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# Oil Spills Control Manual for Fire Departments

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# OIL SPILLS CONTROL MANUAL FOR FIRE DEPARTMENTS

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# ABSTRACT

This report was developed from field tests and actual oil spill control experiences of the Marine Division of the New York Fire Department during a twenty-two month period beginning October 8, 1970. The information offered is intended to assist a community in protecting its area against oil spill damage. Operational procedures described are intended to serve as stop-gap measures, pending the inauguration of cleanup activities by the spiller or responsible Federal Agency.

A survey of cities susceptible to oil spills indicates that most responding fire departments are concerned with containing spills as well as dealing with spill-created fire hazards.

Research and development which culminated in the production of this manual concentrated on the utilization of existing fire department resources. However, a limited amount of useful ancillary equipment was procured or developed. Such equipment is described and its use is explained. The manual describes common sources of oil spills and some ecological effects of oil pollution. Pertinent Federal laws and regulations are outlined. Some feasible techniques for dealing with harbor spills are offered.



This report was submitted in partial fulfillment of Project Number 15080 FVP under the partial sponsorship of the Water Quality Office, Environmental Protection Agency.

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# SECTION I
## CONCLUSIONS

The information contained in this manual should provide the guidelines for a community in establishing a local emergency oil spill response service.

The operational parameters suggested by this manual are confined to oil spill containment and are not intended to include the cleanup operation.

Inhouse resources are utilized for the most part in the spill control techniques offered.

Those Federal Laws and Regulations which are included, should enable a community to assist in law enforcement and should promote cooperation with Federal Agencies concerned with air/water pollution.

## SECTION II
## RECOMMENDATIONS

1. Because of the changing state of the art of oil spill control brought about by the development of new equipment and promulgation of new laws and regulations, periodic up-dating of this manual will be necessary.

2. Even though a Fire Department may be well trained in the use of streams for fire extinguishment, additional active training in the application of fire streams for oil spill control is essential.

3. The occasional staging of simulated spill incidents will enable a community to test the technique described in this manual and to establish command, communication and tactical procedures for an effective local oil spill control program.

# SECTION III
## INTRODUCTION

Before a field supervisor can expect to function effectively at an oil spill in the harbor area wherein he serves as a fire protection officer, a fair amount of basic background and operational knowledge is essential. The background knowledge relates to the possible fate and behavior of an oil slick, which would include some information on the natural weathering and spreading tendencies of oil on water and the way a slick may be expected to behave in a harbor. The operational information would include some of the ways and means for containment, the removal of the oil from the marine environment, and the responsibilities established by law for dealing with spills. Of particular value is the awareness of just how the in-house capabilities of a fire department may assist in limiting the spill damage.

Some of this knowledge may have already been acquired in the normal course of fire protection functions, or even as a result of participation is spill containment operations. In recognition of the fact that fire departments are the local agencies usually responding first to oil spills, prompted by their traditional concern for the fire hazard, and the more recent concern for the ecological damage done by spills, the USEPA made the NYFD the recipient of a grant to determine just what a fire department can do to limit oil spill damage. Especially stressed during the 22-month course of this project was researching and developing the use of the in-house capabilities of fire departments for dealing with oil spills. As a result of this research and development project, some of the valuable knowledge has been acquired and is made available in this manual.

Prior to the preparation of this manual, local community interest in oil spill control throughout the nation was sampled by a widely distributed questionnaire. Cities most susceptible to oil spills were sampled. Of the 64 responding fire departments, 49 indicated active participation in oil spill containment, either by the use of fire streams or deployment of containment boom, or by assisting in various other ways. The vast majority of the departments reporting indicated a concern for the marine ecology, as well as the fire hazard presented by oil spills, and 60 of the 64 departments indicated they respond to spill incidents, either because of the fire hazard and/or ecological concern.

## SECTION IV
## DAMAGE TO THE MARINE ENVIRONMENT

Oil is a complex substance having many constituents nearly all of which are severely damaging to the marine environment in one way or another. The low boiling saturated hydrocarbons found in petroleum can be fatal to lower animals and may be very injurious to young forms of marine life, while the higher boiling saturated hydrocarbons may interfere with the nutrition of marine animals. But the aromatic hydrocarbons which are abundant in petroleum constitute the most deadly fraction. These low boiling aromatics, such as benzene and toluene, are poisonous to all organisms. In recent years, it has been recognized that the treatment of oil slicks by chemicals known as dispersants or detergents tends to add to the destruction of the surrounding marine environment by releasing these toxic elements for the ingestion by, or contact with living organisms. For this reason, the use of these chemicals has been severely restricted by the Federal regulations.

Along with the immediate and poisonous effects of these petroleum constituents are the highly publicized and damaging effects of spills on the bird population, littoral vegetation, recreational beaches and private property. But the long term, less dramatic and unobtrusive effects of oil pollution must also be considered.

Since man derives a considerable amount of food from the seas, lakes, and rivers, the effects of oil pollution on what he eats becomes a matter of concern. Research has found that once hydrocarbons are incorporated into a marine organism, they remain stable and pass unaltered through many members of the marine food chain. These hydrocarbons are not only retained in marine organisms, but may also be concentrated. Ultimately, some organisms which have assimilated the hydrocarbon contaminants are gathered for human consumption. Then, passed along to man are some of the same carcinogenic compounds which research has identified in crude oil, crude oil residues and tobacco tars.

Sunken oil has been found on sea bottoms after some of the historical spill incidents. This oil can move with bottom sediments and it is felt that this sunken oil is not easily biodegraded because there is less oxygen available at the bottom. Therefore, the bottom communities become polluted.

Recent years have witnessed an aroused public awareness to the contamination of the seas and inland waters by petroleum spills. This awareness has prompted many investigations which will ultimately give us a fuller knowledge of the short and long term effects of oil pollution on the marine environment.

## SECTION V
## FATE AND BEHAVIOR

When a spill occurs, the oil is subjected to a process known as weathering. Changes in the composition of the oil result from the weathering process. The principal causes of the changes are the loss of its compounds by biological degradation. These processes are influenced by such variables as the physical properties of the oil, the oceanographic and meteorological conditions at the scene of the spill, and the influence of time.

The principal physical properties of an oil spill which have a direct bearing on its eventual fate are: its viscosity, its specific gravity, its volatility and flash point, its solubility in water, and possibly its pour point. Along with influences of the natural environment in which a spill occurs, these properties will govern the extent of a spill, the degree to which it may damage the marine environment, and the severity of the fire hazard it may present.

Knowledge of some of the principal physical and chemical processes which have a direct effect on the fate and behavior of a spill is essential for emergency service operating personnel. Although the tendencies to spread, evaporate, degrade microbiologically and become lost through other processes in the surrounding environment may result in the eventual "disappearance" of a spill at sea, such is not the case on inshore or harbor areas. The spill damage in the latter areas will be immediate and intense. Whereas it may be difficult to mobilize and employ oil containment and removal resources at sea, the control of a spill and minimization of ecological damage can be affected on a community's waters through some knowledge and training in the use of available equipment and techniques.

### The Spread Process

The first observable process of an oil spill influencing its fate and behavior is its tendency to spread in an even slick on the water's surface. The lighter fractions and water soluble constituents are lost due to evaporation and dissolution, leaving the more viscous residue which comprises the bulk of the persistent slick.

Oil's spreading tendency is influenced by the physical forces of gravity and surface tension. The horizontal movement of the oil is actually caused by the downward pull of gravity and the surface tension of the water which is ordinarily greater than that of the floating oil. As the slick spreads and thins, the force of gravity naturally lessens. But, the tendency to spread due to surface tension differentials does not rely on film thickness, as does the gravity force, and ultimately surface tension will prevail as the spreading force. The forces which tend to retard the spread of oil are viscosity and inertia.

In addition to the natural spreading tendency of oil, a slick will follow the direction of the moving water surface on which it floats. Therefore, currents and tides may move an oil slick a considerable distance from the original spill incident. In calculating the movement of a slick, the speed and direction of the wind are also important meteoroligical factors to be considered. Wind is an influential factor in the movement of surface water, and therefore, also on a floating oil spill. The drift direction of a spill will be the same as the wind, and speed will approximately be 3.5% of wind speed. The wind-driven motion and the motion due to other currents are superimposed to give the net drifts of the oil.

## Estimating the Amount of Oil Spilled

The visual appearances of a spill can serve to estimate the thickness and therefore the quantity spilled when we can also estimate the area covered. Thickness will vary over the spill area so that actual measurement for quantative evaluation is very difficult. Therefore, the following appearance table is offered as a guide in approximating the quantity of the oil spilled.

APPEARANCE TABLE (1)

| Film Appearance | Quantity of Oil (Gallons per sq. mi.) |
|---|---|
| Barely visible | 25 |
| Silvery sheen | 50 |
| Slight trace of colors | 100 |
| Bright color bands | 200 |
| Dull Brown color | 600 |
| Darker brown | 1,300+ |

## The Evaporation Process

The various fractions of the oil begin to evaporate as soon as a spill occurs. These lighter compounds will, of course, evaporate more rapidly than the heavier. The rate of evaporation into the atmosphere is influenced by the type of oil spilled and its viscosity, and also by such factors as the air and water temperatures, water turbulence, wind and the rate of spill spread. Vaporization tapers off after the early loss of volatiles.

In the case of crude oil, while it is felt that evaporation accounts for the greatest volumetric loss, solubility in sea water also plays a significant role in volume reduction. The high volatility of some of the refine products such as gasoline or naptha not only accounts for the rapid volumetric reduction of the spill, but also creates an ignition possibility in the surrounding atmosphere. The table which follows, gives some indication of the rate of evaporation of #2, #4, and #6 fuel oils, under controlled conditions at a temperature of 77° F for a period of 40 hours.[2]

| Fuel Oil | Percentage of Oil Evaporated |
|---|---|
| #2 | 13.1 |
| #4 | 2.5 |
| #6 | 2.0 |

Other Natural Processes

Several other natural physical and chemical processes may assist in the dissipation of oil in the environment. But these processes are dependent on such variables as time, meteorological conditions, microbial species and oxygen content of the water, air and water temperatures, and the quantity and type of petroleum spilled. In one such process, microbial degradation, certain water borne bacteria, fungi and yeasts consume hydrocarbons for food. This process is rather slow even under ideal conditions. But most of these microorganisms found in both salt and fresh water require oxygen, which unfortunately our polluted and oxygen depleted harbor waters do not supply. Therefore, little of the oil can be oxidized, and each spill serves to further contaminate the ecology, and further reduce the oxygen content of the water. The combination of hydrocarbons with atmospheric oxygen referred to as autoxidation is another one of the weathering processes of petroleum. It is a rather slow process because of the small amount of oxygen penetrating into the oil.(3)

Influence of Wind and Water Conditions on the Movement of Oil

Whereas the surfaces of sheltered bays and lakes may show little movement, rivers and open tidal basins possess known and predicable surface speeds. Ordinarily, a spill will move in the same direction and at the same speed as the surface water on which it rests. In the absence of a natural current or floating debris, a spill will drift with the wind at about 3.5% of the wind velocity. This drift will occur regardless of such factors as spill size, spreading tendencies of the oil, size of the spill and water depth(4). Therefore, depending on the waterfront geography of the locale, the movement of the water surface is a deciding factor as to whether a spill will be localized or widespread. Prior knowledge of local weather, current, tidal and geographic conditions are necessary in planning operational strategy to limit spill damage.

## SECTION VI
## LAWS AND REGULATIONS

Several Federal, State and Municipal laws are intended to prevent oil spills and to control spill damage to the marine environment. Only the more pertinent Federal statutes of interest to municipalities shall be summarized herein.

### The Refuse Act of 1899

#### Provisions

Prohibits the discharge of refuse into the navigable waters of the United States or their tributaries from any vessel, wharf, manufacturing establishment or mill of any kind.

Is applicable to oil discharges, both chronic and accidental in origin, and case law has extended the "refuse" concept to valuable products, such as gasoline.

#### Penalties

Violations are misdemeanors punishable by fines of $500.00 to $2,500.00 and/or imprisonment of not less than 30 days nor more than one year. One-half of the fine penalty is payable to those giving information leading to the conviction.

### The Federal Water Quality Improvement Act of April 3, 1970

This law supersedes the Water Pollution Control Act of 1965-1966 in regard to oil pollution control. Some of the more significant provisions of the new law are:

The discharge of oil is prohibited except in such "quantities and at times and locations or under such circumstances or conditions as the President may, by regulation, determine not to be harmful".

Note: Regulations promulgated by the Secretary of the Interior in the Federal Register dated September 11, 1970, interpret "quantities harmful to the public health and welfare" as being those which:

"(a) violate applicable water quality standards, or
(b) cause a film or sheen upon or discoloration of the surface of water or adjoining shorelines or cause a sludge or emulsion to be deposited beneath the surface of the water or upon adjoining shorelines".

The owner or operator of a vessel or an onshore or offshore facility from which oil is <u>knowingly</u> discharged can be assessed a civil penalty not to exceed $10,000.00 for each offense.

The person in charge of a vessel or an onshore or offshore facility who fails to immediately notify the appropriate Federal agency (U. S. Coast Guard or Environmental Protection Agency) of a harmful discharge of oil can be fined an amount not to exceed $10,000.00 and/or imprisoned up to one year.

The owner or operator of an onshore or offshore facility which discharges a harmful quantity of oil may be assessed for cleanup costs not to exceed eight million dollars. Discharges resulting from willful neglect or willful misconduct within the privity and knowledge of the owner renders the owner or operator liable to the U. S. Government for full cleanup costs.

The owner or operator of a vessel which discharges a harmful quantity of oil may be held liable for cleanup costs not to exceed $100.00 per gross ton of the vessel or fourteen million dollars, whichever is less.

The Federal Government may remove discharged oil from navigable waters or the contiguous zone at any time if the responsible party is not properly removing the oil.

The Federal Government may remove or destroy a vessel involved in a marine disaster in navigable waters and take action against on/off shore facilities which present a substantial pollution threat.

The Federal Government shall issue regulations establishing methods and procedures for the removal of oil; procedures, methods and requirements for equipment to prevent oil discharges, and the governing of the inspection of oil vessels carrying oil cargoes.

The owner or operator of a vessel over 300 tons shall provide evidence of financial responsibility to the extent of $100.00 per gross ton or fourteen million dollars, whichever is less.

The Federal Government will prepare and publish a National Contingency Plan for dealing effectively with oil spills, including containment methods, removal procedures, and the regulations for the use of dispersants and sinking agents.

A revolving fund is available to finance Governmental oil removal operations in cases where the violators fail to act. Any other monies received as a result of this act shall also be deposited in this fund.

Federal Oil Spill Prevention Regulations

The implementation of the Water Quality Improvement Act's provisions for equipment to prevent oil discharges from vessels and onshore and offshore facilities can be expected in the near future.

According to Vol. 36, No. 244 of the Federal Register, dated December 18, 1971, responsibility and authority for "non-transportational" facilities shall be vested in the Environmental Protection Agency. These responsibilities include the regulation of drilling, producing, refining, storing, disposing and certain transferring operations.

Whereas the Department of Transportation (Coast Guard) will be responsible for regulating the "transportational" phases of the oil industry. Included are the transferring of oil to or from a vessel at any facility, including terminal facilities; transporting oil via highway, pipeline, railroad or vessel and certain storage operations.

Federal Oil Spill Contingency Plans

Pursuant to the Water Quality Improvement Act's provision for the preparation of a National Contingency Plan for effectively minimizing spill damage, on June 2, 1970, the Council on Environmental Quality promulgated the National Oil and Hazardous Materials Pollution Contingency Plan. The Federal Register of August 20, 1971, promulgated the revised Nation Contingency Plan.

National Objectives:

The Plan provides for the coordinated response of Federal Agencies to protect the environment from the effects of pollution spills. It also promotes the coordination of Federal, State and local response systems and encourages local government and private capabilities in dealing with spill incidents.

The Plan creates Federal strike forces. It provides for a notification, surveillance and reporting system and establishes an operational center for coordinating Plan operations. The Plan, among other features, contains a schedule for chemicals to treat spills; procedures for the investigation of spills and enforcement of pertinent laws, and instructions relating to on-scene coordination at spill incidents. A pre-designated On-Scene Coordinator (OSC) is provided for spill response activities. The National Plan also provides for the creation of Regional Plans for dealing with oil spills.

Accordingly, the Environmental Protection Agency furnishes the OSC for inland navigable waters and their tributaries. The U. S. Coast Guard provides the OSC for the high seas, coastal and contiguous zone waters and for Great Lakes coastal waters, ports and harbors.

The U. S. Coast Guard is responsible for developing, implementing and revising as necessary, Regional Plans for those areas where it is assigned the responsibility for providing the OSC. The Environmental Protection Agency has similar responsibilities for those areas to which it furnishes the OSC.

The Primary Objectives of Regional Plans are:

Provide a Federal response at the regional level.
Determine, through the OSC, if the person responsible for the spill has reported it in compliance with Federal Law and is taking adequate action to remove the pollutant or adequately mitigate its effects.

When the person responsible for the spill is taking adequate action, the Federal role shall be to observe and monitor progress and provide advice as needed.

If the responsible person does not take or propose to take appropriate cleanup action, or if the discharger is unknown, the Federal Government is authorized to take steps to remove the oil. In the former instance, the responsible person is liable to the U. S. Government for cleanup costs to the limit of the law.

Questions relating to the Federal Water Quality Improvement Act or Federal Oil Spill Contingency Plans should be directed to the Federal Agency which supplies the OSC for a particular area. Furthermore, the establishment of liaison with the pre-designated OSC will prove valuable to a community in planning to protect its waters from oil spill damage.

Legal Interpretation

The regulations as summarized in this manual should not be considered lawfully binding. The actual Local, State, and Federal laws should be consulted when considering this legal interpretation.

## SECTION VII

## A SPILL NOTIFICATION SYSTEM

Although Federal statute requires that the person in charge of a vessel, an onshore or an offshore facility, immediately notify the nearest Environmental Protection Agency or U.S. Coast Guard office in case of a spill on navigable water, shorelines or contiguous zones, it is also advisable to have the local fire department notified as well. The fire department's nearby presence and quick response capability may result in promptly stopping the flow of the oil, eliminating a fire hazard and/or reducing the environmental or property damage.

An exchange of spill notification information between local and Federal agencies will be mutually advantageous by initiating operating liaison and thereby expediting control and cleanup activities. In some instances the Federal response agency may be required to engage the services of the cleanup contractor when for some reason the spiller has not done so or when the source of the spill cannot be determined.

The identification, location and telephone number of the Federal agency responsible for providing on-scene coordination at spills on navigable waters in the various geographic areas of the nation is available at the nearest EPA or Coast Guard office. A knowledge of this information for quick use by a community will insure a more rapid Federal response in case of a spill.

## SECTION VIII
## FAMILIARITY WITH LOCAL WATERS AND WATERFRONT CONDITIONS

The susceptibility of a community to oil spill damage is predicated on several factors related to its navigable and surrounding waters, its waterfront geography, and the uses to which these waters and shorefronts are devoted. In evaluating the extent to which a spill may injure a community, and in estimating possibilities for the control of a spill, familiarity with the waterfront areas, through data and map study and personal inspection, will prove helpful.

An oil slick on a fast moving stream may present little opportunity for containment in the rapid current, but the angular diversion of some of the spill into a quiescent cove or bay for eventual recovery may be possible. A spill on tranquil water will provide a much better opportunity for containment and recovery. The efficiency of spill boom increases as the current decreases. Also, the performance of skimming equipment is more effective in quiet water conditions.

Knowledge of the extent to which local waters are affected by tidal changes is important in minimizing spill damage. Reference to published tide tables giving high and low water predictions will be helpful in formulating strategy for containment boom deployment or other spill control operations. It may be necessary to effect some radical changes in the positioning of spill boom when the tidal flow changes from ebb to flood. Otherwise, especially when a spill cannot be fully encircled, oil may escape from behind the barrier.

Based on this information, sensitive areas such as marinas may be protected by boom in advance of the spill, work crews may be alerted to construct protective sand berms on beaches and to participate in the general removal of oil from beaches. Obviously, there is no assurance that a slick which has been carried out on an ebb tide won't return on the next flood tide.

The type of spill control operations also depend on the water depth beneath the spill. When the water is sufficiently deep, there will be no problem with deployment of boom by boat and utilizing floating skimming equipment. Should the water be very shallow, other means of boom deployment, possible from the land side, may be necessary. In tidal zones the water depths will vary as predicted in the tide tables. A first hand knowledge of the community's shorefronts will aid in the prompt formulation of spill control operations. The presence of sea walls and accessible roads along the waterfront can mean quick delivery of control equipment by land. Without access to the waterfront, equipment must be transported and deployed by boat, which may be slower in certain circumstances. Spill control operations from a pier or bulkhead would differ from operations undertaken from a beach.

Beach protection may entail boom deployment from the land side alone, whereas operations from piers or bulkheads where water depth is greater, may require the use of boat equipment. The type of skimming equipment to be used will also vary with the kind of waterfront. Beach areas may prohibit the approach of vacuum trucks of cleanup contractors, oil companies, etc., whereas, approach to the floating oil pool may be afforded by piers or roads along sea walls. Also, since oil can accumulate beneath shorefront structures and re-appear during low water periods, it becomes necessary to sweep it from beneath these areas during low water periods, possibly by fire streams, into a captive pool for ultimate recovery.

It is hardly possible that a cleanup contractor or an oil company can possess the knowledge of a community's waterfront that its fire service can. Having this information available for the cleanup people on their arrival can aid materially in the expeditious recovery of the spill.

