TYPICAL METHODS AND DEVICES FOR HANDLING
OIL-CONTAMINATED WATER FROM SHIPS
AND INDUSTRIAL PLANTS

BY

F. W. LANE, A. D. BAUER, H. F. FISHER
and P. N. HARDING
# CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>1</td>
</tr>
<tr>
<td>Acknowledgments</td>
<td>2</td>
</tr>
<tr>
<td>General discussion</td>
<td>3</td>
</tr>
<tr>
<td>Treatment of bilge water</td>
<td>4</td>
</tr>
<tr>
<td>Handling of ballast water and other oily wastes</td>
<td>5</td>
</tr>
<tr>
<td>Disposal in port</td>
<td>5</td>
</tr>
<tr>
<td>Petroleum harbors</td>
<td>6</td>
</tr>
<tr>
<td>Petroleum harbor, Amsterdam, Netherlands</td>
<td>7</td>
</tr>
<tr>
<td>Proposed petroleum harbor for Strasbourg (Alsace-Lorraine)</td>
<td>7</td>
</tr>
<tr>
<td>Proposed petroleum port at Talmont (Gironde), France</td>
<td>8</td>
</tr>
<tr>
<td>Oil harbor proposed for port of New Orleans</td>
<td>8</td>
</tr>
<tr>
<td>Other petroleum harbors and oil ports</td>
<td>9</td>
</tr>
<tr>
<td>&quot;Bilge-water&quot; pumping stations for oil-burning ships</td>
<td>10</td>
</tr>
<tr>
<td>Description</td>
<td>10</td>
</tr>
<tr>
<td>Oil-refuse barges and reclamation of oil wastes by port facilities</td>
<td>10</td>
</tr>
<tr>
<td>General statement</td>
<td>10</td>
</tr>
<tr>
<td>Barge project for port of New York</td>
<td>12</td>
</tr>
<tr>
<td>Estimated cost of a barge and reclamation project for the</td>
<td>17</td>
</tr>
<tr>
<td>port of New York</td>
<td></td>
</tr>
<tr>
<td>Ballast-separating barges for Thames</td>
<td>19</td>
</tr>
<tr>
<td>Air-emulsion method</td>
<td>21</td>
</tr>
<tr>
<td>Summary</td>
<td>24</td>
</tr>
<tr>
<td>Disposal of ballast water and oily wastes on shipboard</td>
<td>24</td>
</tr>
<tr>
<td>Chemical methods</td>
<td>25</td>
</tr>
<tr>
<td>General statement</td>
<td>25</td>
</tr>
<tr>
<td>Colloidal coagulant</td>
<td>26</td>
</tr>
<tr>
<td>Oil-water separators for shipboard use</td>
<td>28</td>
</tr>
<tr>
<td>General discussion</td>
<td>28</td>
</tr>
<tr>
<td>Advantages of separator on shipboard</td>
<td>30</td>
</tr>
<tr>
<td>&quot;Gravity&quot; separating devices</td>
<td>31</td>
</tr>
<tr>
<td>Centrifugal separators</td>
<td>44</td>
</tr>
<tr>
<td>Filtration methods</td>
<td>46</td>
</tr>
<tr>
<td>Reclamation systems used by ship-repair yards</td>
<td>49</td>
</tr>
<tr>
<td>Description of one reclamation system</td>
<td>49</td>
</tr>
<tr>
<td>Other reclamation systems</td>
<td>50</td>
</tr>
<tr>
<td>Refinery and gas-plant separators</td>
<td>51</td>
</tr>
<tr>
<td>Refinery separators</td>
<td>52</td>
</tr>
<tr>
<td>Description</td>
<td>53</td>
</tr>
<tr>
<td>Efficiency</td>
<td>54</td>
</tr>
<tr>
<td>Fundamental factors</td>
<td>55</td>
</tr>
<tr>
<td>Gas-plant separators</td>
<td>60</td>
</tr>
<tr>
<td>Comparison with refinery separators</td>
<td>60</td>
</tr>
<tr>
<td>Additional information</td>
<td>61</td>
</tr>
<tr>
<td>Future developments in land separators</td>
<td>62</td>
</tr>
</tbody>
</table>
Miscellaneous devices of minor importance ...................................................... 62
Summary and conclusions .................................................................................. 63
  Disposal by port or harbor facilities ......................................................... 63
  Disposal by apparatus on shipboard ......................................................... 64

