries of restriction so that frequent spot announcements can be made to the public. When necessary, the railroads serving the polluting incident areas should be advised to direct and divert rail traffic away from the restricted access area.

Airports servicing the area, if they are near the problem location, should be alerted to the situation so that they may cancel impending flights and divert incoming flight landings. This action would, however, be applicable only in cases involving a traveling vapor cloud that, because of its toxicity or flammability, could endanger the aircraft. It would also be advisable, when the circumstances warrant, to apprise the local Civil Defense Agency of any hazardous chemical situation, since it maintains equipment that could be used in restricting access into a hazardous area.

5.5 RESTRICT IGNITION

Restricting of ignition primarily applies to small discharges or slow discharges of flammable materials and hence is appropriate to the adjacent waterways and nearby shore facilities. Where large flammable clouds might form, the restriction of ignition sources on land may enlarge rather than reduce the hazard. If the cloud is allowed to travel far enough to envelop populated areas before it becomes ignited, on burning it may cause massive and severe injury and damage. If ignition sources are not restricted on land, the cloud may ignite soon after it reaches the shore and its movement inland will generally be halted.

Restricting ignition will, as a general rule, require the *restricting of access* to the area where the flammable liquid or gas may be present. For vessels that are already in the hazard zone and cannot be moved, or for those that may have to enter into or near the hazard zone for response purposes, special precautions are necessary.

Sources of ignition include internal combustion engines that are not adequately equipped with flame arresters through the carburetor and, perhaps, from backfire through the exhaust. Smoking, gas fired cooking stoves and heaters, flares, and hot surfaces also may cause ignition. The impacting of certain dissimilar materials (e.g., a wrench dropped on concrete) may also initiate the burning of a combustible mixture. Great care must be taken to ensure that these sources are not present in (or allowed to enter) the general area where the flammable chemical may be present.

The use of automobile and small craft electrical and ignition systems can be restricted by the police. For this reason, vehicles used for evacuation purposes should have their inward travel restricted to a predetermined safe distance, and evacuees should walk to the vehicle meeting point. Even the use of USCG vessels should be closely supervised to control potential ignition sources.

Vehicles and equipment used to clean up a hazardous chemical incident can represent an ignition source since many small craft, skimmers, pumps, and spill-recovery trucks do not have explosion-proof systems. Extreme caution should be exercised in the utilization of such equipment; and whenever practical, only explosion-proof cleanup equipment should be used if an explosion hazard exists as a result of the hazardous chemical discharge.

5.6 EVACUATE PERSONNEL

The evacuation of people from an area threatened by toxic or flammable vapor conditions requires considerable planning and assistance for the alerting and transportation of individuals to a safe zone. The Regional Contingency Plan Data Base should serve as the primary source of information on assistance that may be available from governmental agencies and civilian groups. Prior planning by the OSC for events of this kind, particularly in areas where there are frequent shipments of those chemicals listed in Tables 5-1 and 5-2, should be carried out so that the groundwork for a well organized and quick response may be laid.

An evacuation can be most effectively accomplished when a given area is threatened, but not yet exposed to the hazardous gases. After an area has been exposed, the urgency of the situation can become more acute and the immediate availability of protection, rescue, and evacuation of personnel can be critical.

Contingency plans for evacuation should be developed, where appropriate, coordinated with other emergency service groups, and kept in a ready status. Some of the factors that should be included in the development of contingency plans include the following:

- Methods of identifying threatened or exposed areas.
- Notification and warning of those that are threatened.
- Provisions for transportation from the hazardous zone.
- Surveillance of the area to monitor the effectiveness of the evacuation procedures and the presence of the hazardous gas.
- Establishment of priorities for evacuation based on such factors as the degree of (potential) exposure, available time for notification and effecting evacuation, distance and access to hazard-free areas, density of the population and availability of resources.
- Provisions for readily available personal protection equipment for both those that are threatened and rescue and evacuation personnel.

5.7 RESTRICT HUMAN USE OF CONTAMINATED WATER

Many municipalities utilize major river and lake water as a potable or domestic water supply source. The water treatment system could either be overtaxed or not capable of treating specific chemicals. In such cases, the water supply for domestic use should be restricted by promptly notifying the water supply agency and the public health authorities. Meanwhile, radio and television service announcements should be used to alert the general public to the problem, and to prevent use of polluted water that may have entered the water supply system before the main supply could be terminated.

Special attention should be given to food-processing plants that utilize water as a cooking agent since such facilities rarely use radio and television during production periods. The local port authority should be promptly advised of the situation to prevent the intake of contaminated water by marine vessels.

Coast Guard personnel should be aware of facilities and agencies that control water intakes.

5.8 RESTRICT FARM AND AGRICULTURAL USE OF CONTAMINATED WATER

Farmers use water taken directly from rivers for irrigation and drinking water for livestock. Since farm personnel are generally out in the fields, communication by radio and television may be difficult, if not impossible. Personal contact may be warranted using a messenger, a telephone call to the farmhouse, or a loud hailer from helicopter, patrol craft, or automobile. Well developed contingency plans for notification of those controlling agricultural use of the water in areas that may be particularly vulnerable and where chemicals that may be harmful are frequently shipped will greatly improve emergency response. The availability and knowledge of water monitoring devices to detect and follow the movement of the hazardous chemical in the water body are also important to efficient response action.

Coast Guard personnel should be aware of facilities and agencies that should be notified when farm or agricultural water use may be threatened.

5.9 RESTRICT INDUSTRIAL USE OF CONTAMINATED WATER

Industrial plants use fresh water, river water and, in some cases, sea water for cooling, quenching, liquid slurry transportation of material, and cleaning purposes. Electrical power plants (including nuclear power generating stations) use large quantities of water from adjoining water bodies for cooling purposes. Considerable damage to the power plants may be caused by some chemicals if they are allowed to enter the system. In most cases, the method of reducing or eliminating the potential damage is to shut down the intake pumps. Since a shutdown can cause difficulties associated with the safety and operation of the plant, accurate information is needed about the concentration and location of the chemical in the water body.

Filtered river water is also used at up-river locations for boiler feed water and for the operation of jacketed cooking vessels. Many firefighting systems (hydrants and sprinkler systems) use both salt and fresh water. Problems would obviously be encountered if the contaminant in the water supply proved to be highly flammable. Ships use river and harbor water for ballast, and serious problems could result if the ballast water source contained a chemical contaminant, explosive material, or a chemical that would be reactive to the cargo that the vessel would eventually unload.

The location of water intakes and the telephone numbers and personnel to be called at industrial companies where contaminated water may harm their facilities should be listed in the Regional Contingency Plan Data Base.

5.10 SOURCES OF ASSISTANCE

There are many sources of assistance which should have been contacted in the course of formulating the Regional Contingency Plan Data Base. The data base should explain the extent of aid that can be made available in the event of a chemical discharge. Assistance sources which will naturally vary by geographical location and urban or rural locations are presented on the following pages.

5.10.1 Federal Sources

(a) *The Department of Defense* This agency can provide military assistance to patrol selected areas and divert pedestrian, vehicular, marine, and aircraft traffic. In the event that local resources are clearly inadequate to cope with the situation to prevent loss of life, the Army, Navy, and Air Force can provide assistance to feed, transport, and house displaced personnel during evacuation procedures; field-type communication systems can also be obtained from this source. The Army Corps of Engineers may be particularly helpful in controlling the movement of the hazardous chemical in or on the water body through adjustments in the flow of water over dams and through locks.

(b) *Environmental Protection Agency (EPA)* Along with the USCG, the EPA has a prime responsibility in the control and cleanup of polluted waters. The agency can provide personnel who have had broad experience in the process and storage of hazardous polluting substances and are very familiar with the bodily injury and property damage associated with chemical products. In addition, they can readily advise on response techniques that can be used effectively to control or otherwise treat accidental chemical discharges. Close coordination should be maintained with this agency.

(c) *The Department of Agriculture* This Department can provide many services to meet the emergency needs for agriculture. These include the provision of surplus food to relief organizations and the determination of crop damage due to chemical contamination.

(d) *Defense Civil Preparedness Agency* This agency can supply water pumping equipment, water purifiers, generators, steel pipe and fittings to meet emergency needs.

(e) *The Public Health Service* This body can provide assistance for emergency health and sanitation measures.

(f) *National Weather Service NOAA* The local office of NWS NOAA provides weather forecasts on a 24-hour basis. The office also maintains modern communication services with all state civil defense agencies. The agency can provide up-to-the-minute forecasts and pertinent weather information through NAWAS, teletype, telephone and the new VHF Weather Broadcast Information System operating on 162.40 MHz. Wind direction and force data are vital to determining where and how far the evacuation should take place.

5.10.2 State Sources

The names of the various departments, divisions, and agencies in each State will vary; however, their duties should be similar. Typical assistance will be as follows:

(a) *State Environmental Protection Agency* Environmental, civil, mechanical, and sanitation engineering assistance can be readily gained from this source. Many states have also employed marine biologists and oceanographers who have become very familiar with the marine conditions and resources within their state. Some states have acquired and stockpiled pollution control equipment such as booms, skimmers, and chemical treatment systems which can be promptly deployed for fast-response action. Water analysis service can also be obtained from this agency and, in some areas, mobile biological and water analysis laboratories can be provided. A close coordination should be maintained with this state agency.

(b) *Department of Public Works* This Department can assist in restricting water flow, control of sewerage systems, debris and mobile clearance, building temporary restraining dikes and earthen barriers, and providing emergency vehicles and personnel for emergency transportation requirements.

(c) *Department of Health* - This Department can provide water analysis service, casualty control and reports, and emergency health personnel.

(d) *Transportation and/or Highway Department* This agency can aid in the safe and efficient movement of traffic around affected areas and provide some vehicular assistance for evacuation.

(e) *State Police* The State Police can aid greatly in the control of pedestrian and vehicular traffic and in settling panic situations, and they generally have an effective communication system that can be used to advantage. In addition, most State policemen have had extensive first aid training that can be used to advantage following either inhalation or physical contact with chemicals or in the event of fire and explosion injuries. The police, in most cases, can be more effective than USCG personnel in executing evacuation procedures, and their vehicles can be readily used for the transportation of personnel from critical locations.

(f) *Department of Education* This Department can provide temporary housing facilities for evacuees, bus transportation, and frequently maintenance-type personnel who can be of valuable assistance in stemming leaks and providing plumbing repair and carpentry.

(g) *State Fire Marshal* Although most staffs are limited, the Fire Marshal can assist in obtaining mutual aid fire fighting assistance and can provide personnel trained in the techniques of fire prevention and damage assessment, and in determining the sources and causes of hazardous chemical incidents.

(h) *State National Guard* Activation of the National Guard requires a proclamation by the Governor of the State or other individual acting in the Governor's absence. Since most of the Guard personnel have regular employment, there is a time delay in alerting them to action. Time variations of from 4 to 10 hours have been given for full activation. On this basis, since fast-response action is of vital concern, the National Guard may be able to provide only limited assistance. However, the Guard is a source of trained personnel who can provide a variety of field equipment such as trucks, mobile kitchens, ambulances, pumps, bridge-building equipment, helicopters and planes, and communication equipment. The duration of response, surveillance, and monitoring requirements should be estimated before calling for National Guard assistance.

(i) *Civil Defense Agency* Most civil defense organizations have emergency plans that have been developed for some time and, in many cases, have been subjected to tests or actual operation. Each city generally maintains a CD HQ and a full-time operational staff. They maintain workable communication systems and maintain a

close liaison with other agencies that can provide emergency response action. It is suggested that the CD organization be immediately alerted of any incident. The individual CD organization's familiarity with the area, the terrain, industrial sites, and other response personnel can be a valuable asset. It is also possible that the CD organization may assume the responsibility of evacuation. In any event, people, equipment, and an operational communication system can be made readily available from this source, and most CD agencies have been preparing to aid in response to polluting incidents.

5.10.3 County

The response from the county involved in the hazardous chemical incident and mutual aid counties that adjoin the stricken county or could eventually feel the impact of the incident will, in a slightly lesser degree, duplicate the assistance available from State sources. The following departments should be contacted when the need warrants such action:

- Public Works,
- Health Department,
- Highway and Road Department, and
- Sheriff's Department.

5.10.4 Municipal

The large municipalities are generally well organized and equipped to respond and aid in the control, containment, and cleanup of a hazardous chemical incident. In most cases the various agencies again duplicate their State and county counterpart aid sources, involving the following departments:

(a) City Police Department — Aid action from the City Police would duplicate that available from the State Police, with the exception that a greater familiarity with the city should be evident.

(b) City Health Department — In line with State assistance, emergency health and sanitation services can frequently be obtained from this source.

(c) Street and Transportation Department — This Department can provide detour and traffic movement and frequently it can provide vehicles for the movement of equipment and personnel as well

(d) *City School System.* Bus fleets can be obtained from the City School System for evacuation purposes, and the school buildings could be used to house and feed persons evacuated from the area of a hazardous chemical discharge.

(e) *City Fire Department.* Both full-time and volunteer fire departments are a valuable source of assistance. An intercommunication and mutual aid system has been developed and has been tried and tested many times between local fire departments. Many of the major cities have trained their personnel on the basic factors of hazardous chemical containment and control. High-pressure water hoses can be used to move surface slicks from beneath piers and to herd the slick to a collection system. Fire boats, using their high-pressure hoses, can counteract tidal action to herd surface slicks and facilitate cleanup action. Many fire departments have acquired their own surface skimming and collection systems and have become adept in the use of such equipment. The wash or wake of the propeller or propellers on fire boats can be utilized to agitate, disperse, and dilute water soluble materials that may be stagnating in the water column. Fire department personnel have in some instances also developed a familiarity with flammable materials transported, stored, and processed in their service area and are equipped to extinguish chemically originated fires. A high-pressure hose injection system can be utilized to spread many types of chemical treatment materials onto hazardous chemicals.

(f) *City Sanitation Department.* By pre-arrangement, the Sanitation Department can frequently assist in the disposal of chemicals recovered from the contaminated area, and may be capable of processing the material through the municipal sewage treatment system. Services can also be provided in the disposal of solid materials such as chemically impregnated absorbents and debris (flotsam and jetsam) recovered during cleanup operations. On a number of past polluting incidents, controlled burning and burying of straw and similar materials have been efficiently handled in the municipal dump.

5.10.5 Industrial

(a) *Industrial Mutual Aid Groups and/or Oil Spill Cleanup Cooperatives.* There are many mutual aid groups (Appendix B) in the United States. Most of these are industrial organizations which have purchased and or pooled and stockpiled pollution control equipment and have trained plant personnel in the use of the equipment. The mutual aid organizations can be of valuable assistance in the event of a hazardous chemical incident, since a number of them have developed their own contingency plans. In most cases, plant supervisory personnel have an intimate knowledge of chemical products produced within their own plant and in other plants in the area.

These groups can provide floating containment booms, skimmers, and chemicals used to combat and reduce the damage resulting from a hazardous chemical discharge. Many industrial facilities have acquired small craft for the deployment of pollution containment, recovery, and chemical treatment systems. They can also muster a host of trained personnel to fully utilize the equipment and or systems.

Other industrial organizations that can provide advice and practical assistance are described below.

(b) *Gas and Electric Company* In some municipalities the gas and electric companies are totally separate units; in other communities the two services are consolidated. In any event, the conditions of operation should be well known to the OSC within the service area. The electric company can extinguish electrical ignition sources by a power shutdown in a selected area. They can also provide special service equipment and personnel who have had extensive experience in emergency response. The gas company can provide manpower and equipment capable of monitoring explosive vapor discharges.

(c) *Telephone Company* By pre-arrangement the local telephone company can readily establish a temporary telephone exchange at any land-based location, and should the situation warrant such action, they can close strategic circuits to ensure uninterrupted telephone service. It may also be possible, depending on the location, to obtain personnel for telephone-answering service, message-taking, and electrical and electronic repair and maintenance personnel.

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(d) *Private Consulting Organizations and Testing Laboratories* These organizations can provide a source of chemists, chemical engineers, mechanical engineers, civil engineers, environmentalists, biologists, oceanographers, ocean and marine engineers, and physicists who can be pressed into service in the event of an emergency.

(e) *Shipping and Barge Lines* - These lines can provide marine craft that can be used to contain hazardous chemicals that may be transferred from a leaking vessel. When secured together in a cross-stream fashion, the barges can be used as surface dams to restrict surface flow. Barges can also be utilized as temporary bridge structures to cross a river. Water-separation systems can also be barge-mounted for on-scene response action. Coastal-type tankers can also be used as a means of temporary storage for recovered materials.

(f) *Full and Part-time Pollution Control Companies* - The OSC and other Coast Guard response personnel should be familiar with the various cleanup contractors' capabilities, availability, and past performance so that a quick selection may be made during an emergency and the contractor's services deployed as soon as it becomes feasible.

(g) *Trucking Companies* - At each locale there are numerous trucking companies which can provide tank truck-type vehicles with capacities up to 8,000 to 10,000 gallons. They can be used to enter a hazardous chemical control zone to collect recovered waste materials. During the summer months many fuel oil delivery companies have fleets of vehicles that stand in off season idleness. These vehicles could be used for the containment and eventual disposal of recovered waste material. Other vehicles that are empty and in onload standby status can also be diverted into hazardous chemical control activity.

(h) *Railroad Companies* - When railroad sidetracks are close to the zone of activity, railroad tank cars could be used as waste containers in lieu of, or in conjunction with, automotive tank trucks. Such containers frequently become available at the immediate site of the hazardous chemical discharge since many empty tank cars may be standing idle on in-plant railroad tracks or in railroad marshalling yards prior to reshipment. Normally tank cars have a storage capacity of up to 60,000 gallons.

(i) Ambulance and Oxygen Services At urban and rural locations privately operated ambulance and oxygen service agencies are available. Such services can extend and supplement the regular hospital and fire department ambulance services. This type of aid is frequently needed when hazardous chemicals are accidentally discharged at a coastal location. Listings can be made from the telephone company yellow pages, the local civil defense agency, or the local health department.

5.10.6 Volunteer Assistance

Volunteer response assistance in the past has resulted in a number of lawsuits due to inexperienced persons suddenly becoming involved in actions for which they have had no training or with which they were not fully familiar. There are, however, a number of well established and experienced volunteer organizations that can assist in the response action. They include the following:

(a) U.S. Coast Guard Auxiliary At coastal and other waterfront locations the USCG/Aux, a voluntary civilian auxiliary of the USCG, can provide personnel, small craft, and a marine communication system to aid in a response action.

(b) American National Red Cross The American Red Cross charter provides that the agency should continue and carry on a system of national and international relief in time of peace in mitigating suffering caused by pestilence, famine, fire, flood, and other great national calamities and to devise and carry on measures for preventing the same. It can be readily seen that a major hazardous chemical incident might under the right circumstances meet one or more of the requirements of the Red Cross charter. This relief organization will traditionally provide services to victims of a serious hazardous chemical incident by supplying food, clothing, shelter, and emergency medical care as well as assistance in rehabilitation of damaged property and primary disaster resources.

(c) Other Welfare Agencies Other welfare, religious, and charitable institutions, such as the Salvation Army, are equipped and trained to assist governmental agencies in meeting the effects of a disaster during the immediate emergency period. A listing of such agencies should be developed and used when the response situation warrants such assistance.

(d) *Civil Air Patrol (CAP)* During a response action that is beyond the capabilities of available personnel, the local Wing of the Civil Air Patrol (CAP) can employ facilities, personnel and equipment to support the U.S. Coast Guard. The available services would be consistent with the CAP's other missions as a volunteer civilian auxiliary of the United States Air Force.

(e) *U.S. Power Squadrons and Yachting and Boating Clubs* From these sources an armada of small craft can be quite promptly obtained for patrol duties similar to the USCG/Aux assistance.

5.10.7 Universities

Specialized knowledge of chemical hazards may be found in local colleges and universities and be utilized for guidance during response. Their laboratories may be able to furnish chemical monitoring equipment and to perform chemical analyses on samples brought to them.

6.0 Corrective Response Methods

6.0 CORRECTIVE RESPONSE METHODS

To Apply Corrective Response

First	be sure that hazardous nature, precaution and first aid are understood
Second	rescue exposed or threatened personnel and take appropriate action to prevent accident from getting worse
Third	select applicable response methods using Response Index (Table 4-1)
Fourth	apply *cautionary* responses (utilize the CHRIS manuals and Regional Contingency Plan Data Base where applicable)
Fifth	apply *corrective* response based on a full evaluation of the chemical characteristics and the local situation that prevails

- stop the discharge and transfer cargo where appropriate
- initiate other applicable corrective responses
- dilute and disperse only when safe, and only if other responses cannot be applied

For general description of response equipment and systems, see Appendix A, Part I

For equipment listing by manufacturer, see Appendix A, Part II-A

For specific description of response equipment, see Appendix A, Part II-B through F.

For list of protective clothing, see Table 7-2, page 7-3

6.1 Stop Discharge

6.1 STOP DISCHARGE

Potential Methods

- Turn off pumps and close valves
- Ballast or trim the vessel
- Patch holes and perform structural repairs
- Transfer the remaining cargo to another vessel
- Move the damaged vessel to a less dangerous location

In many circumstances, stopping or reducing the amount of discharge of a hazardous chemical into the water body may be the most effective response that can be made. The actions required to perform this response can require considerable judgment and necessitate guidance from vessel and terminal operators as well as salvage personnel. Since hazardous chemicals are involved, responses associated with the source of discharge may be particularly dangerous. A general outline of available methods is presented below.

6.1.1 Turn Off Pumps and Valves

Terminal operators and tankermen should be trained to promptly shut down pumps and close valves. The OSC, however, should be prepared to take action in the event that operators are disabled. The prior establishment of the availability of backup operating personnel and an understanding of the transfer system will help to promote prompt and safe actions during an emergency.

6.1.2 Ballast and Trim

Under special circumstances the rate of discharge may be reduced by ballasting or otherwise trimming the vessel so that the height of the liquid above the discharge hole is reduced. Grounding the vessel may also prevent it from sinking further into the water, and thus prevent the escape of an additional quantity of the chemical. Again, the vessel operator must be relied upon for guidance and to perform or supervise some or all of the necessary operations.

6.1.3 Patch Holes and Perform Structural Repairs

Casualty engineering and the effective practice of damage control may be necessary in circumstances such as stranding, collision, sinking, or fire on board ship or barge, and some similar actions may also be applicable to containers in bulk storage facilities. Prompt action may minimize the progressive nature of a casualty. In the case of a hazardous chemical discharge, patching the hull and making structural repairs on decks and bulkheads may be necessary to prevent further loss of liquid. These actions should be accomplished quickly, and they must be performed safely, according to a master plan. Too often, ill-conceived plans have caused the loss of life and property. Difficulties experienced by salvage and response personnel may be numerous and complex and may require attention to detail. Specific measures should be taken to ensure that spaces are freed of gas and remain so during the operations.

Small leaks, left unattended for extended periods of time, can cause large losses of cargo. The amount of water that will enter a ship through an opening or will flow from one compartment to another varies directly as the area of the hole and the square root of its depth of submergence. Also, the flow of a hazardous chemical from an opening above the water will likewise vary directly as the area of the hole and the square root of the height of liquid above the hole. If the discharge hole is below the water line, then the flow will be reduced as the result of the head of water above the hole. By reducing the hole area, a significant decrease in discharge may be obtained. An indication of the hole blocking effect can be seen in Figure 6-1 where flow rates are given for unplugged and partially plugged holes for a case on which the vessel is taking on water.

Minor leaks may develop in rivet holes, plate seams, or through small hull cracks. Corrective measures for this type of leak include lead, sawdust, oakum, prepared leak-stopping compounds or caulking, and the use of soft wooden plugs or wedges, which will swell on contact with water effecting a closure.

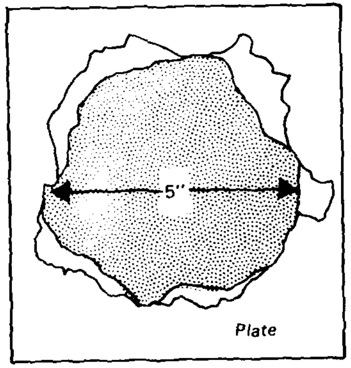
Several structural patching methods have been developed by salvors for both small and large holes. Several examples are illustrated in Appendix C.

6.1.4 Transferring Cargo

Liquids may be transferred from a stricken ship to a second tanker, barge, or to sound compartments within the same ship by a variety of methods. These include pumping, blowing with air, and allowing the liquid to flow freely into another compartment.

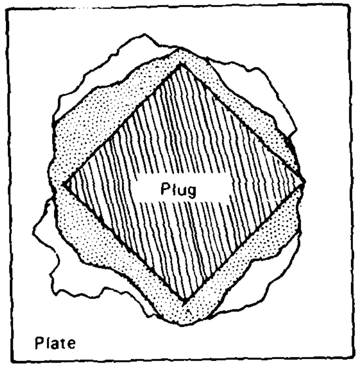
EFFECT OF PLUGGING HOLES – The Amount of Water Entering a Ship Through a Hole Varies Directly as the Area of the Hole and the Square Root of its Depth of Submergence. "Pumps" are the Number of Electric *Submersible (250 gpm)* Pumps Required to Handle the Flooding.

UNPLUGGED HOLES

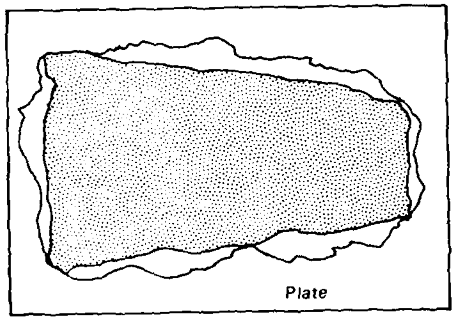


UNPLUGGED HOLES			PARTLY PLUGGED HOLES		
Depth	Gal. per Min.	Pumps	Depth Ft.	Gal. per Min.	Pumps
1	301	3	1	114	1
2	425	4	2	160	2
3	512		3	192	
4	603	5	4	227	
5	676	6	5	254	
6	739		6	277	3
7	794	7	7	286	
8	853		8	320	
9	904		9	339	

SAME HOLES PARTLY PLUGGED

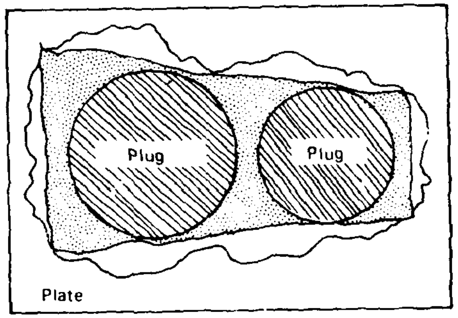


Area of Hole – 19.65 Sq. In.
Area of Plug – 12.25 Sq. In.
Area of Leak – 7.40 Sq. In.



Depth	Gal. per Min.	Pumps	Depth Ft.	Gal. per Min.	Pumps
1	319	3	1	91	1
2	451	4	2	129	
3	552	5	3	158	2
4	638		4	182	
5	713	6	5	204	
6	782		6	224	
7	844	7	7	241	
8	902		8	258	
9	957	8	9	273	3

These Figures Show How Important it is to Put Some Kind of Plug into a Shell Hole Right Away.



Area of Hole – 21.00 Sq. In.
Area of Plugs – 15.00 Sq. In.
Area of Leak – 6.00 Sq. In.

FIGURE 6–1 FLOODING AND FLOW RATES

Caution is required to ensure that gas fumes will not cause hazards in liquid transfer operations; appropriate venting and certification of gas free spaces is advisable.

6.1.4.1 Mechanical Pumping Systems

A variety of pumps suitable for use in emergency operations is available. Salvors and damage control crews have utilized electric, mechanical, air, hydraulic, water, steam, and a wide variety of other pumps for the emergency transfer of liquids. Great care is required to ensure that the selected pump is suitable to the cargo. Corrosives and cryogenic materials require the use of special pumps specifically designed for application to the material. Certain cargoes are explosive and require that non-explosive pumps be used; in such circumstances air, steam, or water-driven pumps may be suitable for application.

While air pumps have generally a low rate of delivery, they are small, portable, lack the hazard of shock from an electrical charge, and are highly reliable. The delivery of compressed air can be varied in pressure and volume only affecting the pump's output and not operation. Most air pumps can also be operated without lubrication and without fear of overheating. They are generally excellent emergency pumps and the supply of compressed air can be located on board ship.

6.1.4.2 Air Pressure Systems

Pressurized air can also be used to transfer liquids in some circumstances. An air-lift, as shown in Figure 6-2, may be used to lift high-viscosity liquids, for example.

In other cases, air pressure can be applied to compartments and tanks to blow out liquids. In the case of hold compartments, all but bottom openings are secured. An air fitting is located at the deck fitting and air pressure is applied. A similar procedure can be used to blow liquids up a sounding tube. Great care is required to ensure that the air pressure does not exceed the hydrostatic rating of the container, however.

6.1.4.3 Special Methods

For recovery of cargo from a sunken ship, a hot-tap method for drilling a hole into the liquid compartment and transferring the liquid to another vessel on the surface has been developed. This has been applied to several oil-recovery operations from sunken ships. Specialized equipment and techniques for attaching the system to the sunken ship and accessing the liquid is required.