## SECTION IX
## SOURCES OF OIL POLLUTION

Concurrent with the increased transportation, storage, and use of petroleum, is the increase in spill incidents. Oil is introduced into the nation's waters from both stationary sources and transportational sources. The stationary sources present in many communities are the refineries and bulk storage facilities usually situated along shorelines; the pipe lines, which may be situated above and below the ground and beneath some bodies of water; and the sewer outfalls which discharge into local waters. The transportational sources of oil traffic are the passenger, cargo, and military vessels fueled by oil; and the railroad tank cars and tank trucks which carry petroleum. In spite of the continuing efforts devoted to oil spill prevention, spills continue to occur for the simple reason that the vast majority are attributable to human error.

A barrel of petroleum will be transferred between ten and fifteen times between the different modes of transportation from the time it is produced until it is finally used. It is during these actual transfers that the spill frequency is exceedingly high. Statistically, one barrel is lost for each one million transported.

### Major Sources of Oil Pollution

It is difficult to estimate the number of spills from ships and barges in the United States inland and offshore areas for several reasons. Although it's illegal to do so, oil can be discharged into the open waters and rivers during ballasting, cleaning of oil tanks, and pumping bilges. However, even the scattered data on hand indicates that spills are frequent. The pollution potential from deballasting alone may exceed 100,000 tons per year.[5]

Because of the nature and volume of its cargo, the tanker poses the threat of creating the most serious pollution incidents. The historic Torrey Canyon disgorged 119,00 tons of crude oil in the memorable 1967 grounding incident.[5] Some government and petroleum sources estimate conservatively that 33,000 bbls of oil are lost daily in the oceans of the world from tanker operations along.[6] Port areas are highly vulnerable to spill damage resulting from tanker collisions as evidenced by the fact that 80% of a 10-year total of 550 collisions occurred entering or leaving ports.[7]

In addition to the 387 tankers and 2,900 barges engaged in the business of transporting petroleum on the nation's waters, some 217,000 miles of pipe lines, 158,000 tank trucks and 81,000 railroad tank cares are also employed in the delivery business. Accidental discharges from any of these modes of transport can pollute our waterways.[6]

Besides the transportational sources of spills, stationary sources from industries, refineries, storage facilities and sewer outfalls, continue to cause water pollution. Since these sources are present in most municipalities, a knowledge of their locations, and pollution potential will assist the fire department in planning spill control possibilities. These chronic, local sources volumetrically exceed that spilled from all waterborne sources.

Defective piping, storage tanks and dyking at some of these shorefront terminal facilities, which number about 6,000 nationally, have created some noteworthy spill incidents. One tank failure alone released 200,000 barrels of crude oil into the marine environment of several communities in the New York-New Jersey area.(8) Notwithstanding, the susceptibility of terminal operations to human error, plant personnel training and periodic inspections can effectively reduce spill incidents.

It is estimated that of the 1.25 billion gallons of waste crankcase oil generated by automotive engines, half a billion gallons are being discharged into the environment in an illegal manner. Much of this poisonous discharge finds its way into the aquatic environment and reveals itself as an oil slick, possibly near a sewer outfall. The enlistment of the cooperation of those involved in the sale of automotive oil, gas station operators and the general public is essential if this pollution nuisance is to be overcome. Also, a concerted effort must be made to provide and utilize nonpollutive means of disposing of waste crankcase oil.(7)

A prior knowledge of the location and pollution potential of these static sources will be valuable to a fire department in formulating its spill response plan. Furthermore, inter-community planning may be necessary due to the vulnerability of communities to spills occurring outside their corporate limits.

## SECTION X
## TECHNIQUES USED IN CONTROLLING OIL SPILLS

Several different techniques, some of which are controversial, are used with varying degrees of success in controlling oil spills. Under certain circumstances, slicks are burned off into the atmosphere or even sunken into the water column by adding high density particulate solids. At times chemical surface-active agents or emulsifiers are employed to disperse the oil in the water. While a method quite the opposite to dispersion, still in the developmental stage, is gelling the slick or the oil cargo of a leaking vessel to prevent its spread. Gelling is accomplished by the addition of a chemical agent which solidifies the oil. But the most widely used technique for controlling spills, particularly in port areas, involves the combined use of flotation barriers called booms and skimming devices for removing the spilled oil entirely from the water. At times, sorbents which may be granular substances or slabs of oleophilic (oil attracting) but hydrophobic (water repelling) materials may be used to soak up the oil for subsequent removal from the water. These various techniques will be outlined, and the dual technique of containment and removal will be described in greater detail, since this appears to be the most acceptable method of oil spill control in port areas.

### The Burning Technique

The disposal of oil spills on water by burning them off, may seem at first glance to offer an ultimate solution to the oil pollution problem. Hopefully, all the oil could be consumed without adversely affecting the marine environment, and, under closely controlled conditions, the inherent fire hazard can be minimized. However, several problems associated with the burning technique, must be solved before burning can be considered a practical means of disposing of oil spills.

Whereas, under certain circumstances burning might be considered for a spill at sea, it can hardly be recommended for inland waters or harbor areas because of the inherent air pollution and fire extension possibilities presented. Along with some actual experience with burning and the tests conducted by the Federal Environmental Protection Agency, some valuable information has been made available on the burning of oil slicks.

Some of the problems associated with the burning technique have been emphasized as a result of historic spills from tankers and other vessels at sea, experienced during the past few years. It has been found that after a short period of time, a spill is difficult to ignite and burn. The more volatile and lower flash point components are lost rapidly to the atmosphere and as the slick spreads, it becomes thinner and begins to emulsify with the water. Ignition then becomes very difficult. The heat loss to the body of water then makes sustained combustion improbable. Some investigators report that oil slicks less than 3 millimeters thick (about 1/8 in.) won't burn, and that kerosene, fuel oil or lubricating oil on water won't burn without a "wick". Nevertheless, fresh spills within harbors or confined areas involving light crude oil, gasoline or other low flash point products can present fire hazards which should be given the prime attention.

Research experiments have been conducted by the U. S. Navy and the Environmental Protection Agency, both with and without special burning agents.(9) Burning agents were used to ignite and sustain the combustion of a spill, while wicking agents were used to increase oxygen access and insulate burning oil from the cooling water. Priming agents may be gasoline, light, south Louisiana crude oil or various commercial products. Wicking agents may be straw or manufactured glass beads or silane treated fumed silica. The results of these tests indicate:

Burning of uncontained oil slicks is extremely difficult unless the oil is 2 millimeters thick or greater. These results closely parallel those of other researchers.

Eighty to ninety per cent of contained south Louisiana crude oil was burned without the use of burning agents but Bunker C could not be ignited under the same conditions.

Bunker C was burned to an eighty to ninety per cent reduction when seeded with a priming fuel and a wicking agent.

Experience and limited experiments with burning, to remove oil from beaches, indicate that burning of the heavy tarry patches causes liquification and therefore, penetration into the sand. The present techniques for physical removal of the oil are therefore preferable.

Until the research efforts aimed at the production of a "floating incinerator" to cleanly and safely burn off oil slicks are successful, the burning technique cannot be recommended for inland waterways or harbors.

The National Contingency Plan, as revised in August, 1971, regulates the use of burning agents. These agents are allowed so long as they do not in themselves or in combination with the material to which they are applied, increase the pollution hazard and their use is approved by appropriate Federal, State and local fire prevention officials.

The Sinking Technique

The National Contingency Plan, as revised in August, 1971, defines sinking agents as "those chemical or other agents that can physically sink oil below the water surface." The Plan allows the use of sinking agents "only in marine waters exceeding 100 meters in depth where currents are not predominantly onshore, and only if other control methods are judged by EPA to be inadequate or not feasible." A brief explanation of the technique follows, so that sinking may be better understood, even though inland and harbor water depths preclude its use.

In the normal course of events, some of the oil spilled on harbor waters finds its way to the bottom by clinging to or possibly by adsorption on particulate matter suspended in the water column. Experiments and experience with sinking as a method for disposing of oil slicks indicate that when sand or other high gravity hydrophobic (water attracting) substances, such as ground chalk or cement, carry oil to the bottom, the results are only temporary. The oil can be expected to resurface in a short while. Some other granular, oleophilic (oil attracting) substances, such as sulphur, permit the oil to cling to the grains and keep the oil submerged. The eventual elimination of sunken oil will depend on the biodegradation process and the dispersion caused by tides and currents.

To be effective, a sinking agent should be a high density, particulate solid having a large specific surface area. The sinkant should be oleophilic or capable of being conveniently made so, and it should bind with the oil so that it will be retained on the bottom. The agent must be capable of being distributed over the slick to achieve sinking of the oil.

Continuing investigations, tests and evaluations, both in the United States and abroad on various types of sinking agents and methods of application indicate that:

The numerous natural and manufactured products which might be used as sinkers require the application of large quantities to be effective. In addition to their purchase price, storage, transportation and application, add to costs. It, therefore, appears that clean sea sand which can be conveniently provided by dredges and transported to the slick, can be considered a practical sinkant. Sand slurries, treated with a chemical oil wetting agent have been effectively sprayed on slicks; the sinking effect experienced in these operations has been reported to be between 50 to 95% of the sprayed oil.[10] [11] The wide variation in results may be attributable to differences in the thickness of the oil slicks.

The heavier, more viscous oils are more susceptible to sinking than lighter oils.

Sinking is more appropriate to deep water sea spills where the fish population is less dense and marine biology would be less likely to be affected. Although sinking will localize the spill, damage may be more intense in the localized area.

Sand containing a minimum quantity of clay and silt is more effective than sand with higher quantities.

Although too coarse a sand may adversely affect oil retention, the use of sand which is too fine can be costly because of the increased surfactant requirements. However, regardless of the sand grading, wax coated sand is an efficient sinkant.

The logistics of dredging up large quantities of sand, transporting it to the spill site, treating it with chemicals and spraying it over the slick is a tested technique applicable only to large spills at sea.

The rate of application of sinkers is an important factor in their use. Fine powders are preferably applied at a rate not much faster than that of which they are encapsulated by the oil.[12]

The Dispersing Technique

This method of treating oil spills consists of the application of a chemical agent to the slick to reduce the oilwater interfacial tension and create an emulsion. Dissolved in the oil, these chemical agents render the oil more dispersible in the water; small droplets are formed and coalesence is prevented as the oil is "lost" in the water column. Besides the obvious removal of the oil from the water's surface, its dispersion in the body of water can be expected to promote biodegradation.

Some of the early dispersants used on oil slicks were actually emulsifying degreasers intended for such purposes as cleaning oil tanks.

Today, many more efficient and less toxic dispersants are available. Usually, chemical dispersants contain three types of ingredients:

The surface active agent which is the principal active component.
The solvents which may or may not be present to dilute the surface active ingredient and promote mixing with the oil.
The additives which stabilize the emulsion and aid dispersion.

Some of the surface active agents used are soaps, for fresh water use; sulfonated organics; phosphated esters; caroxylic acid esters of polyhydroxy compounds; and ethoxylated alkyl phenols and alcohols.

There are three general classes of solvents used in dispersants. They consist of hydrocarbons, such as kerosene, mineral spirits and in some cases, naptha; alcohols, glycols and glycol ethers; and water, which although the least toxic, does present problems in regard to miscibility in oil and freezing.

The additives in dispersants may consist of sodium phosphates, sodium silicates and liguin sulfonates among many, which are dispersant aids.[13]

Since the use of dispersants is controversial, some of the pros and cons concerning their use are worth knowing.

On the positive side are such benefits as the increased rate of degradation; injury to birds is reduced; the fire hazard is reduced; damage to beaches and solid surfaces is reduced and the formation of floating agglomerated oil masses is avoided.

The principal arguments against the use of dispersants revolve around their innate high level of toxicity and the toxicity of the dispersed oil. The low boiling point aromatic solvents used in some dispersants are known to be toxic to marine life. And certain surfactants, although efficient emulsifiers, have been found to be detrimental to marine life. Considerable effort has been undertaken in recent years to produce dispersants of considerably reduced toxicity. As a result, some effective and practically non-toxic dispersants are now available. The penalty paid for dispersing the oil several feet into the water column is that the oil is transferred from the surface to an area where it can damage forms of marine life which would have escaped if the oil had remained on the surface.

Another concern recently voiced is for the ultimate oxygen demand of the dispersant or the disperant-oil emulsion which might further reduce the dissolved oxygen in already polluted coastal and inland waters.

Section 2000, Annex X of the National Oil and Hazardous Substances Pollution Contingency Plan, promulgated August 20, 1971, describing the restricted uses of dispersants, follows:

2000. Schedule of Dispersants and Other Chemicals to Treat Oil Spills:

2001.1 This schedule shall apply to the navigable waters of the United States and adjoining shorelines, and the waters of the contiguous zone as defined in Article 24 of the Convention on the Territorial Sea and the Contiguous Zone.

2001.2 This schedule applies to the regulation of any chemical as hereinafter defined that is applied to an oil spill.

2001.3 This schedule advocates development and utilization of mechanical and other control methods that will result in removal of oil from the environment with subsequent proper disposal.

2001.4 Relationship of the Environmental Protection Agency with other Federal agencies and State agencies in implementing this schedule: In those States with more stringent laws, regulations or written policies for regulation of chemical use, such State laws, regulations, or written policies shall govern. This schedule will apply in those States that have not adopted such laws, regulations, or written policies.

2002. Definitions:-Substances applied to an oil spill are defined as follows:

2002.1 Collecting agents - include chemicals or other agents that can gell, sorb, congeal, herd, entrap, fix or make the oil mass more rigid or viscous in order to facilitate surface removal of oil.

2002.2 Sinking agents - are those chemical or other agents that can physically sink oil below the water surface.

2002.3 Dispersing agents - are those chemical agents or compounds which emulsify, disperse, or solubilize oil into the water column or act to further the surface spreading of oil slicks in order to facilitate dispersal of the oil into the water column.

2003. Collecting agents - Collecting agents are considered to be generally acceptable providing that these materials do not in themselves or in combination with the oil increase the pollution hazard.

2004. Sinking agents - Sinking agents may be used only in marine waters exceeding 100 meters in depth where currents are not predominately onshore, and only if other control methods are judged by EPA to be inadequate or not feasible.

2005. Authorities controlling use of dispersants, 2005.1: Regional response team activated: Dispersants may be used in any place, at any time, and in quantities designated by the On-Scene Coordinator, when their use will:

2005.1-1 in the judgment of the OSC, prevent or substantially reduce hazard to human life or limb or substantial hazard of fire property;
2005.1-2 in the judgment of the EPA, in consultation with appropriate State agencies, result in the least overall environmental damage, or interference with designated uses.

2005.2 Regional response team not activated: Provisions of section 2005.1-1 shall apply. The use of dispersants in any other situation shall be subject to this schedule except in States where State laws, regulations, or written policies that govern the prohibition, use, quantity, or type of dispersant are in effect. In such States, the State laws, regulations or written policies shall be followed during the cleanup operation.

2006. Interim restrictions on use of dispersants for pollution control purposes: Except as noted in 2005.1, dispersants shall not be used:

2006.1 On any distillate fuel oil;

2006.2 On any spill of oil less than 200 barrels in quantity;

2006.3 On any shoreline;

2006.4 In any waters less than 100 feet deep;

2006.5 In any waters containing major populations, or breeding or passage areas for species of fish or marine life which may be damaged or rendered commercially less marketable by exposure to dispersant or dispersed oil;

2006.6 In any waters where winds and/or currents are of such velocity and direction that dispersed oil mixtures would likely, in the judgment of EPA, be carried to shore areas within 24 hours; or
2006.7 In any waters where such use may affect surface water supplies.

2007. Dispersant use - Dispersants may be used in accordance with this schedule if other control methods are judged to be inadequate or infeasible, and if:

2007.1 Information has been provided to EPA, in sufficient time prior to its use for review by EPA, on its toxicity, effectiveness and oxygen demand determined by the standard procedures published by EPA (prior to publication by EPA of standard procedures, no dispersant shall be applied, except as noted in Section 2005.1-1 in quantities exceeding 5 p.p.m. in the upper 3 feet of the water column during any 24-hour period. This amount is equivalent to 5 gallons per acre per 24 hours); and

2007. Applied during any 24-hour period in quantities not exceeding the 96 hour $TL_{50}$ value of the most sensitive species tested, in parts per million, by 0.33; except that in no case, except as noted in Section 2005.-1 will the daily application rate of chemical exceed 540 gallons per acre or one fifth of the total volume spilled, whichever quantity is smaller.

2007.3 Dispersant containers are labeled with the following information:

2007.3-1 Name brand, or trademark, if any, under which the chemical is sold;

2007.3-2 Name and address of the manufacturer, importer, or vendor;

2007.3-3 Flash point;

2007.3-4 Freezing or pour point;

2007.3-5 Viscosity;

2007.3-6 Recommend application procedure(s), concentrations(s), and conditions for use as regards water salinity, water temperature, and types and ages of oils;

2007.3-7 Date of production and shelf life.

2007.4 Information to be supplied to EPA on the:

2007.4-1 Chemical name and percentage of each component;

2007.4-2 Concentrations of potentially hazardous trace materials, including, but not necessarily being limited to lead, chromium, zinc, arsenic, mercury, nickel, copper, or chlorinated hydrocarbons;

2007.4-3 Description of analytical methods used in determining chemical characteristics outlined in 2007.4-1, -2 above;

2007.4-4 Methods of analyzing the chemical in fresh and salt water are provided to EPA or reasons why such analytical methods cannot be provided; and

2007.4-5 For purposes of research and development, EPA may authorize use of dispersants in specified amounts and locations under controlled conditions irrespective of the provisions of this schedule.

Note: In addition to those agents defined and described in Section 2002 above, the following materials which are not a part of this schedule, with eautions on their use, should be considered:

Biological agents - those bacteria and enzymes isolated, grown and produced for the specific purpose of encouraging or speeding biodegradation to mitigate the effects of a spill. Biological agents shall be used to treat spills only when such use is approved by the appropriate State and local public health and water pollution control officials.

Burning agents - are those materials which, through physical or chemical means, improve the combustibility of the materials to which they are applied. Burning agents may be used and are acceptable so long as they do not in themselves, or in combination with the material to which they are applied, increase the pollution hazard and their use is approved by appropriate Federal, State, and local fire prevention officials.

## SECTION XI

## THE CONTAINMENT-REMOVAL TECHNIQUE

Based on the current state of the art of oil spill control in sheltered areas, the physical containment and removal of the oil from the marine environment is the most universally accepted approach. The containment-removal technique is not intended to add any pollutants to the water, and recovery of the spilled oil is followed by its proper disposal.

Containment is ordinarily attempted by the use of spill booms and in the case of fire departments, particularly, their fire streams can be of value in controlling and herding spills. The use of containment boom and fire streams for spill control purposes will be explained in detail, since either or both of these tools might be used by emergency personnel arriving first in an oil spill harbor or an inland waterway.

Some chemical containment techniques are in the development stage. One consists of the application of a gelling agent, either on the surface of the spill or into a leaking tank or compartment to gel the product and prevent further escape. Another is the application of a monomolecular or "piston" film substances on a spill to drive the oil into a compacted area for easy recovery. Although both of these means of chemical control offer promise; to date neither has been sufficiently accepted to be of concern to a fire department.

The physical recovery of the oil from the marine environment is a sure method of preventing the ecological damage which a spill may cause. Several types of "skimming" devices are employed in removing slicks from the water's surface. Among these are circular, floating weir suction units; the revolving disc or endless belt; suction hoses suspended or floated close to the water's surface; also numerous experimental recovery units using a variety of approaches for removing oil from the water are now in existence. "Sorbents" are those substances used on spills which float on water and attract the spilled oil. To be efficient, such substances must have a greater attraction for oil than for water and they must retain the oil long enough to allow the removal of the oil-soaked sorbent from the water's surface. A variety of natural and manufactured products are used as "sorbents" in the cleaning up of oil spills.

## SECTION XII

## CONTAINMENT BOOMS

Next to stopping the flow at its source, the most urgent need at a spill operation is to restrict the spread of the oil to the smallest possible area. Due to the speed with which oil spreads on water, quick containment efforts are essential if the damage is to be localized. These efforts should be harmless to the ecology and should assist the oil recovery operations. At the present time, a quickly deployed containment barrier is the most practical means of containing a spill on quiescent waters. This spill containment is usually achieved by the deployment of a manufactured containment boom.

At some waterfront installations where petroleum is transferred or used in volume, spill booms may be permanently maintained in the water around the potential spill sources. Thus, oil spills are almost automatically confined, and recovery of the spilled oil is simplified. At those plants or transfer points where oil spill boom is not kept in the water, a plant plan for quick boom deployment is essential. Spills at such unprotected locations present the possibilities for serious pollution incidents, as do those transportation accidents involving oil carrying vessels, barges and pipe lines. Furthermore, spill incidents may occur at locations where spill boom is remote from the scene or when most working personnel are unavailable to deploy boom stored ashore.

It therefore becomes obvious that an emergency response service is needed in many communities. Such a protective service can be made available by equipping a local agency, such as the fire department, with some containment boom and by training some personnel in its use. To supplement this 24-hour response availability, an agreement is desirable whereby the fire department can assist plant personnel in the deployment of plant boom. Such an arrangement can be especially valuable when spills occur at times when plant personnel are too few to effectively deploy their boom.

The arrival of the professional cleanup contractor should normally terminate the need for the fire department's services at a spill. Because of the lack of boom cleaning facilities at fire stations, prior arrangements should be made with persons responsible for spill cleanup to have the fire department's boom cleaned and returned as soon as possible.

### Criteria for Emergency Spill Boom

As a result of one year's experience in a research and development project, sponsored by the Federal EPA, the NYFD established some performance criteria for an ideal oil containment boom which an emergency service, such as a fire department or a plant team might use to control harbor spills. The criteria is an outgrowth of the NYFD's use of different types of boom at spills and in test exercises; reviews of publications containing boom information; consultations with manufacturers' representatives, and observations at spill operations in the Port of NY. Suggestions for the storage and use of boom which follow, are also products of NYFD experience.