ILLUSTRATIONS

Figure
1. Petroleum harbor at the port of Amsterdam, the Netherlands..... 6
2. Petroleum-harbor development proposed for the port of New Orleans... 8
3. Diagram of proposed floating boom for use at entrance of petroleum harbor for New Orleans ................................................................. 9
4. Diagram of bilge-water pumping station for oil-burning ships ........ 11
5. Battery of four “gravity” separating units ........................................... 31
6. Battery of separating units for installation on land .......................... 32
7. Proposed method of installing one type of “gravity” separator aboard ship .......................................................... 33
8. Diagram of later modifications of separator shown in Figure 5 ......... 36
9. Method of adapting No. 2 cofferdam of tanker for use as ballast-separating tank .......................................................... 38
10. “Gravity” separator consisting of three concentric vertical cylinders with spiral baffle............................................................... 40
11. One type of “gravity” separator developed abroad .......................... 41
12. Separator of the U-tube type ................................................................. 44
13. Proposed method of separating oil from bilge or ballast water by filtration through carbon .................................................. 48
14. Typical refinery separator; approximate capacity, 4,000,000 gallons in 24 hours ................................................................. 56
15. Elevation of a typical gas-plant separator ............................................. 62
TYPICAL METHODS AND DEVICES FOR HANDLING OIL-CONTAMINATED WATER FROM SHIPS AND INDUSTRIAL PLANTS

By F. W. Lane, A. D. Bauer, H. F. Fisher, and P. N. Harding

INTRODUCTION

The rapid expansion of the petroleum industry, the steadily growing use of oil fuel for ships, the transportation of oil in tankers, and the extensive use of petroleum products by many land industries have given rise to new problems that involve the development of suitable apparatus for handling and disposing of oily wastes in order to prevent the pollution of navigable waters.

Because of the great importance of this problem to the petroleum and shipping industries, the Bureau of Mines, in cooperation with the American Petroleum Institute and the American Steamship Owners Association, has undertaken to ascertain the facts bearing upon certain typical methods and devices in use and proposed for the separation of oil from water and the disposal of oily wastes from ships and industrial plants. Thought has also been given to certain methods that may conceivably be developed in the future, and the physical and economic practicability of each of the methods and devices has been considered.

This study was conducted by a committee of four, representing the organizations above mentioned, and is concerned only with apparatus for preventing pollution by petroleum oils. No attempt has been made to study methods of handling other polluting substances. In general, the petroleum oils which give the greatest trouble are the heavier products, such as bunker fuels and the asphaltlike residues often encountered. The more volatile constituents, like gasoline, kerosene, and naphtha, evaporate quite readily and are not commonly associated with the term “oil pollution.”

The question naturally arises, Why is there an oil-pollution problem and how does such pollution originate? As even a brief reply would require considerable space, the reader who desires information
on the sources of oil pollution is referred to a Bureau of Mines publication which has discussed them at some length.

This report makes no attempt to describe in detail the methods and devices mentioned or even to name all the apparatus that has been suggested for solving the problem of oil pollution. Certain methods and devices chosen as typical are discussed more with respect to their adaptability than to details of operation and construction. Broadly, the methods comprise two classes—those designed to dispose of oil-contaminated water and other oil wastes by the use of facilities provided on land or in port, and those designed for use on ships. Of methods in the former class, special attention is given to oil-refuse barges, used in conjunction with suitable reclamation plants, and to refinery and gas-plant separators. Gravity separators are considered quite fully as being applicable for shipboard use.

ACKNOWLEDGMENTS

The committee desires to express its appreciation of the aid given by H. Foster Bain, former director; A. W. Ambrose, former assistant director; F. B. Tough, former chief petroleum engineer; and H. H. Hill, chief petroleum engineer, of the Bureau of Mines, for assistance and helpful criticism.