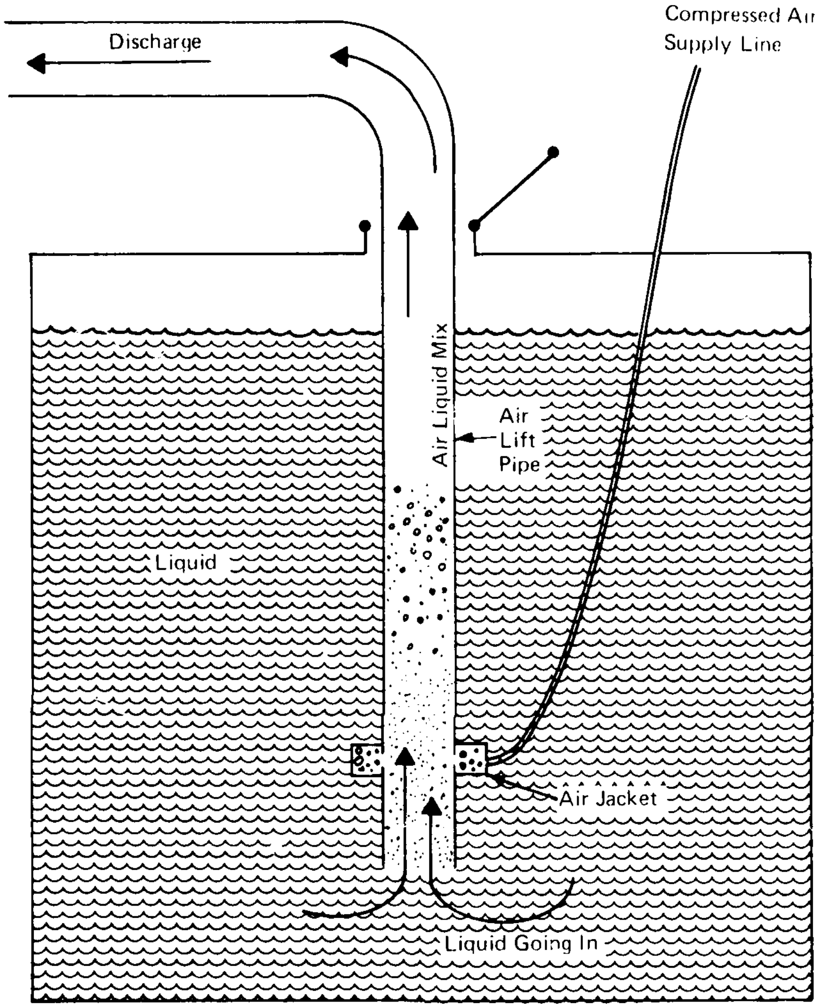


FIGURE 6–2 TECHNIQUE FOR AIR LIFTING LIQUIDS

6.1.4.4 Heating or Cooling of Cargo

A heating or cooling capacity is a good backup system for cargo transfer, especially if flow characteristics, pumping rates, or operation conditions are unknown.

Hot-tap systems and standard emergency cargo-pumping systems may be used in conjunction with the heating of the liquid cargo to lower the viscosity of the liquid so that it is free-flowing. This is most often done by heating with steam tracing through the hoses into the cargo tanks.

Alternate heating techniques available are:

- injection of steam into the cargo tank, and
- injection of steam into the spool piece of the hot-tap adaptor.

Cooling of the liquid cargo may be necessary in case of a flammable or explosive cargo which is temperature-sensitive, e.g., aviation gasoline. The technique of cooling cargo largely involves a continued water wash over the storage tanks.

6.2 Contain

6.2 CONTAINMENT

Potential Methods

6.2.1 Buoyant Floating Booms

Most booms were developed to contain oil slicks and may be used for a number of chemical products. However, the materials used in boom fabrication are vulnerable to damage from solvent, acid, and chemical attack.* They are generally not effective in seas running more than 2 to 4 feet and begin to hydroplane and fail in currents that exceed 0.7 knot.

A number of problems can be experienced with existing booms, and they can be defined as follows:

- Booms built by different manufacturers are rarely compatible, and no standardized means of end-to-end physical attachment exists. When multiple-boom sections are used, applied seamanship is required to jury rig and join different boom sections together.

  In addition, problems will be experienced in joining compatible boom sections, since fast methods of attachment are not yet state-of-the-art. Numerous attachment parts, nuts, and shackles must be assembled and secured – frequently in heavy swells from a gyrating small craft. Galvanized connectors for booms rust rapidly and can become worthless within 6 months.

- Many booms, especially units made of high braced or stayed freeboard material, are prone to hydroplane under even moderate wind conditions. Such action permits the accumulated chemical to escape under the submerged skirt.

- Float or buoyancy materials, especially porous and cellular synthetic materials, are easily damaged by impact or compression. Some material has even been rendered worthless when attacked by seagulls. Several containment booms operate on a principle of float removal for easy stowage; this entails physical attachment of the floats prior to deployment and use. Again, when working from a heaving small craft, such action is difficult and delays deployment.

- Ballast material, used to keep the containment skirt submerged, generally consists of lead or galvanized steel weights or chain. On some units the chain is stitched into the boom material or passed

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***See the Hazardous Chemical Data Manual for details on chemical reactivity.**

Change 3

through canvas webbing straps. When deployed for extended periods of time (for example, two days) failure has occurred from the movement and chafing action of the chain which wears out the attachment material and thus releases the ballast chains, rendering the boom worthless.

- Rubberized or plasticized canvas booms have to be cleaned promptly after use. The cleaning action itself creates environmental problems in disposal of the contaminated scrub and rinse water. Booms fabricated of such material also deteriorate while in idle storage. Cases have been documented in which booms have rotted and lost their structural strength after only two years of storage.

- Head wave buildup (entrainment) can force the chemical under the skirt of the boom, unless the boom is properly angled across the stream to reduce the headwave buildup.

- Certain booms, especially units with a low freeboard, are inclined to dip at the hitching post or section-to-section attachment area. The "dip" is frequently much lower than the normal freeboard *section and leakage results.*

- Tidal action can leave the shore attachment section of the boom hanging high and dry, permitting leakage at the water/shore interface. Frequent adjustment is required to prevent this leakage source and, in some cases, it may be necessary to dig a ditch and insert the shore side sections of the booms in the ditch.

- Some booms utilize synthetic beads as a buoyancy medium. Should the boom fabric tear or otherwise fail, the buoyant beads escape and float on the surface of the water. Problems could be encountered if the buoyant beads were to be drawn into the intake of the response craft and thus incapacitate its cooling system, rendering the vessel inoperative.

6.2.1.1 Standard Configurations

Boom manufacturers that provided data for this handbook are listed in Appendix A. However, the list will be changing, since the numbers of manufacturers is continually increasing.

In addition to their commercial lines of equipment, many plants have fabricated their own "one-of-a-kind" booms. Such booms range from the interconnection of old pilings, telephone poles, and wooden construction beams either attached to or without a supporting skirt and freeboard structure. Some typical cross sections of containment booms are illustrated in Figures 6-3 and 6-4 and Appendix A contains photographs of various containment booms.

When joining dissimilar boom sections together, the following factors should be taken into consideration:

- Splicing of flexible skirt materials can usually be accomplished by clamping (two battens bolted together). Rigid-skirt barriers generally have flexible joints at which a splice can be made. It is usually possible also to make an effective clamp between rigid and flexible material.

- Use of lightweight clamps is highly desirable. Where necessary, flotation and ballast must be added at the clamps, so that they will float in the same position as the barrier and not cause any moment or weight to distort the skirt from its normal position.

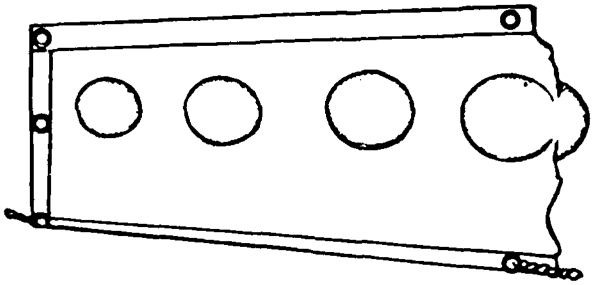
- A splice introduces a "hard" spot into a flexible skirt. Precautions to prevent damage during flexing and cyclical loading include evenly distributed clamping pressure, rounded corners and edges on solid components, and avoidance of any projections or irregularities which might act as local stress-raisers.

- The critical point in splicing dissimilar sections is that one section should not be restricted by an adjoining section from being able to float at its intended depth. Improper location of the connection between sections can result in undue stress being placed in the areas where they are joined and, perhaps, reduced performance of one or both sections. It may be necessary to use a specially designed transition piece between the two sections to avoid this problem.

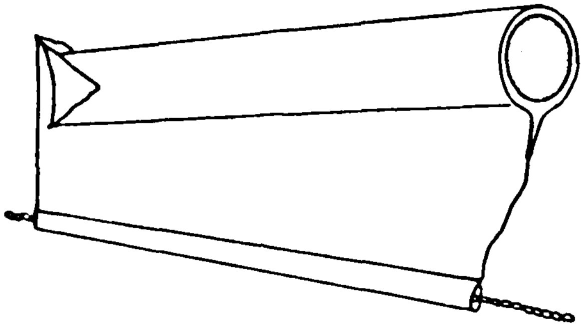
6.2.1.2 Boom Utilization

- *"U"-shaped Boom (See Figure 6-5a)*

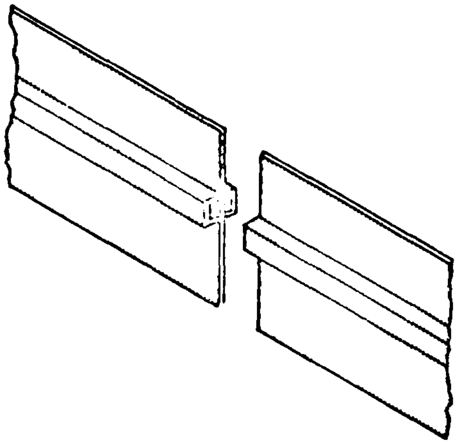
  The U-shaped boom is applicable to moving slicks driven by current or wind. It is preferable that the boom be stationary and that current and wind movement be used to entrap the slick. This configuration can also be used with "active moors," that is, with craft holding the barrier or towing the barrier as a sweep. If a long length of barrier, i.e., multiple sections of barrier, is required for large discharges, intermediate moorings spaced 100 to 150 feet



Flexible, closely spaced individual floats, flexible skirt



Semi flexible, articulated-foam floats, inflatable floats, flexible skirt



Rigid, articulated-solid floats and/or rigid skirt

FIGURE 6–3 TYPICAL BOOM TYPES

From: E. A. Milz
Shell Pipeline Corp.
Ocean Industry
Vol. 5, No. 7, 7/70

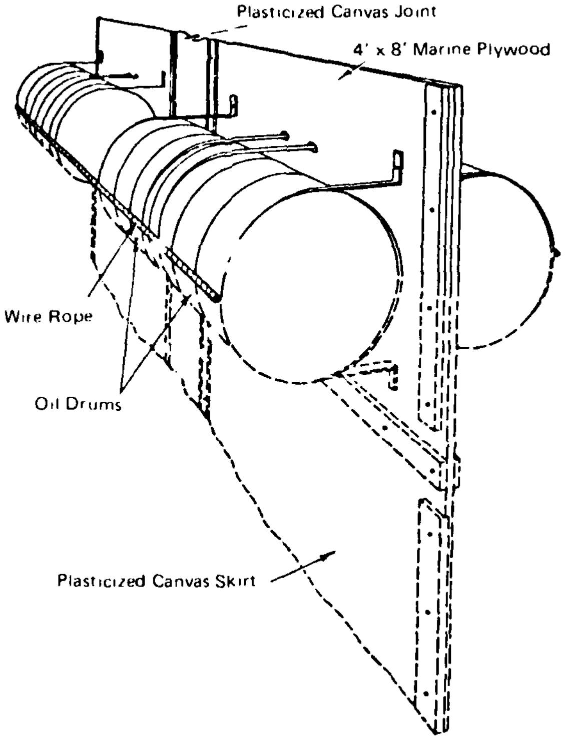


FIGURE 6–4 SCHEMATIC OF TSF OIL BOOM SEGMENT

From: Capt. W. F. Searle, Jr., USN
Ocean Industry
Vol. 5, No. 7, 7/70

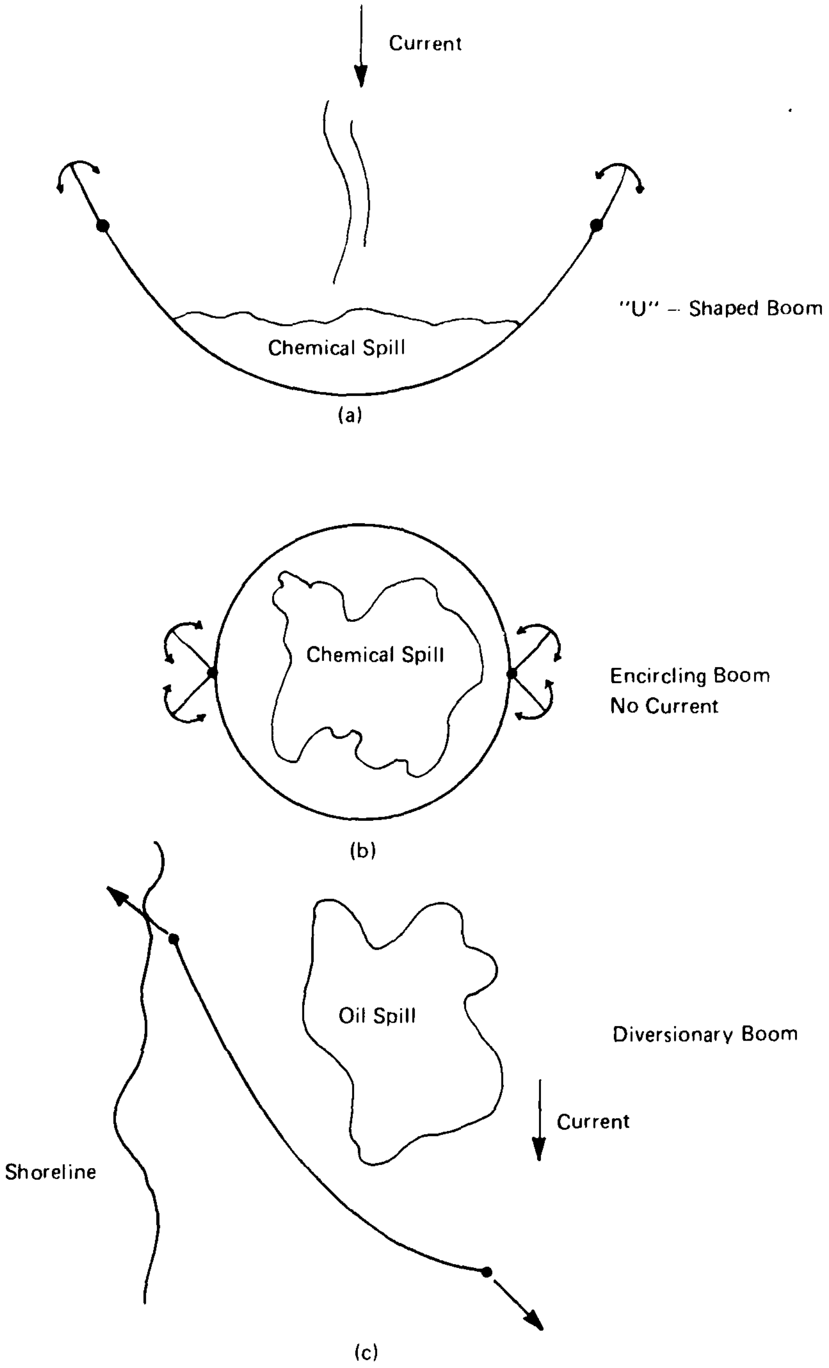


FIGURE 6-5 BOOM UTILIZATION

feet apart are required to keep tension stresses in the barrier below the strength limits of its material. This configuration is effective only for the duration of unidirectional flows.

Some barriers are "one-sided" because the main tension member is not in the plane of the barrier, or because the flotation is unsymmetrical. These barriers must always be oriented properly in regard to the spill and cannot be permitted to reverse themselves in a reversing current.

- *Encircling Boom (See Figure 6-5b)*

For spills from a continuing point source, or in a varying or cyclical current, or of limited area, or in zero current and wind, it is desirable to encircle the spill area completely. Except in rare cases of no current and large spill quantities, it will be necessary to use multiple moors to prevent the barrier perimeter from collapsing. Both normal end moorings and backmoors will be required. Backmoors must be attached in a manner to maintain the stability of the barrier. Part of the perimeter may be formed by a shoreline or a ship. An encircling barrier is applicable to a damaged and leaking vessel.

In the latter case, if the leak should be low in the underwater hull, it may take considerable time and distance for the leak to surface. The boom must therefore be positioned to compensate for the time and distance factors, so that the chemical discharge will not escape under the deployed boom. In brief, the distance of rise and the depth of the hole in the stricken vessel must be known to gage the desired position of the boom.

- *Diversionary Boom (See Figure 6-5c)*

In cases of currents above the boom-retention capability, it may be desirable to divert a slick away from a vulnerable shoreline or fixed structure, or to guide it into an area where it can be controlled and collected. Experience has shown that when spanning a river, the boom should be angled at approximately 50 degrees to the surface water flow. This action reduces the head-wave pressure and current velocity acting on the submerged section of the boom. The angling of the boom can also divert a surface slick away from a critical or damage-vulnerable shoreline to develop a concentrated source of collection and recovery. Multiple moorings will again be required to maintain the barrier in a reasonable line or curve.

In some inshore coastal situations the boom can be anchored ashore and to an offshore vessel following which the wash from one or more of the ship's propellers can be utilized to direct and entrap the surface slick in an angled barrier. In a similar manner diversion tactics, using a piston film or surface tension modifier can be employed to direct a surface slick away from critical areas, such as recreational beaches and rocky coastlines, to an isolated beach for damage reduction and simplified collection. The owner of the property should, however, be consulted and permission to use the property should be gained from the owner before diverting the chemical onto or near his private property.

6.2.1.3 Deployment

Deployment methods vary, depending upon the characteristics of the barrier and of the situation. Barriers may be launched from piers, the beach, barges or ships. The following points are important in planning the deployment.

a) All splicing and adjustment should be performed prior to launch. It is easier to work on a dry platform than from a small craft;

b) The barrier must not be permitted to twist (corkscrew) during deployment;

c) Continuity of skirt and strength members must be ensured;

d) Mooring connections compatible with the barrier structure must be available;

e) Most barriers can be towed effectively from one end at low speed;

f) Barriers may be temporarily moored at one end and permitted to stream;

g) Provision must be made for lighting the barriers and moorings during hours of darkness since they can be an obstruction to navigation;

h) In very shallow water, or at low tide in the intertidal zone where grounding of the barrier may occur, barrier stability will be impaired and the barrier will become ineffective. Unless it is artificially stabilized, leakage past the barrier will occur at such places and times; and

i) In deployment of a barrier section, it is usually best to moor one end of the barrier in a predetermined location. The other end can then be towed to a second predetermined position and the second mooring set. In full currents, the full tension will develop in the barrier as it is extended and a craft of sufficient tow force will be required to position the boom.

Seasonal current data should be known and are available from the U.S. Corps of Engineers. Simultaneously, the U.S. Weather Bureau can readily provide historic and average wind force data. In any event, current and wind forces should be overestimated rather than underestimated to ensure that the boom will perform effectively. *It should also be stressed that the OSC should consider* deploying available booms while waiting for a cleanup contractor to appear at the response site with additional equipment.

Boom deployment sites should also be selected on a preplan or response basis taking into consideration sites for maximum protection of water intakes and agricultural irrigation sites. Clear unrestricted access to the boom-deployment sites is of paramount importance, as is the attitude of the property owner toward the passage of pedestrian and vehicular traffic over his property. Whenever practical, bridge locations should be used as boom deployment sites since bridges provide a stable work platform and since the bridge support structures can be of assistance in supporting the boom against current and surface water velocity.

6.2.1.4 Floating Boom Deployment

The physical limits on the capability of booms to contain floating chemicals are severe. Nevertheless, booms and barriers are useful in guiding and diverting the passage of these materials.

The velocity of flow at right angles to a section of boom determines the barrier's capability to contain the material. If the barrier is placed at an angle to the flow, the velocity component across the line of the barrier is reduced. For example, if the barrier is 45 degrees to the flow, the velocity at right angles to the barrier is equal to the basic velocity times the sine of the angle, or 0.707 times the basic velocity. If the barrier is effective in containment at a velocity of 1.5 knots, it would prevent passage of the chemical up to a velocity of 2.12 knots when placed at 45 degrees to the flow, and it would be effective up to 3.0 knots at 60 degrees.

In laying out a barrier, it must be remembered that the barrier will not lie in a straight line under the load of the current. Since, the boom's capability will be determined by the largest angle that it acquires, it may be advantageous to use multiple moorings along the length of the boom to keep sections from attaining larger than desired angles with respect to the current.

This type of application is useful for the protection of shoreside facilities in currents along the shore. They can be used to force the slick offshore when one end is anchored at the beach and the other in the stream. Another typical application may be to divert the slick into an area where reduced currents exist and where it can be contained and picked up. This type of application also is reasonably simple since the barrier may be launched from shore and only limited use of small craft is required to carry the moorings into position. When considering a barrier for this purpose, careful consideration of the cyclical tidal currents must be made. The barrier must be set for the highest velocities expected to be encountered and may require resetting when currents reverse themselves at high or low water. It may be feasible to set out two series of moorings, one for each direction of current, so that the barrier can be shifted with minimum time delay.

Another obvious use of a barrier in this mode is to block off the entrance to a body of water. Provided the currents are sufficiently low, a barrier may be placed from shoreline to shoreline. Marinas, ship berths, docks, inlets and small bays may be susceptible to such treatment. In this and other instances, care must be taken that the barrier is properly oriented since some barriers are "one-sided," that is, unsymmetrical and unequally effective.

6.2.1.5 Mooring

Mooring forces for a barrier are the same as the tension forces and are functions of barrier length, draft, gap or opening, current velocity, and sea state.

Most barriers have limited reserve buoyancy and cannot sustain large vertical mooring loads at their ends. Long scopes of mooring line, resulting in a low angle from the horizontal, may be adequate, but it is preferable to place a float or buoy between the barrier and the mooring to absorb any vertical component, and, in most cases, a terminal anchor chain is desirable. For example, a scope of 5 on a synthetic fiber line implies that the vertical load is about 20-1/2% of the barrier tension or horizontal mooring force. For a 1000-lb force, a 204-lb vertical force is generated and a body with at least that buoyancy is required. About 100% reserve buoyancy is desirable and therefore a body with 400-lb total buoyancy is required. This might be equal to a spherical buoy of about 30 inches in diameter.

Any type of mooring suitable to the bottom and to the expected loads may be used. Ship or craft appropriate to handling the weight and configuration of the moorings are required for setting the moorings which might include patent anchors, concrete blocks, or any other readily available weight.

If the position of the barrier has to be shifted periodically, it is easier to emplace moorings at all required alternate locations and to shift the barrier between them rather than to pick up and reset the moorings when the barrier is changed.

Onshore mooring equipment can be as simple as the nearest tree, driven stakes or pipe, or mushroom or Danforth-type anchors which must be carefully positioned and dug in to gain maximum anchorage.

Two characteristics frequently present problems:

a) The sea surface level rises and falls with the tide, whereas the fixed object remains at constant level;

b) Surf or breaking waves place undue strain on the floating barrier and reduce its effectiveness.

In the absence of tides, the end of a barrier can be clamped to any section of a reasonably straight vertical or inclined surface. Tension members may require an additional fitting (such as an eyebolt) for attachment. On man-made structures, welding or bolting of fixtures, such as an angle iron, is usually feasible. As previously described on open shore areas, a wooden or metal terminal fitting usually can be devised and this fitting may then be guyed to natural objects, such as boulders, trees, or "deadmen" as used to anchor power and telephone poles.

In tidal areas there are two alternatives. If there is a straight vertical section, a guide may be affixed with the barrier attached to a slider within the guide. Sufficient flotation must be provided to absorb the weight of the slider and to provide the motive force to overcome friction when the water level changes. If there is no such convenient place, the barrier must be brought to the high-water mark where it can be terminated. In this case, the sections out of the water at low tide will require artificial support — in the nature of struts, guys, or other objects — for the periods when they are not fully immersed.

When waves or surf exist, the barrier must retain flexibility to conform to the wave profile and must be oriented normal to the wave crests. Compliance of the barrier greatly reduces the stresses imposed and, in severe conditions, is the only preventative to destruction of the barrier. At best, the effectiveness of such measures and the endurance of floating barriers under these conditions are questionable.

In the case of ships, if the vessel is afloat no tidal differential between ship and barrier will occur. However, the draft of the ship may change as cargo is lost or is off-loaded. Direct attachment of a fixture to the hull may be impractical but a suitable end fixture could perhaps be held against the hull by hogging lines and guys. In this method, some adjustment in height of the fixture could be made to keep it in proper position relative to the waterline. In some past response actions, *magnetic anchors* attached to the boom and the ship hull have been effective.

If the vessel is firmly grounded, it will not move with the tide and the situation is analogous to that of a fixed object.

Complete encirclement is possible in many ship situations, thus precluding the problems associated with connecting a barrier to the ship's side. Approximately three times the length of the ship is required for full encirclement, together with an appropriate number of moorings (a minimum of four) to keep the barrier from the ship's sides and ends. The quantity of barrier available becomes a factor in deciding between encirclement and attachment.

A typical situation is that of a storm drain contaminating navigable waters with a hazardous material. In this case it is desirable to place a barrier around the outfall. Two end attachments are required, as well as moorings, to keep the barrier extended and to brace it against long-shore currents.

No fixed rules cover all the possible situations that may be encountered where floating barriers may be useful. A great deal of on-scene ingenuity may be required to ensure that the barrier-to-shore attachment is tight, that adjustment to varying water levels is made, and that the special problems of wave action and relative motion are overcome.

6.2.1.6 Reversing and Backmooring

A "U"-shaped barrier will lose all the substance it contains when the current reverses. Attempting to re-orient the barrier at the exact moment of slack water is impractical. The accumulated substance instead should be restrained by an additional opposing barrier which could use the same moorings.

When this is done, the first barrier must be kept near its original shape and position to prevent the slick from being squeezed out from between the two barriers. For this purpose one or more moorings on the backside of the first barrier can be used. These moorings can be lighter than the main moorings as the barrier will not be configured like or loaded as heavily as in its normal operating position.

If it is desired to re-orient "one-sided" barriers in a reversing flow, the barriers have to be physically turned end-for-end between the moorings. A "two-sided" barrier may be permitted to move across to a reversed position without switching ends.

6.2.1.7 Joining and Splicing

When multiple sections of barriers are joined into a larger barrier system, continuity of strength between mooring points and retention capability throughout the system must be ensured.

When multiple sections are arranged side-by-side with adjoining ends moored to separate (or common) moorings, there is no excess load and strength problem. The respective skirts, however, must be joined at their ends or any existing gap must be closed by the addition of a short portion of barrier.

When multiple sections are used to make up a longer span of barrier, the tension members as well as the skirt must be continuous.

For sections of the same type of barrier, the tension-carrying members must be identified so that they can be joined effectively (spliced, shackled, tied, or lashed).

Since various barriers carry the loads at various heights within the barrier, care must be taken at transition points so as not to introduce upsetting moments.

6.2.1.8 Effects of Debris, Flotsam, and Jetsam

Debris, either as a direct by-product of the casualty which caused the discharge or as an inevitable presence in coastal and harbor waters, causes problems in the containment and collection of a discharged chemical.

In currents and waves, floating debris presents danger to those barriers which include skirts or components made of light materials and plastics. Rips and tears may be initiated by impact which can propagate and destroy the retention capability of the system.

Most collection systems are so constructed that the collected material passes through confined sections or orifices. Floating debris, including that stemming from marine organic growth, tends to clog these systems. Pumps and separators with high-velocity rotating parts may be severely damaged by these materials; diaphragm pumps are less susceptible to such difficulty.

Viscous, non-soluble substances will coat flotsam; complete removal of the substance will include the removal of the contaminated debris.

In those instances where retention and collection of a floating substance is feasible, the removal of debris becomes a necessary function. In general, this implies the presence of small craft within the retention area or near the location of the collection device. Large floating objects such as logs, piles and planks can be *towed* out of the immediate area. Small debris however must be handled by nets and rakes; to prevent re-dispersion it is desirable to remove the debris from the water as soon as it is brought together.

Removal of collected debris requires:

- Suitable small craft of good maneuverability with experienced operators. Where available, ramped boats with wells, such as an LCM, are most useful.
- Equipment in the form of hand tools such as rakes, nets, tow lines, grapnels, etc., as well as protective clothing and equipment for personnel are vital requirements for debris control.

The debris must be expected to be saturated with the discharged chemical and to present the same hazards as the chemical itself. All precautions for personnel and equipment must be observed.

Disposal of the debris may require different methods than those for the collected liquid. Separate off-loading facilities and transportation facilities must be considered for this dripping mass of miscellaneous material.

Craft and equipment will require thorough cleaning and decontamination after the operation.

Since debris is one major cause of containment, collection, and handling equipment failure, some discussion on the problem is warranted. Floating debris stems from both natural and man-made sources. Tree trunks and limbs may be carried to the sea by floods and high water; timbers and piling may be thrown overboard. Smaller bits of organic materials may be washed into the waterways or may pass through man's hands before being dropped into the water. Seaweed and grasses become uprooted or go adrift from storms and currents. The infestations of plastic objects now found in every port and every sea are strictly attributable to man. Garbage residues, bottles and beer cans, and styrofoam cups also are human handiwork.

The debris of concern is generally floating solids ranging from large objects weighing hundreds of pounds and more to small pieces which have one large dimension (such as straw, kelp, plastic sheeting, etc.) sufficient to cause clogging and matting. The distribution of man-made components of this general mass has increased in recent decades; unfortunately these items are less biodegradable than the naturally caused elements. The variations in shape, size, and material greatly complicate required countermeasures. Small items, for example, could be macerated, but are difficult to screen; large items conversely can be screened but not macerated.

In a response area, debris invariably becomes mixed with the discharged substance. Collection and removal acquire the problems of both. At the present time, there are no equipments available to deal with these problems alone.