A summary of these boom criteria are offered to assist a fire department in the selection of a satisfactory boom from the many manufactured products now available:

1. A draft of 12 inches and a freeboard of 6 inches proved adequate for harbor spills. The increased capacity of a larger boom is slight, and the weight and deployment time penalties are large.

2. The boom weight should be under 2 pounds per foot.

3. Flotation, ballast and stiffeners should be permanently attached, preferably inside the fabric to avoid snagging and simplify cleaning.

4. The fabric should carry the tension distributed over its height, with possible sewn or molded reinforcement at top and bottom. In addition, the fabric must be tough, abrasion-resistant, stable in solar radiation, thermally stable, and resistant to petroleum oils and products. A bright yellow color is recommended.

5. The cost should be under $12.00 per foot.

6. Grab handles should be provided on the top edge.

7. The boom should have an overall tensile strength near 6,000 lbs without external tension members.

8. Fire resistance is not recommended due to high weight and cost penalties.

9. The ballast and float configuration should afford stability in 15-knot winds, 0.5-1.0-knot currents and 2-ft waves.

Boom Storage & Handling Considerations

Since the use of boom was not envisioned when fireboats or waterfront fire service facilities were designed, no space or facilities for the storage and handling of spill boom were included. The adaptability of existing facilities may well be the deciding factor as to the kind and quantity of boom acquired by a fire department. The decision as to whether all boom storage should be concentrated in one location or distributed throughout a harbor community will depend on the size of the community, location of the spill potentials, the storage facilities and the personnel available.

In the course of the NYFD demonstration project, four different types of spill boom were tested for their handling and storing features. These booms were 36-in. boom with self-contained flotation and weighing about 4 pounds per foot; a light 36-in. boom with attachable flotation and two types of light boom with self-contained flotation, weighing between 1.5 and 2.5 lbs per foot. Four types of storage facilities were studied to determine acceptable modes applicable to an emergency service whereby four men could launch about three hundred feet of boom in a short period of time. The Tested modes involved storage aboard a fireboat, or at waterfront fireboat berths from which boom could be readily transported by boat or truck to a spill. Due to the quick response requirement and manpower limitations, the 36-in. heavy boom was eliminated from consideration. Its weight and bulk precluded storage aboard a boat and prompt loading either on a boat or truck. However, if manpower, storage space and lifting equipment are readily available, a heavy boom provides some containment and strength advantages.

Storing a reasonable amount of boom in the "ready" aboard a boat or truck for prompt transportation to a spill eliminates loading delays. Since the dedication of a truck exclusively to this service is not ordinarily possible, storage aboard a boat which may have some unused deck space, should be explored. Furthermore, having boom already aboard a fireboat insures prompt boom deployment should the boat encounter a spill while away from its berth.

## Boat Storage

Three alternatives are offered for fireboat storage, namely:

1. On a standard fire hose reel
2. In a storage box
3. On deck pallets.

This storage mode necessitates the use of a flat, flexible boom with little buildup when wound on a reel, or a flat boom with detachable flotation. Limited deck space may necessitate the use of a reel for storage and the use of a flat, flexible boom. However, the New York experience indicates that 300 ft of 36-in. boom with detachable floats can be stored on a reel measuring 5 ft in diameter and 5 ft wide with core spool measuring 9 in. in diamter. Although this storage is quite compact and convenient for boom launching, the attachment of the floats delays launching. In tests, 300 ft of wound, detachable flotation boom was launched in 18 minutes while an 18-in boom with built-in flotation was launched in 3 minutes from the deck of a fireboat.

## Deck Storage on Pallets

A convenient deck space can servce for this type of storage. The pallets are intended to keep the boom off the deck and allow for deck drainage. A tarpaulin cover, secured with line, will serve to protect the boom from the elements, especially from snow and ice. Most booms are adaptable to this type of storage, and readying the boom for launch can be accomplished with relative ease.

## Box Storage

The measurements of the boom to be stored (especially its articulations) must be considered to insure maximum space utilization within the box. A stern location for the boat storage box is preferable. The long measurement of the box should parallel the vessel's length since the boom will usually be fed out over the vessel's stern. To facilitate removal of the boom from the box, the cover and the rear (stern) end should be removable.

A convenient construction material for the box is 3/4-in. marine plywood. The bottom should be raised slightly above the deck and bottom drainage should be provided. Auxiliary equipment such as end connectors, tow plates, tow and securing lines can be conveniently stored in a box along with the boom.

A box measuring 6 ft long by 4 ft wide by 3 ft, 6 in high should be capable of holding 300 ft of light, 18-in. boom. An initial response of 300 ft of boom should be a fire department's planning objective.

## Shore-side Storage

Storage inside a building is preferable to storage in the open. Accessibility to a means of transportation (truck or boat) should be considered in selecting a storage building, and when placing the boom in the building. A compact package of the boom's auxiliary equipment (connecting and tow plates and line) should be kept with boom.

If a boom must be stored in the open, it should at least be placed on pallets and covered with a secure tarpaulin.

## Readiness of Boom Equipment

A program of periodic inspections should insure the boom's readiness for emergency use.

Important items to be inspected are:

Tension member connections. Connections of tension members (chain, cable, etc.) between each length must be made up to each other when joining sections of boom. Shackles may form the connecting links. If the stress members are not joined, tension put on the boom will be transmitted to the boom fabric instead of the tension member, and result in serious tearing of the fabric.

The end connector system. Sections of similar boom are connected by various systems. Some use bolts through matching grommet holes at the end of each section; some use connector plates which accomodate the two ends to be joined; and others may use snap hooks which connect to eyelets in the ends to be joined. Whatever the system used, these ends must be properly joined before the boom is put in the water, otherwise oil will escape at these connection points.

Flotation system. For boom using detachable floats, adequate plastic floats must be available and means of attaching them to the boom must be in good condition. If an internal flotation system is used, the encapsulating fabric must be closely inspected for tears or abrasions which might cause the release of the flotation material, particularly if pellets are used. Loss of flotaltion, even in one section of boom, can result in the escape of a spill. Also, the prior detection of the need for a small repair patch may result in a substantial monetary saving, in view of the costliness of boom.

Auxiliary equipment. The presence and serviceability of such items as tow plates, end connectors and tow lines, small light anchors and floats must be assured, as should a small reserve of such expendable items as connecting bolts, shackles and light securing line.

## Adaptability of Dissimilar Booms

It is improbable that all the boom in a community will be of the same size and make. Yet, on occasions it may be necessary to join these different booms to contain a spill. To do this, some improvised universal adaptor plates can be made from light aluminum stock. The plates should be 4 in. x 18 in. and 4 in. x 36 in. with two vertical rows of bolt holes drilled at intervals to match the grommet holes of boom ends and to accept tension member connectors. Such plates should permit connection of dissimilar 18-in booms or

18-in booms to 36-in booms. It is easier to join dissimilar booms, using adaptor plates, before the booms are launched. Joining the ends of floating booms, especially during adverse weather or in darkness can result in the loss of nuts and bolts or even the plates themselves.

## Transporting Boom to a Spill

In the large port communities boom may be transported to the spill site by fireboat and/or truck. Boat transportation may be used when larger boats having storage capability are available. Delivery and deployment of the boom is usually simpler from such a vessel than from a truck, since less manhandling is required, and the assistance of a small boat is more or less assured when a fire boat is used. Such small boats are usually carried as routine equipment on the larger fire boats. Also, on occasions, a truck may have difficulty getting close enough to the water to permit quick and efficient launching of boom.

In the industrial heart of the community, a fireboat willusually arrive promptly at a spill. Fireboats are usually situated in these areas and water traffic doesn't present the response delays which can be expected by vehicles on busy roadways. But, for spills which may happen in the outlying areas of a city, transportation by truck may be a practical means of getting boom to the spill site. When truck transportation is used, arrangements should be made to acquire the services of a small boat, such as an outboard, to deploy the boom on the water.

Storing a few hundred feet of spill boom aboard a fireboat as part of its normal operating equipment is preferable to storing all boom ashore. On-boat availability can save much valuable loading and responding time. This is particularly true when a fireboat which is a considerable distance from the nearest boom storage location receives a radio notification to respond to a spill incident. Having the boom already on board eliminates traveling to the boom storage location and loading boom on board the boat prior to responding to the spill.

## Planning for Boom Containment of a Spill:

To effectively control a spill, the officer responsible for boom deployment should seek the following information as soon as the spill notification is received:

The kind and quantity of oil spilled.

The exact location of the vessel, tank or sewer outfall observed discharging oil. Whether or not the leak has stopped flowing.

The direction and speed of the current in the main channel or river as well as the current in the immediate (usually sheltered) area of the leak.

The velocity and direction of the wind.

The type of shorefront (beach or bulkhead) and the sensitivity of the exposed area to spill damage.

Whether the spill is restricted to a small area or has spread. If it has spread, the possibilities for extended damage must be evaluated, and appropriate oil diversion or containment plans formulated. If the original spill notification is vague, it may be necessary to have fire personnel close to the reported spill investigate and radio any clarifying information which may assist the unit responding with the spill control equipment.

When the existence of a spill is verified, the Federal Agency (Environmental Protection Agency or the U. S. Coast Guard) charged with providing the on-scene coordinator should be notified promptly to guarantee cleanup by the person responsible for the spill.

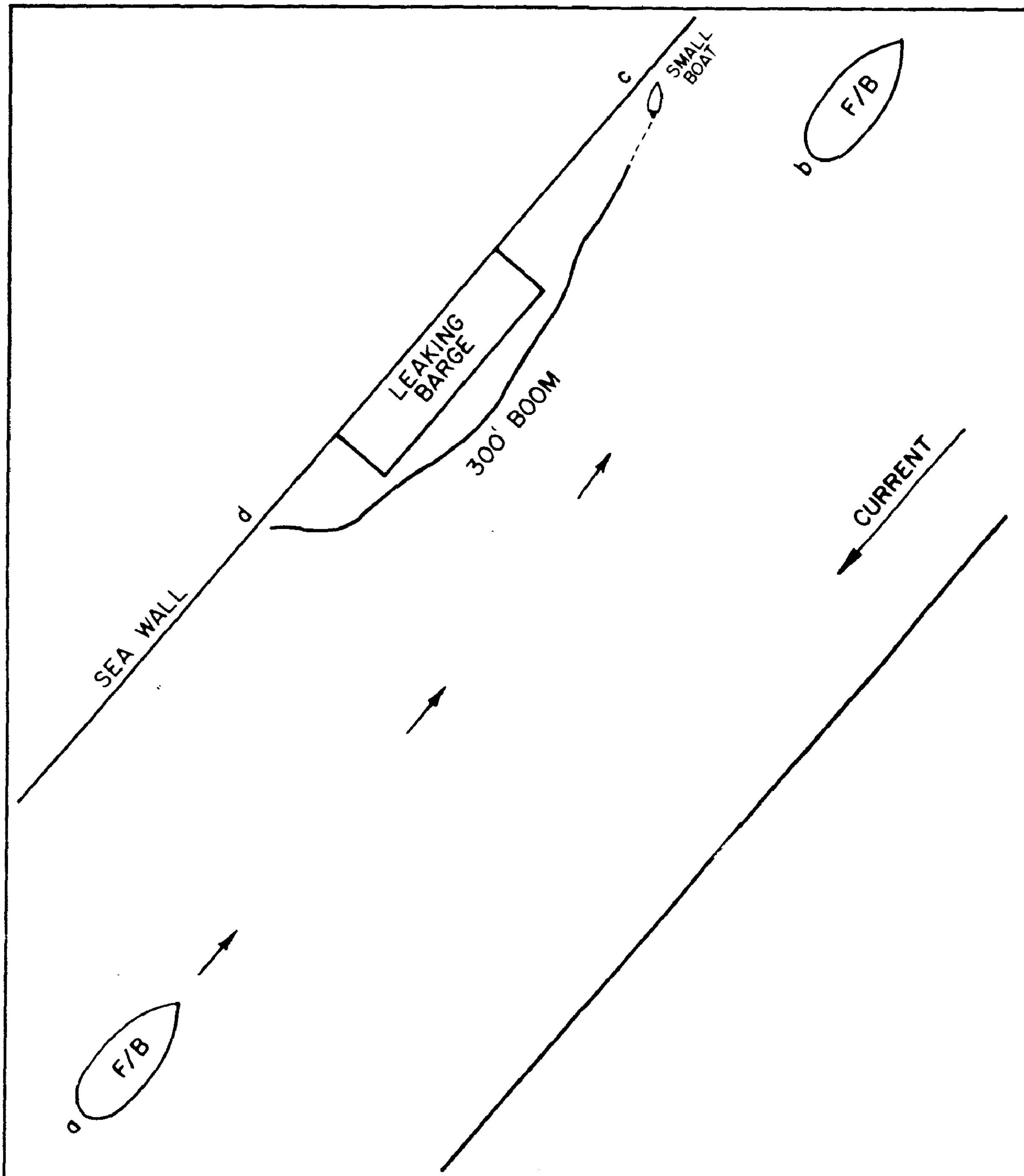
Evaluation of the spill information and existing meteorological conditions, combined with his knowledge of the harbor, the fire officer should be able to reach decisions as to:

Whether or not full containment of the oil with a boom is feasible. If current/wind conditions make full boom containment unfeasible, how and to where diversion of the oil by boom may be undertaken. If containment is feasible, the quantity of boom which may be needed; the methods of launching and deploying to be used, the type of termination which may be successfully used, such as running the boom up on a beach or securing to a wood or concrete bulkhead; the method/s of sealing the gaps at boom terminals against oil escaping.

A boom array which can be expected to facilitate recovery of the oil.

When excessive currents preclude containment, boom can be placed at an angle to the flow, causing floating oil to be diverted toward quieter areas where containment and recovery are feasible. Consideration should be given to the accessibility of the various types of recovery equipment to the slick before the boom is positioned. In some cases the pickup area in which the oil is concentrated may necessitate the use of shore-based equipment whereas in others, floating equipment may be necessary.

If reconnaissance indicates that the slick has spread, it may be advisable to boom a remote, sensitive area for protection, as well as the immediate spill site, for containment. In this case, provisions would have to be made for simultaneous boom deployment in separate




a – POINT AT WHICH FIRE BOAT LAUNCHES BOOM OVER STERN
b – POINT AT WHICH LAUNCHING IS COMPLETED AND TOW LINE IS DROPPED INTO THE WATER
c – FIRST POINT AT WHICH SMALL BOAT SECURES THE BOOM
d – SECOND POINT AT WHICH SMALL BOAT SECURES THE BOOM

FIGURE I
ENCIRCLEMENT OF A LEAKING BARGE BY A MOVING FIRE BOAT

areas of a community.

## Launching Boom from a Fire Boat

Two methods of launching boom from a fire boat have proven successful. Either may be used as the circumstances dictate. The first method consists of launching the boom from a boat which is underway, the second, from a boat which is moored.

## Launching Boom from a Moving Boat

This launching method may be used when it is desired to boom a rather wide slip or embayment at its open end or to encircle a spill source accessible to a fire boat. (Figures 1 & 2).

Boom with built-in flotation is more adaptable to launching and deploying from a moving fire boat than boom to which flotation members must be attached prior to launching. The attachment of floats slows the operation and requires the commitment of personnel beyond that needed for boom with built-in flotation.

## Steps to be Taken Preparatory to Launching Boom

While enroute to the site, sufficient boom to form the containment barrier should be laid out on deck, along the length of the boat. The needed number of boom sections should be joined; an end plate should be connected to the array's leading end (first end off the moving boat) and a tow plate should be fastened to the bitter end (last end off the moving boat).

A neatly folded securing line, about 25 ft long should be attached to the end plate and a tow line about 100 ft long should be fastened to the tow plate. If attachable end plates or tow plates are not required for the boom being used, the end lines should be tied to the boom to form "bridles". Therefore, any stress will be transferred to the boom's tension member and the boom will be held upright when in the water. The 100 ft tow line will allow sufficient distance between the boat's propellers and the boom itself during towing operations, thus, fouling the fire boat's propellers or damaging the boom itself, will be avoided.

In boom operations, flotation line has been found to be preferable to line which lacks buoyancy. The floating line will tend to avoid propeller fouling. Also, locating the floating line for boom towing and handling will be simplified for personnel working in small boats. Towing of both ends of a boom by two fire boats in a "U" configuration would not ordinarily be expected of a fire

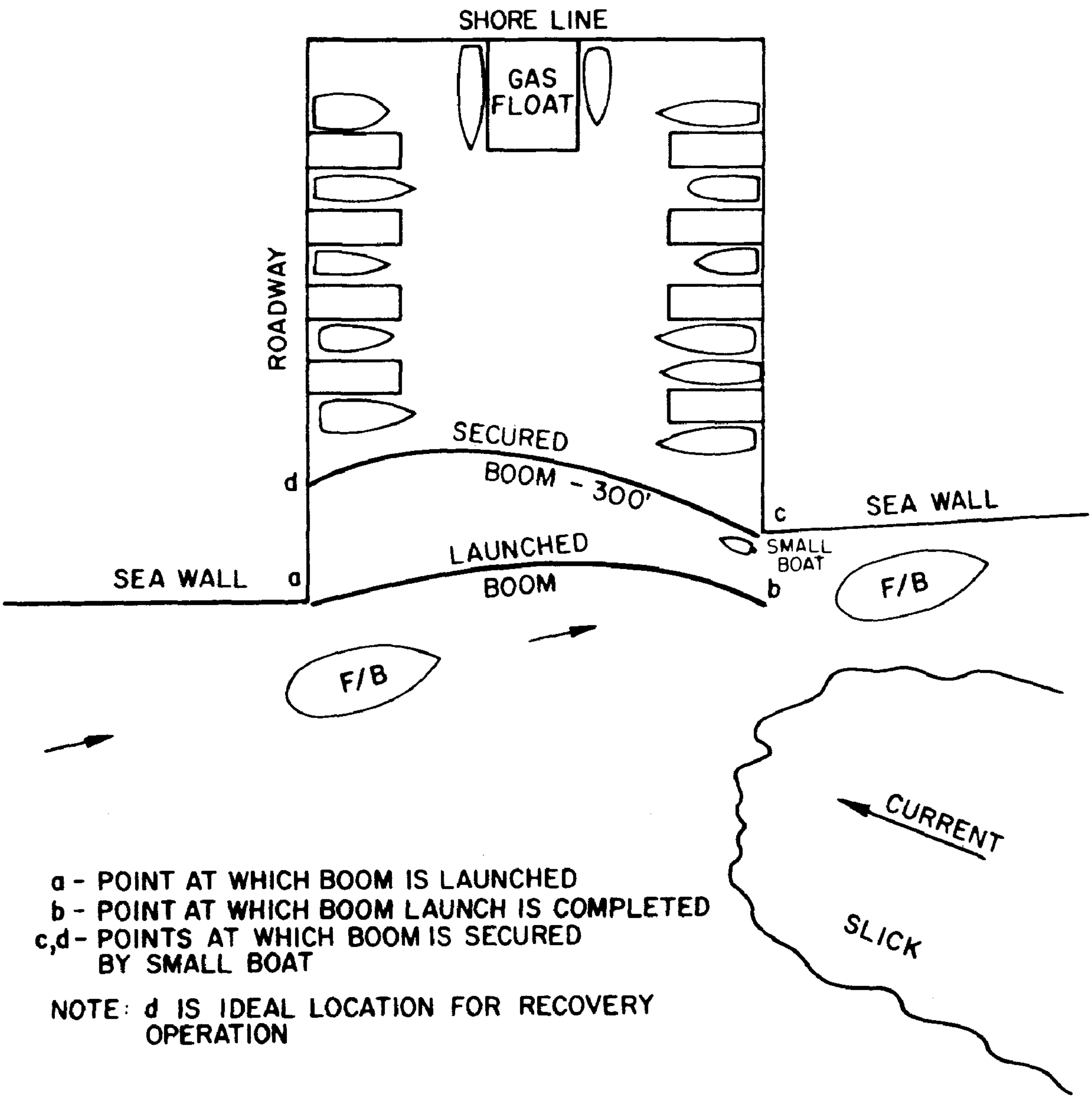



FIGURE 2

PROTECTION OF A BOAT BASIN BY A MOVING FIRE BOAT department. However, should this be undertaken, both boats should have 100-ft tow lines ready; means of constant communication should be established so that the slow speed and maneuvering of both vessels can be closely coordinated. A small utility boat should be readied for launching.

## The Utility Boat

Boom ends must be secured to piers or bulkheads at or near the water's surface. If a taut mooring line leads down from a high mooring point, such as a pier deck, a gap will be created between the boom and the water, which will allow the oil to escape.

The main decks of the larger fire boats are normally too high above the water to allow personnel to tie boom ends snugly to piers or bulkheads near the water's surface. Therefore, a small utility boat is a useful adjunct to a boom deployment operation.

When preparations for launching the boom have been completed aboard the responding fire boat, the small boat (usually an outboard) is readied for launching. The initial function of the two men in the small utility boat is to pick up the boom tow line cast from the stern of the fire boat and to secure the boom snugly at a mooring point. Two men in the utility boat can handle walkie-talkie communication, boom deployment and operate the boat.

A practical location for launching the small boat is usually about 1,000 ft from the anticipated boom mooring points. After launching, the utility boat should head for the area at which the boom is to be deployed and be ready to receive the boom tow line when it is cast from the fire boat. After one end of the boom is fastened, the small boat should proceed to the other end and likewise secure it. Other boom tending functions will be performed as directed by the officer in charge.

In quiescent water, a utility boat with as little as 6 hp can tow a more or less straight array of boom as long as 300 ft with relative ease. Towing boom in narrow circles or redeployment in a circular configuration, particularly when one end of the boom is secured, is slow and difficult for such a small boat. If necessary, two small utility boats can effectively tow 100 ft of light boom in a "U" configuration to corral a slick in a quiet area.