Acknowledgment is made of the aid of Dr. Van. H. Manning, former director of the Bureau of Mines, and of the officials of the American Steamship Owners Association and the United American Lines in establishing contact with public officials, organizations, and companies actively interested in the various phases of this problem.

The following persons have rendered valuable assistance during the present investigation; Capt. P. N. Olmstead, United States Navy, former supervisor of New York Harbor; Commander O. L. Cox, Bureau of Engineering, United States Navy; George Uhler, supervising inspector general, United States Steamboat Inspection Service; E. P. Rust, assistant manager, operating department, United States Shipping Board; Frank Withers, Department of Docks, New York City; Charles Crotty, assistant director of the port, Houston, Tex.; Bancroft Hill, president of harbor board and harbor engineer, Baltimore, Md.; and the American Bureau of Shipping, New York City.

D. V. Stroup, of the United States Bureau of Standards, has read the manuscript and has given much valuable information, particularly with regard to the more recent developments. Numerous State and municipal authorities have also given valuable help.

---

1 Pollution by Oil of the Coast Waters of the United States; preliminary report, prepared by the Bureau of Mines in cooperation with the American Petroleum Institute and the American Steamship Owners Assoc., September, 1923, pp. 27-44, 83-144, obtainable by addressing the Director of the Bureau of Mines, Washington, D. C.
A large number of companies have permitted inspection of their plants. The following representatives of the industries have rendered valuable aid: Robert F. Hand, assistant manager, marine department, Standard Oil Co. of New Jersey; J. P. Roney, general superintendent, marine department, The Texas Co.; J. W. H. Mencke, marine department, Standard Oil Co. of New Jersey; and T. S. Toomey, agent, New England Oil Refining Co.

GENERAL DISCUSSION

This report discusses certain typical methods and devices in use, as well as some that have been proposed or may be developed, for the handling, separation, and disposal of oil-water mixtures, oil-contaminated bilge and ballast water, and other oil wastes. The problem of satisfactorily disposing of oil refuse from vessels, both on board the individual ships and by means of suitable facilities in harbors, has been studied, and the unavoidable difficulties involved in such disposal are considered.

Land plants, in general, are handling the problem of oil-waste disposal with some measure of success. The report discusses the methods and developments characteristic of the best practice. The petroleum industry, primarily as a measure to prevent industrial waste, has devised and applied means for largely eliminating pollution by oil from refineries. Certain other land industries, including ship-repair yards and particularly gas-manufacturing plants, have also adopted measures that reduce the amount of oil escaping into the water. These methods were studied particularly to obtain fundamental data that are not only valuable in themselves but may aid materially in solving the problem with respect to vessels.

The shipping industry as a whole, including the United States Shipping Board, does not appear to have succeeded in developing or applying a wholly satisfactory method or device generally applicable for properly handling oil waste or oil-contaminated water from ships (1925). Unfortunately, the shipping industry is in a less favorable position than are most land industries with respect to actively following a definite program for the development of such a device or method. The industry does not seem to have the requisite organization and facilities for conducting the necessary experimental work on land, and the use of vessels in regular commercial service for the development of new apparatus is usually considered impracticable.

The operators of a large fleet of tankers seem to have developed a promising device for use on tank steamers, and it is believed that

---

2 Since this investigation was made, the United States Shipping Board has cooperated actively with manufacturers interested in the development of oil-water separators for shipboard use, even to the extent of permitting the installation on its ships of separators for development and test.
continued effort may solve the problem for this class of vessels. In addition, the committee has had its attention called to several cases where individual operators of oil-burning and passenger ships have made efforts to minimize the pollution by utilizing the means available on board ship. These methods are described later in this bulletin.

Although, in general, naval vessels do not use water for ballasting, the Navy has tested several promising devices for separating oil from water on board ship, keeping two objects in view: (1) The extraction of water from fuel oil, and (2) the elimination of oil from bilge and other water which may be pumped overboard. It is understood that the Navy has not developed a device or method of its own for separating oil-water mixtures.