In areas of high concentrations of floating debris, some containment measures in the form of nets and grates are desirable. Handling of larger items of debris involves towing or lifting, and craft fitted for these tasks are necessary, particularly craft with a ramp and/or well-deck onto which such items can be dragged. Equipment which operates in motion, i.e., in a sweeping mode or anchored in a current, may be protected by screens. Removal of the accumulated debris from the collecting screens is accomplished by manpower. None of these approaches is particularly efficient, but in the absence of better devices they are necessary.

After the debris has been collected and accumulated on a boat or barge, it must be brought ashore for disposal. The majority of debris, being of organic nature, might be incinerated. Open burning frequently is impractical because of the water content of the debris. In view of its contaminated nature, the results of burning, in the form of air pollution or damage to the incinerator, must be investigated lest the hazards be further spread or increased. In some instances, the debris may require washing before incineration while the wash-water is treated the same as the collected chemical. In other instances, the only solution may entail burial at an approved site. The nature of the discharged chemical is a principal criterion in making the selection of a disposal method.

6.2.1.9 Containment Boom Retrieval

The process of bringing the various equipments back ashore will occur at the end of the operation, or under the threat of changing environmental conditions. In the first case, the time element is not pressing; in the second case, speed is important.

Floating barriers can either be picked up by a tug, barge, or tender at the site; or they can be towed to protected waters and picked up at a later time; or, they can be towed to the site of a shore-based lifting facility or a sloping beach or ramp.

Light barriers can be man-handled onto a deck or onto shore. Heavier barriers which require power assistance (winches or cranes or hoists) are vulnerable to damage during handling. Forces applied must be commensurate with the local strength of the structure. For example, the tension member usually provides a good lifting point, but even here care must be taken that local attachments and fittings are sufficiently strong to withstand damage. The identification of a specific strong point for lifting and handling should be made as soon as the barrier type is considered for use and becomes available.

The retrieval equipment in all probability will be contaminated with the discharged chemical. During retrieval, ships, personnel, and equipment will be exposed to the substance; precautions during the retrieval operation, and clean-up after the operation will be required. Where a barrier is towed from the site through clean water for an extended distance before retrieval, the degree of contamination may be reduced considerably. The availability of hoses for wash-down during the pickup operations is recommended at all times.

Due to the bulk and relative fragility of most barriers, handling during retrieval frequently is expedited by the use of cargo nets or similar gear. Large lengths of flexible barrier can be temporarily stowed in this manner and transported to areas where further cleaning, refurbishment, and repacking can be accomplished. Experience has indicated that qualified rigger or deck crews can readily find quick and effective methods of picking up and stowing particular types of barriers; it is of great assistance if an adequate assortment of handling equipment and gear is available in support of these operations.

6.2.1.10 Boom Acquisition Factors

When actually acquiring a boom or booms careful considerations should be given to the weight per foot to ensure easy handling and deployment. The boom should not be stored in a warehouse; preferably it should be stored on or near a dock, and rollers or a chute should be provided for easy deployment. Towing factors should be carefully considered, and every effort should be made to ensure that each boom section in a given area is of compatible joining design.

6.2.2 Other Barriers

6.2.2.1 Pneumatic Barriers

Pneumatic barriers use a screen of air bubbles (released below the water's surface) to act as a barrier to the movement of floating liquids. Their use is limited to calm waters and relatively thin layers of floating material. Off-the-shelf items are generally not available, although systems can be fabricated quite quickly from readily available materials. Pneumatic barriers have limited use for emergency response. They are described here because they may be useful in special circumstances where it is desired that the barrier not impede navigation.

6.2.2.1.1 Principles of Pneumatic Barriers

When air bubbles are released below the surface, they rise and expand as the hydrostatic pressure decreases. During their rise, they also generate an upward water flow. When they reach the surface, they burst and join the atmosphere; however, the accompanying water flow is diverted into the horizontal plane at the surface. This surface current flows in both directions away from the vertical bubble stream and is effective in retaining or moving substances floating at the surface. The velocity of this horizontal current is mainly a function of the quantity of air released (per foot of barrier length). Experimental and theoretical investigations have shown that the improvement in velocity of the surface current ceases beyond certain depths of air ejection. At the same time increased depth of air ejection requires a proportional increase in air pressure supplied with a commensurate increase in power requirements for compression. From a combination of physical and economical factors, a relatively shallow depth is usually considered optimum. Similar examinations have indicated that surface velocities above 1 knot (1.6 ft/sec) make bubble barriers uneconomical or impractical. Barrier performance can be estimated in terms of a densiometric Froude number. In stagnant water they begin to lose effectiveness at a critical Froude number of about 1.2 where this number is defined as $U/[[gh(1\text{-}SG_0)]^{1/2}]$ and where h refers to the thickness of the floating spill material, U is velocity in ft/sec, g is the acceleration of gravity at 32.2 ft/sec^2, and SG_0 is the specific gravity of the spilled material. In waves, where orbital velocities produce increased local surface velocities, induced current speeds equivalent to a Froude number of about 3.0 are required.

6.2.2.1.2 Pipe Depth

Rising bubbles rapidly achieve a limiting velocity of ascent. Release from a great depth does not increase the velocity at approach to the surface nor the velocity of the entrained water. Therefore, there is little gain in submerging the barrier manifold to depths greater than about 10 or 15 feet, or to the minimum depth necessary to permit the passage of ship traffic, whereas deeper submergence exacts the penalty of greatly increased power requirements.

6.2.2.1.3 Anchoring

The manifold nozzles usually are small drilled holes. Even though the air tends to blow them out, they are vulnerable to sand, mud, and marine growth when on the bottom. In view of this clogging danger and the optimum operating depth limitations, it is desirable to have the manifold raised above the bottom. This means that the pipe system must have positive buoyancy and be anchored to the bottom. A two-legged moor will prevent horizontal sway of the barrier; the larger the buoyancy of the pipe (when in operation and filled with air), the greater will be its resistance to movement in currents, but heavier moorings will be required.

Alternatively, the manifold may be suspended from floats at the surface. In this case, a number (a minimum of two) moorings are also required to maintain the barrier in place.

The spacing of the moorings – and therefore the number of moorings depends on the physical strength of the manifold pipe, the distribution of buoyancy, and the depth of water. Because of the requirement for emplacing the manifold at a particular depth between the bottom and the surface, the system must be adapted to the particular location before it is deployed.

6.2.2.1.4 Configuration

As generators of a uniform current over their length, pneumatic or bubble barriers have most frequently been used in a straight-line configuration as a closure across a harbor entrance, a dock, or a channel. They are not particularly suitable for use in motion, as when they are towed as a sweep, although this mode has been tested. Furthermore, as an active device requiring power and attendance, they are most appropriate for operation and use from shore.

6.2.2.1.5 Additional Benefits

A bubble screen tends to suppress small waves and some installations have been used for this purpose. The decreased mean density of the water in the way of the bubble sheet, as well as the vertical velocities induced on either side, appear to disrupt wave propagation. These installations have met with varying success.

Installations similar to bubble screens have been deployed around ships and fixed shore structures to prevent the formation of surface ice. The induced vertical velocities bring warmer water from the depths to the surface. The temperature increase as well as the motion suppresses the formation of surface ice. In limited form, these screens promote a mixing action in the vertical direction and may find use in this respect for certain types of response action under adverse or very cold weather conditions.

6.2.2.1.6 Pressure and Volume

Hydrostatic pressure, which must be overcome in the delivery of air to the submerged manifold, is approximately 0.5 lb/in.^{2} per foot of water depth. For example, if the manifold is 20 feet below the surface, the air will emerge at a pressure of approximately 10 psig or 25 psia.

6.2.2.1.7 Quantity of Air

The induced surface velocity which controls the effectiveness of the barrier has been found to be related to the quantity of released air by the approximation:

$$U_{max} = 1.5\,(gQ)^{1/3} = 4.8\,(Q)^{1/3}$$

where Q is $ft^3/sec/ft$ of barrier length and g is the acceleration of gravity at 32.2 ft/sec^2.

6.2.2.1.8 *Power Requirements*

For an ideal adiabatic compression (no heat exchanged to or from the air) the horsepower required is:

$$HP = 0.225\ Q[(p_2/p_1)^{0.286} - 1]$$

where Q is ft^3/min and p is absolute lb/in^2.

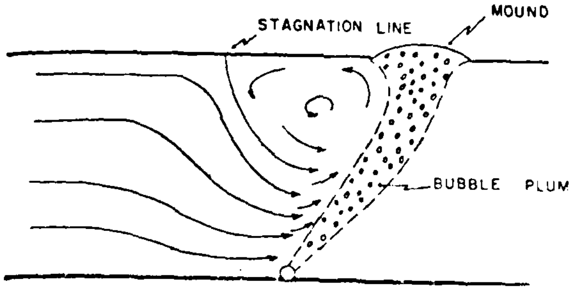
For an isothermal compression, the horsepower is:

$$HP = 0.00436\ p_1\ Q\ \ln(p_2/p_1)$$

For very low pressure ratios ($r = p_2/p_1$), the horsepower is approximated by $0.00436\ (p_2 - p_1)\ Q$.

6.2.2.1.9 Efficiency

Tests conducted by the Shell Pipeline Corporation (E.A. Milz, Ocean Industry, July 1970) revealed that current forces cause distortion of the air bubble plume as illustrated in Figure 6-6. This distortion creates a flow pattern which gradually allows an oil or chemical slick to disperse through the bubble curtain. When viewed from above the water surface, the slick appears to be retained, but droplets are torn from the bottom of the slick by the turbulent current produced by the air barrier and they are subsequently dispersed through the air curtain.



From: E. A. Milz
Shell Pipeline Corp.
Ocean Industry
Vol. 5, No. 7, 7/70

FIGURE 6–6 CIRCULATION PATTERN UPSTREAM OF AN AIR BARRIER IN A CURRENT

The OSC should realize that air barriers cannot be considered as readily available off-the-shelf items. They are generally custom-made for a given area and at some industrial locations are permanent installations that cannot be utilized in a portable fashion. It is possible, however, to fabricate a response barrier quickly by using PVC pipe and a readily available internal-combustion-engine driven compressor common in construction work. Such units are applicable to emergency barrier use. They are self-contained units which can be selected on the basis of cfm and pressure output requirements. When air volume and pressure requirements in the manifold have been determined, the pipe and fitting losses must be estimated. Manifold pressure plus pressure losses equals the required output pressure of the compressor.

Pneumatic barriers are effective principally against floating substances; horizontally induced velocities drop rapidly below the surface. The barriers are active systems requiring both power and attendance. Their capabilities are limited in comparison to floating barriers. They possess a large advantage by not providing any impediment to navigation. As such, they have been applied mainly to calm water situations, where one or both ends are shore-based, for continuous preventive operations and non-interference with marine traffic. In the case of discharges of floating substances, they may form a useful method for providing barriers across harbor, dock, or channel entrances.

6.2.2.2 Porous and Absorbent Barriers

The porous and absorbent barriers depend upon a material with high surface area to which the spilled substance adheres preferentially, permitting water to pass by. They have been constructed mainly of oleophilic materials for oil spills, held together by netting or a structure which takes the tension forces, and provided with any necessary flotation.

There is no experience with these barriers other than for oil spills. Since the effectiveness depends upon the wetting effect of the spilled substance upon the barrier material and its adherence thereto, the effects between the substance and the barrier material are of principal significance. In view of the multiplicity of chemicals which may be discharged, and the probable applicability of only a few substances to any one absorbent material, the practicality and utility of this type of barrier are limited. Considerably more investigation and development are required to establish and widen further use of these barriers.

The capacity of this type of barrier is fundamentally limited by the absorption and retention which takes place within the barrier. The capacity of an absorbent is normally stated as the ratio between the weight of absorbed substance and the weight of the absorbent. For example, for a substance of specific gravity 0.9, that is, for a weight of 7.7 lb/gal, at an assumed retention ratio of 2, some 3.8 pounds of absorbent material would be required per gallon of spill. The implications are that excessively large quantities of absorbent material would be required for large discharges.

Retrieval for these types of barrier is difficult. While the barrier is waterborne, its weight is uniformly distributed and buoyed. When the barrier is lifted, local forces tend to squeeze the absorbed chemical out of the barrier. Even when beaching such barriers on a gentle incline, much of the absorbed chemical is lost due to gravitational effects.

Absorbent barriers are applicable to non-miscible floating chemicals. They are most useful as an ultimate line of defense to catch any minor leakage passing a principal barrier, or to clean up small discharges. They may be towed as a sweep at low speeds, but they are useful only if the absorbent is compatible with the spill substance. Retrieval must be performed in an area where the runoff can be contained or controlled and which, in turn, can be cleaned. Disposal normally involves cleaning the entire barrier section. Extensive man-handling is normally required during retrieval and disposal; precautions against the effects of the absorbed chemical upon both by personnel and the equipment involved must be observed.

6.2.2.3 Nets

Nets are not specifically associated with chemical discharges, but they may be useful in the case of floating solids occurring in pieces of limited individual size. Nets may be either strung between fixed points, as across a harbor entrance, be towed in a "U" shape (trawl) as a sweep, or be used to encircle an area (seine). Flotation units will be required at the surface in all instances. Mesh size must conform to the particle size of the discharged chemical. Too large a mesh will permit escape of the substance; too small a mesh will pick up additional unwanted materials and will increase the loads which must be handled.

The fishing industry is the principal source of nets of natural or synthetic fibers. Compatibility of the netting with the discharged chemical must be ensured. Metallic nets have been used for special purposes. Their weight and stiffness make handling difficult and their use for chemical discharges questionable. However, metal cables are frequently used with fiber nets as reinforcements and tension members. Nets are of particular use in the retention and collection of debris in an area which has been contaminated by a liquid chemical spill. They may be towed as a sweep or they may be moored within a larger retention area to protect a collection device. In the latter instance, metallic mesh nets suspended from appropriate floats are effective.

In all cases where nets are used to collect solids (either a contaminant or debris), the loads on the nets and their moorings will rise as quantities of the solid pack at the net, and the effectiveness of the net will decrease. Periodic removal of the solids will be required. This can be accomplished by closing the net (encircling the material) and towing it away for disposal, or by raking the accumulations onto a small craft or barge.

6.2.2.4 Chemical Barriers

In the field of oil spills, chemical barriers have been developed which operate by transforming the qualities of the oil at the edges of a slick by one or more of three aspects, or by adding a surrounding film:

a) Increasing the cohesiveness of the oil so that it can undergo small tension loads,

b) Solidifying or gelling the oil into a semi-solid; or

c) Increasing its surface tension so that the expanding forces within the slick are counteracted.

These barriers are formed by distributing (spraying) an agent around the periphery of a slick. The barrier thus formed contains the slick and keeps it from spreading. They are commonly called "piston films."

The slick remains free-floating. Additional means are required to prevent movement of the slick. The nature of the chemical barrier prevents any attachment or handling method. The barriers are weak and can be fragmented by wave action. They are useful in calm waters for such purposes as containing spills, while additional equipment is brought to the scene, in keeping the slick from spreading under fixed structures, or in keeping the slick from spreading away from a collecting device. No known equivalent agents have been developed for a substance other than oil.

6.2.3 Spill Herding Systems

6.2.3.1 Surface Tension Modifiers

Slicks of oil and oil-like insoluble, lighter-than-water liquids can be contained by chemical as well as physical barriers. The surface tension modifiers are high molecular weight organic liquids which alter surface tension and which have a spreading force on water greater than that for oil. Thus they compete with oil for the available water surface area and confine and prevent an oil slick from dispersing. In their performance they are the exact opposite of oil dispersants.

Oil herders can be applied to the polluted waters as a spray. The herder should be applied at the periphery of the spill and in such a way as to move the spill in the desired direction. Below 36°F it is necessary to prewarm the chemical to keep it liquid. The recommended application is about 2 gal/linear mile. Application should be made as soon after the spill as possible, not only to prevent further spreading, but because herders become less effective as the spill ages. Herders are ineffective for congealed oil spills, oil-in-water emulsions, or in detergent-contaminated waters. The chemical has an indefinitely long shelf-life. It is insoluble, biodegradable (and hence makes a BOD), and tests have indicated that it is not injurious to biota if used in the recommended dosage.

The oil herders collect and hold oil slicks for several hours and this type of chemical barrier can be used under sea-state conditions where the deployment of mechanical containment devices is marginal.

6.2.3.2 Water Hose Streams

The use of water hoses has proven to be an efficient means of herding and containing a surface slick to a selected area. Careful use of hoses is warranted to avoid breaking up and spreading the slick. Hoses have been used very effectively to combat surface materials by reversing the natural current to avoid surface spread and in removing slicks from inaccessible locations such as under piers. Most industrial plants have numerous hose sections located at in-plant standpipe locations. Some facilities maintain and operate their own pumpers. Available harbor fire boats can be of great value, and naturally the local fire department can furnish extensive quantities of hose line and individuals who are well trained in the use of high- and low-pressure hose line.

The momentum of water emerging from a hose, such as a fire hose, can be transformed into a surface movement where the stream strikes the sea surface. It establishes a fan-shaped pattern of turbulent, aerated water with radial velocity components which diminish inversely with their distance from the impact point. One or more hose streams may be used to generate surface currents which prevent the spread of floating chemicals in the direction from which the hoses are aimed. The greater the pumping power available, the stronger the current which may be formed or the wider the surface flow which may be maintained.

This type of response approach is most useful for the protection of limited facilities and areas. For example, a useful application is the prevention of oil entering under a pile-supported pier. Land-based pumping equipment, or fire engines, can be used from the pier itself. Another application lies in the protection of cooling water intakes at the water surface. When used to counter an existing current, a particular point called the rip can be identified where the surface stream dissipates to a degree where it no longer overcomes the basic current. For example, a 3-inch hose tip aimed horizontally and operating at 100 psi will have a distance of about 45 feet between impact point and rip in a 1-knot current; in a 0.1-knot current this distance will be on the order of 200 feet. The fan angle usually lies between 80 and 90 degrees.

Maximum utilization of the hose stream momentum occurs when air losses and vertical component losses are minimized. This means that the hose tip should be fairly low and close to the surface; that it should be aimed near the horizontal; and that the impact should be at a low angle. High angles of impact cause excessive turbulence and losses due to the vertical component of velocity. Experience has demonstrated that the tip should be set to avoid fine spray or mist which causes high energy loss in the air portion of the trajectory. Pressures below those which result in coning of the stream at the tip should be used.

Ships' fire fighting systems may be used for the same purpose. Fixed monitors on fireboats, tugs, and liquid carriers usually are located as high as possible and therefore have limited effectiveness, but flexible fire hose installations which can be hand-held near the surface, or at deck level, can serve this purpose. Portable fire pumps (handy-billies) can be placed on small boats and used for this type of protection. The general availability of fire fighting equipment both on board ship and ashore makes this approach practical for protection of limited areas or lines of defense.

6.2.3.3 Ships' Propeller Diversion

In a similar manner, the propeller stream of a ship may be used to generate currents for constraining or moving a slick of a discharged chemical. However, a ship propeller operates below the surface and results in a turbulent, cylindrical flow with helical velocities. Thus it has a tendency to mix surface layers of water into the water column and thereby to distribute the chemical also. Small boat propellers generate smaller wakes, but are closer to the surface and have less deep-mixing effect.

When a ship uses its main power plant for this purpose, it cannot avoid generating thrust; the ship must be firmly moored. Moreover, mooring gear is conventionally fitted at the bow of the ship and the resultant system of thrust at the stern and restraint at the bow tends to be unstable. Stern anchors therefore are more practical for this type of operation, but unfortunately are rarely fitted or, when fitted, are only of light capacity.

This approach therefore entails two problems which must be considered before it is applied. First, the propeller wake tends to be very turbulent and may do damage by mixing the chemical into the water column. Second, the practical aspects of holding the ship in position and heading are difficult and permit use of the system only under special conditions, and in depths of water where anchoring is feasible. For chemicals which naturally spread throughout the water column, such as those that mix with water or are about the density of water, the method does provide a way of generating deeper currents than the fire hose surface current method. The velocity of current measured in line with the ship is essentially a function of propeller RPM. Due to the anchoring or mooring requirements, the RPM and horsepower generated by the vessel must be limited. A typical application might also take place when a ship is secured alongside a pier headed toward shore with its wake used to keep a slick from entering the slip. In this case the ship is secured to the pier and thus is at a fixed heading; the strength of the pier and the strength of the mooring lines control the amount of power that may be applied for generating a current.

The wake spreads in a slightly conical shape and the turbulence gradually dissipates the rearward velocity components. As with the fire hoses, a point is eventually reached where the net rearward velocity becomes negligible and beyond which the wake is ineffective for this purpose.

6.2.3.4 Wind, Tide, and Currents

The natural meteorological and hydrological effects may be used to advantage for floating chemicals. Winds generate surface currents which have a velocity of about 3% of the wind velocity. The direction is close to the wind direction, and in the Northern Hemisphere may be up to 20 degrees to the right of the wind direction due to the Ekman Spiral effect. Tidal currents, as given in hydrographic publications, normally are measured at the water surface. However, in many enclosed channels the velocity profile varies greatly with depth, and may even contain a reversal with depth. Local information on these phenomena is frequently available and must be considered in the cases of chemicals distributed through the water column. Tidal currents are cyclical, but in many locations inshore, the cycles are not symmetrical. Ebb and flood velocities and durations may vary. For major harbors, tidal current charts, usually for 2-hour intervals and related to time of high or low water, are available. These charts indicate local currents and eddies which might affect the path of a slick or volume of polluted water.

In riverine situations, the tidal cycles are superimposed upon a unidirectional downstream flow. As the location gets closer to the sea, the cyclical tides become more predominant and the river current effects decrease. Basic river current velocities are sometimes noted in hydrographic publications, but they tend to vary greatly with seasons and current run-off conditions. The Corps of Engineers maintain records of these flows and are a source of velocity predictions.

The utilization of these natural phenomena depends upon reasonably accurate predictions. Winds and wind patterns come from the Weather Service. Tidal cycles are stated in hydrographic publications. River flows are measured by the Corps of Engineers. All must be related in estimating the future path of chemical discharges or releases.

6.2.3.5 Water and Spill Flow Restrictions

The movement of water into which the chemical is released makes containment difficult. In many instances, the accompanying turbulence assists the spreading and dispersal of the chemical. Therefore, any reduction in water movement will assist in containment and pickup (except when the chemical already is in contact with sensitive areas and flushing is desired).

In general, such a reduction of water flows is not feasible, but in the river systems it might be possible. Dams and locks -- and even in some cases dry docks -- permit control over the flow. When downstream from some such control point, there exists an appreciable time lag between the point when action is taken and the point when its effects are felt. Therefore, early investigation of such possibilities is necessary. On the river systems, the Corps of Engineers is responsible for such action and the potential actions should be discussed with them. Likewise, the Corps will be most knowledgeable concerning the effects, time delays, and secondary effects of any actions taken.

In some instances it may be possible to contain chemical discharge between two control points such as dams. The relative merits of permitting the material to flow downstream and dilute, as opposed to containment at higher concentration, must be evaluated in the light of the environment. In the case of floating chemicals, dispersal and spreading as opposed to containment and greater thicknesses of slick must be considered.

Whereas this type of action will only be feasible in few instances, it may provide valuable assistance when it can be accomplished. Feasibility can be established at an early time in the response sequence and should be examined wherever possible.

6.3 Collection and
Recovery

6.3 COLLECTION AND RECOVERY

Potential Methods

Collection (page 6-37)

- Skimming (page 6-38)
- Pumping (page 6-43)
- Dredging (page 6-43)

Recovery (page 6-43)

- Separators (p. 6-43)
  - Centrifugal
  - Vortex
  - Linear
  - Settling
  - Filtering
- Storage (p.6-47)
  - Bulk
  - Drums
  - Barges
  - Tank Trucks
  - Tank Cars
  - Bladders
  - Diked Areas

6.3.1 Collection

6.3.1 Collection Systems

The ultimate response is the complete removal of the hazardous chemical discharge from the water. Collection devices are most effective when working in high concentrations of the discharged material. Barriers are used both for holding and for concentrating the discharged chemical, so that the collection process becomes easier. However, the storage capacity of barriers usually is small in terms of the size of potential discharges. The barrier may not have sufficient capacity to store the entire spill until collection commences. Therefore, collection frequently must be carried on at the same time as the holding and storing process. The barrier becomes a surge tank with additional chemical flowing in and some chemical being removed; the amount of substance "in storage" in the barrier depends upon the two comparative rates. In this case, the collection system is closely linked into and defined by the entire spill control system.

The characteristics of the discharged chemical have major effects upon the nature of the collection system, as shown below:

a. Solids lighter than water:	These are susceptible to a mechanical scooping process by rakes, nets, and gratings. If the solid is in small particles, it can be pumped, using water as the medium, as a slurry into a tank.
b. Solids heavier than water:	Since these will accumulate on the botton, a form of dredging is indicated. The substance, together with some proportion of bottom material, is deposited into a barge or is pumped ashore as a slurry.
c. Liquids, non-miscible, heaver than water:	These will settle on the bottom and will probably adhere to particles of bottom material. Some form of dredging is required to bring this combined material to the surface and transport it away by barging or by pumping it out as a slurry.
d. Liquids, non-miscible, lighter than water:	It is desirable to collect only the surface layers containing the chemical; various methods of selective pumping and selective adherence and the use of certain absorbents are feasible.
e. Liquids, miscible:	Where the chemical spreads through the water column, collection requires the handling of the entire mixture; pumping is indicated and large pumping rates are required.

Since oil falls into the non-miscible, lighter-than-water liquid category, this group shows the most experience and variety of equipment. With non-miscible chemicals, the efficiency of collection is related to the proportion of chemical picked up in respect to the total volume picked up. Some collection devices therefore contain separation features which discard the water before it is actually picked up. In other devices, separation occurs only after collection; in all cases, some secondary separation treatment is required before the discharged chemical is disposed.

In all collection systems, it is a primary goal to limit the material collected as far as possible to the discharged chemical. The costs of handling, storage, and treatment increase rapidly when a large proportion of water is included in the flow. Collection systems are operated in unconfined discharge areas; within discharges which are restrained and concentrated; and in contaminated areas for cleanup purposes. These different uses encompass an extremely wide range of concentrations of the discharged chemical. Both the efficiency (proportion of discharged chemical to total recovered) of collection as well as the rate of collection must be considered in selecting a particular equipment for a particular task.

6.3.1.1 Skimming

There are a variety of devices that skim floating liquids from the surface of the water. They are described in the following subsections.

6.3.1.1.1 Suction Skimmers

Suction skimmers operate at the surface by drawing surface layers into a manifold or chamber through some type of orifice. Suction is generated by a remote pump. The height of the orifice and its vertical position in relation to the surface control the depth to which water - or a mix of water and discharged chemical is drawn into the skimmer.

Except in completely stagnant water, the surface contains waves and varies in elevation with time at any given point on the surface. To maintain the orifices in the design position, it is necessary that the skimmer move vertically with the surface of the water. When wave lengths are small in relation to the dimensions of the skimmer, this is not possible. When wave lengths are longer than skimmer dimensions, it is possible to achieve a good response. Low weight (low inertial forces) and a high-water plane area (large restoring forces) are required to achieve such a response. High-water plane inertia is required to maintain the stability of the skimmer (rotational motion), so that it will respond to the inclination of the water surface and keep all orifices at the same level relative to the surface.

The connection from the skimmer to the pumping and discharge system must not apply any forces to the skimmer which would degrade its response to waves. Therefore, this system usually consists of flexible floating hose which applies neither weight nor torque to the skimmer.

The size of the skimmer must be traded off against efficiency in short waves. Efficiency also is proportional to the depth of the discharged chemical; in deep layers, efficiency may reach 100% in calm water. Skimmers can be designed to any size. Pumping facilities must be situated on some floating craft not too far from the skimmer; their horsepower is directly proportional to the quantity of water and chemical taken in and the head against which they work is small (losses in the skimmer and piping, as well as height of discharge above water level). When dealing with non-miscible chemicals, the problem of emulsification must be addressed by selection of valves and pipe fittings which generate a minimum of turbulence and the selection of appropriate pumps such as diaphragm pumps.

Suction skimmers can be designed with a variety of manifold configurations. They can be used as a linear array along a natural or artificial barrier. They can be incorporated into the design of a barrier. They can be configured to encircle an area, or they can be designed to operate as a point sink. They are subject to clogging by marine vegetation and small debris, and therefore methods of protecting the orifices must be provided in the design, or by adopting efficient operational and maintenance procedures. For small systems, hand-held heads are available which are operated from shore or from a floating craft.

The pumps associated with suction skimmers must be able to handle a mixture of water and the chemical. Additionally, in view of the debris involved, they must be able to handle particles of solids. Piping should be of sufficiently large diameter to keep velocities (and losses) down, together with turbulence and emulsification, and to preclude the possibilities of clogging by debris, while at the same time the velocities must be maintained sufficiently high to prevent the settling out of solid contaminant particles. The pumps should be of a type which do not initiate emulsification. Diaphragm pumps are of this type.

6.3.1.1.2 Vacuum Systems

A related type of suction system utilizes a vacuum tank in lieu of a pump to induce flow into a collecting head. For small spills and cleanup operations, these systems are effective for recovering floating materials. Use of a vacuum tank reduces the mixing and emulsification problems and provides a storage facility for the collected material. When operated in a batch mode, there is no requirement for a power source and pump near the collection device; however, the tank must be removed periodically for emptying and for redrawing of a vacuum. These systems usually are fitted with a hand-held collecting head and act like a vacuum cleaner. Their capacities are governed by the size of the vacuum tank and, as such, are usually limited.

Tank trucks fitted with tanks of appropriate strength are frequently used in these systems for cleanup purposes. It is possible to use an air pump to continuously draw down the tank pressure and a liquid pump to remove collected material, thereby converting the system into a continuous process. Most vacuum systems are custom-built arrangements suited to the particular needs of the user.