## Boom Launching Methods & Considerations

So that a boom array will be launched without becoming twisted or fouled in its own folds and be ready for easy towing and securing by the small boat crew, it is preferable to launch boom in a straight line over the stern. As the boom is payed out, it will be carried aft in a straight line away from the fire boat's stern.

A supervising officer should observe the boom launching function on the boat's stern, the prospective boom site and the small boat's activity. He should be equipped with a local field frequency radio, and he should serve as the communications link between the small boat crew and the pilot of the fire boat. The pilot should be informed when boom launch begins and he should be given status reports as the launching proceeds. This information will assist him in maintaining the proper headway so that the boom will tail out behind the fire boat as it is launched. It will also assist him in maneuvering the boat to achieve a boom array which can be easily deployed and secured by the small boat personnel.

The location from which boom launch should begin depends on several factors:

The length of the boom.

The facility with which boom can be payed out over the stern.

The speed at which the floating boom is carried aft by the combined effects of the wind, current and the boat's headway.

If only a few hundred feet of boom are to be launched from the fire boat, launching can begin as close as 500 ft from the objective, provided all the boom can be water borne in that distance. When the utility boat is launched and underway toward the objective area, the decision is made as to the direction of approach the fire boat will take to accomplish the boom launching. Also considered are the points at which boom launch will begin and end.

Should the current or wind be negligible, the boat's headway will allow the boom to tail out behind as it is launched over the stern. Thus propeller fouling can be avoided and a reasonable straight boom array will be achieved.

Existing wind and current conditions can be utilized to advantage when launching and deploying boom. But if the elements are disregarded they can work against such an operation. Although a fire boat may respond to a spill site in a favoring current, the boom should be launched over the stern while the boat is headed into the current. This procedure will allow the boat to go as slow or fast as needed to achieve the controlled launching of the boom. If a noticeable current is flowing near the spill source or area to be protected, it may be advisable to resort to the following launching procedure:

1. The fire boat takes an upstream position in relation to the booming objective, with the bow pointed into the current.

2. While working ahead on the propulsion engines, but making little or no headway, the boom is launched over the stern and carried aft as desired, by the current.

In the absence of a natural current, wind may create a surface current which should be considered for its effects on the boom. It may be advisable under some wind conditions to head a fire boat into a wind and let the wind assist in the launching operation over the stern, as a natural current would.

In all cases, the speed of a fire boat must be regulated to achieve the desired launching results and to insure that all the boom is waterborne as the boat approaches the tow line mooring or the location from which the small boat may conveniently take the boom in tow. If there is any doubt about when to start launching a boom, it has been found that it is preferable to begin launching prematurely and then slowly tow the boom a short distance if necessary. If launch is delayed, the boom objective may be passed and the small boat may have to re-position the boom by towing, and this may be time consuming.

In most cases a "slow ahead" boat speed is prescribed both for launching and towing by a fire boat. Tests incidate that an 18-in. harbor boom can be towed from one end at speeds up to 5 knots without physically damaging the boom. Dynamometer readings on 300 ft of such boom towed at 5 knots indicated a stress of about 230 pounds. The tow line should be able to withstand this tension with some factor of safety. Faster boat speeds during launch operations may not only allow deck personnel insufficient time to launch the boom in the desired area but may cause damage to the boom itself by overstressing it.

The pilot of a fire boat is normally concerned about what is happening ahead and in fact may have no visibility astern, where the boom is being launched and towed. Walkie-talkie radio information from the officer can keep him aware of the stern activities so he can regulate his speed or modify this course as necessary.

There should be no hesitance to allow a boom array to float unsecured for short periods while maneuvering the fire boat. The tow line can easily be picked up by the small boat crew and secured or returned to the fire boat if necessary.

It is poor practice to secure one end of a boom to a stationary object while boom is being launched from the deck of a moving boat. At times this may appear to be an easy way of launching boom near a shore line or pier front; however, this method of launching can result in injury to deck personnel or damage to the boom if the boom becomes snagged or fouled.

## Launching Boom from a Moored Fire Boat

The circumstances surrounding most harbor spills usually require the launching of boom from a moored fire boat, rather than one underway. Shallow water and confined waterways usually restrict the movement of a large fire boat. Under these conditions, a small boat may effectively deploy the boom launched from a moored fire boat. In some situations boom may be walked ashore from a fire boat or taken on a pier, then manually deployed onto the water around the leak source.

When a size-up of a spill situation indicates that the quickest and surest way of launching and deploying boom is from a moored fire boat rather than a boat underway, the following operational suggestions should prove helpful:

1. Boom should be prepared for easy launching while enroute to the site. Preparations are the same as when launching is from the fire boat underway.

2. If one is carried, the small utility boat should be prepared for launching. It may be necessary to launch this boat before the fire boat moors, because of its location on the fire boat. If no small boat is carried, the requisitioning of one at the spill site may be possible

3. Personnel should be assigned definite functions and field communications should be organized to control the operation. The cooperative use of workers at the spill site, particularly the personnel of the spiller, should be considered. An extra willing hand can save some valuable time.

4. As the fire boat approaches the spill source, the decision should be made as to where and how to position the fire boat so that the small boat and boom can be launched with the greatest facility.

5. Boom launch or off-loading should begin as soon as the boat is moored and the propellers stop turning. Little time can be saved in launching while the boat is approaching a mooring, and the likelihood of fouling the propellers is created.

6. An attempt to hurry boom launching by dumping large sections over the side for deployment by a small boat, is poor practice, which will only cause delay. The boom will become fouled and twisted and will have to be straightened before it can be deployed. It is preferable to pay out the boom over the boat's stern in a straight line for towing and deployment by a small boat. This launching procedure is not unlike that recommended for boats underway.

7. Even though a moored launching usually takes place in a sheltered area, wind and current (tidal flow in some cases) should be considered and used to advantage for boom launching and deploying. The objective should be to let these forces assist the small boat in carrying the

boom over the stern toward the containment objective.

## Launching Boom from a Truck

Before boom is loaded on a truck for transportation to and launching at a spill site, boom sections should be connected. The end and tow plates should be affixed, and such auxiliary equipment as small anchors, floats and light line should accompany the boom. Mooring and tow lines should be attached to the boom ends and then neatly folded to prevent unravelling while being carried.

To minimize manhandling the boom, the truck should approach as close as possible to the mooring site. Unloading should be planned so that the boom can be fed in a straight line to a small boat for deployment on the water. If the boom is to be hand-carried along the waterfront and lowered into the water around a leak source, many hands will be required. Extra help is needed to actually carry the boom rather than drag it any distance on the ground. Boom isn't nearly as rugged as fire hose which is less inclined to snag and is more abrasion resistant than boom.

## Boom Fastening

Boom ends should be fastened close to the water's surface and as snugly as possible to the vertical surface to which it is secured.

In a harbor, boom ends may be expected to be tied to the timbers of pier or other wooden structures; fastened to concrete or steel bulkheads, or at times run up on a beach and secured to some object ashore. When tied to waterfront structures (piers, bulkheads etc.), it is advisable to tie the boom snugly to the mooring point to prevent oil from getting through. If the boom is to remain in place during tidal height changes, it will be necessary to adjust the mooring lines accordingly to compensate for the rise and fall of the tide. When this is not practical, other means must be considered to prevent oil escaping through the gap between the shore and the boom. (See suggested methods)

The availability of a hammer and some heavy nails will prove useful at times when securing a boom line to some wooden structures. A power-actuated stud driver has proven satisfactory in providing fastenings to which boom line can be tied, when steel sheathed or concrete bulkheading is encountered.

## Boom Retrieval

When boom is sufficiently clean to be taken back on board a fire boat, the boat's power equipment should be used when practicable, to assist. If the boom is retrieved in a straight line over the stern, some of the

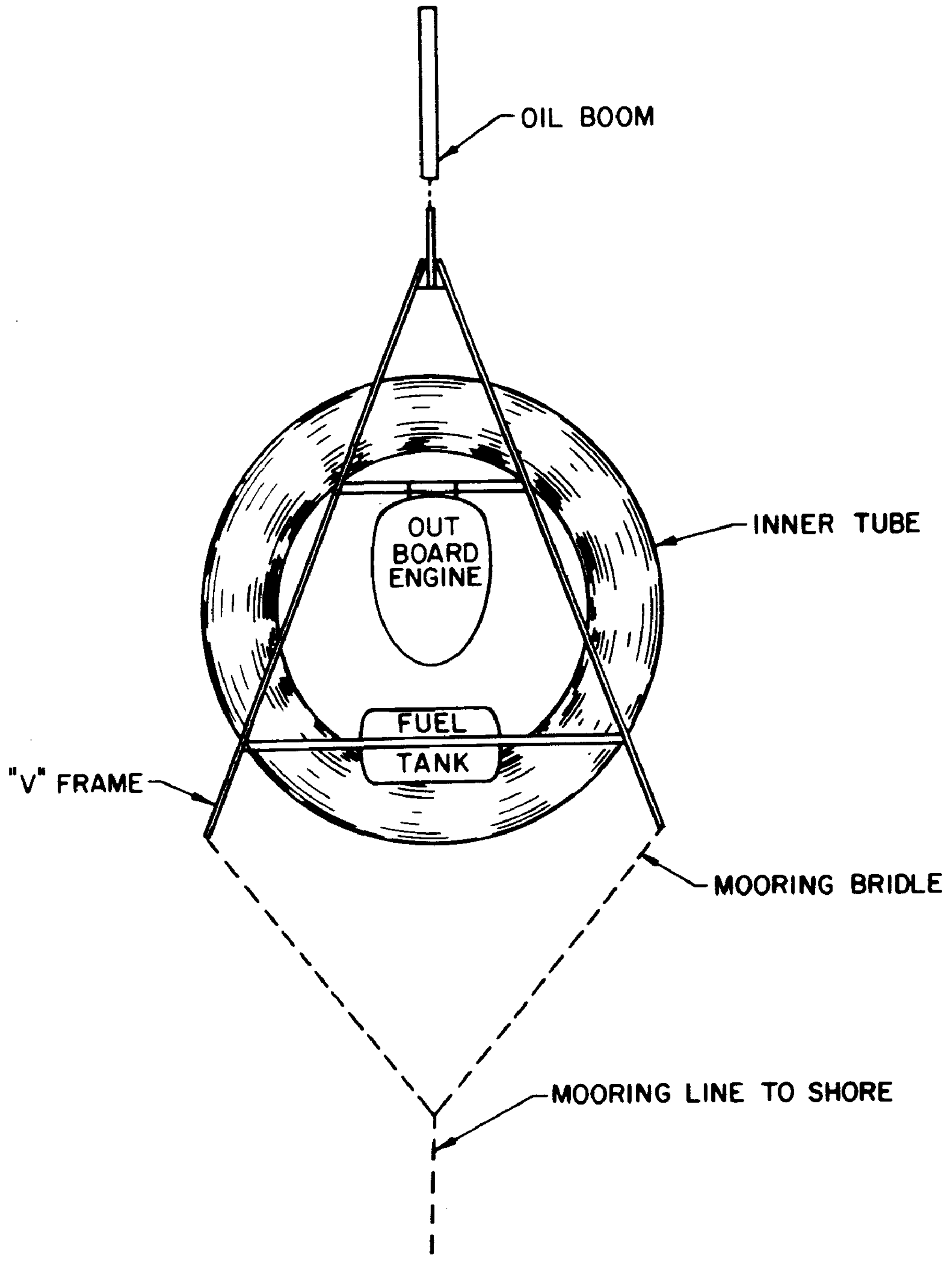



FIGURE 3
BOOM TERMINATOR SCHEMATIC

work can be done by tying a rope onto the boom and pulling it in with the boat's capstan. One man can operate the capstan pulling on the line while one man can guide the boom over the rail. The small boat can be useful in keeping the boom array straight during retreival. For easier retreival under some conditions, it might be better to tow a short array of boom back to a fire boat's berth for reloading.

## Control of Spill Leakage at Boom Shore Terminal Gaps

A common source of boom failure at oil spills is the leakage of oil between the boom end and the adjacent shoreline or bulkhead. Some of the proven methods for preventing leakage at boom terminal gaps are:

Use of fire stream commensurate with the size of the gap. A fire stream (hand line or monitor stream) can be used to generate a counter current to prevent oil escape. For most gaps (5 ft - 10 ft) a 1-1/2 in hose line with a 1/2 in tip and 20-30 psi nozzle pressure will effectively create a surface counter current to prevent the escape of oil. The stream is held more or less stationary and directed to impinge downstream from the boom so that the edge of the fan-shaped current fills the gap spanned by the mooring line. If for some reason a wider gap must be spanned by a fire stream-generated current, heavier caliber streams may be used in the same manner, but greater care must be exercised in using heavier streams. Heavier streams should impact on the water's surface a greater distance from the gap to avoid the increased possibilities of upsetting the boom or emulsifying the slick. Since the use of fire streams to develop counter currents at boom end gaps may tie up a fireboat or personnel, an alternate means was developed in the NYFD Demonstration Project. It is referred to as a shore termination for oil spill booms.

## The Shore Termination for Oil Spill Booms

A simple flotation implement was developed during the course of the NYFD project to dynamically seal the gap between the boom end and the shore. The terminator utilizes the propwash from a small outboard engine to create a counter current and thus keep the oil within the containment area (Figure 3). Except for periodic refueling of the engine, the unit operates without much attention and adjusts to various types of shore lines and to tidal height changes.

The principal components of the terminator unit are:

1. A plywood "V" frame for the basic which supports structure and barrier extension.

2. A 6-hp outboard engine to generate the counter current.

3. A large (1,000 x 20) truck tire inner tube to provide flotation.

Complete construction and performance details of this terminator are contained in a report related to this project entitled, "Shore Termination for Oil Spill Booms".

A less efficient alternative method of sealing a boom gap is to use a small boat equipped with an outboard engine, in lieu of the terminator described above.

Boom Tending

After boom has been deployed to contain or divert a spill, it should not be left unattended. The constant observation of a boom array will detect conditions which may destroy the effectiveness of the booming efforts. Some of the situations which should receive constant attention are:

1. Changes in tidal current direction which can nullify a boom's effectiveness unless the boom array and recovery operation are repositioned. Since tidal behavior is predictible, prior knowledge and close observations of surface currents should result in the timely re-alignment of a boom array to avoid the escape of a spill.

2. Leaks caused by loss of detachable flotation members. The availability of additional floats or possibly an instant repair may correct this condition.

3. The intrusion of debris which may physically damage the boom or cause oil escape. Screening out such debris or actual removal from the captive pool may be necessary.

4. The unauthorized entrance into the boom protected area by vessels or the actual damaging of the boom by such vessels. Intervention by the USCG or the local police may be indicated in such instances.

Most of the functions associated with boom tending can best be performed in a small utility boat.

Personnel Familiarization

Probably the best way to familiarize operating personnel with the use of containment boom is participation in occasional training exercises. Handling and deploying boom and observing its performance in the water will improve operating efficiency and generate innovative suggestions.

## SECTION XIII
## RECOVERY OF SPILLED OIL

The national policy in regard to techniques for dealing with oil spills is embodied in Annex S of the National Oil and Hazardous Substances Contingency Plan which in part "advocates development and utilization of mechanical and other control methods that will result in removal of oil from the environment with subsequent proper disposal." Although a fire department may have little oil removal capability, its prompt deployment of light boom, and the use of fire streams to contain or herd oil can facilitate removal of the spill by the persons responsible for the spill or contractors. The efficient recovery of a spill is feasible only as long as it can be contained.

Spill booms have containment limitation imposed by their size as well as the meteorological and hydrological conditions under which they are employed. A slick tends to thicken at a boom barrier, but it may be lost over the sail (freeboard) of a boom by wind or wave action. Also, failures may occur beneath a boom's skirt (submerged portion) by either of two mechanisms. These are known as droplet loss and drainage loss. Drainage loss occurs when oil builds up against the skirt and passes under. Droplet loss occurs when particles of the slick are entrained in a current and carried beneath the skirt. Both the institution of prompt skimming and the application of sorbents are the counter measures which may be employed to prevent boom failures.

Unless skimming is undertaken reasonably soon after boom containment, boom failure becomes a possibility. Although oil recovery isn't usually considered a fire department function, under certain circumstances some skimming capability might be required, such as: (a) when the community desires to recover spills for which it alone is responsible, or; (b) when cleanup contractors are unable to respond reasonably soon to the area.

### A Small Oil Skimming System

In the course of the NYFD demonstration project, it was found that, in order to expedite the research into effective utilization of fire streams and boom for herding and containment of oil slicks, an oil skimming system was needed to familiarize fire department personnel with this type of equipment as it related to their prime mission of rapid containment. The booms had to be deployed and the streams directed to facilitate the ultimate objective of removing the oil from the water. The tests with boom and fire streams also entailed the use of plastic floaters which duplicated to a large degree the action of oil on water. The skimming system had to provide a means for recovering these floaters for further use, and be keyed to the unique needs of the project and the capabilities of the fireboats.

Given the options of weir or vacuum type skimming devices, a small compressed air-driven vacuum type unit was selected based on power and handling criteria. Each fireboat was equipped with an air compressor and sufficient length of air hose; and air eductor vacuum equipment is relatively light compared to electrically driven equipment of the same capacity. These units are commercially available, off-the-shelf units normally used in conjunction with standard open top 55 gallon drums for wet vacuuming in factories. Only minor modifications are needed to adapt the equipment for oil skimming and all the components are light in weight and easily transferred from boat to boat or boat to dock with a minimum of personnel. For test purposes, the 55 gallon capacity is sufficient, and when the system is used at an actual spill, the system capacity is only limited by the available supply of drums or other utilizable oil storage space. (Figure 4).

Of the modifications to the vacuum unit, one was made to the head itself and the other to the drum. The first made it possible to transfer oil from the open top drum into standard drums with 2 in. pipe fill and 3/4 in. vent holes. The second allowed drain off the water from the bottom of the drum after the oil/water mixture had decanted. The drum was raised on an angle iron frame so that a 2 in. gate valve could be installed in the bottom. Since none of the ready-made vacuum accessories was suitable for skimming oil from the water, that section of the system had to be fabricated. The open end of the 2 in. vacuum hose, when held approximately 1/2 in. to 1 in. above the surface, was found to perform quite adequately as a skimmer and a float was designed which would hold the hose in this configuration with the correct hose-to-surface gap. This float was actually made to perform two functions. In addition to holding the hose in the correct position, it provided a collection area into which the oil contained by the booms could be driven for pickup. It consisted of a simple V-shaped structure made of two 3 ft x 4 ft sheets of plywood with foam flotation outside the V and a mounting bracket for holding the vacuum hose. (Figure 5). Provisions were made to attach oil spill boom to the open ends of the V. It was therefore possible to place this pickup unit in any location where there was a splice in the oil boom and it was convenient to herd and pickup the oil.

The only critical design parameter was the flotation configuration. The system normally operates as would a typical vacuum cleaner with the oil/water entrained in the air stream and the hose essentially full of air. If, however, the hose end happens to dip under the surface due to wave action and start picking up 100% water, there is an effective increase in weight causing the unit to sink further. The flotation area must be sufficient to allow only small changes in the gap spacing due to this weight variation.

This small skimmer performed quite adequately in meeting the requirements of the demonstration project. It picked up the plastic chips used to simulate oil with no problems, and also did an effective job of oil skimming on those occasions when it was tested on spills of opportunity.