The disposal of oil wastes from vessels on the high seas has not, up to the present time, been regulated by international law, and it has been the general practice to discharge such wastes in nonterritorial waters or in territorial waters, according to prevailing conditions. Within territorial waters laws, rules, and regulations relative to the discharge of refuse matter in general have been in effect for a great many years, and within the last decade much attention has been directed toward legislation pertaining to oily matter. If the discharge of oil-contaminated water or oily material of any character from ships on the high seas is prohibited by international agreement, the only practical way of permitting the successful operation of oil-burning and oil-carrying vessels seems to be to handle these waters by suitable separating devices on board the individual ship, by harbor facilities after the vessels arrive in port, or by a combination of these methods.

As far as can be ascertained, oil-contaminated bilge and ballast water and tank cleanings are the principal sources of oil waste discharged from ships. The proper disposal of ballast water and tank cleanings presents the greater difficulty. The disposal of bilge water will be considered first because the problem is simpler.

**TREATMENT OF BILGE WATER**

Some oil-burning vessels do not resort to the use of water ballast in fuel tanks, and only their oil-contaminated bilge water need be considered.\(^3\)

To operate oil pumps and other oil-handling equipment without a slight loss of oil is practically impossible, and some of this lost oil drains into the engine and fire room bilges. Ordinarily the oil content of the bilges is relatively very small.

---

\(^3\) For a discussion of bilge water as a source of water pollution see *Pollution by Oil of Coast Waters of the United States*, preliminary report, p. 86.
Since the total bilge volume is small as compared to ballast volumes, it is believed that the problem of bilge water can be overcome at a reasonable cost. The following suggestion, made by an experienced marine engineer, is offered as a possible solution for those oil-burning vessels in which the bilges are the main source of oil-contaminated water.

A small pump with a flexible hose suction is mounted immediately over one of the fire-room bilges. The oil floating on the surface of the bilge is skimmed and discharged into a small settling tank of approximately 5 barrels capacity. This small tank should be placed at such a height that the water which settles out may drain by gravity back to the bilge and the recovered oil may similarly return to the main settling or bunker tank and there mix with good oil. As the amount of oil that gets into the bilge is very small, skimming the bilges two or three times a week might suffice. The relatively small amount of oil recovered from the bilges can be returned to the fuel-storage tanks without materially affecting the quality of the fuel.

**HANDLING OF BALLAST WATER AND OTHER OILY WASTES**

Methods and devices for disposing of oil-contaminated ballast and other waters from vessels are discussed under two main divisions; the first covers methods which contemplate the disposal of the material through facilities provided in port, and the second deals with proposed methods of proper disposal on shipboard. Full consideration of these methods involves a study not only of the relative merits of various devices and means for separating oil-water mixtures or collecting this material from the ships, but also of the final disposal of more or less oily refuse and water to a refinery or other adequately equipped commercial reclamation plant.

**DISPOSAL IN PORT**

Three methods have been suggested for disposing of oil-contaminated ballast water and other oily wastes by use of facilities provided in port, as follows: (1) Incoming vessels to proceed to a definite disposal point and there discharge the ballast water; (2) wharves and docks utilized by oil-burning vessels to be equipped with pipe lines leading to a collecting reservoir into which vessels may pump ballast and bilge water; (3) collecting barges to receive the oil-contaminated refuse from vessels while at customary loading piers and to transport the refuse to a final point of disposal.

---

*For information on ballast water as a source of oil pollution see Pollution by Oil of the Coast Waters of the United States, Preliminary Report, p. 84.*
The methods suggested for disposing of oil-contaminated water on board ship are enumerated later under "Disposal on shipboard."

The building and use of petroleum harbors, which are sometimes suggested, may be considered as included in the first method.

**PETROLEUM HARBORS**

Petroleum harbors may be of different designs, but the general plan of all is an inclosed water area into which ships may enter to load or unload cargoes of oil or to obtain oil fuel. The entrances to these inclosed water areas are protected by a floating boom, so that any oil spilled on the water through accident will be confined to a small area and not spread over the entire harbor or port.