6.3.1.1.3 Weirs

A large variety of weir-type devices are available. The most common weirs are circular and attached to some flotation system at a specific distance below the water surface at rest. Suction is taken at the center of the circular weir. The floating chemical passes over the weir and is drawn into the suction piping. The height of the weir usually is adjustable so that it can be set for the thickness of slick and nature of the chemical. Some systems have a pump incorporated into the floating head; others require a separate pump at a remote location.

As in the suction skimmers, the position of the device in relation to the instantaneous water surface level is critical to the efficiency of the device and analogous motion response problems appear. The performance of the weirs drops rapidly with increasing sea states, but they are less susceptible to clogging than suction skimmers.

6.3.1.1.4 Inverted Planes

The problems of motion mismatch between a collecting device and the sea surface are reduced in a proprietary development in which a floating chemical layer is depressed beneath the water surface along an inclined plane which is actually the bow and underwater hull of the skimmer unit (see Appendix A, JBF skimmer). Hydrostatic forces make the buoyant layer rise into a holding tank at the end of the plane, whereas the water continues its flow in a horizontal direction past the opening to the holding tank. This development is somewhat analogous to an inverted weir effect.

The device is incorporated into a self-propelled boat hull. The rate of collection and the storage capacity are bounded by the hull dimensions. The effectiveness of the system in waves is strongly affected by the motion response of the entire system. The system may be used as a sweep in either a confined or unconfined discharge. It can handle both lighter-than-water liquids and particulated solids; thus it can also be used in the collection of floating absorbent materials.

6.3.1.1.5 Floating Discs and Drums

Several disc and drum devices have been used in oil incidents. They depend upon a partially immersed rotor to which the contaminant clings, and from which it is wiped or squeezed in the upper portions of the cycle. Rotating drums covered with special foams as well as multiple discs have been developed.

All of these devices have some value. In calm water and high concentrations of contaminant they are effective. In most instances, however, their efficiency drops drastically with increase in sea state.

These devices have been developed on the basis of preferential wetting of various surfaces by the viscous, non-miscible oils. No information is available at this time on the potential of these devices for the recovery of other chemicals. Under the present state-of-the-art, they appear to have little utility for non-oil discharges.

6.3.1.1.6 Absorbent Belts

As an extension of the rotating drum concept, belts of oleophilic material have been applied to oil discharges. In one version, the continuous belt runs between two end rollers and the entire structure is partially submerged. In another version, a long length of neutrally buoyant belt runs free between the collection device (on shore or on a craft) and a distant block held by a separate mooring.

In all cases, the belt runs between rollers which squeeze out the adhering oil and divert it to a transfer pipe or holding tank. The limitations of these systems lie in relatively low collection rates and the short life of the belts. Particularly when solid particles or debris become mixed with the oil, the wear at the point of removal of the oil becomes great.

Since these systems have been designed and tested for use with oil, their applicability to other chemicals is generally not known. For other classes of chemicals other belt materials undoubtedly would be required. For substances less viscous than oil, it may be presumed that lower collection rates would result. These devices may be useful for secondary or cleanup purposes, but are not applicable for major discharge-collection purposes.

6.3.1.1.7 Grates and Nets

Nets which can be used as barriers can also be used as a collection device for floating solids or for solids with a specific gravity of about 1.0 which are dispersed in the water column. The collection function implies that there exists a relative velocity between the net or grate and the water, and that there exists a continuous or intermittent capability of removing the accumulated material from the net.

Power plant cooling water intakes frequently are fitted with a moving belt-like grate against debris, with the solids washed off near the top of the cycle. In the case of nets, hauling techniques similar to those used in the fishing industries are required.

Neither of these types of gear has specifically been built for use in discharges, and they cannot be considered a readily available method or resource. In these cases where they are directly useful by the nature of the discharged chemical, investigation of local fishery capabilities may provide an employable system.

As mesh size decreases to very small dimensions, the "nets" approach the porous barrier or sweep concept which has been applied for oil discharges and other semi-solids. Removal of the accumulated material and the prevention of clogging of the net remains a problem.

Many liquid collection devices have been fitted with grates for protection against debris, the continuous removal of accumulated debris has been a problem in most instances. Rotating belts of netting or grates are invariably heavy and cumbersome and have therefore shown limited adoption; in addition, when used in conjunction with an oil-collection device, they tend to promote emulsification and reduce the efficiency of the basis device.

6.3.1.2 Pumping

The simplest and most direct collection system is a pump whose inlet pipe is immersed in the liquid to be removed. For non-floating chemicals, where there exists no premium for the inflow being taken from a thin surface layer only, a simple pump system with a simple open inlet is suitable.

In the case of miscible liquids in closely confined waters where only limited mixing can occur, a pump suffices for removal of the liquid bulk. The intake head must be flexible to permit its placement within the volume of contaminated mixture at any depth suitable to the behavior of the discharged chemical. If used near the bottom, the probability of ingesting sand, mud, or gravel develops.

These systems collect at high rates and require high capacity elements for further handling the chemical mixture. Thus, they must be associated with high-capacity, on-line separation or treatment facilities, or with large storage facilities such as ponds, diked areas, or major tankage. These facilities generally are not available in portable form or in a form immediately available for emergency response action. High-capacity processing facilities of this type are frequently found at major chemical and manufacturing plants. Chemical discharges *may* be associated with such plants and there is some possibility that plant facilities can be used in alleviating the discharge effects. However, this collection method cannot be considered a broadly useful method suitable at all locations.

This method, nevertheless, is most important for discharges that are miscible and for heavier-than-water substances. The difficulties of assembling suitable components (size, weight, availability, portability) indicate the difficulties of responding to discharges of these categories of material.

6.3.1.3 Dredging

Dredging may be required to remove insoluble chemicals that are more dense than water from the bottom of the water body. Dredging methods are well developed and equipment may generally be available in those areas where the water depth would warrant their use. Dredging equipment and services should be listed in the Regional Contingency Plan Data Base. Since chemicals that settle to the bottom may disperse due to bottom currents and/or diffuse into the bottom sediments with time, it can be important to recover the material as soon after the discharge as may be reasonable.

6.3.2 Recovery Systems

6.3.2 Recovery Systems

6.3.2.1 Separators

Disposal or recycling of discharged substances requires that a degree of purity of the substance be achieved, and similarly any water returned to a waterway must meet rigid quality standards. Collection devices produce a mixture of the discharged chemical and water. Therefore there exists a requirement for separating the collected mixture into its constituents so that each may be disposed of. This is possible by mechanical means only for immiscible liquid and insoluble, finely particulated solids. Some *other substances can be separated by a combination* of chemical and mechanical means.

The technology of performing this type of separation has been developed to a high degree in the process industries in fixed plant installations, but these are not directly applicable to the discharge problem. Oil water separators are common on ships, but this equipment likewise is not directly applicable since either its capacity or power *requirements are unsuitable. Separation in* connection with a chemical discharge requires that the equipment handle large volumes of mixture between extreme ranges of concentration and that it be transportable (together with prime mover) to the site or vicinity of the chemical discharge.

6.3.2.1.1 Centrifugal

A *centrifugal separator generates* a radial force field by rapid rotation of the mixture. The denser components are displaced to the periphery of the container. The forces can be generated many times greater than those of a gravity field and separation occurs rapidly. Both batch-type separators (centrifuges) and continuous-flow separators (De Laval) are based on this principle. However, no large capacity separators of this type have been produced to date for general response use. High degrees of separation can be achieved in these separators.

6.3.2.1.2 Vortex

The same principle can be applied to the vortex separators but the rotational velocity is induced by a vertical flow of the mixture rather than by mechanical means (Figure 6-7). The flow is established in imparting a high inlet velocity to the mixture at entry into a specially shaped and baffled chamber. The rotational velocities are not as high as those of a centrifugal separator, and therefore the separation efficiency is not as high. However, large quantities can be handled with less power.

FIGURE 6-7 VORTEX CREATED BY IMPELLER ACTION
Care must be taken to prevent the oil from reaching the impeller, this would cause the oil and the water to become emulsified.

Development of large capacity separators of this type, stemming from a specific requirement in the oil discharge and shipping fields, is now underway and equipment of this type will become available. For use in a general response, it is desirable that the unit together with its pump and prime mover, be transportable, if not portable, and that its weight and volume be kept to a minimum. For use in a general response it is furthermore desirable to have the separator versatile, so that it can handle chemicals of specific gravity both smaller and larger than 1.0. The wide range of concentrations which the vortex must handle presents many engineering development problems which will require time for satisfactory solution.

The vortex principle also has been applied in conjunction with other devices. For example, it can be used with a circular weir to provide an immediate concentration function at the collection device.

6.3.2.1.3 Linear

For completeness, a further class of industrial equipment must be mentioned. The flow of mixture is directed along a folded linear baffled path which utilizes differences in specific gravity and viscosity to separate two immiscible liquids. These installations are large and immobile; they suffer from the same drawbacks in regard to discharge response as many of the other types of separation equipment.

6.3.2.1.4 Settling

Many plant locations have extensive water-treatment pits, lagoons, or ponds with vast liquid and suspended-solid capacities. A number of plants also maintain a "panic pond" which is actually a reserve water-treatment pond that can be pressed into service in the event of an emergency, such as an accidental discharge that might overtax the capacity of the normally used water treatment facilities. An intimate knowledge of such facilities can be of great value to an OSC, since water containing suspended chemicals can be pumped to such ponds where precipitation will in time result in a natural separation of the chemical and the water. The pumping problems can best be overcome by the utilization of conventional suction dredging equipment and floating pontoon discharge lines which can be positioned to direct the liquid into a nearby waste water-treatment pond. When the location and depth of water permit, and when the emergency of the response warrants such action, the U.S. Army Corps of Engineers' suction hopper dredges may assist in the response. These large ship-shaped dredges could pump the polluted water into their large capacity holding hoppers, and later the contaminated water could be transferred to a waste-treatment pond, or the chemical could be dribble discharged while under way to an offshore location.

Barges provide a capability afloat for use as settling tanks. Liquid cargo barges or hopper barges, which normally have a capacity of 500 to 2000 tons, can be used for this purpose. Additionally, they can be towed to anchorages where the settling process can take place over extended periods. Although tank ships are likewise suitable for such a purpose, the use of barges is more economical and provides greater flexibility.

The "doughnuts" of various sizes used by the navy at its industrial activities are special floats used as settling tanks for oil. They have an enclosed and air-tight top to maintain buoyancy and an open bottom which permits outflow of the separated water. This inverted bowl configuration has been effective for immiscible lighter-than-water substances.

In general, any tank can be utilized for settling purposes, provided it meets the capacity requirements and can be protected from motions which would re-agitate the mixture. Railroad tank cars, tank trucks, ship's tanks, and stationary tanks can all be used when convenient. This choice provides considerable latitude of action when the spill response includes a separation problem.

Settling of suspended solid-contaminated water can, in many cases, be expedited through the use of flocculants or coagulants. Such chemical and physical processes can effect a form change in the discharge chemicals so that they may settle out or be filtered out more rapidly. The chemical additives change the finely distributed or dissolved discharged chemicals into a solid or semi-solid form, or cause them to agglomerate into large composite particles.

In either case, settling or other forms of removal becomes practical. The process is initiated by the addition of agents to the mixture; the nature of the agent depends upon the type of discharged chemical. No universal agents or complete set of agents exist.

When such treatment is feasible, requirements similar to those for settling occur. Large volumes must be stored under undisturbed conditions until the natural process is complete. The facility for distribution and mixing of the agent must be suitable for decanting and for removal of the discharged chemical in its new form.

6.3.2.1.5 Filtering

Filtering is applicable mainly to fine particulate, non-soluble solids. Large-capacity filters are used in the process industries, but these are not suitable for general response use. Current developments include "self-cleaning" configurations which permit automatic switchover and backflushing which, in turn, permit continuous operation. While filters will prevent passage of finely particulated viscous liquids, these generally clog the filters and prevent continuous use of the equipment.

Filters are in the same position as many other separators in that industrial equipment exists, but transportable equipment usable at a discharge site does not. Unless local plant facilities in the immediate vicinity of the discharge can be utilized, these methods are not practical in formulating response action.

6.3.2.2 Storage Systems

6.3.2.2.1 Bulk Storage Data

For any discharge response in which the discharged substance is collected or in which a mixture of water and discharged chemical is collected, it is necessary to store this material temporarily until it can be removed for further processing. Obviously, the larger the quantity of material which is collected the greater is the problem of storage. Furthermore, the type of storage must be predicated on the hazards of the chemical or the mixture, such as *flammability* or *toxicity*.

Storage facilities on shore are generally rated in terms of their volume; (1 cubic foot equals 7.48 *gallons*).

Tankage in ships may be rated in terms of cubic feet or gallons, but gross capacities are *frequently stated in tons, which* is expressed as a *weight* measurement; i.e., 100 cubic feet = 1 ton.

Another common measurement used both in tanks and in ships is made in terms of barrel capacity. The standard "barrel" contains 42 gallons or 5.61 cubic feet. The barrel measurement is common in the oil industry and a barrel of oil *may weigh in the range* of 310 to 350 pounds (net). One ton is therefore made up of about 6.4 to 7.2 barrels of oil.

If the density of a material in pounds per cubic foot is designated by ρ, the following conversion formulas are available:

$\text{lbs}/\rho = (\text{cu ft})$
$\rho(\text{cu ft}) = \text{lbs}$
$(\text{tons})\ 2240/\rho = (\text{cu ft})$
$(\text{cu ft})\ \rho/2240 = (\text{tons})$
$(\text{tons})\ 16{,}755.2/\rho = (\text{gals})$
$(\text{gals})\ \rho/16{,}755.2 = (\text{tons})$
$(\text{cu ft})\ 7.48 = (\text{gals})$
$(\text{gals})/7.48 = (\text{cu ft})$
$(\text{gals})\ \rho/7.48 = (\text{lbs})$
$(\text{lbs})\ 7.48/\rho = (\text{gals})$

The density of salt water is approximately 64 lbs/cu ft and for fresh water it is 62.4 lbs/cu ft.

Collection, pumping, or processing *rates* commonly are expressed as gallons per minute (gpm), or as gallons per second (gps). Air or gas-handling equipment commonly uses *cubic feet per minute (cfm) or cubic feet per second (cfs) in* reference to the air or gas at atmospheric pressure. The relationship rate x time = volume is used to determine storage requirements or conversely to determine the time required to fill a given storage volume.

Major chemical discharges are frequently characterized in tons as, for example, in the case of tanker casualties. Heavy oils, including the crude oils, have a specific gravity of between 0.90 and 0.95 which means on the order of 56 to 61 lb/cu ft. Liquified natural gas (LNG) has a specific gravity of about 0.45 which is equivalent to about 28 lb/cu ft. The specific gravity of a material is a basic characteristic and can be found in CG-446-2.

In the case of particulated solids, the density of the material (as given in references) is related to the solid material only. When stowed or packaged, the air spaces between the particles reduce the mean density of the *bulk material*. If the quantity of material is given as a *weight*, conversion to volumes must take into account this *stowage factor*. The volume will equal the *weight* divided by the *density* times a *stowage factor* (of less than 1.0). The smaller the particles of material, the closer will they stow and the closer will the stowage factor approach 1.0; the larger the material chunks, the more space will be lost in stowage and the stowage factor will become smaller. In some instances, a chemical will be characterized in stowed condition in terms of cubic feet per ton; this takes into account both the density of the material as well as its stowage factor.

The capacity of a storage facility may be limited either by volume or by weight. Rail, truck, and ship facilities frequently are weight-limited, while some stationary tanks are volume-limited. Where weight limitations exist or are suspected to exist, both weight and volume for the particular substance must be calculated to identify the limits to which the facility may be filled. This is particularly necessary when the facility is designed for use with substances lighter than water.

6.3.2.2.2 Drums

The standard drum has a capacity of 55 gallons (7.35 cu ft), is made of sheet metal, and is used as a common shipping container for a large variety of liquids. It is noted that the capeity of this standard *drum* is larger than the standard *barrel* of 42 gallons. Tare weight of a drum is in the range of 60 pounds to 75 pounds.

Handling of 55-gal drums may be accomplished by specially designed drum-handling devices, slings and hooks, fork-lifts, and pallets. There are no hand-holds fitted on the standard drum and man-handling is difficult. The drums may be stacked in a vertical position or pyramided in horizontal position.

The filling/emptying holes are usually small, and funnels, hoses, and pumps are required for handling the contents of the drums. Filling or emptying by gravity is a slow process.

The 55-gal drums provide the basis for a large variety of temporary and make-shift containers. With one head removed, or cut in half, they become a versatile vessel available in almost every industrial location.

Many solid industrial chemicals and materials are shipped in cardboard or fiberboard drums, some of which approximate 55-gal drums in size (2 ft dia. by 3 ft high). These containers have a short life in a damp marine environment and are of limited usefulness in a discharge response.

When utilizing 55-gal drums, the original contents must be determined. There exists the possibility of a hazardous incompatibility with the chemicals which might be put into the drum. These drums are difficult to clean, and it is improbable that a previously used drum has been cleaned *after its original* use. In particular, if the drum is going to be modified by welding or cutting, the complete absence of explosive vapors must be verified prior to any work.

6.3.2.2.3 Barges

Barges which are available in many sizes and configurations are a highly practical storage container class. Capacities up to 1000 tons or more are common. There are tank barges, hopper barges, deck barges, and other special types. Tank barges are most suitable for storing liquids, but hopper barges might be used for certain types of collected materials, particularly if these residues contain a proportion of solids. The hull tanks of deck barges, if subdivided, can also be used. Stability problems arise mainly in single-skinned barges with one continuous hold, such as are common to hopper barges; stability must be examined before such barges are used for liquid storage.

In all cases, the venting of the tank compartments, if used with volatile residues, must be examined, and the hazards associated with the vapors must be determined. The advisability of using internal combustion engines on deck must be specified, and electrical spark and smoking hazards and toxicity dangers must be considered and countermeasures taken as necessary.

Barges combine the storage and transportation functions in the collection of discharged chemicals. In many instances they also can provide a working platform for response equipment (pumps, separators, instrumentation, storage of equipment and gear, lifting equipment, etc.). The conventional rectangular barge is reasonably seaworthy and suitable for in-shore and protected waters; in a seaway the first difficulty usually arises in trying to tow the barge.

Use of barges implies the requirements for:

- Tugs or workboats for moving the barge;
- Suitable heavy moorings and bridles for the barge on site;
- Pumps and hoses for loading and unloading the barge; and
- Provision of methods to remove sludges and solids.

The smaller barges are sometimes constructed of wood; steel is the most common construction material. In all cases, the compatibility of the collected material with the barge tank surfaces must be considered. Bare metal surfaces, fittings, and fasteners can be attacked by pitting in a short time (days) by reactive chemicals to a degree where major repair and overhaul would be required.

6.3.2.2.4 Tank Trucks

The common tank truck is used for distributing petroleum products and hauling other liquids ranging from milk to chemicals to sludge. Special configurations for hauling bulk solids (sugar, cement, etc.) are available as well as those adapted for liquids at low or high temperatures or under pressure or both.

Highway limitations bound the size of tank trucks to the 10,000-gal range, but larger, special-purpose vehicles do exist. Of course, the specific gravity of the material becomes important. If a truck designed to highway limits for a load of gasoline at about a specific gravity of 0.8 is filled with water, it might become 25% overweight on axle loadings, even though the tank itself may be quite satisfactory under the additional weight.

As noted in the section on collection systems, if a tank is capable of withstanding *external* pressure, it can be used as a vacuum tank for collecting as well as transporting discharged chemicals.

Tank trucks are sufficiently common that detailed description is not necessary. In considering the suitability of tank trucks in a discharge response, the following points are important:

a) Compatibility of the collected material with the tank material, piping, and safety features;

b) Availability of road access to the vicinity of the discharge site, if applicable;

c) Truck filling pumps and piping;

d) Road access to the further processing or disposal areas; and

e) Numbers of trucks required to meet the collection rates (both tractors and tank trailers, in the large sizes).

6.3.2.2.5 Tank Cars

Tank cars are used for the transportation of bulk petroleum products and industrial chemicals and materials. Tank sizes range up to the 25,000-gal level. While tank cars are eminently suitable for the collection and transportation of collected chemicals, a prime consideration is the availability of rail trackage and sidings where the cars may be filled and emptied. Except in large port or industrial areas, waterfront spur tracks are not common; this restricts the use of tank cars even more than the availability of roads limits the use of tank trucks.

While tank trucks are self-propelled, tank cars require locomotives for movement. This, in turn, requires a greater co-ordination, planning, and scheduling effort. As with tank trucks, appropriate and compatible transfer and handling systems must be available as auxiliary equipment.

For semi-solids, debris, and solids, open gondola cars and hopper cars can be used. A total response operation may therefore require a variety of types of railroad cars.

6.3.2.2.6 Bladders

The concept of a flexible, towable bladder has been extended to offloading petroleum products from damaged or stranded ships. These bladders are filled from the ship while afloat and are towed back to shore for emptying. Some bladders and associated deep-well pumps can be transported and delivered by air, thereby precluding overland or surface ship transportation.

Bladders can be utilized for collected liquid spill materials provided:

a) The bladder fabric is compatible with the discharged chemical, and

b) The discharged chemical has a specific gravity of less than 1.0.

As with barges, the bladders can be filled at the site of the incident, away from the immediate shore line. In cases of discharges from ships offshore, at anchorages, or in major waterways, where the discharged chemical cannot be attacked from shore, this capability is valuable.

Under a similar concept, much smaller containers are manufactured for commercial and military use, in sizes of up to about 500-gal capacity. These reinforced rubber drums can be lifted, towed, or rolled. For military use where they carry fuels and water, they are fitted with special filling/emptying connections; the containers can be fitted with other connections more appropriate to the response operation hardware. Piping and connection compatibility is essential for placing any such system into operation in minimum time. This compatibility should be ensured during the planning of the operation.

Bladders of all types can be highly practical in responses to hazardous chemical discharges. They are not in widespread use commercially; on short notice, however, existing government agency stocks would appear to provide the most immediate resources.

6.3.2.2.7 Dikes

Frequently it is possible to construct storage areas for liquids on shore by dikes. The open ponds or lagoons thus formed can be built to contain appreciably larger amounts of liquid than could be stored in containers or tanks. The dikes usually are constructed of local on-site materials (sand and soil and gravel) by bulldozers, backhoes, and similar heavy construction equipment.

Either the dikes alone, or the sides and bottom of the pond, are sometimes surfaced with an impermeable substance (such as asphalt, or by a liner of plastic film) to prevent seepage which causes both loss of stored material and weakens the dikes.

The cross-sectional geometry of the dikes is a function of the materials of which they are built. The weaker the material (in shear), the smaller must be the angle of the sides to the horizontal and the more material is required for a given height of dike. If a dike core of stone or other strong, heavy material can be constructed to absorb part of the hydrostatic liquid pressure forces, the slope of the earthen side covering can be increased. Compaction of the dike material is desirable under any circumstance and serves a similar purpose, provided the basic material can be effectively compacted to increase its strength.

Simple earthen dikes can be thrown up rapidly with normal construction equipment. Frequently use can be made of natural depressions or rises for part of the enclosure. This type of containment for large quantities of collected material is highly suitable for emergency use, but is subject to the following problems, particularly when an unlined, earthen structure is used:

a) The natural permeability of the soil will permit large volumes of earth to become contaminated with the collected substance, and

b) Seepage may occur and the collected chemical may reach the water table or other water sources, or appear in the natural run-off.

Both of these events would require extensive corrective measures which might outweigh the advantages of using this type of containment. The nature of the collected chemical will form an important part in an evaluation of the use of a diked pond for a particular discharge situation especially in the light of current protective regulations which prohibit any release of hazardous substances into the environment.

While diked ponds are commonly used in industrial plants as settling ponds or collection ponds for unwanted residues, they usually are carefully prepared to avoid potential seepage and leakage. The subsoil and substrate conditions are identified and the pond constructed accordingly. In a response to a hazardous chemical discharge, less preparation time is to be expected and the risks become commensurately greater.

The use of existing ponds for impounding collected materials suffers from similar risks. Seepage, leakage, dilution, and overflow must be prevented. Furthermore, existing ponds are liable to have extensive bottom accumulations of decomposing or decomposed organic materials. Once these layers are contaminated, their later removal and disposition may become a major task. Most natural ponds are associated with a water source, such as a spring, or stream, or surface run-off. Neither dilution nor overflow of a chemical which could be introduced into such a pond, is desirable. Furthermore, natural ponds usually form an important link in the local ecological system; disturbing or polluting a natural pond may cause considerable damage to the local ecosystem comparable in extent to that of the original hazardous chemical discharge. Man-made ponds may be more controllable and may be less liable to have far-reaching environmental effects if used as a chemical disposal site. In either case, the use of existing ponds is not recommended, except after thorough investigation of the impact such use may have been made.

6.4 Chemical and Physical
Treatment

6.4 CHEMICAL AND PHYSICAL TREATMENT

Potential Methods

6.4.1 Burning

CAUTION: Burning-off is one of the most dangerous treatment operations. Burning should only be considered when it can be determined that the risks to people would be greater if burning were not attempted. Changing meteorological conditions or water surface currents can create hazardous conditions during burn-off. *

When burning may be considered:

- Removal of *floating flammable liquids.*

  only consider burning after evaluating --
  a. collection methods,
  b. potential chemical and physical treatment, and
  c. severity of hazard if burning were not attempted.

- To stop downwind travel of *flammable gases* in order to localize the hazard.

  should not be attempted unless well established plans have been developed prior to the accident, and then only under the most critical conditions where large vapor clouds may endanger a large populated area.

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[*] In many areas burning is prohibited or restricted by air pollution regulations. Burning sometimes leaves a sooty deposit on the water which, while not highly harmful, can result in unsightly deposits on the shoreline. It is worth noting, therefore, that in the code of oil discharge practice developed by the petroleum industry in Western Europe, burning-off, either with or without incendiary aids, is "not recommended" under all circumstances, except for spreading oils far from harbors or under ice conditions. Even then, it is given a fourth or fifth response priority.[†]

[†] Benyon, L.R., *Proc. Conf. Prevention Control Oil Spills,* AEP-API-USCG, Washington, D.C., 1973.

6.4.1.1 Background

Methods for igniting and burning flammable chemicals that have been discharged into water bodies have not been well developed. Attempts have been made to burn oil that has been discharged by tankers and experiments have been performed with special agents for assisting the burning of oil on the water. There is no known case where flammable gases that have been accidentally discharged have been intentionally ignited.

Because of the lack of knowledge and experience, assistance from knowledgeable experts should be sought and the prevailing conditions fully evaluated before intentional ignition of flammable discharges is attempted. In addition, it should be realized that there will not be sufficient time to seek assistance nor fully evaluate the risks associated with intentional ignition *after* a discharge of a flammable gas. Because the burning of the gas can endanger those in the vicinity of the discharge, it should *not be* attempted without having made plans for doing so prior to the accident. The potential location, weather conditions, special characteristics of the chemical, life that may be endangered, the size of the discharge, and the method of igniting the material should all be considered in these plans.

6.4.1.2 Ignition

It is very difficult to ignite flammable discharges on the open water without endangering the personnel that are performing the act. Sufficient distance must be maintained between the flammable chemical and the person igniting it so that he will not be engulfed by the resulting flames nor injured by thermal radiation at some distance from the fire. The ignition of flammable gases requires large distances because of relatively rapid movement due to shifts in wind. Flare pistols are one possible method of igniting flammable gases from a distance.

For flammable liquids of low volatility a torch or flaming rag on a long pole may be used from an *upwind* position. In some cases, the chemical may be particularly difficult to ignite and specially prepared incendiary devices may be required.

6.4.1.3 Burning Agents

A number of agents can be spread on oil and oil-like discharges to facilitate combustion. These materials are usually silica in nature, and they may be treated to be hydrophobic and or to alter the surface properties of water. However, they must be porous so that they can act like a "wick," taking up the pollutant and promoting its vaporization and subsequent combustion. (Figure 6-8). In addition to wicking or sorbing oil readily, a good burning agent should be (a) lighter-than-water, even when saturated with the hazardous chemical, (b) indestructible by pyrolysis, and (c) readily recoverable and or not injurious to the environment.

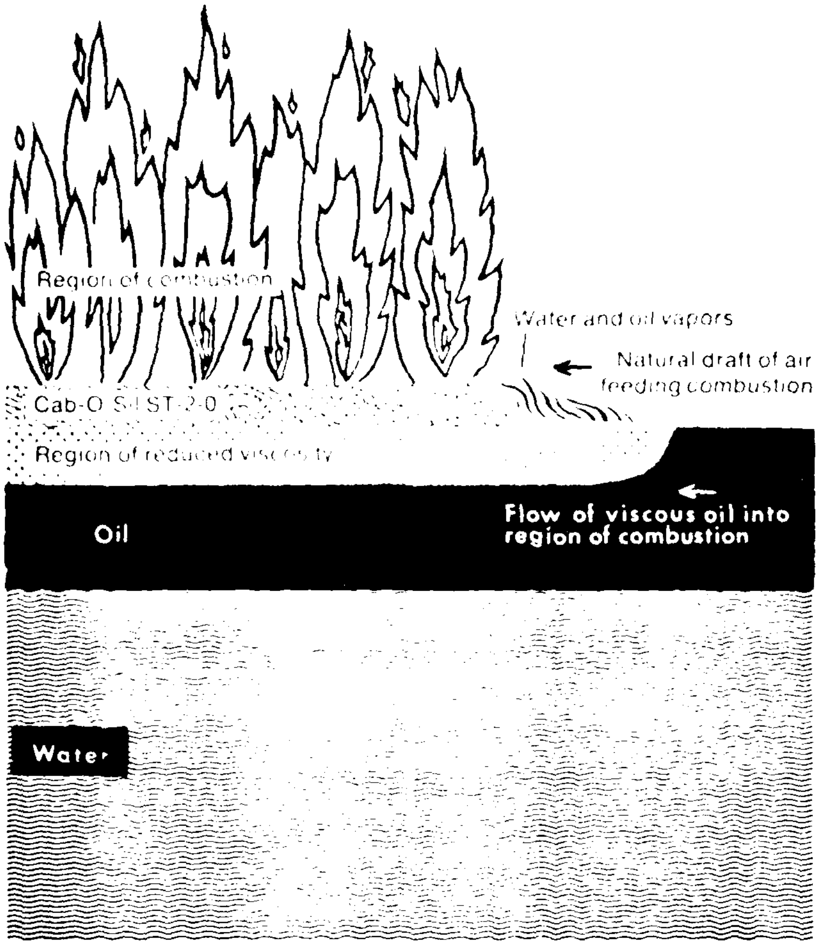

FIGURE 6–8 CONTROLLED COMBUSTION

Diagram illustrates the mechanism of controlled combustion assisted by Cab-O-Sil ST-2-0 on floating slicks of heavy oil. Acting as a wick, Cab-O-Sil on surface draws up oil by capillary action, increasing the rate of vaporization. Burning of surface oil heats oil below it, reducing viscosity and facilitating further wicking. At edge of burning, oil and air flow towards flame.