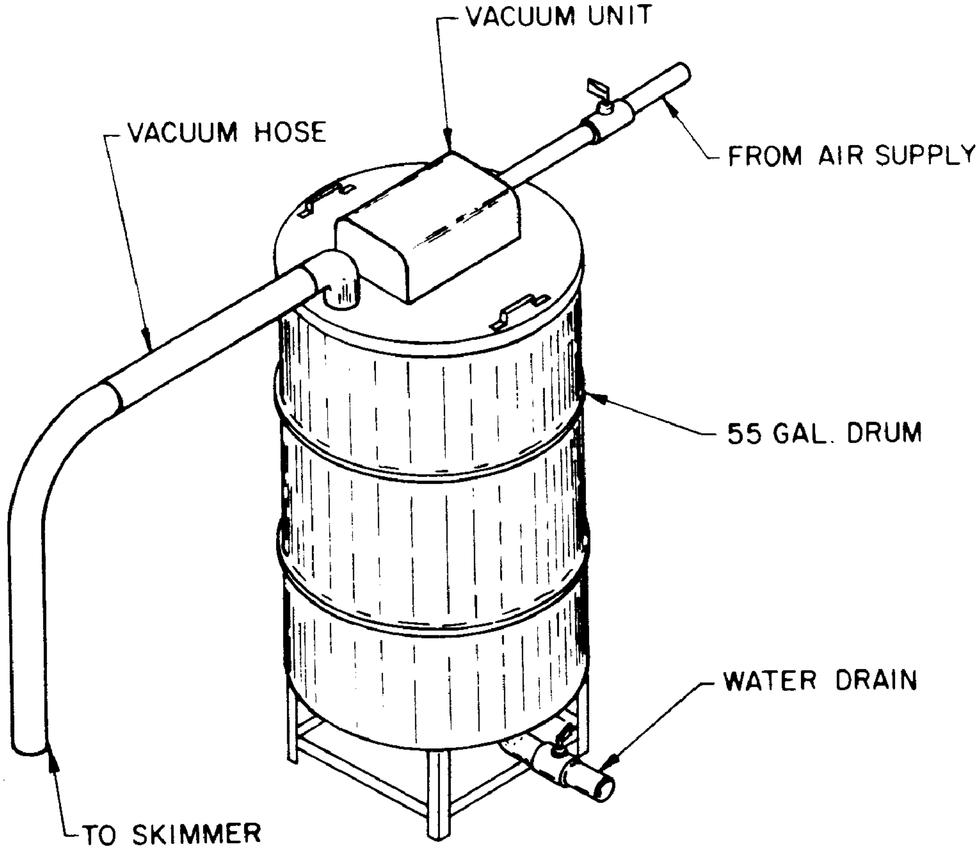



FIGURE 4
PICK-UP SYSTEM

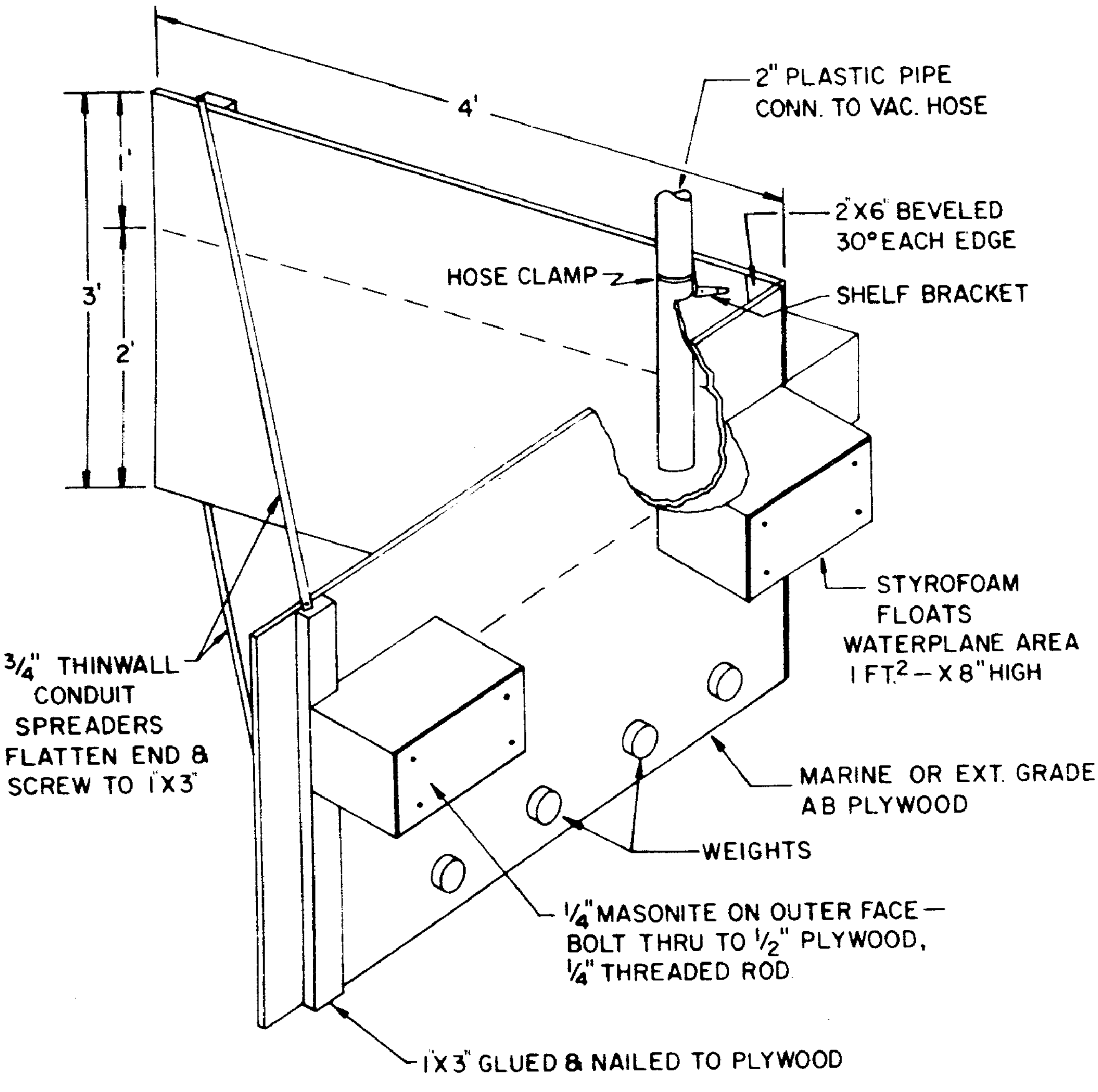



FIGURE 5

**BOOM CORNER SKIMMER**

More complete construction and performance details of this recovery system are contained in a separate report related to this project entitled, "A Small Vacuum Oil Skimming System."

Use of the System

In conjunction with the deployment of boom, the decision should be made as to where to situate the skimmer. Spill situations vary but experience indicates that some proven procedures can be helpful:

1. Consider wind and current influences on the movement of oil along the boom so that the skimmer may be placed at the location where the slick is likely to be the thickest.

2. Containment boom must be connected to each side of the "V" skimmer to channel oil toward the angle apex. If it is not possible to affix the boom ends to the skimmer with attached hardware, a flexible boom may be looped around and secured to the skimmer so that the open end of the "V" is facing the direction from which the oil is being herded or driven by the elements.

3. A long array of boom will ordinarily be connected to one side of the "V" skimmer and a short array to the other. The longer array will constitute the prime deflection barrier while the short array will prevent loss of oil which may be herded toward the skimmer.

4. In some tight situations, where the leak may be coming from a moored vessel, it may be necessary to place the skimmer between the ship's hull and the dock or bulkhead.

5. The skimmer head may be lowered into the water by hand, from a dock, or a boat's davit may be used. A lifting bridle fastened to the unit will facilitate lowering or raising. The services of two men in a small boat are essential for positioning the skimmer (it can be towed short distances) and for inserting it in or looping the boom array around it. A screwdriver will be needed by the men in the small boat for affixing the 2 in. flexible hose to the pickup pipe. These men can also be helpful in removing any large debris which may obstruct the vacuum inlet. The inlet itself can usually be cleared quite simply by merely shutting down the vacuum momentarily.

6. The vacuum drum should be placed close to the skimming head and other receiving drums should be situated reasonably close to facilitate transfer of oil and removal of the drums.

7. While the vacuum drum and head, the receiving drums and the flexible hose are being set up by 2 men, 2 others stretch the 1 in. air hose to the vacuum unit.

8. One end of the air hose is connected to the air manifold or discharge

outlet, the other is connected to the vacuum head; valves at both connections remain closed until ready to pick up oil.

9. Using universal hose clamp fittings, a man at the vacuum drum connects the vacuum hose to vacuum head and drain hose to drain fitting. A screwdriver is used to connect these fittings. The drain valve is closed. Then the flexible hose is connected to the skimmer's vertical pipe.

10. The vacuum head's automatic overflow cut-off is then seated by pushing down the flat disc on top of the unit.

11. When the boom is in position, the recovery system ready, and herding operations are directing oil into the skimmer, the air compressor is started. The air valve at the vacuum head is opened and the skimming has begun.

12. Effective herding is an integral part of skimming. Fire streams properly used can keep a steady stream of oil flowing into the skimmer.

Training exercises involving some limited herding and a small recovery system can be devised, utilizing a procedure employed in the NYFD project. A sealed containment basin may be created in a sheltered area, using about 150 feet of boom. The boom can be deployed to create a circle, or across a solid bulkhead corner, to create a containment area. Some chopped up data processing cards can be scattered on the water surface to simulate oil and a small fire stream can be used to herd the "slick" toward the skimmer. This simulates in miniature the problems involved and the corrective procedures associated with oil spill.

## SECTION XIV
## FLOATING SORBENTS

"Sorbents" include those natural or manufactured substances used in oil spill control, which are either absorbent or adsorbents. Oil clings to the surface of adsorbents but is assimilated into absorbents.

The sorption process is dependent on several natural phenomena, namely, wetting, spreading and capillary action. Also, the sorbent capacity of a substance is proportional to the substances exposed surface, provided it has the necessary wetting characteristics. Effective sorbents have high oil and low water sorption capacity; that is, they are oleophylic and hydrophobic. Their oil retention should be high and they should remain buoyant.

### Materials Used as Sorbents

The floating substances used as sorbents may be categorized as inorganic, natural organic and synthetic organic. Some of the inorganics are perlite and vermiculite, which are usually treated to improve their efficiency. The natural organics include ground corn cobs, wheat straw and treated wood cellulose fiber. Among the synthetics can be found the sorbents which have exhibited the greatest degree of oil sorption. These are the polymeric foams, such as shredded or cubed polyurethane, polyethylene fiber, urea formaldehyde and polypropylene fiber.

### Use of Sorbents

Sorbents are applied to spills in several physical forms such as mats, slabs, cubes, shavings or powders. Ideally, sorbents should be applied only to the oil, to the exclusion of the water. But under actual spill conditions, only partial coating by oil can be expected. For optimum effectiveness, the particle or powdered forms should be broadcast evenly over a spill. The physical mixing of sorbents with the oil mass will improve their sorption effectiveness. Wind and wave may accomplish this or some convenient manual or mechanical means may be used to promote mixing. The larger forms, such as slabs or mats must be moved through the slick so as to contact as much oil as possible.

Surface active agents, such as detergents can seriously interferewith the usefulness of sorbents. They break down the hydrophobic properties of the sorbents allowing water to contact them excluding the oil.

Some of the drawbacks associated with the use of sorbents are:

1. Because of bulk, their storage and transportation become problems.

2. Although systems for efficient distribution over spills have been developed, they are not as yet generally available.

3. Their use entails the use of a considerable amount of manpower in what can be messy work.

4. Some skimming and pumping systems will clog with the oil-soaked mass.

5. Disposal of the sorbed oil is more difficult than the disposal of simple emulsions, which can be separated and processed for re-use.

Some benefits associated with sorbents, are:

1. When used on a controlled spill, sorbents will assist the boom array in containing the spill.

2. They can assist in agglomerating a spill to limit its spreading and pollutive tendencies.

3. They can minimize shore damage, either by being applied on uncontained spills or spread on beaches in anticipation of a slick on the incoming tide.

4. They do not add to the toxicity problems as do dispersants.[14]

Fire Department Use

The storage and use of large amounts of sorbents by a fire department are not likely. The problems created by the need for considerable storage space and the amount of equipment needed for dispersal recovery, and disposal, seem to preclude sorbents from consideration as a major tool for an emergency response force. Under some circumstances, a fire department might, however, assist in the application of sorbents, and should be familiar with their use.

## SECTION XV
## USE OF FIRE STREAMS FOR CONTROLLING OIL SPILLS

Until recently the main use of fire streams at an oil spill was to "break up" the oil by playing the fire streams directly onto it. In cases of highly volatile petroleum products, this still may be the best procedure for reasons of fire safety. But, where explosion or fire is not a hazard, it has become vitally necessary to control and contain the oil so that environmental and property damage can be minimized, and as much of the oil as possible can be recovered. This is exactly opposite to dispersal - the previous approach. Whereas dispersal required little in the way of special knowledge or techniques, control and containment are a far more difficult matter.

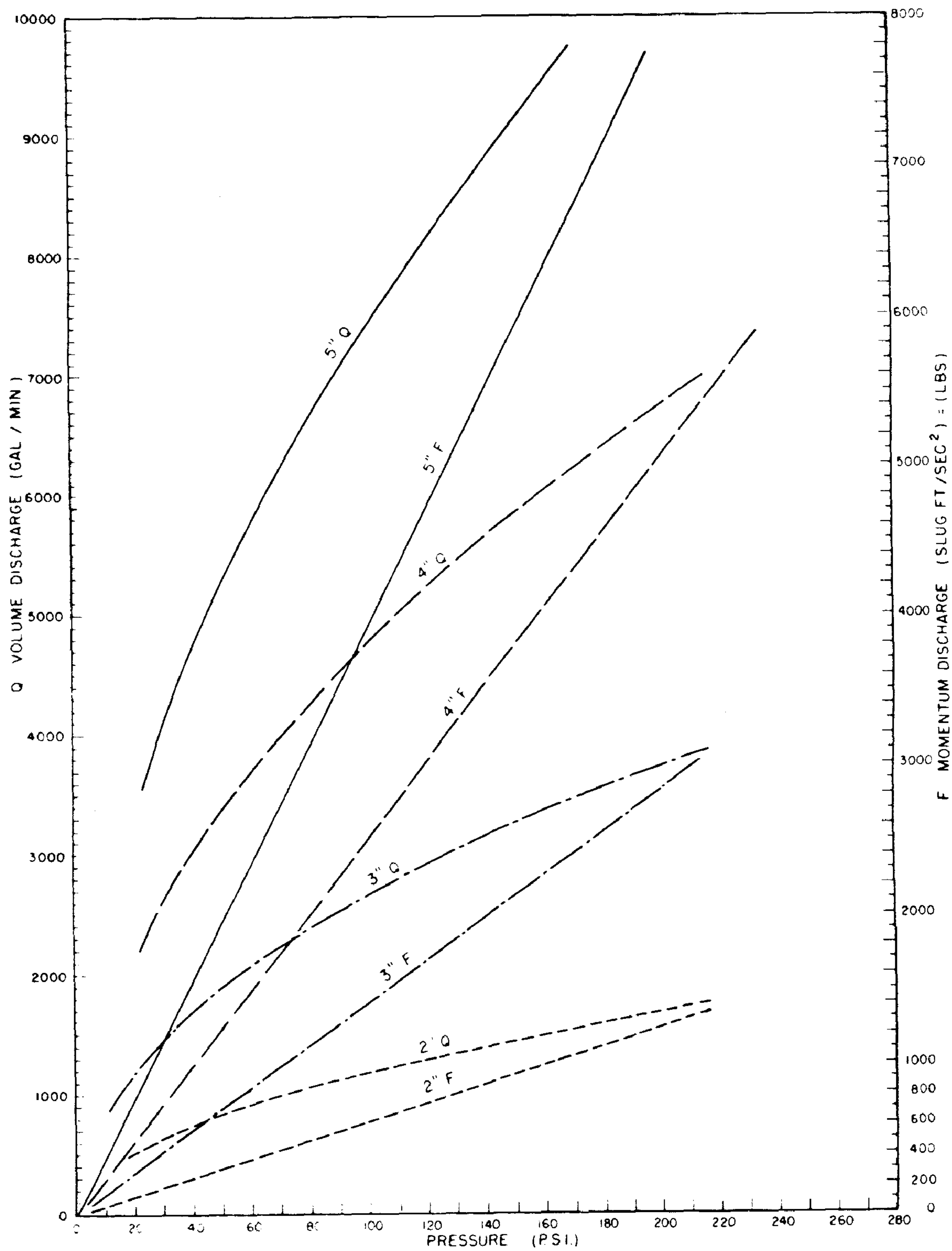
### Fire Streams

For purposes of controlling oil slicks, the useful output of a fire stream is its continuous discharge of momentum. This momentum discharge - the time rate of momentum output - is proportional to the product of the mass rate of water discharge multiplied by the discharge velocity, therefore, it is also proportional to the product of nozzle tip area and tip pressure (velocity head). It is, in fact, equal in magnitude, but opposite in direction, to the reaction force on the nozzle. Figure 6 shows the volume discharge, Q, and the momentum discharge, F, vs. tip pressure for several different tip diameters.

Unfortunately, the entire momentum output of the tip is not usable. There are two reasons for this:

(a) The fire stream usually enters the water at an angle. Therefore, it has a horizontal and a vertical component. Only the horizontal component is useful for the control of floating oil. The smaller the angle of entry the larger the horizontal component will be. The angle of entry is affected by the height of the tip above the water, the tip pressure, and angle that the tip makes with the horizontal. Decreasing the height of the tip, and increasing the pressure have the effect of reducing the angle. For any particular height and pressure, the angle will be the smallest when the tip is aimed horizontally, and will increase as the angle between the nozzel and the horizontal (whether elevation or depression) increases.

(b) A portion of fire stream's momentum is lost to air resistance. Although the process by which this happens is not fully understood, it is known that, with the same pressure, air resistance increases with increasing tip size and, with the same tip, air resistance increases, at an even faster rate, with increasing pressure.[15] Also droplets are much more affected by air resistance than solid streams, and the smaller the droplets the more they are affected. Thus nozzles which tend to break up the fire stream into fog or fine spray are generally ineffective. By the same token, solid streams should be operated at pressures well below those at which coning occurs.




DISCHARGE (Q GAL / MIN) & MOMENTUM RATE (F SLUG FT/SEC$^2$)=(LBS) VS NOZZLE PRESSURE (PSI) FOR SEVERAL NOZZLE DIAMETERS

FIGURE 6

Of course, the longer the fire stream, the greater the effects of air resistance. Thus, while the smallest angle of entry is achieved when the nozzle is aimed horizontally, a slight downward angle of aim would shorten the fire stream, and the increase of momentum loss due to increased angle of entry would tend to be offset by the decreased loss due to the shorter fire stream. On the other hand, an upward angle of aim increases the fire stream length and the air resistance loss as well as increasing the angle of entry. Thus, depressing the tip from horizontal by several degrees will have little effect, but elevation from the horizontal produces rapid deterioration.

## Fire Stream Effects

When a fire stream plunges into a body of water, it establishes a fan-shaped pattern of turbulent, aerated water with velocity components in the general direction of the fire stream. The shape of the pattern depends on the angle of the fire stream with respect to the natural current (see Figure 7). Its size for a particular angle depends on the magnitude of the horizontal momentum flux at the surface due to the fire stream, and on the magnitude of the natural current. Velocities in the pattern, of course, vary, depending on where in the pattern they are measured.

When the fire stream induced current has components directed opposite to the natural current, a rip zone will be established in the region where these opposing currents cancel each other out. This zone determines the up-stream boundary of the pattern. The rip zone is not a stable region; it is turbulent and it meanders. However, it is by means of this rip zone that floating oil may be affected in a useful way. In open water the net flow in the rip zone is tangential to it and directed away from a horizontal axis drawn longitudinally through the fire stream. But when the fire stream induced current is confined in a narrow channel so that the rip zone extends across the full width of the channel, there is no net flow in the rip and it becomes a null-current zone.

The distance of the rip or null-current zone from the impact point depends on the horizontal momentum flux of the fire stream at the impact point and on the speed of the natural current. For a 3 inch tip, about 15 feet above the surface, aimed horizontally, and operating at 100 psi, the distance from the impact point to the rip zone will be about: 45 feet against a 1 kt current, 75 feet against a 1/2 kt current, and 200 feet against a 0.1 kt current.

The length of the rip zone (approximately the width of the fan-shaped pattern at its furthest from the impact point) is probably also related to the horizontal momentum flux of the fire stream and the natural current speed, but because end points of the rip zone are difficult to see when the natural current is small, not enough observations have been made to establish this relationship. However, a number of observations

FIRE STREAM INDUCED PATTERNS FOR VARIOUS ANGLES, θ, OF ORIENTATION BETWEEN THE FIRE STREAM AND THE NATURAL CURRENT.

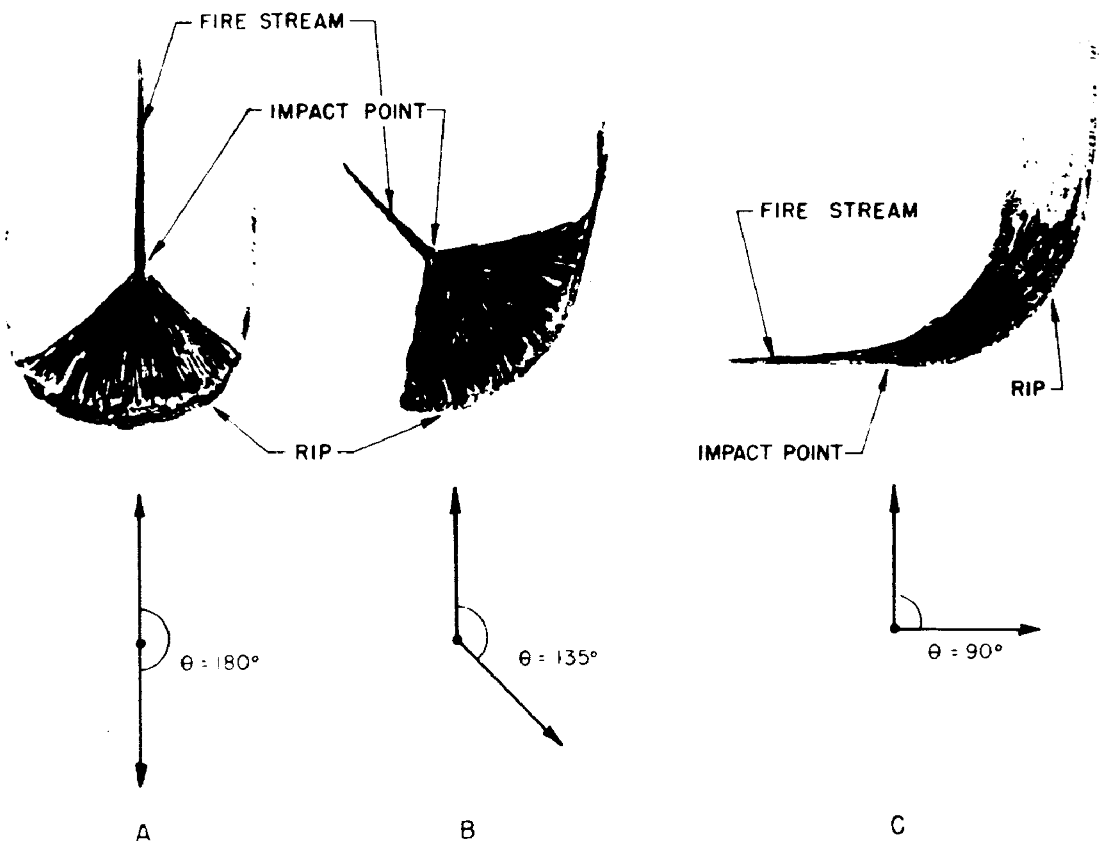



FIGURE 7

THE RIP IS THE TURBULENT ZONE IN WHICH OPPOSING COMPONENTS OF THE FIRE STREAM - INDUCED CURRENT AND THE NATURAL CURRENT CANCEL. IN A NARROW CHANNEL THE RIP BECOMES A NULL-CURRENT ZONE.

of the angle subtended by the edges of the fan, at several different natural current speeds, have all yielded values between 80 and 90 degrees. If this angle remains constant with distance from the impact point, which it seems to do, the relationship between the length of the rip zone and its distance from the impact point is a simple geometric one.