The main advantage of a petroleum harbor is that it provides facilities for refineries, fuel-oil stations, and storage terminals at one locality in a port. All oil spillage is kept within a restricted area, and piles and bulkheads throughout the remainder of the port are not incrusted with residues. This minimizes the fire hazard to the port in general, and a fire originating in the oil-polluted area would be confined there. Such a harbor also eliminates the transportation of oil by barges over the entire port.

The main obstacle to constructing a petroleum harbor is the enormous cost. In congested districts, as New York City, necessary space in a convenient location would be difficult to obtain. Should space be found, the cost of transferring or rebuilding storage terminals and fueling stations in one locality would alone be prohibitive, without even considering refineries. Then, too, so many oil-burning ships and oil tankers enter a large port at times that for all of them to dock in the oil harbor would require an excessive proportion of the port area. It might be feasible to have such a harbor for tankers alone were the building of refineries and storage terminals adjacent to this area practicable; but it might be a hardship on the merchant marine, for it seems impracticable to require all oil-burning vessels to refuel at this one place. The hardship is caused primarily by the lengthening of the turn-around period of the vessel, for this period must be kept to a minimum if shipping is to be profitable. The method, therefore, seems impracticable for American shipping conditions.

Many oil-carrying vessels or tankers are now in a position to follow this practice, in that many of the refinery docks are equipped to dispose of oil wastes from the loading or unloading of cargoes. Any loss of time that may be incurred is apparently not serious enough to prevent the encouragement of this practice in the oil-carrying trade when oily wastes have to be disposed of in territorial waters.
Petroleum Harbor, Amsterdam, Netherlands.—For a number of years a petroleum harbor has been in successful operation at Amsterdam. The account below is taken from The Port of Amsterdam, published by the municipality in 1919:

This harbor or dock is provided with two floating iron booms with which the dock can be closed in case of fire, so that burning oil is prevented from drifting into the North Sea Canal. The area of the dock is 70 acres, while the grounds surrounding it, of an extent of 30 acres, have been fitted with petroleum tanks, pumping stations, sheds, barrel-filling shops, spaces for the storage of barrels, railway sidings, and everything else required for carrying on the concern, which is done by the corporation. On the island, in the center of the horseshoe-shaped dock, is storage space for naphtha and benzine. Besides the tanks with a capacity of 155,000 barrels which the corporation leases, any firm may also lay down their own plant on the grounds, as the American Petroleum Co., the Petroleum Trading Co., and the Creosote Export Co. have already done and several other concerns will probably shortly do, because they wish to store and manipulate benzine in the precincts of the port of Amsterdam, as, being centrally situated, seems most convenient for the purpose.

The petroleum dock is lighted by electricity, so that electric current for power and heating oils is available. This dock and its plant is proving insufficient for the increasing traffic and should be extended.

Figure 1 gives a view of this harbor.

Proposed Petroleum Harbor for Strasbourg, Alsace-Lorraine.—The main center of importation and distribution of petroleum for Alsace-Lorraine is Strasbourg. This city, now on a national boundary and well situated on the Rhine, an international river, with an outlet to the sea via Antwerp, has splendid opportunities as a center of distribution of all kinds of staple goods. The community, realizing these facts, has planned some farseeing projects for the improvement and extension of the Rhine Harbor. Chief among these is the construction of a petroleum harbor. At present, importing companies have private harbors, with rail connections, along the canals leading to the Rhine, Rhone, and Marne Canals. The measurements of the projected petroleum harbor are: Length of basin, 3,270 feet; width of basin, 228 feet.