(Diagram Courtesy of the Cabot Corp.)

Wicking or burning agents can come in the physical forms of powders and small beads or pellets, but their handling and inherent problems in these two forms differ somewhat. Good coverage of the slick area to be burnt is necessary. Burning should be carried out as quickly as possible before the light fractions evaporate to make ignition difficult and to avert further spreading of the slick. If the burning agent is in powdered form, it can be dispersed from ships or aircraft in any of a number of ways, including even by hand-spreading. One manufacturer suggests that its product, which has been treated to make it hydrophobic, can be applied with a water stream by use of standard fire-fighting foam generators. They suggest an application of about 5 pounds of burning agent per 100 gallons of oil. Investigations into applying "slippery water" techniques whereby a chemical can be added to the water prior to discharge to increase the length of the water jet are in progress.

Another manufacturer's burning agent comes in the form of porous glass beads. These beads may be fragile and, to avoid dusting and bead fractures, this material should not be handled more than necessary. The beads range in diameter from 1/8 to 1/4 inch and can be applied by a commercial seed or mulch spreader. During deployment the ship should take care *not* to pass through areas it has previously treated, because (a) the ship's wake and propeller action can break up the slick and perhaps sink some of the burning agent, (b) the ship can endanger itself from the fire, and (c) the incendiary material is abrasive and, especially in the case of the beads, can cause damage if taken into a ship's sea water intake, thus blocking condenser tubes, pipelines, valves, and strainers.

After the burning agent has been spread, a few minutes should be allowed prior to ignition to enable the contaminant to be wicked up. Then a small area of the slick should be primed by adding a combustible liquid. A torch or a rag dipped in lighter fluid should then be used to ignite the slick. The entire slick does not suddenly ignite. Rather the burning proceeds slowly until it finally encompasses the whole area treated.

The burnoff can be very sooty and ships, equipment, and personnel should be kept upwind from the burning area. After the chemical has been burned away, the powdered agents leave a sort of crust which, while not injurious to the environment (it is mostly silica), is rather unsightly and should be removed. Similarly, the burning of beaded wicking agents should leave the water clean, and again the beads are not harmful to the environment. However, for reasons noted above, the floating beads should be removed.

The site, wind and geographical conditions must be carefully assessed before applying this response technique. Failure to fully determine all conditions that can be affected from burning pools of material, surface slicks, or leaks could increase the hazards developed from the discharge.

6.4.2 Neutralization

6.4.2.1 Guidelines

6.4.2.1.1 General Considerations

Before proceeding with the detailed planning of a chemical neutralization response, four questions (cited below) should be answered. Extreme caution should be employed if the answer to one or more of these questions is negative.

Question 1: Is neutralization listed as a possible response method for the discharged chemical? (Check the response matrix of Table 4-1 of this Handbook and Section 7.4 of CG-446-2 under the chemical name.)

Question 2: Are the amount of the chemical discharged and the current location of the discharge known?

Question 3: Can a relatively safe neutralizing agent be obtained and deployed effectively at the site? Can it be done quickly, e.g., within a few hours?

Question 4: Have the original containers of the discharged chemical been checked to see if information on possible spill responses is provided?

6.4.2.1.2 Specific Considerations: Neutralization of Acids and Acidic Substances

Step 1: Obtain, if possible, a pH meter, pH paper, or alternate aid (e.g., litmus paper) that will allow measurement of the acidity of the contaminated water. Measure the pH (the hydrogen ion concentration) of the water at various locations (and depths, if possible) in the discharge site. An acidic condition will be indicated by a pH of less than 7. No further action may be necessary if the pH is nowhere found to be lower than 6.

Step 2: Obtain an adequate quantity (see Step 3 below) of limestone ($CaCO_3$), dolomite ($MgCO_3$-$CaCO_3$), "soda ash" ($NaCO_3$), or other similar weakly basic substance. Section 7.4 of CG-446-2 may list a preferred chemical. All of the chemicals listed above are solids and should be obtained in fine powder form.

Step 3: Deploy the neutralizing agent (see Sections 6.4.1.2.7 and 6.4.1.2.8). In the absence of more detailed information, a rule of thumb is that the weight and/or volume of the neutralizer added should be two to three times the weight and or volume of the chemical discharged. This ratio of 2 to 3 is good for the treatment of discharges of *concentrated* acids. In the discharge of a *dilute* acid, the ratio may be reduced to 1 to 1.

Step 4: Monitor the pH of the contaminated water as the neutralizing agent is added. Restoration of the water to a pH of 7 would be ideal; neutralization can be considered adequate, however, if the pH falls in the range of 6 to 8.

6.4.2.1.3 Specific Considerations: Neutralization of Bases and Basic Substances

Step 1: Obtain, if possible, a pH meter or alternate aid (e.g., litmus paper) that will allow measurement of the pH of the contaminated water. Measure the pH of the water at various locations (and depths, if possible) in the discharge site. A basic condition will be indicated by a pH of greater than 7. No further action may be necessary if the pH is nowhere found to be higher than 8.

Step 2: Obtain an adequate quantity (see Step 3 below) of a weak acid, e.g., *dilute* acetic acid (vinegar), citric acid, or dry ice. The vinegar will be in liquid form. The citric acid will probably be in granular form; either the anhydrous chemical (no water molecule attached) or the monohydrate (one water molecule attached) is acceptable.

Step 3: Deploy the neutralizing agent (see Sections 6.4.1.2.7 and 6.4.1.2.8). In the absence of more detailed information, a rule of thumb is that the weight and/or volume of the neutralizer added (after dilution factors have been extracted) should be roughly equal to the weight and/or volume of the discharged chemical.

Step 4: Monitor the pH of the contaminated water as the neutralizing agent is added. Restoration of the water to a pH of 7 would be ideal; neutralization can be considered adequate, however, if the pH falls in a range of 6 to 8.

6.4.2.1.4 Specific Considerations: Neutralization of Oxidizing Agents

Step 1: Obtain, if possible, an analytical instrument that can measure the concentration of the discharged chemical in the water. Measure the concentration at various locations (and depths, if possible) in the discharge site. Alternatively (and in addition to the above), look up the solubility of the discharged chemical in the Hazardous Chemical Data Manual, many ozidizing agents have limited solubilities which will indicate the maximum concentration possible in solution. No further action may be required if the measured or deduced concentration is below harmful levels.

Step 2: Obtain an adequate quantity (see Step 3 below) of a naturally occurring reducing agent such as carbon (e.g., powdered carbon or powdered activated carbon), a vegetable oil, or corn syrup. Try to match the behavior of the chosen reducing agent with the behavior of the discharged chemical: e.g., the carbon will sink in water, the vegetable oil will float, and the corn syrup will dissolve.

Step 3: Deploy the reducing agent (see Sections 6.4.1.2.7 and 6.4.1.2.8) using roughly twice the weight and/or volume as the weight and/or volume of the chemical discharged, or until there is reasonable assurance that the concentration of the discharged chemical is below harmful levels.

6.4.2.1.5 Specific Considerations: Neutralization of Reducing Agents

Step 1. Obtain, if possible, an analytical instrument that can measure the concentration of the discharged chemical in the water. Measure the concentration at various locations (and depths, if possible) in the discharge site. Alternatively (and in addition to the above), look up the solubility of the chemical in the Hazardous Chemical Data Manual, some reducing agents may have limited solubilities which will indicate the maximum concentration possible in solution. No further action may be required if the measured or deduced concentration is below harmful levels.

Step 2: Select an aeration method that is appropriate for the area of the chemical discharge, e.g., agitators, dams and wiers, or bubblers in shallow or deep waters.

Step 3: Aerate the water (see Section 6.4.1.2.9) until there is reasonable assurance that the concentration of the spilled chemical is below harmful levels.

6.4.2.2 Neutralization Factors

6.4.2.2.1 Introduction

Chemical substances can be broadly classified into two categories: (a) acids and bases and (b) oxidizing and reducing agents. A given chemical substance can fall into both of these categories: nitric acic, for example, is both a very strong acid and a powerful oxidizing agent. The word "acid" does not necessarily imply hazard. Citric acid is safe enough to drink in solution (and one does in many soft drinks) and has not been placed in CHRIS. Dangerous acids do not necessarily have the word "acid" in their names: for example, oleum is a commonly used name for fuming sulfuric acid. Some substances react with water to form acids or bases: aluminum chloride hydrolyzes in water to form a strong acid (hydrochloric acid) and a weak base (aluminum hydroxide — not in CHRIS), thus making the water acidic. Metallic sodium reacts explosively with water to form a very strong base (sodium hydroxide or caustic soda). Similarly lime (calcium oxide) reacts with water to form a strongly alkaline (basic) solution. Table 6-1 lists selected CHRIS chemicals and indicates whether they are (or form in water) strong acids, bases, or oxidizing or reducing agents.

Natural waters are very nearly neutral: that is to say, they are neither acidic nor basic. If the waters are well aerated, they will be slightly oxidizing; however, if the waters are stagnant, they may represent reducing conditions. Large departures from natural water conditions are very injurious to living things. The waters will tend to restore themselves to their natural condition of near neutrality, but this process is slow and great damage can occur in the interim. Therefore, when possible, it is desirable to restore the neutral condition of the waters rapidly by the application of neutralizing chemicals. Conventionally "neutralization" is used only in connection with acids and bases, but the term is also extended here to include the neutralization by the impact of oxidizing and reducing agents.

To neutralize a chemical exactly is a difficult task, even in a well equipped laboratory. To neutralize a chemical discharge exactly under field conditions in a body of natural water is virtually impossible. Neutralization, therefore, is one of the most difficult and potentially dangerous corrective responses. The neutralizing chemical must be readily available in large quantities and it *must be weak* and

TABLE 6-1

SOME STRONG ACIDS (A), BASES (B), OXIDIZING (O), AND REDUCING (R) AGENTS*

	Acid-Base	Ox-Red.
Aluminum chloride†	A	
Ammonium hydroxide	B	
Ammonium perchlorate†		O
Calcium carbide†	B	
Calcium hydroxide†	B	
Calcium oxide†	B	
Caustic potash	B	
Caustic soda	B	
Chlorosulfonic acid	A	
Chromic anhydride†	A	O
Dibenzoyl peroxide†		O
2, 4-Dinitrophenol†	A	
Ferrous sulfate†		R
Formic acid	A	
Hydrazine	B	R
Hydrochloric acid	A	
Hydrofluoric acid	A	
Hydrogen chloride	A	
Hydrogen peroxide		O
Lithium aluminum hydride†	B	R
Nitric acid	A	O
Oleum	A	O
Phosphoric acid	A	
Potassium dichromate†		O
Potassium hydroxide†	B	
Potassium permanganate†		O
Sodium†	B	R
Sodium amide†	B	
Sodium dichromate†		O
Sodium hydrides†	B	R
Sodium hydroxide†	B	
Sodium sulfide†	B	
Sulfuric acid	A	O

*These are examples. The fact that a CHRIS chemical does not appear on this list does NOT mean that it is not a dangerous acid, base, oxidizing, or reducing agent.

†Chemicals that may be shipped in solid form. If spilled on the dock, vessel, or land, they should be scooped up, placed in a container, and disposed of by an approved procedure. Care should be taken to wear protective clothing and to use equipment that is compatible with the chemical.

non-injurious to the environment; otherwise the application of an excess could do more damage than the original chemical discharge.

Neutralization as a corrective response to the discharge of a hazardous chemical in open waters has *not* been attempted, except in a very few cases. Consequently there is little or no guidance from previous experience, and it is difficult to say with certainty that neutralization will, even in the best of circumstances, be a viable alternative.

The generalized information on neutralization given in Sections 6.4.1.2.2 through 6.4.1.2.5 below will allow some basic understanding of the processes and problems involved. More detailed instructions are given in Section 6.4.1.2.6. Whenever possible, the advice of a person with chemical expertise should be obtained to supplement the very general information given here; the dangers and problems involved in neutralization and the diversity of chemical species that are involved allow only limited guidelines to be given here.

6.4.2.2.2 Neutralization of Acids and Acidic Substances

Acids are neutralized by bases to form salts and water

Acid + Base → Salt + Water

Example:

hydrochloric acid + sodium hydroxide → sodium chloride + water

$HCl + NaOH \rightarrow NaCl + H_2O$

Weakly basic substances that might be available in large quantities at or near a spill site include:

Limestone ($CaCO_3$)
Dolomite ($MgCO_3$-$CaCO_3$)
Sodium carbonate or "soda ash" (Na_2CO_3)

Limestone and dolomite are naturally occurring mineral substances and, even if added in excess, should not chemically damage natural waters. Soda ash and slaked lime will also neutralize an acid discharge, but these chemicals are more strongly alkaline and the addition of an excess could be harmful.

6.4.2.2.3 Neutralizing Bases and Basic Substances

Discharges of bases or caustics are much more of a problem for there may be no plentiful, weakly acidic, harmless substances available to neutralize them (naturally occurring mineral substances tend to be basic). Most weak inorganic acids are poisonous (such as hydrogen cyanide, sulfur dioxide, and hydrogen sulfide). The likelihood of suitable weak organic acids, such as citric or *dilute* acetic acid (vinegar), being available in sufficient amounts at the site of the hazardous chemical discharge is small and response action would be limited by supply. One additional possibility is the use of dry ice (carbon dioxide in solid form). Solutions of CO_2 in water are weakly acidic.

6.4.2.2.4 Neutralizing Oxidizing Agents

Oxidizing agents are "neutralized" by reducing agents to form more stable and usually harmless chemical substances:

Oxidant + Reductant → Stable Compound

Example:

air + coal → carbon dioxide

$O_2 + C \rightarrow CO_2$

Anything that will burn in air is a reducing agent. In the case of a discharge of an oxidizing agent, it is difficult to imagine the addition of a chemical more available, effective, *and safe* than the naturally occurring reducing agents (organic material) in the waters.

> *CAUTION: Powerful oxidants represent serious fire and explosion hazards when in contact with combustible materials (such as wood) on deck or shore.*

6.4.2.2.5 Neutralizing Reducing Agents

The reducing agents listed in Table 6-1 are all very strong. It should be noted, however, that many organic chemicals are weak reducing agents. Some of these organic chemicals, such as vegetable oils and corn syrup, do not represent a hazard to human health, but their large discharges into a water body could make appreciable chemical and/or biochemical oxygen demands (COD and/or BOD) and thus be detrimental to aquatic animal life depleting the concentration of dissolved oxygen. The biochemical processes responsible for BOD are generally slow and, as a consequence, except for confined stagnant waters, natural flow and mixing processes may well dilute and disperse the chemical before the serious level of oxygen depletion occurs.

The natural environment is permeated by a very effective, plentiful, and safe yet strong oxidizing agent — oxygen. It is very difficult to improve upon and, as a rule, there is no better oxidant that man can add to "neutralize" the discharge of a hazardous reducing agent. If the discharged reducing substance seriously depletes the dissolved oxygen content of the water, the oxygen level can be restored by *aeration.*

An extensive technology exists for aeration in shallow lagoons, sewage treatment facilities, and other effluent-treatment complexes. In recent years the effectiveness of aeration in restoring the quality of stream waters has been demonstrated, but very little attention has been paid to the emergency aeration of natural waters.

Aeration methods fall into four categories (Figure 6-9):

(1) Stirring and agitating,
(2) Dams and weirs,
(3) Bubbling, and
(4) Spray Formation.

Stirring and weirs can be effective only in relatively shallow waters. Bubbling is applicable to both deep and shallow waters.

6.4.2.2.6 Quantities

Three approaches to neutralization can be taken:

(a) The preferred approach is to add a neutralizing agent that will neutralize the hazardous material but which will not itself create a hazardous condition if an excess is added. An example is the use of limestone ($CaCO_3$) to neutralize acids which have been discharged into a water body.

(b) The second approach is to monitor the waters and add the neutralizing agent until the monitoring indicates that neutralization is complete.

(c) In the absence of suitable monitoring instrumentation, a quantity of the neutralizer can simply be dumped into the polluted water course. This procedure is rarely justified.

The neutralization of acid and base discharges can be monitored with a pH meter a simply operated, inexpensive, and commonly available instrument. Neutral waters have a pH of 7. Neutralization can be considered complete when the pH of the water is restored to a value of 6 to 8. In the case of large COD/BOD* discharges, the state of oxygen depletion can be monitored with a

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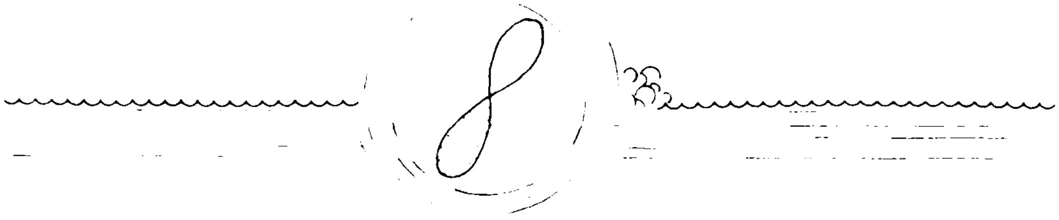
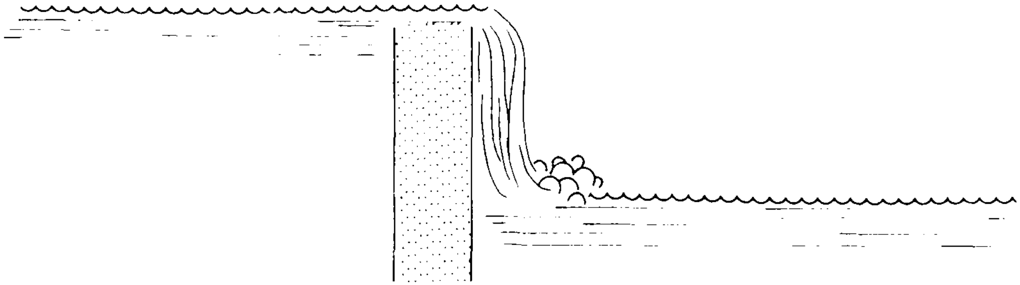
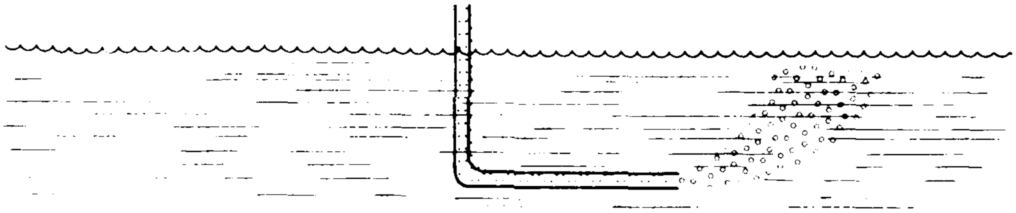
*COD (Chemical Oxygen Demand) and BOD (Biochemical Oxygen Demand) are indicators of the degree to which the chemical might deplete dissolved oxygen from water.



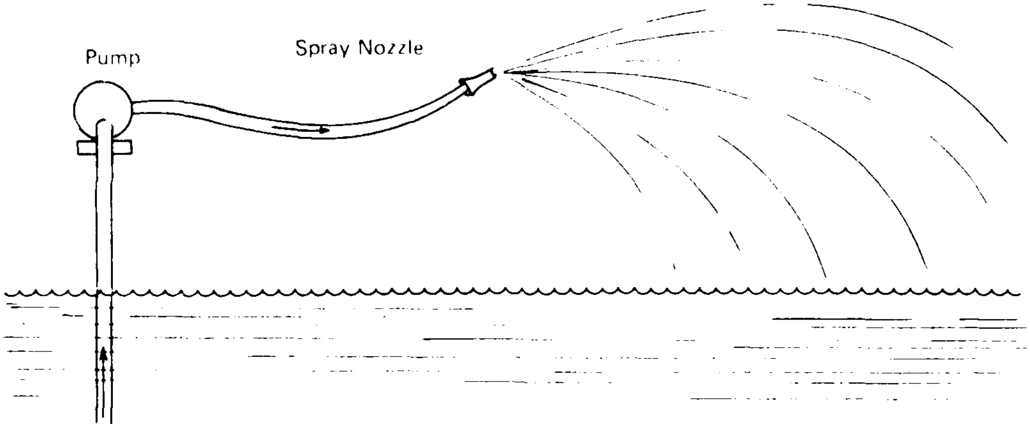
1. Stirring or Agitation



2. Dams and Weirs



3. Bubblers



4. Spray Formation

FIGURE 6–9 FOUR AERATION METHODS

dissolved-oxygen probe, a somewhat more expensive and less common instrument. Surface waters in their natural state will have a dissolved-oxygen concentration of about 5 ml/l. If this is reduced by more than one-half, serious consequences for marine life may result. If possible the waters should be monitored during neutralization (or aeration) over the entire water column affected by the discharge and the neutralization.

If monitoring is not possible, then a rough estimate must be made of the amount of neutralizer added to the waters. As a very rough rule of thumb, the weight and/or volume of the neutralizer added should be two to three times the weight and/or volume of the discharged chemical.

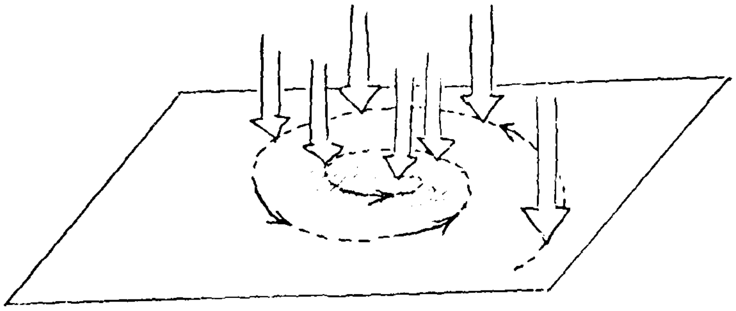
If a solid, the neutralizing chemical will be more effective more rapidly if it is finely divided.

6.4.2.2.7 Deployment – Still Water

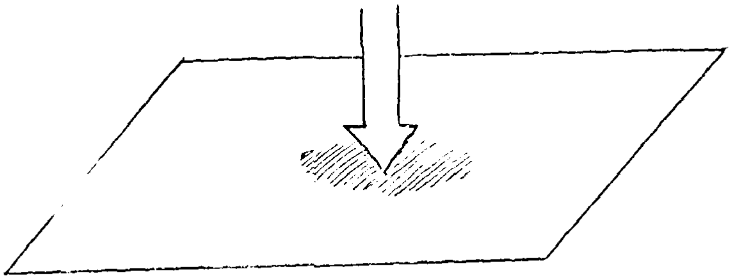
Soluble chemicals may disperse slowly in still water. The preferred strategy of adding a neutralizing agent in such instances is to start beyond the periphery of the discharge and slowly spiral in toward its center. Alternatively, if the neutralizing chemical is promptly available at the discharge site it can simply be dumped into the water at the center of the discharge (Figure 6-10). If possible, it can be spread with some kind of scattering movement, such as one used when sowing grass seed (a barge-mounted road or farm spreader would be ideal for this purpose). For most chemicals, unless the neutralizing substance can be applied within 1 to 3 hours after the discharge, attempts at neutralization are probably not worthwhile. In the absence of other equipment, if the discharge is not too large, hand shovelling can be an effective spreading method.

6.4.2.2.8 Deployment – Flowing Water

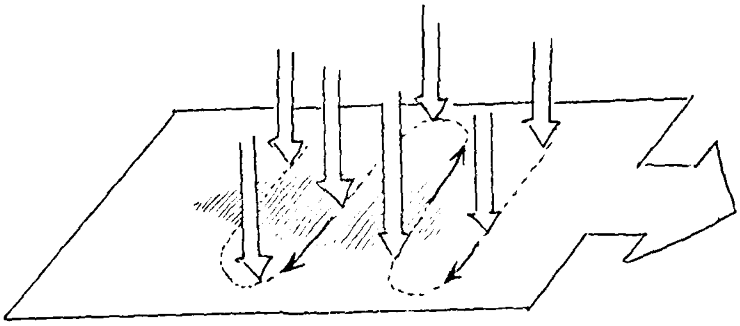
In flowing waters a discharged chemical will move downstream in a constantly growing, but diluting, slug. The preferred strategy is to spread the neutralizing chemical in a zig-zag pattern back and forth across the moving discharge, starting at a point several hundred yards downstream or ahead of the discharge and working upstream (Figure 6-10). If this is not feasible, neutralizer can be added near the leading front of the discharge. Notice that if the neutralizer is heavier than water and insoluble (such as limestone) and is added too far downstream from the discharge, then it may sink to the bottom and the chemical to be neutralized will pass over it. However, limestone, for example, dispersed on the botton could still abate an acid discharge if the water is shallow (less than 2 to 3 feet). Even if the neutralizer is soluble (or a finley dispersed solid powder), if added downstream from the slug it will simply continue to move along as a second slug ahead of the hazardous chemical slug and thus will not be very effective.



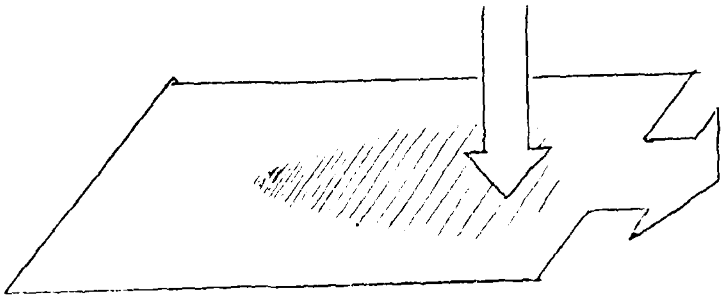
A. Still Water



B. Still Water



C. Flowing Water



D. Flowing Water

FIGURE 6–10 NEUTRALIZING AGENT PATTERNS FOR STILL/FLOWING WATER

6.4.2.2.9 Deployment -- Aeration

Similar considerations apply to the deployment of aeration as a spill "neutralizer." Compressed air lines and tank air and oxygen are all appropriate oxygen sources. Ozone is *not* recommended since it is a dangerous chemical itself and sterilizes water. Bubble barriers can also be deployed as effective aerators. In still water the bubbling should be deployed across the discharge; in flowing waters, downstream from the discharge. In the latter case, since bubbling continues as the discharge passes through the treatment areas, the remarks on neutralizers made above are *not* applicable. Because of the slowness of COD/BOD oxygen uptake, aeration should be deployed at some considerable distance around or downstream from the discharge site (Figure 6-11); otherwise the water will become oxygen-depleted again after the bubbling zone has been passed.

6.4.2.2.10 Recovery Techniques

If the products of chemical neutralization are harmless substances, no recovery is necessary; if they are soluble, recovery is impossible. Since only "safe" neutralizers should be used, recovery of any excess neutralizer should not be necessary.

6.4.2.2.11 Associated Problems

The addition of calcium or magnesium-containing neutralizers (say, for acid spills) will make the waters "hard." This should be a temporary condition, however, unless the waters are naturally "hard."

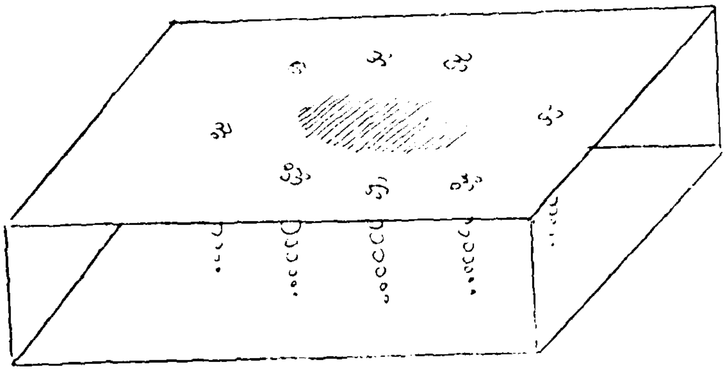
The addition of a large excess of any insoluble neutralizer could be harmful to benthic (bottom dwelling) life by physical burial. It could also temporarily increase water turbidity.