For "small" natural currents (less than 1/2 knot) the rip zone is well separated from the fan-shaped aerated water near the impact point. It is a region of low turbulence which will divert or collect oil and other flotsam. For "large" natural currents, (greater than 1 knot), the rip zone is coincident with the edge of the aerated water. It is a region of high turbulence, and floating oil has been observed to go under or penetrate it. When the natural current is between 0.5 and 1.0 knots, the behavior of the oil in the rip zone cannot as yet, be predicted. Apparently, in this range of velocities other factors (such as the oil's viscosity) become critical. For a more detailed discussion of fire stream effects see reference (16).

## SECTION XVI
## CONTROL OF FLOATING OIL

The foregoing discussion of fire streams and their effects on the water surface shall form the basis for the tactics to be developed for using fire streams to control floating oil. However, it would be futile to try to anticipate every possible situation and develop cookbook methods for handling them. Rather, we shall suggest a number of possible uses of fire streams, and describe methods for their implementation. It will be left to the commanders on the scene to adapt these to specific situations. It should be stressed that no tactic should be followed blindly. The person in charge should frequently and carefully observe the results of the procedure being employed to be sure that the desired effect is being achieved. Often it will be found that the initial evaluation of a situation was in error, or that the conditions (e.g., current, wind) have changed. The required changes in tactics may be minor, such as re-aiming the monitor, or drastic, such as re-positioning the fire boat and/or boom array. Bear in mind that control and clean-up of any fairly large oil spill is likely to be a project of at least several days' duration. In sheltered areas along the edges of the main channels, in peripheral channels, and in parts of large shallow embayments such as New York City's Jamaica Bay, there are places where currents are insignificant. But, in most places currents are mainly tidal; it will be necessary, in such places, to plan on rather drastic changes approximately every six to twelve hours, depending on whether the tides are semi-diurnal or diurnal. All this may seem obvious, but it has been observed that one of the main causes of wasted effort at oil spills is inattentiveness.

In most cases, fire streams will be used in conjunction with and in fairly close proximity to (i.e., within several hundred feet of) a boom array or bulkhead. Unless the current is virtually nil and the extent of the oil patch small, operating a fire stream in open water, far from an enclosure or barrier of some sort can, at best, result in an insignificant diversion, and, at worst, can cause a greater dispersion or emulsification of the oil.

Also, it should be stressed that the fire stream should not be allowed to play directly on the oil, but rather at a point far enough away so that the stream does not "break up" the oil. For large caliber streams and low natural currents this can be from 100 to 200 feet. Remember the movement or blocking of the oil is accomplished by the null-current zone and the flow patterns set up in the water rather than by the fire stream itself. If the fire stream is allowed to play directly on the floating, the oil will be churned up, emulsified, and carried away by the natural current rather than contained.

A constantly shifting fire stream has little opportunity to develop a current structure. To fully develop its flow pattern, the fire stream must play on nearly the same spot for several minutes, and it must continue to play on this spot to maintain the pattern. If the natural current is very small, the angle of train can be varied continuously back and forth through a small arc, but this should be thought of as a broadening of the impact point. Tests have shown, that while it is possible for most fire boats having twin screws to maintain for a few minutes, any heading with respect to natural currents of a few knots in combination with any angle of train of the bow monitor operated at pressures up to 150 psi, it is generally impossible to do this for an indefinite period. And to control oil effectively, the fire boat generally must maintain position as well as orientation. For these reasons it will be necessary, in most cases, to secure the fire boat when using the fire streams to control oil. Furthermore, experience has proved that a large percentage of the spills will probably occur near a bulkhead or dock to which the fire boat can be moored.

As with other methods of oil control, fire streams are far, far more effective in the presence of low natural currents than they are when the natural current is high. Fortunately, in harbors the majority of spills occur near shore, where the currents are often small, even though the current in the main stream may be quite large. For these reasons, and also because the oil film will be thicker and less dispersed near the source, the major effort should be expended at or near the site of the spill. Only after everything possible is being done at the source, should any remaining capability be expanded in more distant areas.

## Tactics for Small Natural Currents

In relatively confined channels, when the natural current is less than 1/2 knot, fire streams may be effectively used to set up a dynamic barrier (the null-current zone) to stop the progress of the oil. For example: They may be used to seal off the mouth of a slip or basin to prevent oil inside from getting out or oil outside from getting in. At 100 psi nozzle pressure a 3-inch tip was found to effectively cover a 200-foot wide basin. These effective fronts can be augmented if necessary, by using additional monitors to create adjacent null-current zones.

The null-current zone is similar to a boom in many ways, and it can be used as a boom in cases where the fire boat can be maneuvered into a suitable position. Its major disadvantage in this respect is that the fire boat could not then be used for other activities. However, it has two important advantages: the null-current zone can be easily penetrated by small boats, while a boom cannot. And a fire stream can be activated or adjusted much more quickly and easily than a boom can be deployed or moved. Where speed is essential, fire streams may be used initially to contain the oil until boom can be deployed, whereupon the fire boat would be free to perform another function. Whether the boom should be deployed between the oil and the fire boat, or the fire boat should be included in the enclosed area, will depend on the nature of the other function.

Fire streams may be used to move oil from under piers or between pilings where it is not readily accessible for recovery; (See Section XVI).

The efficiency of an oil pick-up device can be greatly increased if fire streams are used to herd the oil towards the pick-up point. A pick-up point will be in a semi-enclosed area (e.g., a corner where two bulkheads meet, the apex of a boom array, the juncture between a boom and a bulkhead, etc.). If the area is small, hose and hand-held nozzles will be most effective. The objective is to maintain a continuous layer of oil on the water surface, having the maximum possible thickness, in the vicinity of the pick-up device. If there is no natural current, the oil will continue to move towards the pick-up point until a balance is reached between the hydraulic head in the oil layer and the pressure exerted on the edge of the oil by the fire-stream-induced current. The current should be very slight at the oil edge to avoid churning the oil. As oil is removed by the pick-up device, the edge of the oil will recede towards the pick-up point. If there is a slight current opposing the fire-stream-induced-current, the limit of effectiveness of the fire stream will be marked by a null-current zone. In this case, the edge of the oil will not recede towards the pick-up point. Rather, the oil will tend to collect along the null-current zone, and it will be necessary to advance the impact point of the fire stream. This can be done by elevating the tip, but a price is paid in reduced efficiency. The better way is to increase the tip pressure or to advance the nozzle. Think in terms of advancing the null-current zone (which can be considered to be one of the boundaries of the pick-up area) so that the pick-up area is completely covered by the oil layer. If the natural current is towards the pick-up point fire streams may still be useful in directing the oil.

Tactics for Large Natural Currents

When the natural current is in excess of one knot, the null-current zone ceases to be a barrier to floating oil. It is too turbulent, and the oil mixes downward and is carried past it. In short, it is no longer possible to block the movement of the oil. However, tests have indicated that, for currents up to about 2 knots, it may be possible to divert the oil; the method is similar to entrainment; (see page 84 ). The fire stream is directed perpendicular to the natural current, as in Figure 7C, rather than against it. Oil carried by the current to the fire-stream-induced-pattern will be shunted to the end of the pattern. In this case emulsification of the oil is unavoidable, but there is less tendency for the droplets to be dragged downwards. Diversions of up to 70 ft have been accomplished in this way. Note that the area between the fire boat and the impact point of the fire stream will still be open to the unimpeded flow of oil. However, other streams may be used to close this gap. The impact point of these auxiliary streams should be slightly upstream of the impact point of the main stream. Rail pipes could serve well to generate the auxiliary streams.

Some success in eliminating the gap and lengthening the deflection has been achieved by using nozzles held horizontally very close to the surface of the water so that the fire stream just skims the surface. So far this method has been effective only in the absence of waves. The objective is to concentrate as much high velocity momentum as possible right at the water surface for the full length of the fire stream. This is impossible when the wave height exceeds about half the diameter of the fire stream because the wave crests will interrupt the stream and the wave troughs will allow oil to pass under it. Also wave induced rocking of the boat will often cause the nozzle to dip below the surface thus periodically destroying the stream at its source. Attempts to overcome these difficulties by increasing the vertical spread of the stream and holding the tip higher have been unsuccessful because the momentum output is excessively diluted by the reduced velocity and by the spreading of the stream itself.

Since the objective is clean-up of the oil, it will have to be diverted to a place where this can be done. For the present this means a semi-enclosed area where the currents are small. It may not be possible to accomplish the necessary diversion with one fire boat, but if the other boats are available, additional structures may be established so that the necessary diversion can be accomplished in a step-wise fashion. This diversion technique might also be used to protect an area, for example, a marina, by forcing the oil to flow around rather than through it.

For currents greater than about 2 knots there is very little that can be done in the way of control by fire streams.

## Using Fire Streams to Adjust Boom Configuration

Fire streams can be used to modify the shape or position of a section of containment boom. This is particularly useful at times when it may be desirable or necessary to fasten only one end of the boom to a pier or wall. The technique is more likely to be useful in protecting an area rather than in corralling oil. The up-stream end of the boom is fastened to the pier or bulkhead, and the fire streams are used to push the boom outwards into the main stream, thus forming a protected embayment which can be entered from the open, down-stream end. A like result can be achieved with a number of light anchors similar to the Danforth type. This is an alternative method which is more quickly and easily activated and which might, in some cases, be more effective.

Left to itself the boom will tend to line up with the natural current. With the fire stream in use, that portion of the boom towards which the fire stream is directed will "belly" outwards. Down-stream of the "belly", the remaining boom, if any, will trail in the natural current again. The extent of the "bellying" depends, of course, on the natural current speed, the rate of momentum input to the water at the impact point, the proximity of the impact point to the boom, the overall length of the boom, and the angle between the fire stream and the natural current. Using a 3-inch tip at 30 psi it was possible to hold 100 ft of boom out in a current of 0.2 knots; with 120 psi in a 1 knot current, the boom was held out only 30 feet. Using a 5-inch tip at 120 psi, 70 feet of boom were held out in a 1-1/2 knot current. In each case the total length of boom was 200 feet.

Care must be taken to avoid "spilling" or twisting of the boom, and this imposes limits on the fire stream output and/or the proximity of the impact point to the boom. To achieve optimum displacement without causing the boom to spill or twist it is best to start with tip pressures moderate and/or the impact point at some distance from the boom, and then gradually increase the pressure while closing the distance. The impact point is generally advanced by increasing nozzle elevation, but, for reasons already discussed in the section on fire streams, elevation much above the horizontal is likely to be counter-productive.

There are two basic configurations: In the first, the fire boat is almost directly down-stream of the tied end of the boom; as, for example, when both are secured to a bulkhead which is parallel to the current. The fire stream is directed against the current and between the boom and bulkhead thus forcing the boom outwards. This method can be used to protect an exposed area such as a small marina. Because the fire stream and the current directly oppose each other along a line containing the moored end of the boom, this configuration is somewhat unstable, the boom having a tendency to fold back upon itself, unless the impact point is kept about 100 feet up-stream of the trailing end of the boom. In order to initiate boom movement, it may be necessary to use a small boat to open a space for the fire stream impact point between the boom and bulkhead. Although the fire stream can impact quite close to a wall without causing any damage, it should never play directly onto the wall. If the currents are strong (greater than one knot) some oil will go under any section of the boom making a large angle with the current.

In the second configuration the fire boat is abeam of the boom and directing its stream perpendicular to the current; as, for example, when the boom fastened to the end of a pier, and the fire boat is moored to the side of the pier closer to shore. Though it is not possible to achieve, under the same conditions, as much displacement as with the former method, there are no instability problems. Also there is evidence about a boom supported by a fire stream in this way may be more effective than either boom or fire stream alone. Oil that penetrated the barrier near the moored end has been observed to skirt the inner edge of the boom.

It is frequently impossible to avoid a gap where the boom end is fastened to a wall. This is particularly true where allowance must be made for the rise and fall of the tide. When no other means are available, this gap can be sealed quite effectively by means of fire streams. Since the gap will usually be only several feet wide, small caliber streams will in most cases be quite adequate.

Anchoring

In a previous sub-section we explained the need for securing a fire boat in order to use its monitors effectively. There are other activities (e.g., boom deployment and retrieval) which are much more quickly, safely and easily performed from a moored boat than from one that is hove-to. Yet, in many places where such activities might be required, there are no mooring facilities. For these reasons an effective anchoring system that can be rapidly and safely deployed will, at times, be a very valuable aid.

Almost all boats carry anchors, but, on many fire boats and other type boats of equivalent size, the anchor is a stockless or "patented" type weighing about 1/4 ton. Because of the need for bow fenders, the anchor is not kept in a hawspipe from which it can be readily dropped, and it must be put over the rail. The equipment is so cumbersome that the usefulness of the anchor in an emergency situation is virtually nil. Yet, it is possible to put together an anchoring system which is at least as effective in terms of holding strength, but which can be handled easily, safely, and quickly by only two men. Its components and their specifications are listed below:

(a) Anchor - 85 lb Danforth (lightweight) standard. Holding strength 2,700 lbs in soft mud; 19,000 lbs in hard sand. (For comparison: the holding strength of the 1/4 ton stockless is 1,800 to 7,200 lbs depending on the bottom; the reaction force on a 5-inch tip operating at 100 psi is 3,926 lbs, but surges in anchor line tension up to 1000 lbs greater have been measured.

(b) Chain (50 ft) - 1/2", hot galvanized, proof coil. Working load 4,250 lbs; proof load 8,500 lbs; min. break test 17,000 lbs.

(c) Line (use a length equal to seven times the maximum anchoring depth) - nylon, 1-1/4", 3 strand, hard lay. Working load 4,125 lbs; tensile strength 37,000 lbs.

Whether or not anchoring is possible in a particular situation will depend on the type of bottom, the anchoring gear available, and the current and wind speeds. But once anchored in a steady current, and with the fire stream operating at a constant pressure and angle of train, an equilibrium of forces will develop that will hold the boat steady. However, any change in the natural current, or the fire stream will force the system to seek a new equilibrium, which means that the fire boat will move. If it is possible to set up in such a way that the anchor line, current, and fire stream all have the same line of action these motions will be kept to a minimum.

## SECTION XVII
## REMOVAL OF OIL FROM UNDER PIERS

In any harbor there are likely to be numerous pile-supported structures beneath which spilled oil will collect. These will be places where there is little or no flushing by the natural current, and which usually are inaccessible to pick-up devices. There are several approaches to the problems posed by such trapped oil; however, one should realize that oil under a pier is less destructive to the environment than the same oil would be if it were staining the shoreline, coating the bottom, or dispersed in or floating on the surface of open water. In short, unless the oil can be contained and subsequently picked up, it is better to leave it under the pier. A quantity of oil seeped out over a long period of time will be less noxious than the same quantity released all at once. This does not mean that no attempt should be made to remove oil from under a pier; rather, it means that efforts at containment and pick-up should take precedence over extraction.

### Piers

Although piling does affect the flow of water and oil, in most cases this effect causes minor difficulties when compared with other problems encountered in removal of oil from under piers. It becomes a relatively severe problem only in special circumstances: In the vicinity of specialized structures, such as ferry slips, where the spaces (if any) between piles are narrower than the piles themselves; when the oil is extremely viscous, such as Bunker C in cold weather; or where there is a lot of floating debris that can clog the spaces between the piles. The main problems presented by piling arise from the fact that piling is almost always too dense to permit the maneuvering or manipulation of any reasonable sized equipment in its midst.

The most common type of pier substructure consists of rows of piling which run transverse to the long axis of the pier, whether this long axis is perpendicular or parallel to the shore. The spacings between rows range from about 10 to 25 feet; within a row the pile spacings range from about 1 to 5 feet. There are varying amounts of cross-bracing and cribbing between piles, but many of the more common pier types have some horizontal beams between piles that just clear the water at low tide and are submerged at high tide. Most often they run along a row of piles, but it is also common to find them stretched between rows. Pier corners, especially of piers built for the mooring of large ships and barges, are often very heavily constructed of thick clusters of adjacent piles. The ends and often the sides of piers are generally more heavily constructed than other parts. Many pier ends are faced with solid wood or metal sheathing. Under some piers the piles in a row tend to be grouped, with spaces between the piles in a group being about one foot, and spaces between groups being several feet. Many piers have fire walls underneath. Typically these take the place of one or more of the transverse rows, are made of concrete, are supported by piles so that they extend down almost to the low tide water level, and are placed 120 to 150 feet apart.

Serious difficulties in the removal of oil from under piers can arise from one or more of the following factors:

(a) Large areal extent with respect to the means available for generating water movement. One of the newer piers in New York Harbor for example, covers 15 acres, and there are larger ones.

(b) Limited accessibility because of shallow water, adjacent structures, restricted channels, or moored vessels.

(c) Complex configuration; the plan views of many shore side installations exhibit varying degrees of complexity, from simple finger piers to intricate juxtapositions of platforms and wharves, often of different construction. The shoreward ends of many piers abut onto platforms or roadways which are themselves on piling, rather than onto solid bulkheads or shoreline. This provides additional places for oil to collect, as well as possible escape routes for oil during cleanup operations. Some pile-supported structures abut bulkheads on two or even three adjacent sides, thus forming covered pockets or embayments. In most places where oil is likely to collect, it will be impossible to establish a flow which goes directly through without some diversion.

(d) Low clearance; the under sides of many structures are below the water surface for part of the tidal cycle, and only a foot or so above it at other times.

In practice, any possible combination of these obstacles can arise. When coping with a particular set of problems, various types of equipment will be required. In general, the larger the pier the larger will be the amount, size, and power of the equipment needed. Some structures are big enough to exceed the capabilities of the equipment presently available for driving the oil out. Thus, of the above difficulties, large size is the one that will prove the most intractable. While it is often effective to clear a large area by dividing it into sections and doing one section at a time, this is not always possible.

## General Aspects of Oil Removal from Under Piers

Because the buildings along a shoreline can vary so widely in size, substructure, accessibility, and configuration, it is not possible to develop a set of standard procedures for cleaning oil out from under them. However, there are a number of general techniques that can be applied to a wide variety of situations; these are described below. Which to use will depend on the circumstances, and a proper selection will require a detailed knowledge of the area to be cleared. Therefore, the very first step should be to make a detailed examination of the piers substructure from a small boat. Since the area under many piers, especially those where oil is likely to become trapped, is often very dark, powerful hand lanterns or flood lights will often be necessary for an adequate inspection. The need for such an inspection from a small boat cannot be stressed too strongly, because the details of the substructure must be known if the operation is to be effective, and these are often impossible to ascertain from the deck of a typical harbor craft, from shore, or from a neighboring pier. For example: For piers running parallel to and abutting with a bulkhead and the outer edge, and if there is cross bracing in the path of any proposed flow. Fire wall ends are often recessed from the pier edge, and cannot be seen by an observer who is not at the edge of the pier and well below the platform level, etc. Since we are concerned here with trapped oil, that is, oil which is not rapidly escaping or spreading, there is less need for haste, and we can take advantage of this fact to plan a more effective operation from the start.

There are three phases to any successful removal operation: Extraction, containment and pick-up.

Pick-up involves the use of some sort of skimmer, and is relatively straightforward. Except in rare cases where the piling is very open, the only oil that can be picked up will be that which has been extracted from under the pier and contained by a boom. For all skimmers the efficiency of their operation depends on the concentration of oil in their vicinity. Hence the arrangement of boom and skimmer should be such that oil will tend to concentrate around the pick-up point. In practice this means that the skimmer should be located in a corner or apex towards which the flow is established.

Boom performs a dual function. It not only prevents the escape of oil driven from under a pier, but it also must channel this oil towards the pick-up device. Sometimes boom can be used to keep a cleared area from becoming recontaminated. In general this requires that the boom be deployed under the structure, which will only be possible where: there is enough overhead clearance and space between piles to allow passage of a small boat (a two-man rubber raft can be used), there are no cross braces in the way, and there is no current to force the boom hard up against a row of piles. For use in this way a boom having "internal" flotation is better than one having detachable flotation, since it is less likely to snag. Where the emergent flow is intercepted by the boom, its velocity should be less than a half a knot. (See Section XII). In any case there is no need for the emergent flow to have a large velocity, as a slow, barely perceptible drift into a gradually narrowing corner or pocket will deliver all the oil that most skimmers can effectively handle.

Methods Not Requiring Artificial Currents

The main approach to the problem of oil trapped under piers involves flushing with artificial currents, but, before discussing this, there are several other options that deserve mention:

A strong air flow would be capable of dragging oil from under a pier. It has an advantage over artificial water currents in that it would produce very little turbulence in the water, and would thus cause very little mechanical emulsification of the oil. In addition to a large wind generator, heavy curtains might be required to channel and collect the oil. The necessary equipment is probably unavailable in most harbors; therefore, this method is not one suitable for general use.

Chemical solvents or dispersants would remove oil from under a pier, and their application would be relatively easy. But the dispersed oil would soon spread in substantial concentration though a sizable volume of nearby water, and the damage to the environment would be increased rather than reduced. Even though some of the recently developed dispersants are practically non-toxic, the oil would still retain most of its harmful properties, and is better restricted to the area under the pier if it cannot be removed entirely. Therefore, this method is the least acceptable of all, and would be illegal in many cases.