6.4.3 Absorption

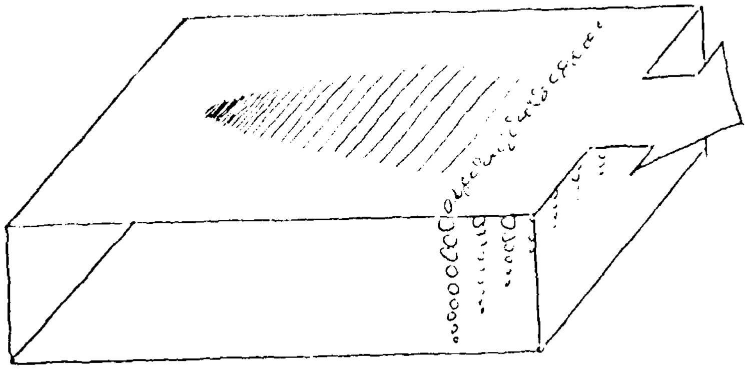
Recovery operations with sorbents fall into five major steps:

(1) Sorbent distribution
(2) Chemical-sorbent collection
(3) Chemical-sorbent separation,
(4) Chemical storage and/or disposal, and
(5) Sorbent reuse and/or disposal.

Each of these steps is discussed below.



Still Water



Flowing Water

FIGURE 6–11 DOWNSTREAM AERATION TECHNIQUE

Specific considerations are given. However, because of the numerous variables involved, detailed instructions that would cover all possibilities cannot be given. If commercial sorbents are to be used, be sure to check the manufacturers' instructions.

6.4.3.1 Specific Considerations: Sorbent Distribution

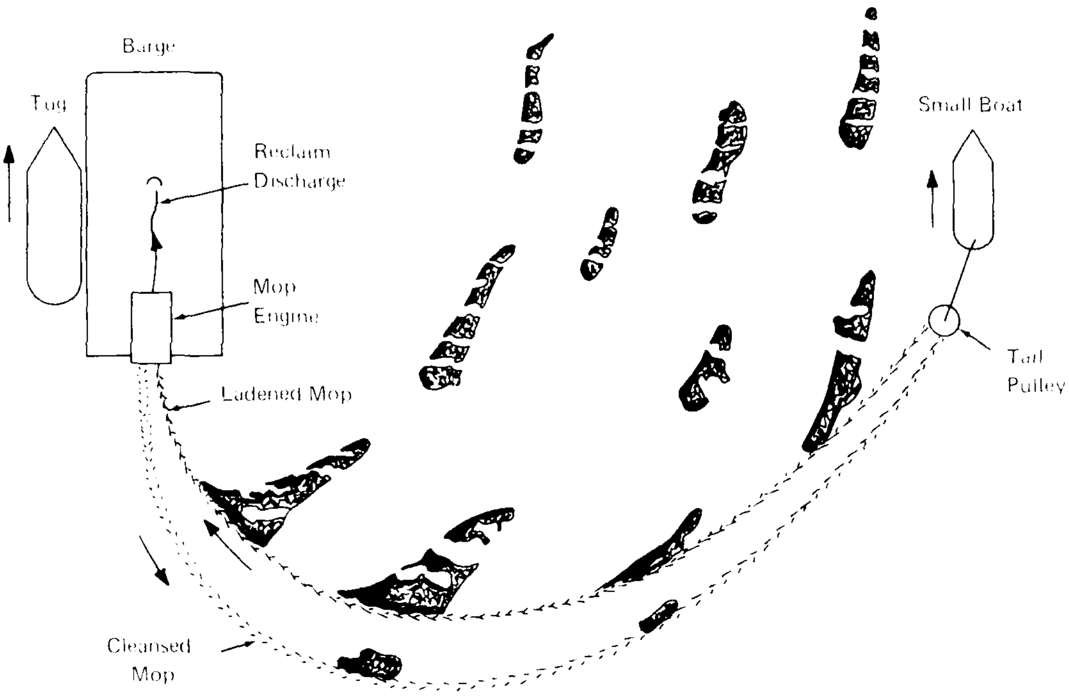
The manner of sorbent distribution (step I) depends on the discharged chemical, the size of the discharge, the circumstances, and the physical form of the sorbent to be employed. In the case of small slicks, sorbent mops can be deployed with lines from ship or shore. In the same way for small discharges, sorbent fibers, chips, and small sheets can be applied or removed by pitchforks or other available hand tools. Sorbent hand mops can be used in the same way. These procedures, it should be noted, are best applicable for small discharges, relatively inaccessible areas, and the final cleanup of the residue that has escaped heavier cleanup equipment such as skimming. Various types of blowers, such as those used by highway construction crews for seeding highway medians, shoulders, and banks have been used quite effectively to distribute hay and other sorbents over the water. Sorbent foams and threads, generated *in situ*, can also be sprayed on the water.

Sorbent sheets are effective, again for small hazardous chemical discharges, and can be effectively deployed from a small boat. The sorbent material may be fashioned of fibrous or chip sorbent which can be contained in an inert material to form a pillow. The covering of the containing material must give free passage to the chemical. In the case of water-insoluble liquids, such as oil, the mesh size must be large, but in the case of the sorption of dissolved chemicals on activated charcoal or ion exchange resins the mesh can be smaller. However, to ensure maximum absorbency of the active material, the containment configuration should be so designed that none of the active material is an extensive distance from the container "walls."

Very elongated pillows can be connected to one another and used as a sorbent boom. Another type of sorbent boom is the rope mop. Figure 6-12 shows how such a device is deployed.

6.4.3.2 Specific Considerations: Chemical-Sorbent Collection

CAUTION Remember that the recovery and handling of chemical-saturated sorbents in sheet and other forms can be hazardous and cumbersome and these difficulties should be anticipated in advance and suitable handling provisions provided.



In open water operations the oil mop system is rigged on a barge with tugs as indicated. The barge supports the mop engine, provides reclaim storage, and supplies perpendicular motion to the mop across the slick. A smaller tug tows the tail pulley in unison with the barge and mop engine. The mop engine draws the mop in a continuous circling motion to reclaim the oil as the mop is exposed to the oil. As the tug tows the system slowly across the slick, a "swath" as wide as the distance between the mop engine and tail pulley is cut through the oil slick. If it is a wide slick, the tow travels back and forth across the slick reclaiming swath after swath of oil until all of the oil is reclaimed.

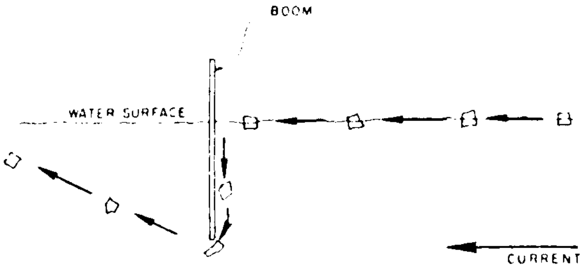
FIGURE 6–12 DEPLOYMENT OF A ROPE-TYPE OIL MOP IN OPEN WATERS
(Diagram Courtesy of Oil Mop, Inc.)

If they are to be recovered, good sorbents should float on the water's surface, even when saturated with the chemical. In moving water surfaces, floating sorbent pellets, fibers, granules, discs, and small sheets can be contained and their movement controlled by the use of surface nets, booms, etc. However, particularly if the current is fast, chemical-saturated sorbents and sorbent foams can be carried under a boom (Figure 6-13). Floating pellets can be drawn into a ship's sea water intakes to cause operating problems. Similarly, floating sorbents may escape pickup machinery (Figure 6-14). Some readjustment of boom and pickup machinery deployment may be necessary to minimize these difficulties. Also immediate application of pickup following saturation of the sorbents to avoid the accumulation of a large amount of sorbent should help. High areas, rapid water agitation, and/or ice can render effective sorbent deployment and make pickup difficult or impossible.

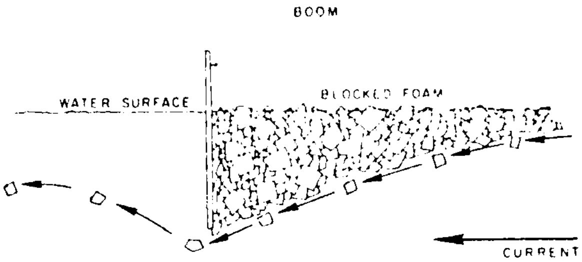
In some instances it may be unnecessary, impractical, and/or impossible to recover the sorbent chemical (step 2). If the sorbent is not recovered, then the sorbent material should either be inert or biodegradable. In the latter case, biodegradation should be sufficiently slow so that the rate of re-release of the contaminant is too slow to endanger the environment. The oil and oil-like substances on sorbent materials, because of increased weight and general messiness, can be far more difficult to handle than the deployment of the sorbents. One difficulty leading to recovery inefficiency has already been noted (see Figure 6-14). The contaminated sorbent can be recovered manually or by machine. Booms and other types of barriers can be used to control the movement of the sorbent and facilitate recovery. In addition to being picked up out of the waters the contaminated sorbent can be hauled in on ropes. In the case of a rope-type oil system, deployment and recovery represent a single operation. Skimmers may be used to pick up floating contaminated sorbents. If the sorbent is finely divided and suspended in the water column, filtration can be used. Heavier-than-water contaminated sorbent can also be settled out either in lagoons or in the body of natural water itself. In the latter instance, it may be desirable to remove the material from the bottom by dredging or some other such operation.

6.4.3.3 Specific Considerations: Chemical-Sorbent Separation

For void-space oil sorbents the chemical and sorbent are easily separated (step 3) by squeezing. For oil mops used in small operations, a single roller wringer can be used. It is important, however, that there be as little delay as possible between collection (step 2) and separation (step 3), because sorbents tend to release some of their oil by drainage (about 20% oil loss in 24 hours). This is readily accomplished by rope-type oil pumps where deployment, recovery, separation, and redeployment are all combined in a single continuous operation. Centrifugation can also be used as a separation technique: a commercial laundry extractor can separate about 80% of the oil out of the sorbent.

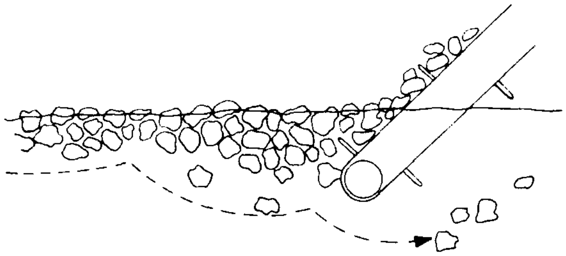


b) FOAM SWEEPING UNDER BOOM

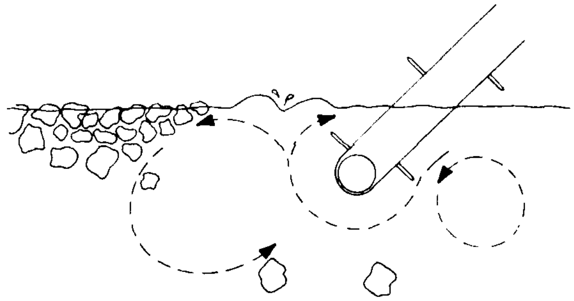


a) FOAM ROLLING UNDER BOOM

FIGURE 6–13 TWO POSSIBLE MODES OF FAILURE FOR FOAM SORBENT BOOM IN ABSENCE OF WAVES. (a) FOAM ROLLING UNDER BOOM, (b) FOAM SWEEPING UNDER BOOM (From J.P. Oxenham et al., Proc. Joint Conf. Prev. Contr. Oil Spills, EPA-API USCG, Washington, D.C., 1973)



a) Harvester moving too slowly.



b) Harvester moving too fast.

FIGURE 6–14 POSSIBLE MODES OF HARVESTER FAILURE
(From J.P. Oxenham et al., Proc. Joint Conf. Prev. Contr. Oil Spills, EPA, API, USCG, Washington, D.C., 1973)

Special methods are required to regenerate special sorbents. Activated charcoal can sometimes be regenerated by heating, while ion exchange resins (similar to the types used in commercial water softeners) can be regenerated by exposure to concentrated salt solutions.

6.4.3.4 Specific Considerations: Disposal and/or Reuse of Chemical and Sorbent

If the contaminated sorbent is recovered, one must face the problem of disposing of the chemical whether or not the chemical and sorbent are separated (steps 4 and 5). If the chemical and sorbent are separated, then facilities must be provided for the temporary and perhaps long-range collection and storage of the chemical and final disposal by some such technique as barrel storage, burial, burning (discussed elsewhere), or chemical treatment. Most large urban areas will have waste oil rerefining companies which may accept collected oil from discharges. Some ports will have waste oil collection tanks which may be available for use. The failure to separate chemical and sorbent simply adds to the bulk of the material and thus increases the disposal problem. The most ideal situation is the one in which the sorbent can be regenerated for re-use. One ingenious solution to the problem of the disposal of the sorbent might be mentioned in passing: void-space oil sorbents are most effective for heavier oils and one manufacturer has developed a sorbent which, with gentle warming, can simply be dissolved in low-weight petroleum. The petroleum is thereby downgraded, but it is not preempted for other uses.

6.4.3.5 Sorbent Materials

Many sorbent materials are available. They are capable of sorbing a great range of chemicals ranging from oil to poisonous salts or deadly gases. Their action mode ranges from simple surface absorption to specific chemical reactions (in the case of ion exchangers). Three areas that have received the most attention are:

(1) Oil sorption from natural waters,

(2) Sorption (from the gas phase and the liquid phase) on activated charcoal or other porous solids, and

(3) Metal ion sorption on ion-exchangers in effluent treatment.

Considerable experience exists in the cleanup of oil discharges with sorbents. Sorbents are most effective for:

(1) small- to medium-size discharges,

(2) final-stage cleanup of the remaining thin film left by skimmers,

(3) use "under" conditions where skimmer and/or boom use is restricted (under wharves and in inaccessible places and/or in the presence of a great deal of debris and/or ice, and in high sea states), and

(4) mop-up of dirtied beaches or shore lines.

Common straw is a popular oil sorbent; however, it may coat and sink and its oil-holding capacity is much less than some of the better synthetic sorbents (Table 6-2). A good sorbent ("binder") picks up oil strongly 20 to 60 times it weight in oil and picks up water weakly; straw picks up between 8 to 30 times its weight in oil (see Figure 6-15). The oil is taken up not only by surface sorption, but also by entrapment in voids such as pores and/or capillaries. As a consequence of the latter, oil sorbents work best on heavy, highly viscous oils (Figure 6-15) and their performance on lighter oils or more freely flowing water-insoluble organic liquids can be poor. They can pick up water-in-oil emulsions, but the effectiveness is low for oil-in-water emulsions. The pickup time of a good sorbent is fast (less than 1 minute.) It should also be storable for extended periods of time. Most oil sorbents will lose oil by evaporation and drainage; roughly about 80% of the oil will be retained after draining for 24 hours, but "Kraton" (Figure 6-15), a modified rubber dissolves oils, and thus has a much higher retention. Another sorbent "Sorb-Oil," made from recycled paper, is reported to sorb, in addition to oil, a number of organic chemicals, including n-pentane, carbon bisulfide, acetone, methyl alcohol, n-hexane, trichloroethane, carbon tetrachloride, ethyl ether, ethyl alcohol, benzene, cyclo-hexane, isopropyl alcohol, trichloroethylene, n-propyl alcohol, n-hextane, dioxane, toluene, epichlorohydrin, tetrachloroethylene, chlorobenzene, furfural, phenol, and methyl ethyl ketone, some which are water-soluble. Absorbents that act as sinking agents are discussed in Section 6.4.4.2 and absorbents that act as burning aids in Section 6.4.1.

Sorbents are available in a number of physical forms (Figure 6-16):

(1) powdered, granular fibers, and pellet material,
(2) chips,
(3) pillows,
(4) mops,
(5) sheets,
(6) ropes, sausages, and brooms,
(7) belts.

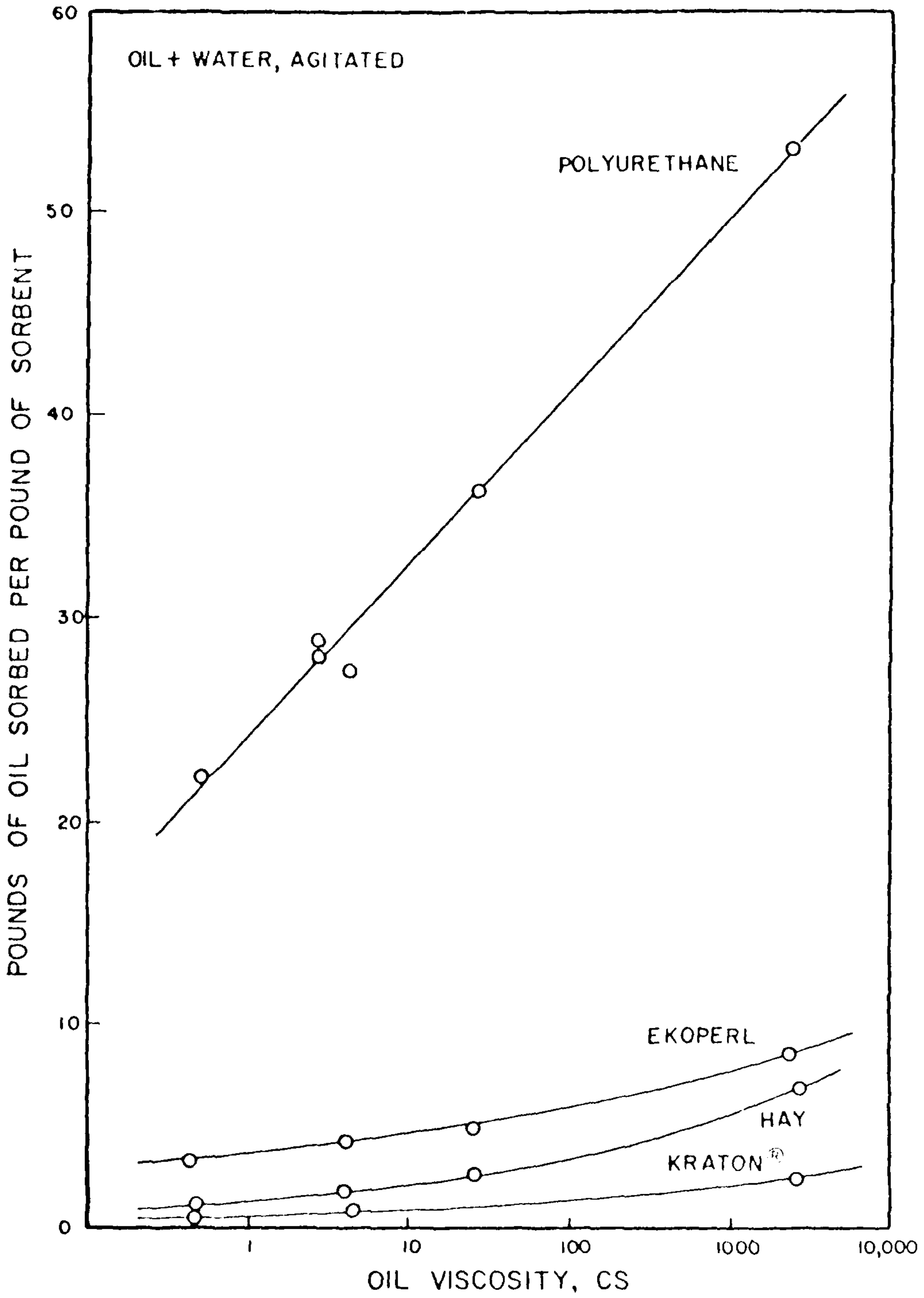
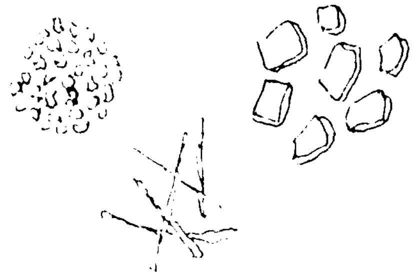
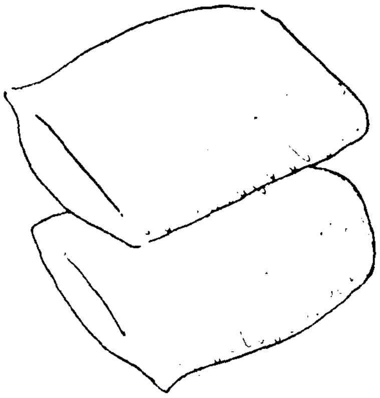


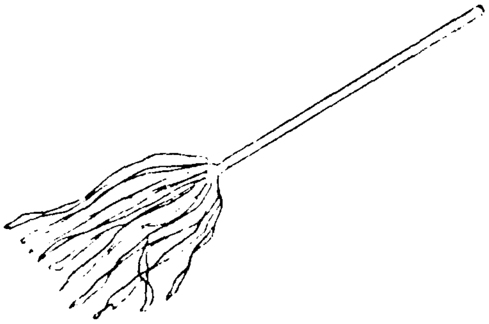
FIGURE 6–15 SORPTION OF OIL BY TYPICAL SORBENTS
(From E.A. Milz, Paper Presented 21st Ann. Pipe Line Conf. A.P.I. Div. Trans.) Dallas, Texas, 1970



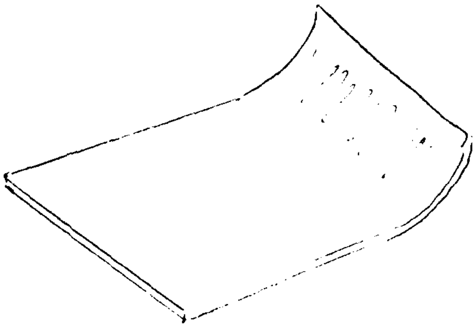
Pellets, Fibers, Granular and Chips



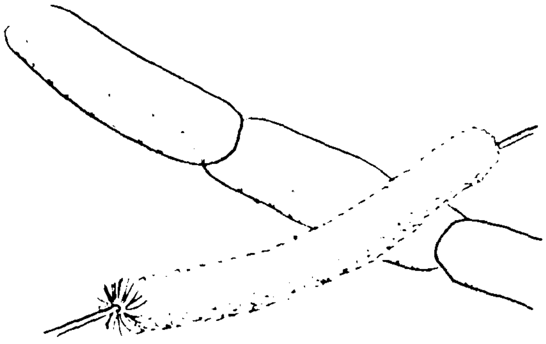
Pillows



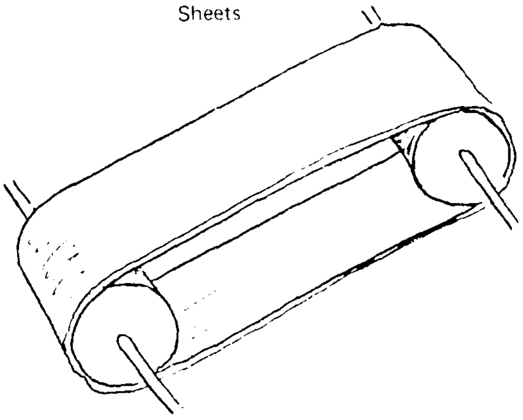
Mops



Sheets



Ropes, Sausages, and Booms



Belts and Skimmers

FIGURE 6–16 VARIOUS PHYSICAL FORMS OF SORBENTS

TABLE 6-2

SORBENTS

Mineral Products*	Vegetable Products	Synthetic Products
Perlite	Straw	Polyurethane
Talc	Hay	Polystyrene
Vermiculite	Sawdust	Polyester Plastic Shavings
Clays	Bark	Urea Formaldehyde
Volcanic Ash	Peat	Resin Type Foams
Chalk	Kelp	
Fly Ash	Corncob Grindings	
Carbon Powder	Modified Wood Fiber	
Activated Carbon		

*Many of these are also used as sinking agents

Since the large volume of "oil sorbents" makes for bulky material with its attendant storage and handling difficulties, the feasibility of on-site sorbent preparation is being investigated. The form used depends on the nature and circumstances of the hazardous chemical discharge. Mops, pillows, chips, and small sheets are useful in cleaning up small discharges, while ropes, sausages, and brooms have been used effectively to contain as well as cleanup discharged chemicals.

6.4.4 Other Methods of Treatment

6.4.4.1 Emulsifiers and Dispersants

CAUTION: Try to contain, collect, remove, and/or neutralize highly toxic chemicals. Do not try to disperse them (in contrast to dilution) since this will spread the damage. Commercially available emulsifiers and dispersants differ with respect to their composition. Therefore, it is important to become familiar with any handling directions on the particular material intended for use. In the absence of specific directions, the general information that follows may be used as a guide

6.4.4.1.1 Guidelines

Emulsifier and dispersant chemicals are usually available in liquid form and, in general, they can be applied to the insoluble-liquid contaminated waters in three ways:

1) Spraying from aircraft,
2) Manifold spraying from ships, or
3) Hose spraying from ship or shore.

Inasmuch as broad distribution and vigorous mixing are essential for the effective application of these chemicals, if some kind of spraying equipment is *not* available, no attempt to deploy these chemicals should be made, and by no means should they be dumped or poured into the water.

The dispersant should be applied to the slick as quickly as possible after the hazardous chemical discharge in roughly 1 part of dispersant to 10 to 50 parts of discharged chemical (depending on the dispersant and the thickness of the slick). The dispersal of the slick should become evident a few minutes after the application of the dispersant. The dispersant can be sprayed from an aircraft in an operation similar to crop-spraying. If a helicopter is available, downdraft from its blades will supply some of the necessary mixing energy. This is particularly important if the waters are calm. If applied from a vessel, some premixing can be effected by diluting the dispersant with water in an educator pump before application through high-pressure spray nozzles affixed to booms. The dispersant should be applied ahead of the bow wake to take advantage of mixing in the wake. High-pressure (100 psi) fire hoses and various other types of hand and machine pumps can be used to apply the dispersant either from ship or shore. The ship's wake and the action of its propellers will help some in agitation (maximum speed about 7 knots), but mixing is so essential that the best results are obtained by also towing an agitator.

Hand spraying of dispersants can also be used to clean up beaches, rocks, and tidal pools.

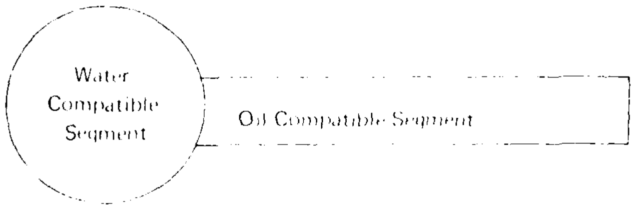
6.4.4.1.2 Background Information

When discharged in natural waters, lighter-than-water, non-soluble liquids and other oil-like chemicals will be dispersed. The rate of dispersal depends on the chemical, currents, sea-state, meteorological conditions, and other environmental circumstances, and commonly is so slow that the discharge may cause extensive damage before it disperses. In the case of crude petroleum a highly stable and persistent emulsion can be formed — sometimes described as "chocolate mousse" — which can cause extensive damage to beaches and other property. The rate of dispersal of oily slicks can be greatly accelerated by the application of emulsifying agents, while the troublesome aggregated stable emulsions can, in turn, be dispersed by commercial detergents. In either event the successful application of chemical dispersants depends on vigorous agitation of the contaminated water. Thus this response is only applicable to situations, such as the open sea, where there are strong water currents and other mixing factors.

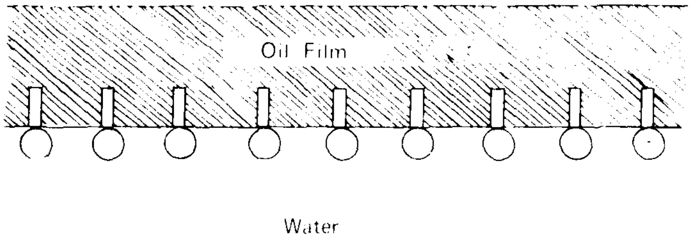
In the Torrey Canyon disaster, 15,000 tons of dispersant were used to treat 75,000 tons of oil, and because the dispersants used were toxic, many observers felt that the response did more ecological damage than the oil would have done. A few experts continue to be uneasy about the massive application of dispersants because they do not remove, but only spread, the contamination and make the toxic chemicals more available (and in higher concentrations) to marine life. However, the majority opinion now seems to be that by spreading the contaminant and increasing its state of subdivision, dispersal hastens its removal by natural processes, and dispersants have been developed which, when properly applied, are not highly injurious to biota.

Dispersants are chemical surfactants, the molecules of which have an oil-compatible segment and a water-compatible segment (Figure 6-17A). At an oil/water interface these molecules arrange themselves with the former segment in the oil layer and the latter in the water (Figure 6-17B). In the case of oil droplets (Figure 6-17C), this results in the enveloping of the droplets with an oil-repulsing zone, thus repelling other droplets and preventing coagulation. Initially the dispersant tends to break up the oil slick and promote droplet formation because of its surface tension-altering characteristics.

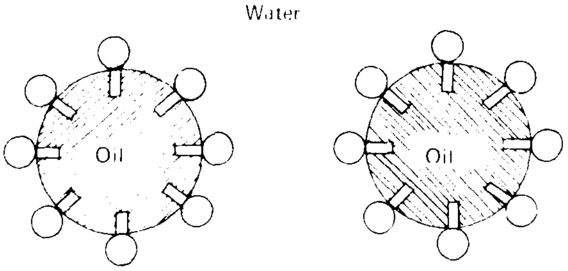
It should be noted that, because they are organic chemicals, dispersants make a chemical and/or biochemical oxygen demand (COD and/or BOD) on the waters in which they are deployed. In addition to its effectiveness a good dispersant should contain no phosphates, halogens, or heavy metals, and it should be readily biodegradable. Its flash point should also be high so that it does not represent a fire hazard.



A. Molecule of an Emulsifying Agent



B. Emulsifying Agent at the Surface of an Oil Film



C. Coagulation of Oil Droplets Prevented by Emulsifying Agent

FIGURE 6-17 HOW DISPERSANTS WORK

6.4.4.2 Sinking Agents, Coagulants, and Flocculants*

Sinking agents, coagulants, and flocculants are used for *transforming dissolved chemicals and chemicals suspended* in the water column so that they will *settle to the bottom.*

6.4.4.2.1 Sinking Agents

There are no established guidelines for the use of sinking agents in response to the discharge of a hazardous chemical. Procedures, agent selection, quantities of application, and the like, should be worked out by qualified personnel at the discharge site.

Sinking agents, generally speaking, are finely divided, heavier-than-water absorbents. They absorb the hazardous chemical, usually oil, and carry it to the bottom where it is then destroyed by bacterial and other natural processes. The suggestion has been made that sinking agents might be inoculated with bacterial cultures to hasten the removal of some pollutants on the bottom. Expert opinion differs as to the effectiveness of sinking agents for removing oil slicks. The settled material may be injurious to fish and benthic organisms. Difficulty has been experienced in the rerelease of the pollutant from the settled material; oil thus released rises to the surface and can reform a slick. The method does not sink all of the oil, only about 50%.

The French tried to sink the Torrey Canyon spill with finely ground Champagne chalk. They experienced so much difficulty in dispersing this material, however, that instead of applying the estimated 1 part of chalk to 6 parts of oil, in practice they found they had to apply 6 parts of chalk to 1 part of oil.

In addition to chalk, other sinking agents include treated and untreated sand, carbon powder, kaolin, calcite, and other mineral substances, treated ground fuel ash, and the gypsum residue from the manufacture of phosphoric acid. The last material has the advantage of "settling" in seawater and forming a fairly hard cake on the sea floor, thus preventing the release of the oil pollutant.

6.4.4.2.2 Precipitation

There are no established procedures for the use of a precipitation reaction in response to the discharge of a hazardous chemical. Virtually no experience with such undertakings has been recorded, and thus this approach to amelioration should only be considered when the chemical discharged is extremely toxic and

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*For a supplier listing of coagulants, flocculants, and sinking agents, see Appendix D.

presents an imminent hazard. Detailed planning, considering all phases of such a procedure and the likely results and consequences, must be carried out. Prior to the incident the advice of a qualified chemist is necessary.

Precipitation can be defined as the removal of a water-soluble chemical by the addition of a chemical with which it forms a new stable insoluble substance. For example, the addition of common salt to silver nitrate would precipitate silver chloride to the bottom:

$$\underbrace{(\mathrm{Na}^{+} + \mathrm{Cl}^{-})}_{\text{common salt}} + \underbrace{(\mathrm{Ag}^{+} + \mathrm{NO}_3^{-})}_{\text{silver nitrate}} \rightarrow \underbrace{(\mathrm{AgCl}\downarrow)}_{\substack{\text{insoluble}\\ \text{silver}\\ \text{chloride}}} + \underbrace{(\mathrm{Na}^{+} + \mathrm{NO}_3^{-})}_{\text{harmless}}$$

6.4.4.2.3 Coagulants and Flocculants

There are no established procedures for the use of coagulants and flocculants to ameliorate the discharge of a hazardous chemical; no experience with such undertakings has ever been recorded to our knowledge. Additionally there are no universal rules or guidelines for the use of these procedures in the waste water treatment field; the final "formula" at each treatment plant is often arrived at by trial and error, and that formula may be quite different from the one arrived at by a similar treatment plant elsewhere.

If this procedure is deemed necessary to remove a hazardous chemical (in collodial form) in water, then the steps given below may be used as a general guide. Efforts should be made to obtain more detailed instructions from such sources as:

- labels on the containers of the discharged chemical,
- labels on the containers of the coagulants or flocculants,
- nearby industrial or municipal waste water treatment plants, or
- water treatment engineers.

Step 1 After consultation with sources (as listed above), select and obtain a sufficient quantity of one or more* coagulants and/or flocculants. Economics and availability will also have to be considered in the final choice. Most all [illegible] agents sold are in dry form.

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* Some waste water treatment plants will use only one chemical, others may use up to five chemicals.

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Step 2 – Prepare the agent(s) for dispersal. They may be applied in dry form or in a premixed water solution. The dispersal equipment available may govern this choice. If more than one agent is to be used, they may be mixed together.

Step 3 – Disperse the agent(s) in the discharge site evenly over the whole area, adding between 10 and 50 grams of the agent (dry weight) for each cubic meter of water to be treated.

Step 4 – Mix or agitate the water *vigorously* for about one minute immediately after the addition of the agents; then follow up with gentle mixing for an additional five minutes.

Step 5 – Allow the coagulants and/or flocculants to settle.

6.4.4.2.3.1 Background Information

Coagulants and flocculants are, in a sense, related to both absorbents and precipitants. They act to coagulate and then precipitate colloids (matter *suspended*, but not dissolved within the water column) and are used in industrial waste water treatment systems. Coagulants are materials which encourage aggregation, such as precipitation and/or flocculation (and are the opposite of dispersants), while flocculants are materials which precipitate themselves and, in so doing, scavenge out and bring down with them other substances, notably pollutants. Alum (potassium aluminum sulfate), the most widely used, is commonly used as a water-treatment chemical. Other coagulants and flocculants given are:

Coagulants	**Flocculants**
Bauxite (aluminum sulfate),	Aluminum ammonium sulfate,
Ferrous sulfate,	Bentonite,
Ferric sulfate,	Calcium carbonate,
Sodium aluminate, and	Carbon dioxide,
Hydrated lime or quicklime.	Sodium silicate, and
	Synthetic acrylic polymers.

The study of coagulation and the formation of flocs is one of the most important subjects in applied colloidal chemistry. They represent a considerable technology, especially in the field of water treatment. However, this technology has rarely been applied to the problem of hazardous chemical discharges in natural water bodies. The physical chemistry of floc formation is highly complex, involving the electrostatics of charge distributions near and on particles and their surfaces, and can be strongly affected by factors such as acidity (pH) and the presence of salts. The behavior of a coagulant can be quite different in fresh, brackish, and sea water.

A special type of coagulation has been proposed to clean up oil discharges - namely, gelatinizing - but no practical use has been made of this suggestion.

The greater the state of subdivision of sinking agents, coagulants, and flocculants, the greater is their effectiveness. Sufficient chemical should be spread in a single pass. A rotating disk-type granular fertilizer spreader can cover strips 50 to 100 feet wide, but this device does not work well for smaller particles and not at all for fine powders. The wind can help in spreading fine powders, but its assistance is unreliable. Crop-dusting techniques from airplanes or helicopters are applicable. In the case of sinking agents treated with surfactants, they will spread upon the water, even if dumped from shipboard. When fine powders are distributed from a ship, the vessel must be navigated in such a way as to keep it out of its own dust cloud. The ship's wake and other water movement help to distribute the powdered agent; however, if too great agitation is sustained, it will impede the coagulation and flocculation processes, prevent settling, and keep the hazardous chemical in suspension.

6.4.4.2.4 Recovery From the Bottom of Chemicals That Have Bee Treated With Sinking Agents

The river beds of heavily traveled inland waterways, harbors, and coastal areas have been found to have a top layer of accumulated organic silt which is mixed with industrial pollutants that have been generated from industrial waste discharges. Serious consideration is being given to removing this spoil material to ease the adverse impact of such objectional deposits. Such action would entail extensive dredging operations in most of our navigable waterways (at least around metropolitan areas). A similar situation would be experienced in a specific area when a heavier-than-water chemical discharge occurs, or when sinking agents, coagulants, and flocculants, etc., have been used to sink a hazardous chemical. Depending on the toxicity of the chemical, a decision must be made either to leave it in place or remove it by dredging. Should a decision for removal be made, surficial sampling of the bottom would be necessary, using a small grab sampler, to determine the area of underwater pollution. Following this action, suction dredging techniques should be applied to recover and safely dispose of the chemical. Suction dredges are recommended since other dredge types that use wire-line bucket techniques are chronic polluting causes in that they rile the bottom on impact and are prone to material "boil-out" during the rise to the surface. Such action would reactivate the suspension of the chemicals in the water column. Both equipment and general advice on dredging may be obtained from the U.S. Army Corps of Engineers.

6.4.4.2.5 Problems Associated with the Use of Sinking Agents, Coagulants, and Flocculants

The main problems associated with water treatment with finely powdered sinking agents, coagulants, and flocculants are:

1) Handling and distribution of fine powders,
2) Burial of benthic organisms,
3) Escape of the pollutant, and
4) Removal of deposits from the bottom.

Protection of personnel from fine powders and cleanup afterwards of the ship and spreading area are further considerations. When the sediment and hazardous chemical are removed from the water, they then present a disposal problem, especially if the volume is large. Ocean-dumping of such contaminated sediments in dredge spoil or hazardous chemical areas is perhaps preferable but not above criticism. Lagooning and burial leave a persistent danger of the escape of the chemical by leaching, or by flooding and other accidents and catastrophes, while, on the other hand, incineration of sediments contaminated with hazardous organic chemicals could produce air pollution. Then too, the removal of the contaminated sediments by dredging or other techniques, if not carefully performed, could result in a resuspension of the hazardous chemical in the water column. Unless there are very compelling reasons for the removal of the polluted sediments, in order to avoid compounding the hazard, it is often just as well to let it lie on the bottom and to accept the damage to local benthic life and that caused by slow leaching into the water column. However, the possibility of accelerated transfer into the water column and into biota in a predation food chain must not be overlooked. For this reason, following the discharge and its cleanup, the level of chemical in the biota, much more so than in the water column or even the sediments, should be carefully monitored.

6.4.4.3 Biological Degradation of Chemicals

Biological degradation is *not an emergency response procedure*. This process is discussed in this Handbook because it is one way in which nature may take care of the discharge. Procedures for initiating this process have not been developed to the point where they can be considered for use during an emergency.

6.4.4.3.1 Background Information

The list of hazardous chemicals may be divided into two general groups organic chemicals and inorganic chemicals. While micro-organisms in the aquatic environment will take up some inorganic chemicals from the surrounding water, the quantities absorbed are low. Therefore, discharged inorganic chemicals tend to stay in the water for long periods of time. On the other hand, many organic chemicals are consumed by micro-organisms and may be removed from the water over a period of time by this biological degradation.

Organic chemicals in the environment (whether from an accidental discharge or from natural sources) are decomposed by natural processes which depend principally on the activities of micro-organisms, such as bacteria, yeast, and molds. The organics are consumed by micro-organisms as food and are either metabolized to carbon dioxide and water or used to build additional cell mass. Once the organic chemical is consumed, the organisms either die and add to the nutrient levels in the environment or enter the food chain of successively larger animal species.

Biological degradation is at best quite slow. Under laboratory conditions, organisms can rapidly decompose organics, but the degree of oxygen transfer, agitation, nutrients, and temperature control attainable in the laboratory cannot be duplicated in the natural environment. This is particularly true for relatively insoluble organics on the surface of the water; the interface between the organic chemical and water (where the micro-organisms concentrate) limits the rate of oxygen and nutrient transfer.

Many suggestions have been made to enhance the speed of action of microbial decomposition. These suggestions have included the addition of bacterial species that have been especially selected for rapid attack on certain organic chemicals, the addition of inorganic nutrients (such as nitrogen and phosphorus compounds) and the provision of additional oxygen by aeration devices.

In lakes, rivers, estuaries, and bays there are usually sufficient inorganic nutrients and a large number of micro-organisms so that microbial degradation of discharged organic chemicals is readily initiated. In these locations, the factor limiting decomposition of the organic materials is usually insufficient oxygen in the water. To overcome the oxygen deficiency, floating aerators or submerged air distribution devices can be employed (see Section 4.4.2). Increased oxygen will not only speed up oxidation of the organic materials, but may prevent injury to fish and other aquatic life due to depletion of dissolved oxygen in their environment.

Addition of special cultures of bacteria is difficult to justify on theoretical grounds in areas such as estuaries and harbors where large diverse microbial populations exist. Furthermore, the practical problem of maintaining stocks of specialized bacterial cultures to attack several hundred possible organic compounds is so burdensome that reliance must be placed on the naturally occurring micro-organisms.

Likewise, addition of inorganic nutrients is usually unnecessary except in the open ocean. Therefore, the only practical method of enhancing microbial biodegradation of hazardous organic chemicals in the water environment is to add oxygen by aeration.

Some other corrective responses, such as skimming, sinking, burning, or dispersion, leave varying quantities of the organic material in the water. Removal of the remaining material depends ultimately on the natural biological degradation caused by the metabolic activity of yeasts, bacteria and molds. If the organic material is spread through a swamp or bog, much of the cleanup must be left to natural biodegradation, as other methods may not be suitable. Where cleanup can be left to natural biodegration or to degradation enhanced by aeration, the method has the advantage of not introducing additional materials which might be environmentally damaging, such as dispersants, neutralizing agents, or fire into the cleanup.

The principal disadvantage of biodegradation, or even enhanced biodegradation, is that it is a relatively slow process. With some organic materials the decomposition rate is so slow that the materials are considered nonbiodegradable. Nevertheless, most of the water-soluble organic compounds and many of the relatively insoluble compounds will gradually degrade and hence be eliminated from the water environment.

6.4.4.3.2 Factors Affecting Biological Degradation

In any natural aqueous environment, indigenous or inoculated microbial strains will decompose many organic chemicals either by aerobic or anaerobic metabolic processes, depending on the availability of oxygen. The most effective of these is aerobic degradation; the anaerobic processes are much slower. The oxygen concentration in a body of water depends on: (1) temperature (oxygen solubility decreases with increasing temperature), (2) biochemical oxygen demand (the biological load in a localized area which consumes the oxygen), (3) re-aeration (the rate of oxygen transfer across the air-water interface), and (4) diffusion (the resupply of oxygen through the water phase).

Open water normally has sufficient oxygen concentration in the surface layers. However, some rivers and lakes may have critically low oxygen concentration levels because of their high temperature or because of oxygen depletion by industrial waste and municipal sewage. Furthermore, except in well mixed environments or shallow water, oxygen is generally more abundant near the surface of the water. Thus, decomposition will proceed faster on the surface than on the bottom.

Depending on the available oxygen concentration, micro-organisms use organic chemicals either (1) to produce a new cell matter or (2) to metabolize it into carbon dioxide and water. It takes approximately two pounds of oxygen to convert one pound of hydrocarbon to new cell matter and more than three pounds of oxygen to convert a pound of hydrocarbon to carbon dioxide and water. As microbial activity increases, the comparatively small amount of oxygen dissolved in the water will be depleted, and the rate of decomposition will then depend on the rate of oxygen resupply. Resupply rates depend on (1) the depth of the receiving body of water, (2) the temperature, (3) the wind velocity, and (4) the level of oxygen dissolved in the water. In a 7-mph wind, typical resupply rates are approximately 40 pounds of oxygen per acre-day. Thus, the long-term rate of decomposition of hydrocarbons by microbial processes would be limited by oxygen availability to approximately 13 to 20 pounds of hydrocarbons per acre-day (approximately 0.0001 inch of hydrocarbon from a surface layer per day). More highly oxygenated compounds, such as glucose, require about one-fourth as much oxygen but decomposition still would only be a maximum of 80 pounds per acre-day.

Whichever process the oxygen level dictates, microbial degradation will depend additionally on the following parameters:

- *Presence of Suitable Micro-organisms* Many different micro-organisms are required to consume the various types of organic chemicals which may be present in a particular discharge. These organisms are widely distributed in nature and are especially prevalent in areas exposed to frequent organic chemical discharges. They multiply rapidly when sufficient nutrients and carbon sources are available. The inoculation of an area with specific micro-organisms might initially speed the decomposition, but the presence of the right organisms often may not be the limiting factor to the overall rate of decomposition.

- *Types of Organic Chemicals* - In general, organisms readily attack water-soluble carbohydrates, alcohols, esters, acids, etc., and more readily attack straight-chain hydrocarbons than naphthenic or aromatic hydrocarbons. Although hydrocarbons are generally considered to be insoluble in water, straight-chain hydrocarbons up to C_{18} have a solubility greater than 6 parts per billion. This concentration is sufficient to allow good sorption by the micro-organisms. It also allows them to grow at a rate sufficient to utilize the oxygen available in most natural water environments. The hydrocarbons of higher molecular weight are very insoluble and thus are consumed more slowly.

- *Temperature* As the temperature rises, the metabolic activity of micro-organisms increases but the concentration of oxygen in the water decreases. The net effect is normally an increase in the overall rate of decomposition. Even at the low end of the temperature range, however, experiments indicate that significant rates of decomposition will occur if sufficient oxygen and nutrients are available.

- *Concentration of Inorganic Nutrients* -- Nitrogen and phosphorus in significant quantities and in a form available to micro-organisms are needed for the utilization of organic chemicals. These nutrients are usually present in most aquatic environments, except in the upper layers of the open ocean, where the small concentrations of phosphorus and nitrogen limit the rate of microbial activity. The total phosphorus content near the surface of the Atlantic Ocean has been shown to be less than 0.003 milligram per liter. Since bacteria are approximately 2% phosphorus, this level of phosphorus in the ocean would support a bacterial concentration of only 0.15 milligram per liter.

- *Water pH* -- Except in spills of acids or bases or near the effluents of certain industrial operations, the pH of the water in most environments is in the range needed for rapid growth of micro-organisms.

6.5 Clean Shoreline

6.5 CLEAN SHORELINES*

Potential Methods

- Cleaning hard surfaces (page 6-97)
- Mechanical removal of the chemical (page 6-98)
- Restoration and Disposal (page 6-99)

The use of *detergents or surfactants* for cleaning shorelines is *not acceptable.*

6.5.1 Cleaning Hard Surfaces

6.5.1.1 Steam and Hot Water Cleaning

Steam and hot water cleaning from a surface craft or by using a portable steam or hot water generator is a proven method for removing oil and other contaminants from rocks, cliffs, piers, and other surfaces. Detergents should not be added to the water being applied. This cleaning procedure drains the contaminant back into the water body. Floating booms or other containment devices should be deployed to entrap the resulting slick effectively for eventual recovery and disposal.

6.5.1.2 Abrasive Blast Cleaning

Abrasive blast cleaning has been used on rock, cement, and other hard surfaces. It should not be used on wood surfaces since the force of the jet and the abrasive will cut into the wood and thus weaken any supporting structure. There are two types of blast cleaning: wet and dry. The dry method raises considerable dust which creates a severe health hazard to the machine operator and nearby workers, especially if silica sand is used as the abrasive. There are two wet method systems. In the first system a premixed slurry of sand and water is fed through a hose to the dispensing nozzle. In the second method water is injected into the sand as it is dispersed from the nozzle. The operator of this equipment

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* Methods described in this section are, for the most part, derived from: Der, J.J., and Ghormley, E., "Oil Contaminated Beach Cleanup," Technical Note N-1337, Naval Ships Systems Command, Civil Engineering Laboratory, Port Hueneme, Cal., April 1974.

should be equipped with full protective clothing, including complete coveralls (generally leather), gloves, and a self-contained, air-supplied protective helmet. As with steam and hot water cleaning, containment booms should be applied around the blasting area, if the surface being cleaned is directly above the water. If the cleaning is conducted at low tide when the deris would fall on the beach or other solid surface, it can be physically removed before the tide returns to cause recontamination.

6.5.1.3 Hydraulic Dispersal

High-pressure water hoses, properly directed, can clean most any type of contaminated surface. Again booms must be deployed to contain the dislodged contaminant. Tide and wave action can, in some cases, be used to advantage as a beach cleaning method, if containment booms can be deployed beyond the breaker zone and surface skimmers are used to recover the resulting slick.

6.5.1.4 Burning

The burning of flammable deposits on rocks and other non-combustible surfaces using a high-intensity flame has not proven very successful. Severe spalling caused by the rapid heating may become hazardous to the operator and cause disfigurement of the material being cleaned. In addition, also the burning of oil and straw used to absorb the material on the beach itself has not proven very successful because of the excessive smoke and odor which ensue. Thus the technique has been discontinued.

6.5.2 Mechanical Removal

6.5.2.1 Mixing and Burying On-Site

Relatively heavy deposits of viscous materials that have not penetrated the sand can be removed by earth-moving equipment and buried in trenches away from the beach where natural biodegradation may eventually degrade the material. The probable behavior of the chemical after remaining buried for a prolonged period should be carefully evaluated before following this procedure.

Where the contamination of beaches is relatively light, but widespread, cleaning may be accomplished by promoting evaporation of the more volatile materials, enhancing biodegradation, and by diluting some materials to acceptable levels. This decontamination may be accomplished by the use of mechanical equipment, such as a harrowing plow or a beach-cleaning machine.

6.5.2.2 Sorption

Sorbents such as straw and sawdust (see Appendix A for other materials) may be used to soak up oil-like chemicals that are on the surface of the beach or at the water's edge and also from rocky pools or depressions. Straw has been employed more than other materials for collecting oil discharges. It performs most successfully, as do other sorbents when it is spread on the shoreline prior to the arrival of the floating oil (and perhaps other chemicals).

It is important that sorbents be properly harvested since, if carried back into the water by tidal action, they will lose their effectiveness and can foul the engine intakes of marine craft as well as pumps and filters of cleanup equipment.

6.5.2.3 Mechanical Equipment

Mechanical removal of contaminated sand and sorbents may be required when the contamination is relatively heavy. If the beach or shoreline is accessible to wheeled or tracked equipment, motorized graders, scrapers, front-end loaders, and bulldozers can be used to remove contaminated layers. Motorized elevated scrapers and wheeled front-end loaders are particularly useful for carrying the material to loading areas or burial sites. Wheeled vehicles are usually preferred over tracked equipment, because they are less apt to grind contaminated material into the sand.

A guide to the conditions under which various types of equipment may be employed is given in Table 6-3 and time estimates of cleaning rates are given in Table 6-4.

Other equipment, such as draglines, may be used to remove material that may not be otherwise accessible. Clam-shell buckets have been used, for example, to load contaminated material onto barges for transport to disposal sites.

6.5.3 Restoration and Disposal

The disposal of contaminated sand, gravel, and sorbents can generally be arranged through the nearest municipality and frequently by the contractor supplying the cleanup equipment. It generally is disposed of by burying at existing or specially prepared land fill sites. Great care must be taken, however, to ensure that the contaminant does not filter into the subsurface water reserves. Local environmental control agencies, as well as the Environmental Protection Agency, should be consulted on the land disposal of any hazardous chemical, including oil. For many chemicals other than oil, specialized disposal procedures may have to be developed at the time of cleanup.

TABLE 6-3

METHODS AND EQUIPMENT FOR CLEANUP OF SAND AND GRAVEL BEACHES*

(oil contamination)

Size of Area	Type of Oil	Depth of Penetration	Type of Beaches Fine Sand	Course Sand	Gravel
Large	Heavy	shallow (½ to 1 in)	Grader & ES**	Grader & ES	–
		moderate (1 to 9 in)	ES	ES	ES
		deep (> 9 in)	–	Bulldozer	WFEL*** or Bulldozer
	Light	–	Harrow plow or beach-cleaning machine		
Small	Heavy	–	Manual removal and replacement of sand		
	Light	–	Manual removal, rake		

*Taken from reference cited in Table 6-4.
**ES – elevating scraper
***WFEL – wheeled front-end loader, for firm ground only

TABLE 6-4

APPROXIMATE BEACH CLEANING TIME RATES FOR DIFFERENT TYPES OF EQUIPMENT*

Equipment	Approximate Rate (hrs/acre)
Combination of motorized grader and motorized elevating scraper	3
Elevating scraper	3
Combination of motorized grader and wheeled front-end loader	6
Combination of motorized grader and tracked front-end loader	30
Bulldozer	50

*Der, J.J., and Ghormley, E., "Oil Contaminated Beach Cleanup," Tech. Note N-1337, Naval Ships Systems Command, Civil Engineering Laboratory, Port Hueneme, Cal., April 1974.

Restoration of the shoreline after removal of the contaminated material may require expert help from marine biologists and environmentalists. Where sand or gravel may have to be replaced, the Corps of Engineers may be able to provide the necessary expertise and equipment.

6.6 Salvage of Waterfowl

6.6 SALVAGE OF WATERFOWL

Potential Methods

CAUTION: Gloves and other protection should be worn when handling the larger birds having strong legs and beaks.

Detailed procedures for treating waterfowl exposed to oil discharges have not been well developed, and there is little or no information on treatment for exposure to other hazardous chemicals. Experiments* with the treatment of waterfowl would indicate, however, that the following general guidelines should be followed when salvaging waterfowl exposed to *oil slicks:*

1. Seek assistance and guidance from personnel knowledgeable in the habits and care of birds and waterfowl. They may be found by contacting agencies, such as --
    - U.S. Sport Fisheries and Wildlife Service
    - State Fish and Game Departments
    - Municipal Zoos
    - Federal Water Quality Control Office
    - Local Universities -- Zoological Departments and Schools of Veterinary Medicine
2. Proceed to salvage the contaminated birds according to the following general procedure:
    - Bring the birds to enclosed pens where they can be properly treated.
    - Remove oil from the plumage using special preparations. Care must be taken to keep physical damage of feathers to a minimum.
    - Waterproof feathers with a recommended preparation.
    - Feed the waterfowl with natural diet as soon as feasible.
    - Release the waterfowl as soon as the treatment has been deemed adequate.

An excellent illustrated booklet on the salvage of waterfowl entitled, "Operation Rescue, Cleaning and Care of Oiled Waterfowl," is available from:

Distribution Services, American Petroleum Institute, 1801 K Street, N.W.,
Washington, D.C., 20006

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* Much of the material for this section of the Handbook has been taken from Griner, L.A., and Herdman, R., "Effects of Oil Pollution on Waterfowl – A Study of Salvage Methods," for the Water Quality Office, Environmental Protection Agency, 1970.

6.6.1 Background

Large oil discharges entering water bodies inhabited by waterfowl can create a serious hazard to the birds, since they have been known to enter the contaminated area with no apparent concern. The primary hazard for waterfowl exposed to oil appears to be the effect that it has on their plumage, since some oils, such as that discharged at Santa Barbara in 1969, have not been found to be toxic to waterfowl. Penetration of the bird's plumage results in a reduction in mobility with a subsequent deterioration of the bird's health. In fact, unless removed, oil contamination may prove fatal to a large percentage of birds that become exposed.

Past attempts to clean birds exposed to oil dischaiges have met with only limited success; however, procedures have been developed which have effected some percentage of complete recovery. It is expected that better methods of treating oil-contaminated waterfowl will be developed in the future.

Treatment methods may also have to be adjusted to the species involved. There is evidence that birds that live on both land and the water, such as ducks and geese, can be handled and cared for more readily than the pure aquatic types, such as grebes and loons, whose primary habitat is the water.

Because of the difficulties associated with the successful salvage of contaminated birds, expert assistance and guidance should be sought. This will be even more important when contamination is caused by other hazardous chemicals.

6.6.2 Salvage Methods for Oiled Birds

The following procedures for the salvage of oil-contaminated waterfowl have been reported in the work (previously referenced) sponsored by the Environmental Protection Agency.

6.6.2.1 Cleaning Operations

The contaminated birds can be cleaned by immersing them in a specially prepared solution, taking care to keep their heads out of it. They are then scrubbed by hand in the direction of the feathers. In severe cases, some ruffling of the feathers may be necessary. After washing, the birds are rinsed in clean water. In one (referenced) experiment, a 1% solution of a water-soluble organic formulation called Polycomplex A-11, manufactured by the Guardian Chemical Corporation, was the most effective. Another compound, called Larodan 127, a three-component cleansing/waxing system produced by Skandinavisk Olje (Goteborg, Sweden), was also tested.

The removal of the oil from the birds' plumage may also remove the waterproofing agent necessary for their buoyancy while in the water. If the cleansing agent, such as Polycomplex A-11, does not contain a waterproofing material, other preparations may be administered after cleaning. Two preparations that were used involved one percent solutions of lanolin and spermacetti wax in hexane. These solutions are layed over the surface of the water in a large basin and the birds immersed in it.

After treatment, the birds are allowed to dry naturally. The use of towels, heat lamps, and other artificial drying methods appears to have been excessively harmful.

6.6.2.2 Feeding

If the salvage of oil-contaminated waterfowl is to be successful, it is important that feed intake equal the energy needs of the bird. A good plan of nutrition is required to counter the adverse result of stress and loss of appetite. For fish-eating species, this may present a problem. Ducks may accept grain and complete poultry rations with little difficulty.

6.6.2.3 Release

The eventual release of the treated birds should be evaluated by competent experts, when feasible. It is important, however, that aquatic species be released as soon as possible, as prolonged, close confinement has been shown to lead to fatal illnesses.

7.0 Protective Clothing and Equipment

7.0 PROTECTIVE CLOTHING AND EQUIPMENT

Response to hazardous chemical discharges requires that all personnel involved in response actions that may lead to exposure in any way be adequately protected. A partial list of manufacturers and suppliers is given in Table 7-1 and an indication of clothing material suitable for protection from specific chemicals is given in Table 7-2. Although this latter table is for the selection of gloves, it provides some indication as to materials suitable for other clothing.

Personal protection must be worn when responding to chemical and acid discharges and the equipment must be adapted to a particular hazard from two aspects:

(1) It must be constructed of materials which are resistant to the hazardous chemical; and

(2) It must protect areas and functions of the human body which are susceptible to the hazard.

For example, a dilute corrosive acid might be harmful to the eyes, but relatively harmless to the skin except for long exposure. Personnel working around such a material should be adequately protected by wearing enclosed safety eyeglasses and impervious rubber gloves. Whenever practicable, shower facilities should be available in the event of unexpected widespread contact with the chemical or acid pollutant.

The compatibility of the construction material of protective clothing with the discharged substance largely depends upon proper identification of the discharged chemical. The elastomers and the polymerized plastics are suitable for a very large spectrum of hazardous chemicals. Indeed, the term "compatibility" is less significant than the usable time before deterioration of the material. For short-term actions, a multitude of materials may provide temporary protection; for long-term actions, only a select few might be suitable. An estimate of the permissible usage time should be made, and a conservative one in the case of highly toxic or corrosive chemicals.