It is also possible to sink the oil. This method is worthy of consideration because the sediment under most piers, especially in commercially active areas, is already badly contaminated, and further damage to this relatively small and useless area might be preferable to the damage wrought by the same oil elsewhere. A similar approach is "entombment" of the oil by enclosing it with sheathing. Though this may seem like doing it the hard way, the fact is that in many cases it will be no harder or more time consuming than extraction and pick-up of the oil. The sheathing need not extend from the pier's deck down to the sediment; a few feet above high water level to a few feet below low water level would be enough. There would be a bonus in that the sheathing would protect the area from contamination by subsequent spills in the vicinity. While it is true that "entombed" oil may eventually seep out, and sunken oil will dissociate and disperse, this will take a relatively long time, during which there will be opportunity for biodegradation of the oil, a process which can be enhanced by seeding with the proper type of organisms and aeration of the water under the pier.

Under certain conditions, a chemical surface collecting agent (SCA) can be used to move oil from beneath a pier. An SCA is a substance which reverses the tendency of most oil to spread on water, and, instead, causes the patches to contract and form "lenses". To remove oil from under a pier, the SCA must move the oil rather than cause it to contract. This can be accomplished only if the SCA is restricted to one side of the oil slick. Once the SCA completely surrounds the oil patch, there is no longer a difference in spreading force on either side, and it can no longer produce net motion. Since surface collecting agents spread far more quickly than most petroleum products that are likely to require removal, it is important that there be no path through the oil slick or along its edges by means of which the SCA can spread to the outer side. In practice, this means that an SCA can only be used for flushing when there is a continuous sheet of oil covering an embayment or cul-de-sac from wall to wall. The SCA must be placed in the deepest corner or against the farthest wall. Unless there is an access hole properly located this will require that a small boat be taken under the pier for placement of the SCA. It should not be poured directly on the oil. Rather, a small patch of water must be cleared into which the SCA is poured.

This work with surface collecting agents has been limited to laboratory experiments and tests made on small spills of opportunity. These have not enabled a determination of the quantities of SCA needed to achieve various displacements with different types of oil. However, the amounts needed will be small, because the SCA need only spread in a very thin layer. For open water, the prescribed dosage is two gallons per linear mile of oil patch circumference. Generally surface collecting agents do not work on thick, waxy oils such as Bunker C, or in waters having a high concentration of detergent. Some are ineffective in cold waters. Wind and currents can also inhibit action of an SCA, but these will probably not be significant in under pier areas where oil is likely to collect.

Artificial Currents

The primary tools for extracting oil from beneath piers are artificially generated water currents. The most common means of generating such currents are: fire streams and propwash. Fire streams are discussed in detail in Section XV and reference (16). The different methods of generation produce currents with slightly different characteristics: The first, of course, is size. A boat's propellers are far more efficient generators of water movement than its pumps, even when they are powered by the same engines. The second is shape. A fire stream's induced current spreads about 80 degrees from the impact point of the stream. The current pattern produced by propellers has a much smaller angle of spread, only 5 to 10 degrees, though it is much wider to start with. The third difference is in the nature of the turbulence. Propellers produce larger eddies than streams of water even when the energy outputs are comparable. And propeller turbulence has a much stronger vertical component which extends much deeper. This is important because turbulence causes mechanical emulsification of the oil, and the large deep eddies can drag the oil droplets down well below the skirt depth of even the largest boom. These droplets have a natural tendency to rise, and will begin to do so as soon as the turbulence subsides; however, the smaller droplets rise very slowly. Thus, while it is possible to contain much of the oil set in motion by propwash if the containment boom is located far enough from the propellers, a substantial portion inevitably escapes. For this reason, the use of propwash should be limited to these situations where fire streams are clearly inadequate, or where no fire streams are available.

Despite these differences, the methods of applying artificial currents are essentially the same whether they are generated by fire streams or propellers. However, fire streams are much easier to position and control. In both cases the boat must be moored, but the mooring required for fire stream operation is much lighter and hence more adaptable. Also monitors can be aimed, whereas to direct propwash the entire boat must be turned, and this will not always be possible.

While it is true in any clean-up operation that the commander should constantly observe the effect of the various measures being employed, it is even more important when using induced currents, because slight changes in the parameters of the operation can change it from an effective one to an unproductive, or even a counter-productive one. For example: A change in the wind can alter the impact point and/or the strength of the fire stream; it can also affect the flow of oil and the configuration of the boom array. Though we are concerned with areas where the natural currents are virtually nil, they could still be an important, though erratic and unpredictable factor. It takes time for an induced current pattern to stabilize, and a procedure that has been working well initially may become unsatisfactory when fully developed. The rise and fall of the tide can open or close channels. In short, the commander should repeatedly assure himself that the effects of his operations are the ones he desires.

Methods of Generating Under Pier Flow Using Fire Streams

Once it has been determined to use artificial currents to flush an under pier area, the two immediate problems are: How to establish the flow, and where and in what direction to establish it. The latter depends on the configuration of the area and will be discussed subsequently. The simplest way to establish a current is by mooring the boat to an adjacent structure in a way that will permit its fire streams (or propwash) to be directed as needed to set up the desired flow. Unfortunately, it will often be impossible to find a suitable mooring. The adjacent pier, if any, may be poorly oriented or too far. The fire stream may not be able to span the distance with enough reserve momentum to establish a sufficient flow. A fire stream's range can be increased, up to a point, by elevating the tip from the horizontal. But, if the angle of elevation exceeds several degrees, the effectiveness of the stream as a current generator suffers. For a 3 inch tip operating at 150 psi the maximum distance between the tip and the impact zone, consistent with the generation of an effective flow, is about 130 feet. In the absence of any natural current this will produce an effective flow extending about 300 feet from the impact zone. Thus, under nearly ideal conditions we can expect to move oil at a distance of about 430 feet from the monitor.

The presence of even a slight wind or a miniscule current from any direction except behind the monitor will substantially reduce this distance. Oil movement has been induced at a distance of nearly 1000 ft from the monitor, but this was an exceptional case, and such ranges cannot be expected in general.

Where it is not possible to operate effectively from an adjacent pier, it may be possible to moor directly to the contaminated pier. If the fire streams are to be directed perpendicular to, or at a large angle to the pier edge the boat must be held 50 to 100 feet away from the edge with long mooring lines. The reaction force on the monitors will be sufficient to hold the boat out, but it may be necessary to use the engines and rudder to compensate for yaw. If only the bow monitor is used in conjunction with a single bow mooring line, the thrust of the reaction force and the pull of the mooring line will tend to assume the same line of action, and the mooring line may get in the way of the fire stream. Two mooring lines to separate ballards or cleats, with the fire stream directed between them, will avoid this. Fore and aft mooring, with the boat parallel to the pier edge, will permit the use of additional monitors and also of rail pipes.

If under pier pipes are available, the fire boat can be moored close to the pier. Since the nozzle is now at the edge of the pier it should, in general, be as close to the water surface as possible. However, if the pier is large and the oil has receded from the edge of the pier, the impact zone can be advanced by elevating the tip. For some applications it would be better to have the tip at, or slightly below the surface; these are described in a later section.

Use of hand lines from small boats is the most versatile method of generating flow under piers. It involves more effort, but it can be used in many situations where other methods cannot, such as: where there is no suitable mooring near enough; where the fire boat cannot approach the pier because of obstructions or shallow water; where (if the piling is not too dense) it is desirable to establish the current deep under a large or complex pier. The only limitation is the amount of hose available. If stand pipes or land pumpers are available, it is not even necessary to have a fire boat present.

Because the effectiveness of the streams depends so much on the discharge, the largest hose, tip, and pressure consistent with safe operation should be used. A 2-1/2 inch hose with a 1-1/4 inch tip operating at 60 psi tip pressure has been used without any difficulty. However, when in operation both the tip and the small boat will have to be secured. The boatshould be secured sideways between piles by fore and aft painters. The tip, operating between the piles, can be secured by one or more hose straps or pieces of line. Reaction force on the tip will be about 150 pounds (1-1/4 inch tip at 60 psi). If the boat's gunwale is fairly sturdy, the hose strap can be hooked directly to it. The line or hose strap may be attached to parts of pier's substructure, but, if attached to piles, two lines to separate piles will be needed. In all cases the attachment of the line to the hose should be far enough behind the tip so that the tip is just outboard of the gunwale.

The hose must be floated. If the hose is not to be taken under the pier, or if the pier's substructure is free of subsurface snags, several large floats are adequate and quicker to attach. But in most cases, it is better to use smaller floats more closely spaced. Quart size floats with 3 to 4 foot spacings and an additional float at the brass coupling supported the 2-1/2 inch hose very well. To further reduce the possibility of snagging, the floats should be attached with their long axis parallel to that of the hose. This can be done with friction tape or with string; there appears to be no reason to prefer one over the other. Because it is much easier to handle uncharged hose, it is better to affix the floats and play out the hose before applying pressure. However, most fire hose is flat when uncharged and round when charged, and the method of affixing the floats must be able to accommodate the change in dimension. With string this is done by first tying the string around the hose using a square knot and leaving ends long enough to encircle the float and tie another square knot. With tape, make a figure "8", lashing with alternate clockwise turns around the hose and counter clockwise turns around the float (or visa versa) and finish with a few turns around the tape intersection between the hose and the float.

Methods of Applying Artificial Currents Under Piers

If it is possible to do so, the best way to flush the area under a pier is to establish a flow perpendicular to the pier's long axis. Attempts to generate a current down the length of the pier will generally be far more difficult and far less effective. There are two reasons for this. The preferred direction of flow is parallel to the rows of piles, and these run perpendicular to the long axis for almost all piers. This is not so much because of piles themselves as it is because of the cross bracing, which is much more dense in a row than it is between rows. Many piers have fire walls underneath; these almost always run perpendicular to the long axis of the pier, and would permit longitudinal flushing only at dead low water. Second, even with fairly open piling, most piers are too long. Pier lengths well over 600 ft are common, while the effectiveness of fire stream generated currents usually vanishes between 300 and 400 feet from the impact zone for the larger monitors. Propwash may be capable of longitudinal flushing under long piers which do not have transverse fire walls. In using propwash, the thrust of the propellers should be at an absolute minimum initially, and gradually increased as the edge of the oil recedes down the length of the pier.

For longitudinal flushing, boom should be deployed along both sides of the pier. The far end is assumed to be closed by a bulkhead or shoreline and the skimmer is located in one of the far corners. In the final stages of the operation, smaller streams from hand lines will be useful in channeling the remaining oil to the skimmer.

Transverse Flushing

Since currents generated artificially by boats have effective widths from about twenty to about 200 feet (depending on how they are used and how they are generated), while pier lengths often exceed 600 feet, flushing under a pier with transverse currents will almost always be a piece meal task. The essentials of the operation are as follows: The current is generated on one side of the pier, and the boom and skimmer array is situated on the opposite side so as to intercept, concentrate, and pick up the emerging oil. After a section has been cleared, the current generator on one side, and the boom and skimmer on the other side are moved down to the next section. When proceeding in this way, it is necessary to prevent the section just cleared from becoming recontaminated. If the artificial current is broad, this is accomplished by making each section about half the width of the current. If the current is not wide, it will be necessary to operate an auxiliary current in the section just cleared. The rows of piles do inhibit broadening of the induced flow; therefore, if the flow is being generated at the edge of the pier by under pier pipes or hand lines, it will generally be possible to clear only one aisle at a time. However, if a large monitor impacting about 30 to 50 feet from the edge of the pier is used, the artificial current will effectively span three or four aisles before it goes under the pier. If it is possible for a small boat to pass under the pier between rows of piling, boom may be deployed to protect the cleared sections. The collection boom will "belly" away from the pier, with the apex of the belly near the strongest part of the emergent flow. If only one current generator is used, the apex will be roughly opposite the generator; if two are used, it will be opposite a point between them. The array should be adjusted so that the skimmer is as close as possible to the apex. If the emerging oil tends to collect uniformly along the boom rather than being channeled towards the apex, the belly should be deepened by slacking the boom. To deepen the belly it may prove necessary to hold the boom and skimmer out by means of a line to a nearby structure or to an anchored float. If, for some reason, it is not possible to obtain a deep enough belly, small hose lines can be used to establish a flow along the inside of the boom towards the skimmer. In this case, it will be easier to locate the skimmer more to one side of the boom array, establishing as much of a pocket there as possible, and operate the hand line from the other side.

The procedures just described are suitable for a pier much longer than it is wide, having bulkhead or shoreline on one or both ends, and open water on both sides. Such piers are comparatively easy to flush out because it is possible to establish a direct flow entering on one side and emerging on the other. Since most such piers extend into a channel where there is a natural current, oil will not usually become trapped under them except near the shoreward end. In general, a pier under which an artificial flow can be easily established will be subject to flushing by natural currents. Conversely, piers not subject to

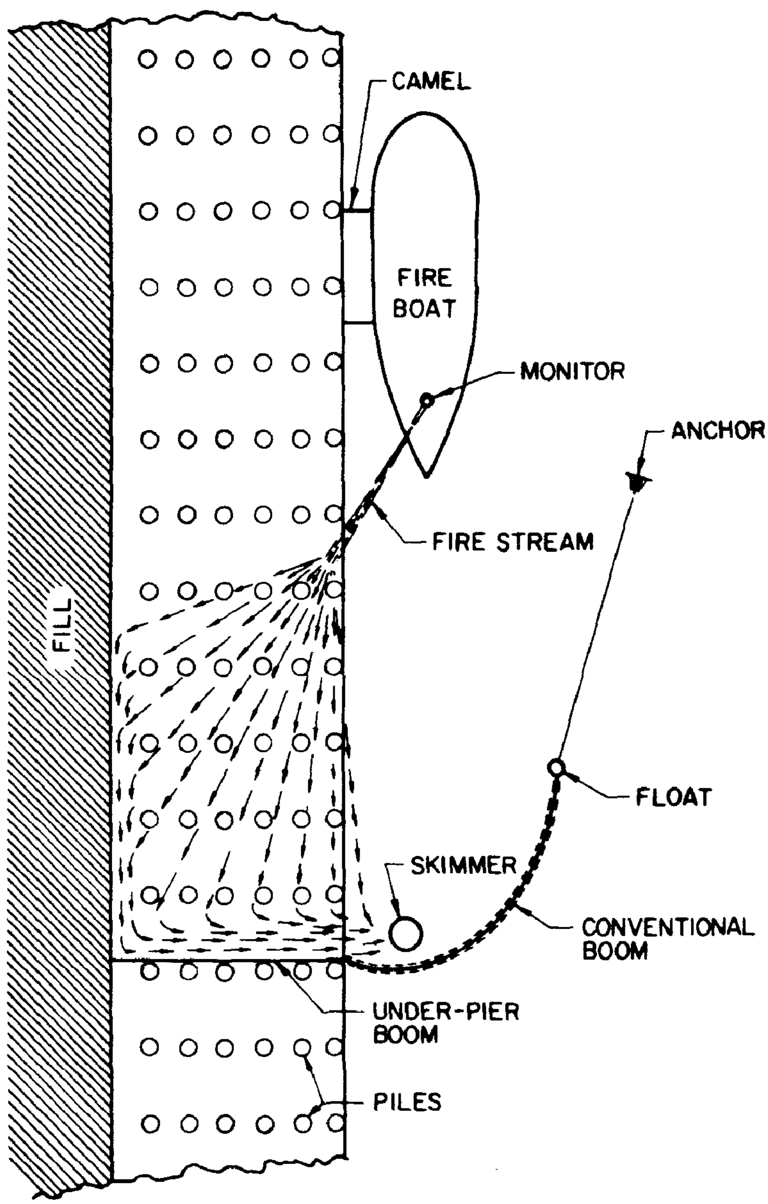



FIGURE 8

USE OF UNDER PIER BOOM

natural flushing, those under which oil is prone to collect, will be the most difficult to clear. The following procedures have been developed for such cases.

Under Pier Boom

Many piers and over-water roadways run parallel to and abut with a shoreline or bulkhead. The only possible exit for a flow directed under such a structure is on the same side as the entrance, but any flow so directed will tend to move along under the structure, with most of the energy concentrated along the bulkhead, or inner edge and very little emerging. In the absence of fire walls, it will be necessary to insert a barrier that will deflect the flow outwards. If there is enough clearance for a small boat, conventional boom can be used, but in many instances the clearance, even at low tide, will be too small. To overcome this problem we have constructed boom using boards with lead weights for ballast and small floats for bouyancy. These are bolted together, with wing nuts and preset bolts, and pushed under the pier. The assembly and positioning is done with the boom in the water by a man in a small boat, which must be moored to one of the piles. As each section is added, the boom is extended further under the pier. Up to 28 ft of this boom has been assembled with relative ease, and greater lengths are evidently possible. To accomplish its task, the boom should extend all the way across the pier from the bulkhead on one side to the outermost piles on the other. The outer end of this boom is matched with any type of conventional boom which is then extended out towards mid-stream and back toward the current generator, and secured to an anchored float. The plank boom is braced against the applied current by a row of piles, and it should be tied to the outermost of these piles in such a way that it can rise or fall with the tide.

The artificial flow should be directed about a 45 degree angle under the structure and towards the boom (Figure 8). To achieve an effective angularity along with an effective stream velocity it may be necessary to hold the fire boat away from the pier. This can best be done by mooring a floating fender (a camel) or another boat between the pier and the fire boat. The boom and the current generator (or impact zone of the fire stream for deck monitors) should be far enough apart so that the axis of the current is intercepted by the bulkhead well before it reaches the boom. This means that the wider the pier (i.e., the greater distance between the outer edge of the pier and the shoreline or bulkhead) the greater must be the distance between the current generator and the under pier boom. The objective is to create a flow under the pier along the closed inner edge which is deflected outwards by the under pier boom. The speed of the current when it reaches, and is diverted by the boom, should be less than a half knot. The ultimate configuration of the boom array will depend on the width and strength of the current, the width of the pier, and the angle of entry of the current. However, the flexible boom attached to the under pier boom will form a belly in response to the flow, and the skimmer should be located at its apex. Since each situation is likely to have its own characteristics, on scene experimentation will probably be necessary to achieve optimum results.

The under pier boom can be constructed of any material having enough rigidity to enable it to be pushed under a pier. The prototype was made of 10 ft x 1 ft x 1 inch pine boards, with 12 lbs of ballast along one edge, and two quart-size plastic bottles for flotation. The boom had about 4 inches of freeboard and 8 inches of skirt. For strength there was one foot of overlap where the planks were joined with four bolts and wing nuts backed by large washers. Because of its rigidity, the under pier boom will not conform with the water surface as waves pass; however, it is designed for use in places where waves of more than a few inches height will only be an occasional problem. If more freeboard or skirt is needed, broader planks can be used.

Cul-de-sacs

The substructures under many shoreside installations form basins or cul-de-sacs having three sides closed and only one side open. For example: A long pier or roadway running parallel to and abutting with bulkhead, as described above, and also having transverse fire walls, will form a series of such covered embayments. The bulkheads are capable of diverting a flow outwards, so under pier boom is not needed. But, because distance between the sides of the basin is usually not much greater than the distance between the mouth and the closed end, a different type of current structure must be established. Instead of directing the current inwards, and at an angle towards the bulkhead which is to deflect it outwards, we try to establish a rotary flow entering along one side and emerging along the other (Figure 9).