The human breathing function can be protected by some form of gas mask. These are of several principal categories:

- Respirators a filter against particulate matter and solid dusts;
- The canister-type mask a passive device which removes a specific vapor or gas as it passes through the canister;

TABLE 7-1

PARTIAL LIST OF MANUFACTURERS AND SUPPLIERS OF PROTECTIVE CLOTHING AND EQUIPMENT

> *CAUTION: This list is neither comprehensive nor does it imply approval or disapproval of products by the U.S. Coast Guard. For complete listings of products and manufacturers consult compilations such as:*
>
> *Best's Environmental Control and Safety Directory, and*
> *Thomas' Industrial Products Register*

American Industrial Safety Equipment Co.
3512 Lakeside Ave., Cleveland, Ohio 44114

American Optical Corp., Safety Products Div.
Southbridge, Massachusetts 01550

Bullard Co., E.D.
2680 Bridgeway, Sausalito, California 94965

Cesco Safety Products, Inc.
2727 West Roscoe St., Chicago, Ill. 60618

Goodall Rubber Co.
Box 631, Trenton, N.J. 08604

Mine Safety Appliances Co.
201 North Braddock Ave., Pittsburgh, Pennsylvania 15208

Pulmosan Safety Equipment Corporation
30 48 Linden Place, Flushing, N.Y. 11359

Safety Clothing and Equipment Co., Division of Safety First Industries
1942 East 69th St., Cleveland, Ohio 44103

Scott Aviation, Fire/Safety Products Division A-T-O Inc.
225 Erie St., Lancaster, N.Y. 14086

Uniroyal, Protective Footwear and Clothing Division
58 Maple St., Naugatuck, Conn. 06770

Welsh Manufacturing Co.
7 Magnolia St., Providence, R.I. 02909

Wheeler Protective Apparel, Inc.
238 West Huron St., Chicago, Ill. 60610

Willson Products Division, ESD Inc.
P.O. Box 622, Reading, Pennsylvania 19603

There are also many local suppliers who act as distributors for the above companies. The names of such organizations should be listed on a pre-response basis.

TABLE 7-2

CHEMICAL GLOVE SELECTION CHART*

(From Best's Environmental Control and Safety Directory)

CHEMICAL HAZARD	CLOTHING MATERIAL					
	Natural Rubber	Neoprene	Buna-N	Vinyl	Polyvinyl Alcohol	Polyethylene
Chloroacetone	F,G,E	E	F	P	G	E
Chlorobenzene	P	F,G,E	G	P,F	E	E
Chloroform	P,F	F,G	G	P	E	G
0-Chloronaphthalene	P	F,G	F	P,F,G	E	G
1-Chloro, 1-Nitro ethane	P	F		F		
Chloropicrin	P	P,F	P	P,F	G	G
Chlorosulfonic Acid	P	P,F		G		
Chlorotoluene	P	P,F		G	G	
Chromic Acid 50%	P,F	F,G,E	F	G,E	P	G
Chromic Acid Conc.	P	P,F		E		
Citric Acid	G,E	E	E	E	P	E
Clorox	F	G		E	P	
Coconut Oil	P	E	G	G	E	
Cod Liver Oil	P	E		G	E	
Coke Oven Gas	G	G,E		E		
Copper Chloride	P	G,E		G		
Copper Sulfate	G	G,E	G	G		
Corn Oil	P	G,E		G	E	
Cottonseed Oil	P	G,E	E	G	E	E
Creosote Oil	P,F,G	F,G,E	G	G	F	E
Cresol	P,F,G	F,G	G	P,F,G	F	E
Cresylic Acid	P	P,F,G		E		
Cyanide Solution	G	G,E		F	P	
Cyclohexane	P,F,G	G	G	P	E	G
Cyclohexanol	P,F	G,E	G	P,F	G	G
Cyclohexanone	F,G,E	P,F,G,E	G	P,F	G	G
Cumene		P	G		E	
p-Cumene	P	P			E	
Decaborane	P	F	F	G	G	G
Decalin	P	P				
Degreasing Fluids	F	F	G	G	E	E
Diacetone Alcohol	F,G,E	E	E	P	F	G
Diacetone	F	G		F		
Dibenzyl Ether	F,G	G	G	P	F	G
Dibutyl Amine	E	P,F		F	G	
Dibutyl Ether	P	P,F		F	G	
Dibutyl Phthalate	P,F	G,E	F	F	E	G
Dichloroacetic Acid	P	P,F		G	P	
0-Dichlorobenzene	P	P,F		G	G	
Dichlorethane	P	P,F	F	P,F,G	E	G
Dichlorpropene	P	P,F	G	P,F,G	E	G
Dicyclohexylamine	F	G,E		E	E	
Diesel Oil	P,F,G	G,E	G	E	E	E
Diethanolamine	F,G	E	E	E	F	E
Diethylamine	P,F,G	F,G,E	E	G	F	G
Diethyl Glycol	G	G,E		E	P	
Diethyl Ether	P	P,F		F	P	
Diethyl Sebacate	P	P,F		F	G	
Difluorodibromomethane	P	P,F		F	G	
Di-isobutyl Ketone	P,F	P,F	P	P,F,G	G	F
Di-isopropyl Ketone	F	P,F		G	G	
Dimethyl Aniline	P	P,F		G	G	
Dioctyl Phthalate	P,F	P,F,G	P	P,F,G	E	G
Dioxane	P,F,G	F,G,E	G	G	P	G
Dioxolane	F	F,G		G		
Dipentene	P	F,G		G		
Diphenylamine HCl	P	P,F		F		
Dow therm (A&E)	P	F,G	G	G		
Ethane	G	E	E	E	E	G
Ethanolamine	F,G	G,E		E	P	
Ethers	G	E	E	E	E	G
Ethyl Acetate	F	G	G	P,F	F	G
Ethyl Acetoacetate	G	G,E		G	F	
Ethyl Alcohol	G,E	E	G	E	F	G
Ethylaniline	F	F,G	F	G	F	F
Ethyl Benzene	P	P,F	G	G	E	
Ethyl Benzoate	P	P,F		G		
Ethyl Cellulose	G	F,G		G		
Ethyl Chloride	P	F,G		F,G		
Ethylene Chlorohydrin	F	P,F		P,F		
Ethylene Diamine	G	F,G,E	E	G	F	G
Ethylene Dibromide	P	P,F,G		P,F	F	
Ethylene Dichloride	P	F	F,G	P	E	G
Ethylene Gas	G	E	E	E	E	E
Ethylene Glycol	G,E	E	E	E	G	E
Ethylene Trichloride	P	P,F	G	P	E	F
Ethyl Ether	F,G	E	E	P	G	G
Ethyl Formate	F	G	G	F	E	G
Ethyl Mercaptan	P	G,E		G	F	
Ethyl Oxalate	G	F,G		G		
Ethyl Pentachlorobenzene	P	G,E		G	G	
Ethyl Silicate	F	F,G		E		
Ethyl Sulfate	P	P,F		G		
Fatty Acids	P	G,E	E	E	E	E
Ferric Chloride	G	G,E		G		

CHEMICAL HAZARD	CLOTHING MATERIAL					
	Natural Rubber	Neoprene	Buna-N	Vinyl	Polyvinyl Alcohol	Polyethylene
Ferric Nitrate	G	G,E	G	E		
Ferric Sulfate	G	G,E		E		
Ferrous Ammonium Sulfate	F	G,E		E		
Fluoboric Acid	G	G,E	E	E	P	
Fluosilicic Acid	G	G,E		E		
Fluorine	P	F	F	E	G	G
Fluorine Gas	G	G,E	G	G	E	G
Fluorobenzene	P	F		F	E	
Formaldehyde 40%	P	G,E		E	P	
Formaldehyle	G,E	E	E	E	P	E
Formic Acid 10%	F,G,E	G,E	E	E	P	E
Formic Acid Conc	F	E		E	P	
Freon 11	P	F	F	G	E	F
Freon 12	P,F,G	F,G,E	F	F,G	E	F
Freon 21	P	F,G	F	F,G	E	F
Freon 22	P	F,G	F	F	E	F
Fruit Juice	P	P,F,G		E	P	
Fuel Oil	P	G,E		G	E	
Furan	P	F,G		G		
Furfural	F,G	G	G	F,G	F	F
Gasoline—Leaded	P	G,E	G	F	E	G
Gasoline—Unleaded	P	G,E	E	F,G	F	G
Glucose	G	G		G		
Glue	G	G,E		E		
Glycerine	G,E	E	E	E	F	E
Grease—All Kinds	P	E		E	E	
Green Sulfate Liquor	G	G		F		
Halawax	P	G,E		E		
Halogens	E	E	F		E	G
Heptane	P	E	G	P,F	E	
Hexane	P	F,G,E	E	P,F	E	G
n-Hexene-1	P	F,G	G	F	E	
Hexyl Acetate	P	F	F		F	G
Hexyl Alcohol	F	G		G	E	
Hydraulic Fluid— Petrol Base	P,F	G	E	E	E	E
Hydraulic Fluid— Ester Base	P	E	G	G	G	G
Hydrobromic Acid 40%	G	E		E	P	
Hydrochloric Acid 30%	G	E	E	E	P	G
Hydrochloric Acid Conc.	G	E		E	P	
Hydrocyanic Acid	G	G		G	P	
Hydrofluoric Acid 30%	G,E	G,E	E	G,E	P	G
Hydrogen Gas	G,E	G,E	E	E	E	E
Hydrogen Peroxide	G	G,E	G	E	P,F,G	E
Hydrogen Sulfide	G	G		G		
Hypochlorous Acid	G	P		G	P	
Iodine	G	G		P,F,G		
Inorganic Salts	E	E	E	G	F	E
Isododecane	P	G		G	E	
Isooctane	P	F,G	G	G	E	G
Isophorone	G					
Isopropyl Acetate	F	G		G	F	
Isopropyl Alcohol	G,E	G,E	E	E	F	E
Isopropyl Chloride	P	G		G	G	
Isopropyl Ether	P	P		F	G	
Kerosene	P,F	G,E	E	G,E	E	E
Ketones	F,G	P,F,G	G	P	G	G
Kraft Liquor	P	P		G		
Lacquer	P	P		G	P	
Lacquer Thinners	P,F	F,G	G	P,F,G	E	F
Lactic Acid	F,G,E	E	E	G	P	E
Lard	P	E		G	E	
Lauric Acid	F	G,E	E	G	E	E
Lead Chloride	F	F,G		G		
Lead Nitrate	F	F,G		G		
Lead Sulfamate	G	G	G	E		
Linoleic Acid	P	G,E	E	E	E	E
Linseed Oil	P	E	E	G,E	E	E
Lithium Bromide	F	F,G		G		
Lubricating Oils—All	P	E		E	F	
Magnesium Bromide	G	G		E		
Magnesium Chloride	G	G		E		
Magnesium Hydroxide	G	G		E		
Magnesium Nitrate	G	G	G	E		
Magnesium Oxide	G	G		E		
Magnesium Sulfate	G	G		E		
Maleic Acid	F,G,E	G,E	E	G	E	E
Manganese Sulfate	G	G		E		
Mercuric Chloride	G	F,G		G	F	E
Mercury	G	G		E	P	E
Mesityl Oxide	P	F,G		G		
Methane Gas	E	E	E	G	E	E
Methyl Acetate	F	G	G	P,F	F,G	G
Methyl Alcohol	G,E	E	E	G,E	F	E

CHEMICAL HAZARD	CLOTHING MATERIAL Natural Rubber	Neoprene	Buna-N	Vinyl	Polyvinyl Alcohol	Polyethylene
Methylamine	F	F,G	G	G	F	G
Methyl Bromide	F	G	G	G	E	G
Methyl Cellosolve	F,G	G,E	E	P	F	G
Methyl Chloride	P,F,G	G,E	G	P	G	G
Methyl Chloroform	P	P,F		F	G	
Methyl Cyclopentane	P	F,G	G	G	E	
Methyl Ethyl Ketone	F,G	G	F	P	F	G
Methyl Isobutyl Ketone	F,G	G	G	G	F,G	G
Methyl Formate	F	G	F	F	E	G
Methyl Methacrylate	P	F,G		G	G	
Methyl Oleate	P	P,F		F	E	
Methyl Salicylate	P	P,F		F	E	
Methylene Bromide	G	G	G	G	G	G
Methylene Chloride	P,F,G	P,F,G	G	P,F	G	G
Milk	P	P,F		G	P	
Mineral Oil	P,F,G	G,E	E	F	E	E
Molasses	P	P,F		G	P	
Molybdenum Acids	F	F,G		G		
Monoethanolamine	F,G	E	E	E	F	E
Mono Ethyl Ether	P	P,F		F		
Monomethyl Aniline	P	P,F		G	G	
Morpholine	F,G,E	E	E	E	F	E
Naphtha	P,F	G,E	G	F,G,E	E	G
Naphthalene	P,F	P,F,G	G	E	E	E
Natural Gas	F	G,E		E		
Nickel Acetate	F	G,E		E		
Nickel Ammonium Sulfate	G	G,E		E		
Nickel Chloride	G	G,E	G	E		
Nickel Nitrate	G	G,E		E		
Nickel Sulfate	G	G,E	G	E		
Nitric Acid 10%	P,F	G	F	G,E	P	F
Nitric Acid Conc.	P	P,F,G		F,G	P	P
Nitric Acid, Fuming	P	P	P	P	P	G
Nitrobenzene	P	P,F	F	P	E	G
Nitroethane	P,F,G	F,G	F,G	P,F	E	G
Nitrogen	G,E	G,E	E	E	E	E
Nitromethane	P,F,G	F,G	F	P,F	E	G
1-nitro Propane	P,F	F	F	P,F	E	G
Nitro-toluene	P	P,F		G	E	
Nitrous Oxide	G	G	G	E	E	G
Octadecyl Alcohol	P	P		G	E	
n-Octane-2	P	F		G	E	
Octyl Alcohol	F,G,E	E	E	E	G	G
Oleic Acid	F	G,E	E	E	E	E
Oleum Spirits	P	P		F,G	P	
Olive Oil	P	E	G	F	E	
Organic Acids	F	P		G		
Oxalic Acid	G,E	G,E	E	E	E	E
Oxygen, Gas	G	G,E		E	P	
Oxygen, Liquid	F	F	F		F	G
Paint Thinners	F,G	P,F,G	G	F	E	G
Paint & Varnish Removers	P,F	F,G	G	P,F	E	G
Palmitic Acid	F,G,E	F,G,E	E	E	E	E
Paradichlorobenzene	F,G	F,G,E	E	E	E	F
Parathion	P	P	F		G	F
Pentaborane	P,F	F,G	F	E	G	G
n-Pentane	P,F,G	E	E	P	E	G
n-Pentane 2-Methyl	P	G		F	E	
n-Pentane 3-Methyl	P	G		F	E	
Pentane 2-4 Methyl	P	F,G		F	E	
Perchlorethylene	P	F,G	F	P,F,G	E	F
Perchloric Acid 10%	F,G	G,E	F	E	P	G
Petroleum Oils	P	F,G,E		E	E	
Petroleum Spirits	F	P,F,G	E	F	E	G
Phenol	F,G	F,G,E	E	G,E	P	E
Phenyl Ethyl Ether	F	F,G		G	E	
Phenyl Hydrazine	G	G,E	G	E	F	G
Phorone	P	P,F		G		
Phosphoric Acid 85%	G	F	E	E	P	E
Phosphoric Bromide	P	P,F		G		
Phosphoric Chloride	P	P,F		G		
Photographic Solutions	E	E		E		E
Pickling Baths	G	G	G	G	P	
Pickling Solution 20% Nitric 40% HF At 150F	F	F,G		E	P	
Picric Acid	G	G,E	E	F,G,E	E	E
Pitch	P	E	E	G	G	G
Pine Oil	P,F	F,G,E	F	G	E	E
Piperidine	P	P,F		F		
Plating Solution	G,E	G,E	E	E	F,G,E	E
Potassium Chloride	G	G,E	G	E		
Potassium Cyanide	G	G,E	G	E		
Potassium Dichromate	P	G,E		E	P	E
Potassium Hydroxide (sat)	G,E	E	E	E	P	E
Potassium Permanganate	G	P,F,G		E		

CHEMICAL HAZARD	CLOTHING MATERIAL Natural Rubber	Neoprene	Buna-N	Vinyl	Polyvinyl Alcohol	Polyethylene
Potassium Sulfate	G	G,E	G	E		
Printing Inks	G,E	F,G,E	E	G,E	E	E
Producer Gas	F	G,E		E		
Propane	F,G,E	E	E	P,F	E	E
Propionitrile	F	G,E		E		
n-Propyl Acetate	F	G	G	F	G	G
Propyl Alcohol	G,E	G,E	E	E	F	E
Propylene Dichloride	P	P,F		P	G	
Propylene Gas	F	E	E	P	E	E
Pyridine	F	G,E	F,G	E	G	
Pyrrole	F	G,E		E	G	
Refrigerants	G	P		P		
Remazit	P	G		P,F		
Rosin Oil	P	E	G	G	E	
Salicylaldehyde	P	P,F		F		
Salt Spray	G	G,E		E	P	
Salt Water	G	G,E		E	P	
Sewage	G	G,E		E	P	
Shortening, Commercial	P	E		G	E	
Silicone	G	G,E		E		
Soap Solution	G	G,E		E	P	
Sodium Bisulfate	G	F,G		E		
Sodium Hydroxide 50%	G,E	E	E	E	P	E
Sodium Hypochlorite 20%	G	G		G	P	
Sodium Peroxide	F	G,E		E		
Sodium Salts	G	G,E	G	E		
Solvesol	F	E	E		E	G
Solvesso	P	P	E		E	G
Soy Bean Oil	P,F	E	G	G,E	E	
Spindle Oil	F	G,E		E	E	
Stannic Chloride	G	G,E	G	E		
Stannous Chloride	F	F,G		G		
Steam	G,E	G,E		E		
Stearic Acid	G,E	E	E	E	E	E
Stoddard's Solvent	P,F	G,E	E	P,F	E	G
Styrene	P,F	P,F,G	F	G	G,E	G
Sugar Solution	G	P,F,G		E	P	
Sulfur	F	G,E		E		
Sulfur Chloride	P	P,F		G		
Sulfur Dioxide (liq.)	F	G		G	P	
Sulfurous Acid 6%	P	F,G,E		E	P	F
Sulfur Trioxide	P	P		G	P	
Sulfuric Acid (up to 50%)	G	G	G	G,E	P	
Sulfuric Acid (up to 80%)	P	F		G	P	
Sulfuric Acid (up to 95%)	P	P,F		F,G	P	
Tannic Acid 10%	G,E	E	E	E	F	E
Tar	P	G		G	E	
Tartaric Acid	G	G		E		
Terpineol	F	G		G	E	
Tert. Butyl Alcohol	F	G		G	G	
Tert. Butyl Catechol	F				G	
Tetrachlorethylene	P	P		F	E	
Tetraethyl Lead	F	G,E	E	E	E	G
Tetra Hydro Naphthalene	P	F		G	G	
Tetralin	P	P		G	E	
Thiophene	P	F		G	G	
Titanium Chloride	F	P		G		
Titanium Sulfate	F	F		G		
Toluene	P	F	E	P,F	E	G
Tri Butoxy Ethyl Phosphate	F	F		G	G	
Triacetin	G	G,E		E		
Tributyl Phosphate	F	P		G	G	
Trichloroacetic Acid		F,G		G	P	
Trichlorethylene	P	F,G	F	F	E	G
Tricresyl Phosphate	F	G	F	F	G	G
Triethanolamine	F,G	F,G,E	E	E	F	E
Trinitrotoluene	P	G,E	E	P,F	E	E
Triptane	P	G,E	E	G	E	G
Trisodium Phosphate	G	G		E		
Tung Oil	P	E	E	G	E	F
Turbine Oil	P	E		E	E	
Turpentine	P,F	F,G	E	F,G,E	E	G
Urea	G	G		E		
Uric Acid		P		E		
Vegetable Oils	G	F,G,E	E	G,E	G	F
Vinegar	F	G		E	P	
Water	G	G		E	P	
Whiskey	G	G		E	P	
Wood Preservatives	F	G	G		P	E
Xylene	P	P,F	E	F,G	E	G
Xylidenes	P,F	F,G,E	E	F	E	F
Zeolite	F	G		E		
Zinc Acetate	G	G		G		
Zinc Chloride	G	G	G	G	P	
Zinc Sulfate	G	G		E		

Safety gloves and clothing for protection against chemical hazards are available in numerous materials. Many of the manufacturers of such protective clothing have published charts showing the suitability of their clothing materials for various chemical hazards. The following table is compiled from several such charts as a general-purpose guide to the selection of suitable chemical safety clothing materials. While the manufacturers' charts were intended primarily for the selection of chemical gloves, the data applies equally to chemical garments such as aprons, coats, hoods, trousers, coveralls, and suits.

It should be remembered that the thickness and specific formulation of a material can cause some variation in its resistance to individual chemicals. This variation is reflected in the occasional differences of ratings shown in the manufacturers' charts and will also be evident in the table presented here. In other words, a material rated as "Fair" by one manufacturer might be rated as "Good" by another. The table here will therefore show both "Fair" and "Good" for the material. It will also be noted that there are no ratings for some of the chemicals under specific materials. This absence of a rating means that manufacturers have given no indication of the material's suitability, or lack of it, for the specific chemical. The absence of a rating should not be interpreted as either a recommendation for its use or as a sign of its unsuitability.

CODE FOR CHART
P—Poor
F—Fair
G—Good
E—Excellent

CHEMICAL HAZARD	CLOTHING MATERIAL Natural Rubber	Neoprene	Buna-N	Vinyl	Polyvinyl Alcohol	Polyethylene
Acetaldehyde	G	G,E	E	P,G	F	G
Acetic Acid	G,E	E	E	E	P,G	E
Acetic Acid Glacial	F	F		P,F	P	
Acetic Anhydride	G	G		F,G	P	
Acetonitrile	G	G		G	G	
Acetone	G,E	G,E	G	F	F	G
Acetophenone	F	P		P	F	
Acetyl Acetone	P	P		P	F	
Acetyl Chloride	F	P		F	G	
Acetylene Gas	F,G,E	F,G,E,	E	F	E	G
Acetylene Tetrachloride	P	F,G	G	F	E	F
Acids & Alkalis	G	G		G		
Acrylonitrile	F,G,E	G,E	G	F,G	E	G
Alcohols	G	F		F		
Alum	G	G	G	E		
Aluminum Chloride	G	G		G	P	
Aluminum Nitrate	G	G		G	P	
Aluminum Sulfate	G	G		G	P	
Amine Hardeners	P	F	G	G	E	G
Ammonia 100%	G	G	G	E	P	
Ammonium Carbonate	F			F		
Ammonium Hydroxide	G,E	E	E	E	P	E
Ammonium Nitrate	P,F	G	G	G		
Ammonium Phosphate	F	G	G	G		
Ammonium Sulfate	G	G	G	G		
Amyl Acetate	F	G	G	P,F	G	G
Amyl Alcohol	G,E	E	E	E	G	E
Amyl Borate	P	F		G	E	
Amylchloronaphthalene	P	F		G	E	
Amyl Naphthalene	P	G		E	F	
Aniline	F,G	G,E	G	G,E	F	G
Aniline Hydrochloride	F	F	F	P	F	G
Aniline Dyes	F	F		G		
Aniline Oil	P	F	F	P	P	G
Animal Fats	P,F,G	G,E	E	E	E	E
Animal Oils	F,G	G,E	E	E	E	E
Anthracene	P	F	G	F,G	E	G
Aromatic Fuels	P,F	F	E	P,F	E	E
Arsenic Acid	G	G		E		
Asphalt	P	F		E	E	
Balcosolve	P	G		E	E	
Banana Oil	P	F	G	E	G	E
Barium Chloride	G	G	G	G	P	
Barium Hydroxide	G	F		G		
Barium Nitrate	G	G	G	G		
Barium Sulfate	G	G		G		
Battery Acid	G	E		E	P	
Beer	G	G		E	P	
Beet Sugar Liquors	G	G		E	P	
Benzaldehyde	P,F	P,F	G	G	F	G
Benzene (Benzol)	P	F,G	G	P,F	E	G
Benzene Sulfonic 10%	P	G		E		
Benzyl Alcohol	F,G,E	E	E	E	G	E
Benzyl Benzoate	F	G,E	G	E	E	G
Benzyl Chloride	P,F	P,F,G	G	P,F	E	G
Black Sulfate Liquor	G	G,E		E	P	
Blast Furnace Gas	F	G,E		E		
Borax	G	G,E		E		
Boric Acid	G	G,E		E	G	
Bromine	G	G		G		
Bromine Water	F	G		E	P	
Butadiene	F	P,F		G	E	
Butane	P,F,G	E	E	P,F	E	G
Butter	P	E		G	E	
Butyl Acetate	F	G	G	P,F	G	G
Butyl Acetyl Ricinoleate	F	G		G	E	
Butyl Alcohol	G,E	G,E	E	F,G,E	F	E
n-Butyl, N-Butyrate	F	P,F		G	E	
Iso-Butyl, N-Butyrate	F	P,F		G	E	
Butyl Stearate	F	P,F,G		F	E	
Butylaldehyde	P,F,G	G	G	G	F	E
Butylene	G	E	E	E	E	G
Butyne	G	G	G	E	E	G
Butyric Acid	F	F,G,E	G	P,F,G	G	
Cadmium Cyanide	G	G,E	G	E		
Calcium Bisulfite	P	G,E		E		
Calcium Chloride	G	G,E	G	E		
Calcium Hydroxide	F,G,E	G,E	E	E	P	E
Calcium Hypochlorite	G	G		G	P	
Caliche Liquor	G	G,E		E		
Cane Sugar	G	G,E		E		
Carbolic Acid (dilute)	F	E		E	F	G
Carbolic Acid (high temp.)	P,F,G	F,G,E	E	F	P,F	
Carbon Dioxide	G,E	G,E	E	E	F	E
Carbon Disulfide	F,G	P,F	G	P,F,G	E	E
Carbonic Acid	G	G,E		E	P	
Carbon Monoxide	G	G,E		E		
Carbon Tetrachloride	P,F	P,F,G	G	P,F	E	G
Castor Oil	P	F,G,E	E	G	E	E
Chlorinated Solvents	P	P,F		G	G	
Chlorine	F,G	F,G	F	G	G,E	G
Chlorine Water	F	G		E	P	G
Chlorine Dioxide	P	P,F		G		
Chloroacetic Acid	P	G,E		E	P	

- The oxygen breathing apparatus a face mask provided with a self-contained oxygen supply which is suitable against *any* air hazard; and

- A face mask or hood with external air supply the mask is fed by hose and from a clean air source (bottle or compressor) and the wearer is constrained to move near this source. If the bottle is small enough, as in a SCUBA unit, the equipment is self-contained and analogous to the oxygen breathing apparatus.

In some forms, these masks take the shape of complete helmets. In many instances, where both breathing protection and splash or mechanical protection is required, such a combined form of helmet serves both functions.

In the more hazardous cases, for example where ingestion, or breathing, or skin contact may be harmful, the protective devices take the shape of entire air and vapor-tight suits. The various pieces of clothing are joined by tight seals and topped by some form of helmet with a clean air or oxygen supply. In many instances, such complete enclosure of the body may bring about requirement for either heating or cooling, in addition to a supply of breathing air.

The most common safety equipments are the hard hat and the safety glasses. Most of the heavy industries and construction industries require use of these two items in all situations, except office work or other limited indoor activity. Similarly, both the military and civilian government agencies require such minimum equipment for industrial activities where other specialized equipment is not required. It is recommended that these items be supplied in all instances where heavy items are handled, such as in the course of the various response actions and in use of the equipment that goes with them.

An entirely different group of safety devices is the class of instruments or equipment used to determine hazards or identify particular substances. Several groups of equipment exist:

- The oxygen-level devices – such as a safety lamp which indicates only oxygen level but not toxicity or explosiveness;

- Explosimeters – which generally are applicable only to hydrocarbon vapors; and

- "Sniffers" – which sample contaminated air against specific reaction substances to identify the contaminant. Over 100 different reactions (contaminants) can be tested.

Outside of a laboratory, in which analytic or spectrographic methods of evaluation can be used, there is no quick and simple field method for identifying a hazardous chemical. It is highly recommended that, except for general classification by physical characteristics, no time be wasted in attempting to acquire and use such field methods. Instead, it would be more fruitful to work from the other end of the problem, namely, from the shipper, transportation agency, consignee, and the documentation going with the shipment.

Protective personal equipment is widespread in use and widespread in availability. Safety equipment available to federal agencies through GSA sources is listed separately in a number of federal supply schedules. A list of typical commercial manufacturers and suppliers is incorporated in this section of the manual. The utilization of protective clothing and devices depends upon the hazards of the discharged chemical as well as the degree of uncertainty as to its true identity. Until type of hazard, strength of reactivity, and concentration or dilution of the substance is determined, it is best to assume a worst condition. Boat personnel initially entering the area for sampling purposes should be equipped with complete protection: eyes, face, hands, body, and feet. They well may become saturated with the contaminated water during the process of taking the samples. However, when the exact nature of the chemical and its strength have been determined from the sampling process, then the protective device and clothing requirements may be relaxed to appropriate levels.

The utilization of protective clothing must be adapted to the particular incident conditions. In general, protective clothing reduces the productivity or activity of the wearer. Also, the entire logistics of supply, use, and disposal are expensive. Therefore, overreaction in regard to protective clothing is nearly as undesirable as underreaction. Except for high precautionary levels in the initial phases of discharge response, where many unknowns exist and where rapid action may be required despite unknown hazards, the use of protective clothing and devices should be tailored as closely as possible to the true dangers of the situation. The use of protective clothing is a vital response factor, and the location and availability of commonly used personal protective equipment, such as safety hats, gloves (general use and chemical) safety shoes, coveralls, fire and chemical resistive suits and respirators should be known. Since discharges frequently occur during night hours, arrangements should be made with a local supply house for a night telephone number that will permit access to special-purpose equipment, and equipment in quantity, during non-business hours.

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