In establishing such a flow it is important that the current enter only one side of the basin, leaving room on the other side for an emergent flow. When using deck monitors, the fire streams should be aimed as though the entering current were required to bounce off one wall of the basin. If it is aimed too directly into the basin, even though the impact zone is near one side of the basin's mouth, the large angle of spread of the current could cause it to span the entire width of the basin before it reaches the closed end; and the only effect would be to drive the oil deeper into the basin. Aiming the fire stream in this manner will cause a part of the induced current to be wasted, since not all of it will be intercepted by the wall and channelled into the basin. The further the impact zone from the mouth of the basin the greater will be the proportion of the momentum flux that is lost in this way, but it should never exceed fifty per cent, since the line of aim should be into the basin's mouth. Aiming the stream more towards the center will reduce this loss, but, unless the basin is very wide or the impact point quite close to the mouth,

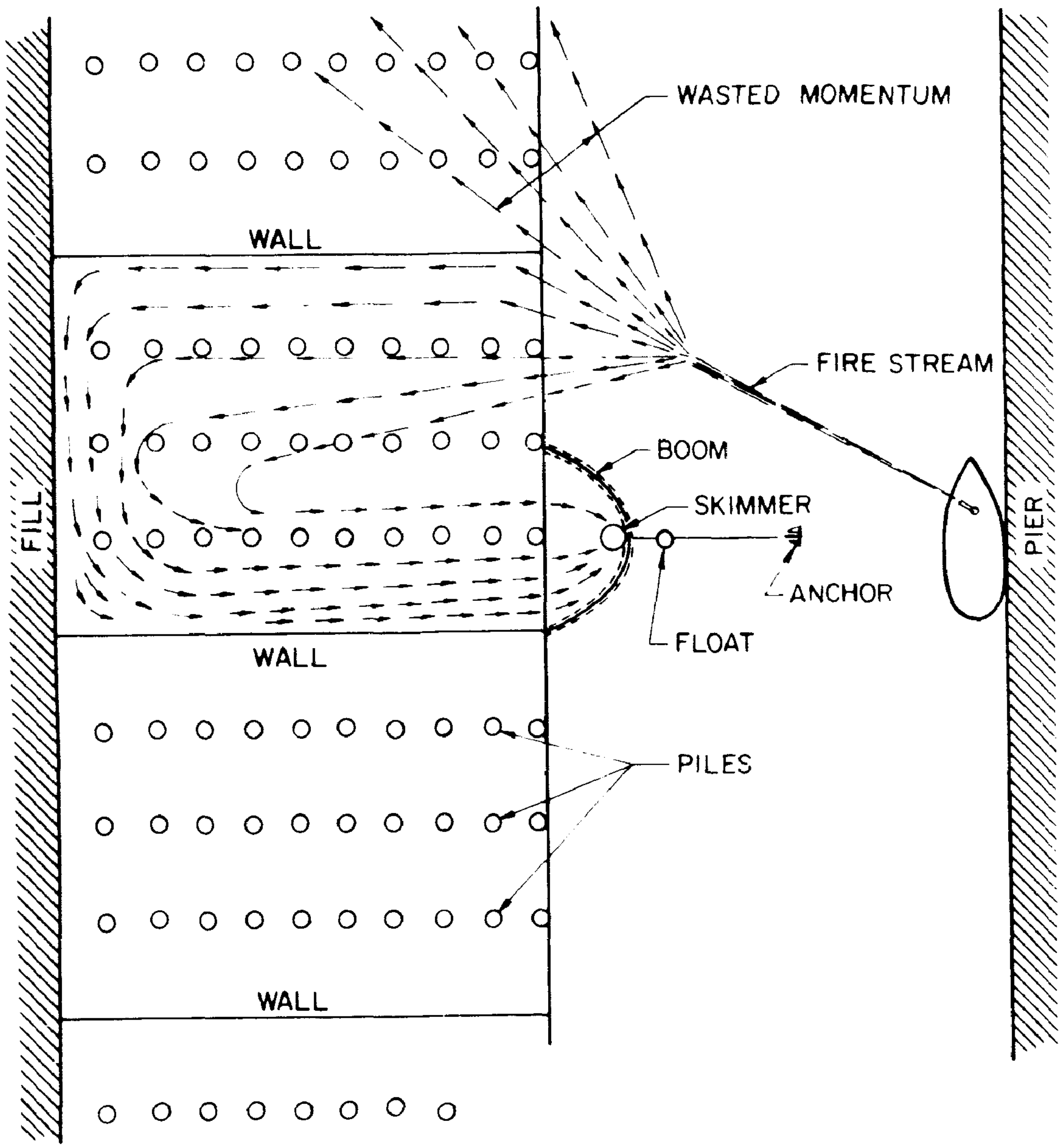



FIGURE 9

CLEARING A CUL-DE-SAC

this loss cannot be eliminated completely without destroying the rotary flow. However, the loss of momentum flux does not appear to present a serious problem. An effective flow was achieved in a 200 x 160 ft cul-de-sac, using a 5 inch tip, operating at 75 psi, and impacting 60 ft from the mouth of the basin with only about 60% of the flow entering it. If necessary the loss could have been reduced by advancing the impact zone along the same line of aim. Under pier pipes and hand lines from small boats can also be used to establish a rotary flow. Since they are operated close to the edge of the pier and the lateral spread of their induced flow is inhibited by rows of piling, they can be aimed directly into the basin near one wall. However, since their output is so much smaller than that of monitors, it may be necessary to use two or more streams, parallel and close to each other. The boom must be deployed so as to intercept the emergent flow without interfering with the entering flow. This will be easier to accomplish when the current generators are close to the pier edge. The ends of the boom can be secured to piles at the edge of the pier, and the central portion, where the skimmer is to be located, should be held away from the pier by an anchored float so that the entire array forms a deep pocket.

If the basin is very narrow and fairly deep, with walls extending to the bottom (in effect a closed channel) it may be possible to set up a vertical rotary flow. To do this an under pier pipe with the tip submerged is used, and it is aimed into the basin at a downward angle, so that the current flows inward along the bottom and outwards near the surface. This is likely to stir up and flush out quite a bit of silt as well as oil. Since the mouth of the channel is narrow, the boom and current generator must be placed in tandem; therefore the tip should be well below the skirt depth of the boom. There are two possibilities: If there is a convenient hose hole or a means of securing the under pipe to the pier edge, the boom and skimmer can be placed outboard of the tip. If this is not possible, the ends of the boom will have to be fastened to the walls of the basin far enough under the pier so that the boom forms a deep pocket with its apex under the edge of the pier. (It may be necessary to drive studs for securing the boom ends.) The under pier pipe can then be operated from the rail of a boat moored across the mouth of the channel so that its stream passes under the boom. So far this method has only been attempted on a laboratory scale, and the limits of its effectiveness are not known.

## Entrainment

A current moving through a body of water will drag some of the surrounding water with it. This process, entrainment, can be used to set up a flow of surface water out of a small basin by establishing a surface flow across the mouth of the basin (Figure 10). On the whole this method is far less effective than the methods described above, but it might be useful in some situations. Since the out-flowing surface water must be replaced, and in the case of a basin, it is replaced by in-flowing bottom water, propwash, because of its depth, is not suitable unless the

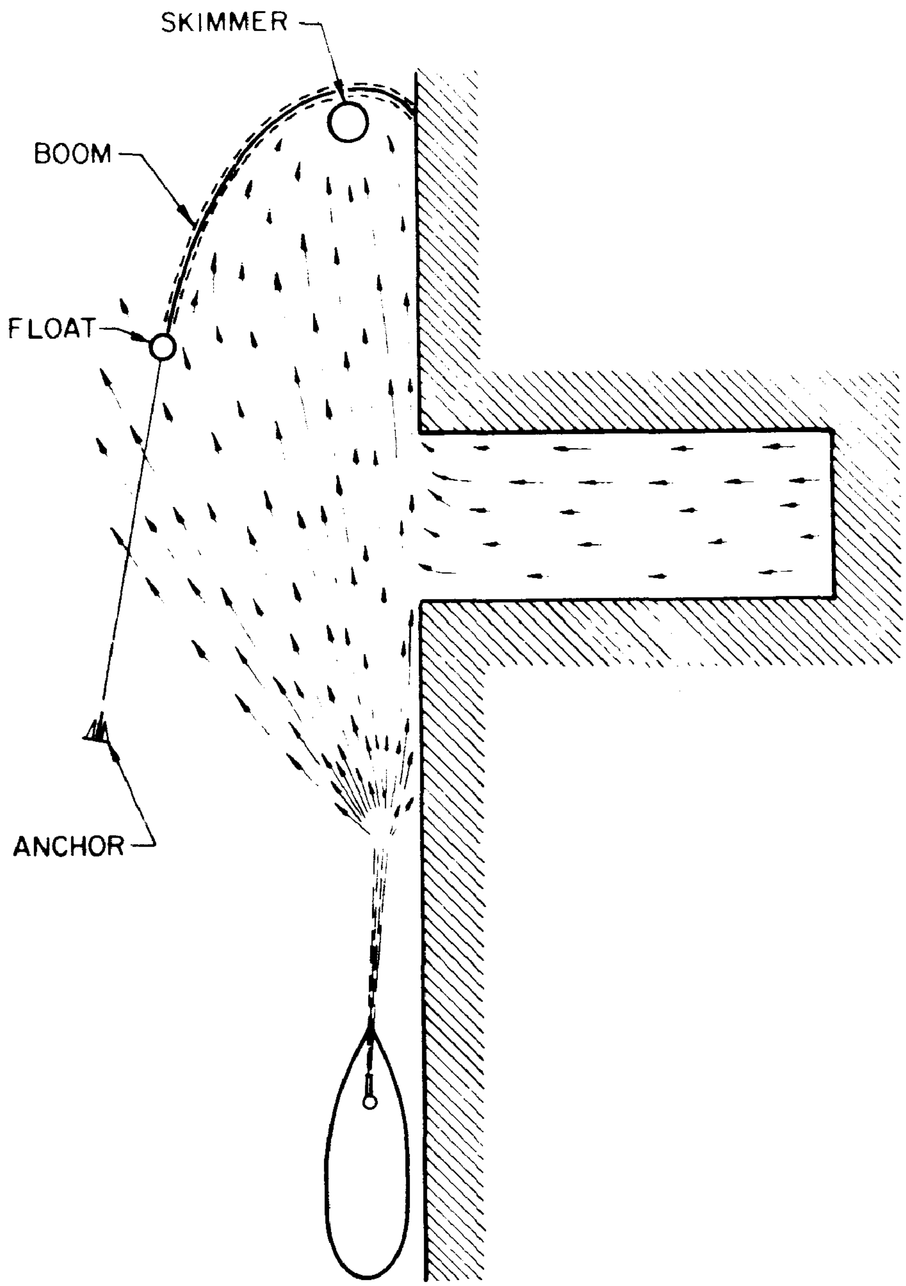



FIGURE 10

DRAWING OIL OUT OF AN EMBAYMENT BY ENTRAINMENT basin is very deep. Because of the large angle of spread of currents generated by deck monitors, it may be difficult to prevent a portion of the entraining current from entering the basin and setting up a rotary surface flow. But it will not be an efficient rotary flow, since much of the entrained emerging water will be recirculated back into the basin. This difficulty can be reduced by keeping the tip as close as possible to the surface. To create a significant flow out of the basin the entraining current must be quite strong. For this reason the size of the area that can be cleared by entrainment is limited; the maximum being about 100 ft on a side. Finally, since the emerging flow becomes a part of the much higher velocity and more turbulent entraining current, the oil is subject to severe emulsification. For successful containment and pick-up the boom must not intercept the entraining current until it has become very weak, that is, less than 1/2 knot.

# SECTION XVIII

## Fire Department Spill Control Capabilities

During the lifetime of Project 15080 FVP the New York City Fire Department received approximately eighty spill notifications. These notifications were received, for the most part, from the office of the Captain of the Port of New York, US Coast Guard. Some notifications were received direct from spillers or those observing spills. The Consolidated Edison Company in particular, was cooperative, both in calling the Fire Department and in confining spills at their waterfront installations.

Early in Project 15080 FVP, the Fire Department mailed some 200 letters to the oil companies and the waterfront industries active in New York City, asking that the Fire Department and the Coast Guard be notified in case of oil spills. On receipt of a notification from any private sources, the Fire Department notifies the office of the Captain of the Port and investigates the report by having a Fire Chief or a fire boat respond to the scene.

These investigations revealed that the Fire Department's services were unnecessary in most cases, either because the spill was too trivial or already contained. However, the Marine Division of the NYFD has operated at enough spills to be able to report on just what functions a fire department may be able to render at a spill incident.

The following digest of 10 such spill incidents is offered to illustrate these functions and to illustrate some operational lessons learned at the incidents.

## INCIDENT 1

| | |
|---|---|
| Date: | 10/24/70 |
| Location: | Greater New York Terminal 1710 Steinway St., Queens, New York (Rikers Island Channel) |
| Reported Quantity and Type of Oil Spilled: | 20 barrels, No. 6 fuel oil. |
| Cause of Spill: | Burst tanker hose. |
| Fire Department Activities: | 1 fire boat and 1 Battalion Chief employed. Used monitor pipes to herd spill into boomed area and to confine spill to the cove when the tanker was moved.<br>On duty - 3 hours and 29 minutes. |
| Comments: | FD herding and containment activities were efficient, particularly when the tanker was being moved. A prompter report to the FD would have probably resulted in better containment of the spill. |

## INCIDENT 2

| | |
|---|---|
| Date: | 11/1/70 |
| Location: | Patchogue Oil Terminal<br>722 Court Street, Brooklyn, NY<br>Gowanus Canal |
| Reported Quantity and Type of Oil Spilled: | 70 barrels, No. 4 fuel oil. |
| Cause of Spill: | A broken pipe flange on plant pipe. |
| Fire Department Activities: | 1 fire boat and 1 Battalion Chief were employed. The bow monitor of a fire boat was used, with limited success, to confine oil which had spread beneath the pier.<br>The same bow monitor worked well in herding oil into the boomed area.<br>A small outboard utility boat was left on the scene by the Fire Department to assist in the recovery operation after the fire boat had left.<br>The FD operated at the incident for a period of 8 hours and 15 minutes. |
| Comments: | A prompter notification of the Fire Department would have made the herding and containment by fire streams much simpler. |

## INCIDENT 3

Date: 11/11/70

Location: Sewer outfall
Cropsey Avenue and 26th Avenue, Brooklyn

Reported Quantity and Type of Oil Spilled: 200 gallons, No. 6 fuel oil

Cause of Spill: A fuel oil delivery truck discharged an excessive amount of oil into a building storage tank. Oil ran from tank vent into a storm sewer and out into Gravesend Bay.

Fire Department Activities: Two Chief Officers, 2 land engines and one ladder unit responded to the alarm at the spill scene and the sewer line was traced.
A Marine Battalion Chief and a fire boat responded to the sewer outfall.
The slick had spread and thinned, therefore the fire boat was returned to its berth. The Marine Chief notified the US Coast Guard. The Marine Chief and fire boat on duty at the spill scene for 2 hours and 15 minutes.

Comments: In this instance the source of the spill was verified but most discharges from sewer outfalls go unnoticed and usually the source is not determined.

## INCIDENT 4

Date: 12/20/70

Location: A barge carrying #6 fuel oil struck an underwater object in the East River, opening its hull and causing an oil leak. The barge was towed about 2 miles north where containment was undertaken in a more sheltered location.

Reported Quantity and Type of Oil Spilled: 1,000 gallons of #6 fuel oil. Oil was pumped from the damaged compartment to limit the amount which might escape.

Cause of Spill: The barge's hull was opened in a underwater accident.

Fire Department Activities: One Chief Officer and 1 fire boat responded to the scene. On the afternoon of the spill

fire department personnel re-deployed boom belonging to the cleanup contractor, when the direction of the current changed.
The following afternoon (12/21/70), the fire boat returned to the spill recovery scene, where a large quantity of boom and two catch basin cleaner trucks were still being used by the cleanup crew. The boat used its bow monitor (3-in nozzle) stream to sweep a large quantity of oil from beneath the East River Drive. The oil had become lodged under the road substructure and the fire stream drove the slick into the boomed area for recovery by the vacuum trucks.

Comments: Without the services of the fire stream, recovery of the oil would have been prolonged considerably. This incident and later tests and spill incidents demonstrated that fire streams can effectively sweep trapped oil from beneath waterfront structures for controlled recovery.

INCIDENT 5

Date: 3/25/71

Location: East River, off the end of an active Brooklyn pier.

Reported Quantity and Type of Oil Spilled: A considerable but undetermined quantity of gasoline escaped through the split hull seam of a barge.

Cause of the Spill: Collision of the barge and a freighter which was backing from a pier into the stream.

Fire Department Activities: A land assignment of four engines, two ladders and a rescue company responded, in command of two chief officers.
A marine assignment of three fire boats and two chief officers responded.
An improvised plug was inserted in the hull opening: the barge was encircled with Fire Department boom and a fire foam blanket was spread inside the boom, around the barge. Explosimeter readings were taken on, around and under the pier. Hand fire streams were directed from the pier to divert the spill into the stream and away from the pier. Propwash

and monitor streams from the two fire boats were used to keep a strong current flowing beneath the pier and prevent the accumulation of flammable vapors.

One fire boat was utilized in the stream to break up the slick and diffuse the vapors, using a 3-in bow monitor stream.

The Fire Department ordered the barge removed to an anchorage for off-loading the damaged compartment.

Duration of fire department operations: 4 hours and 45 minutes.

Comments: The availability of boom to encircle the barge quickly made the application of fire foam around the barge possible.

Recovery of the spill was not the immediate concern because of the spilled product. No fire resulted.

INCIDENT 6

Date: 5/18/71

Location: Pier 3, Brooklyn Navy Yard

Reported Quantity and Type of Oil Spilled: 200 gallons of Bunker "C" fuel oil.

Cause of Spill: Leaking fuel tanks of the destroyer USS Massey, moored at Pier 3, Brooklyn Navy Yard.

Fire Department Activities: Two large and one small fire boat functioned at the spill under the supervision of a Chief Officer.

The first fire boat to arrive used its 3-in bow monitor to prevent oil from escaping from the slip.

Both fire boats deployed boom across the slip. A monitor stream herded oil toward the skimming device belonging to the 3rd party contractor. A small fire stream "sealed the gap" between a boom terminal and the pier.

## INCIDENT 7

| | |
|---|---|
| Date: | 7/4/71 |
| Location: | Kill Van Kull, off 1965 Richmond Terrace, Staten Island |
| Reported Quantity and Type of Oil Spilled: | Undetermined amount of Bunker "C". |
| Cause of Spill: | Oil was leaking from a sunken lighter. |
| Fire Department Activities: | Oil slick was observed by fire boat personnel while performing other duties in the Kill Van Kull. 250 ft of fire department boom was deployed around the barge.<br><br>The US Coast Guard was notified and a cleanup contractor was hired by the Coast Guard. |
| Comments: | Fire Department discovery resulted in containment of the spill. |

## INCIDENT 8

| | |
|---|---|
| Date: | 7/15/71 |
| Location: | A spill which originated in Bayonne, N. J. spread through the Narrows into Lower New York Bay and onto the beaches of Staten Island and Brooklyn. The ship from which the spill originated was moored at the Bayonne Pier. |
| Reported Quantity and Type of Oil Spilled: | 37,000 gallons of Bunker "C" |
| Cause of Spill: | Human error in transferring fuel aboard a ship. |
| Fire Department Activities: | On receipt of notification of the spill, which had actually occurred the evening of July 14, the Fire Department notified the NYC Police Department (for aerial reconnaissance) and the Parks Department, so that beach protection and cleanup would be inaugurated.<br><br>Both land units and fire boats were dispatched to survey the extent of the slick.<br><br>A fire boat's streams were used at the spill scene in Bayonne N. J. to sweep oil from beneath the pier, to seal a boom end gap and to herd oil toward the skimming area. One fire boat performed these functions for a total of 23 hours during a four-day period. |

INCIDENT 9

| | |
|---|---|
| Date: | 9/22/71 |
| Location: | The Narrows, in the vicinity of an anchored tanker. |
| Reported Quantity and Type of Oil Spilled: | The US Coast Guard was notified that 10 bbls of Bunker "C" had been spilled when an off-loading hose line ruptured. |
| Fire Department Activities: | One fire boat worked from about 6:00 AM to 8:00 AM herding a slick from the Brooklyn and Staten Island shores. Later, the Project's small vacuum unit was tested from the fire boat and about 12 gals of the oil were picked up from the water. A third party contractor was on the scene, using a vacuum barge. |

INCIDENT 10

| | |
|---|---|
| Date: | January 27, 1972 |
| Location: | Spill which originated at a bulk storage facility at Carteret, N. J. had spread across the Arthur Kill to the shoreline of Staten Island. |
| Reported Quantity and Type of Oil Spilled: | About 5,900 barrels of mineral spirits. |
| Cause of Spill: | A ruptured 7-in pipe at the waterfront. |
| Fire Department | A surveillance of the shoreline of Staten Island revealed a slick, in the area of Fresh Kills inlet. The slick was between 1/4 in and 1/2 in thick and some had become trapped in a small cover between a barge and a wooden pier.<br><br>Suspecting that the slick in the sheltered area might be flammable and possibly unsafe to skim, the Fire Department took explosimter readings and oil samples. The meter readings indicated a possibility of ignition so the sample was taken some distance away and tested. Since it flashed, the boat swept the slick from the trapped area, using fire streams.<br><br>Close liaison with the US Coast Guard On-Scene Coordinator was maintained during the 2-day period of the spill incident. |

Comment: Although aware of the containment-removal problems created by the spreading spill, the Fire Department's principal concern was the fire hazard created by the low flash point product.

The activities described herein were performed almost exclusively by the Marine Division of the New York Fire Department, which maintains an active fleet of five large fire boats. For those communities which may have smaller fire boats or none at all, the following suggestions are offered:

1. A prior arrangement should be made whereby publicly or privately owned small boats, as small as outboard motor boats would be made available for boom deployment.

2. A plan should be formulated whereby trucks will be made available for the transportation of boom to waterfront locations.

3. As substitutes for fire boat streams, a fire department should consider the possibilities of using fire streams from the standpipes of piers or waterfront structures, hydrants along the shorefronts or from draughting pumpers. These smaller caliber streams can be very effective in herding spills for skimming operations.

4. A fire department should maintain an on-going liaison with the federal agency responsible for providing the On-Scene Coordinator (US Coast Guard or EPA) for oil spills in its community.

## SECTION XIX

## ACKNOWLEDGMENTS

The active participation in field test exercises and at spill operations by the Officers and Members of the Marine Division of the New York Fire Department, during the course of Project 15080 FVP, is gratefully acknowledged.

The guidance of Mr. Howard Lamp'l and Mr. Frank Freestone of the Water Quality Office of the Environmental Protection Agency, and the cooperation of the City of New York and the U. S. Navy in providing the test basin in Wallabout Creek, Brooklyn, New York, are gratefully acknowledged.

SECTION XX

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*16. Abstract* This report was developed from field tests and actual oil spill control experiences of the Marine Division of the New York Fire Department during a twenty-two month period beginning October 8, 1970. The information offered is intended to assist a community in protecting its area against oil spill damage. Operational procedures described are intended to serve as stop-gap measures, pending the inauguration of clean-up activities by the spiller or responsible Federal Agency.

A survey of cities susceptible to oil spills indicates that most responding fire departments are concerned with containing spills as well as dealing with spill-created fire hazards.

Research and development which culminated in the production of this manual concentrated on the utilization of existing fire department resources. However, a limited amount of useful ancillary equipment was procured or developed. Such equipment is described and its use is explained. The manual describes common sources of oil spills and some ecological effects of oil pollution. Pertinent Federal laws and regulations are outlined. Some feasible techniques for dealing with harbor spills are offered.

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*17a. Descriptors* *Training, *Oil Spills, *Oil Pollution, *Harbors, *Inland Waterways, *Hydraulics, *Jets, *Piers, *Docks, *Water Pollution Control, *Pressure, *Basins, *Boats, *Law Enforcement, *Nozzles, Local Governments, Dispersion Emulsions.

*17b. Identifiers* *Surface Currents, *Monitor Streams, *Fire Departments, *Booming, *Herding, *Skimming, *Sorbents, *Oil Spill Containment Boom, *Emergency Service, Boom Terminal Gap.

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