A strip of ground 330 to 600 feet wide surrounds the basin and will be leased or sold to oil companies, which will have to erect their own tanks and buildings thereon and must connect their plants with the railroad. The selling price for a square meter of land (equal to about 11 square feet) is 25 to 30 francs, according to location. The rental price will be 3.50 to 4.50 francs per square meter per annum. An ordinance regarding safety measures and construction of tanks is actually in consideration, but has not been definitely decided upon. The basin will be connected with the Rhine and all canals centering at Strasbourg. The present laws stipulate that a

---

*This description is taken from information furnished by the petroleum division, Bureau of Foreign and Domestic Commerce, United States Department of Commerce.*
tank may not be erected nearer than 60 meters to a building in which people live, and tanks must be surrounded by concrete, reinforced concrete, earth, or similar resistant material. The standard type of canal barge in operation has a capacity of 280 tons and a draft of 1.80 meters, is pulled by horses, is able to pass all locks, and can go to all parts of France. The Rhine boats usually carry 3,000 tons. When work on this project was begun, it was expected that the harbor would be in operation by 1925. Details regarding the present status of the project do not appear to be available at this time.

Proposed Petroleum Port at Talmont (Gironde), France.\textsuperscript{5}—Action is again being taken (1924) toward the construction of a petroleum port at Talmont (Gironde). Authorization for the construction of wharves, as well as tanks for petroleum products, was given by the French Government to the Société Francaise d’Action Economique, and the Société Civile des Entrepots Maritimes de Talmont-sur-Gironde is now engaged in carrying out the work, which is expected to be of great importance to the French petroleum trade. A large plain near Talmont is said to be suitable for the construction of oil tanks. This plain is connected by rail with the central part of France, and communication with the southwest is said to be easy and economical by the Gironde, the Garonne, the Dordogne, and the Canal du Midi. The above description gives all the details of this project that are available at present.

Oil Harbor Proposed for Port of New Orleans.—A civil engineer at New Orleans, La., who has been studying oil pollution, seems to favor a harbor similar in design to that already in operation at Amsterdam, and has designed such a harbor to confine all handling of oil to a restricted area. For the present he has limited his proposed developments to the harbor of New Orleans, although the scheme is claimed to be applicable to almost any port. In these proposed applications, he not only considers the placement of the oil-handling in one locality, but also segregates each other industry in a separate harbor, with a view to greatly improving the economy of harbor operations.

The present investigation is interested primarily in the oil harbor. This is intended to be near the entrance, off the main harbor, and as designed looks like a wheel, the circumference of which is the docking channel for the vessels; and the spokes are the firewalls between tank farms situated on the inner space or island. A small channel connects the circular docking channel with the main harbor.

Figure 2 gives the general layout of the entire system; Figure 3 is a cross section of a suggested floating skimming boom which may be used at the entrance of the oil-harbor channel. It is understood that this scheme has been considered by the port commissioners of New Orleans.

\textsuperscript{5} This description is taken from information furnished by the petroleum division, Bureau of Foreign and Domestic Commerce, United States Department of Commerce.
Other Petroleum Harbors and Oil Ports.—The new petroleum harbor at Hamburg, Germany, is situated on the island of Waltershofen, on the south bank of the Elbe, midway between Hamburg and the village of Finkenwerder. The harbor is about 23 feet deep and permits petroleum cargoes to be handled at a safe distance from the rest of the harbor. Behind the embankments are the warehouses and plants of the various companies engaged in the transfer of oil from tankers to river craft, railroads, etc. The storing, mixing, refilling into barrels, and other handling operations are conducted here. Easily flammable liquids are required to be stored apart from the less volatile oils. Elaborate precautions have been taken to insure safety from fire, both in the construction and arrange ment of storage and other operating facilities and in the handling of oil.

Pollution of the general harbor by petroleum and other oil waste, particularly from tanks of petroleum steamers and lighters, is forbidden. If such waste has to be removed, it must be put in receptacles and dumped into the petroleum harbor.

Fuel oil may be pumped from tank steamers into lighters in the petroleum harbor only. When fuel oil is to be loaded directly from a tank steamer into an ocean vessel outside of the petroleum harbor, permission must be obtained from the harbor captain.

It is understood that petroleum harbors have also been established at Constantza, Rumania, and at Panillac, a subport of Bordeaux.

A series of articles dealing mainly with the oil ports of Great Britain has been published in "Oil Engineering and Finance."  

---

6 This description is taken from information furnished through the courtesy of the State Department.
“BILGE-WATER” PUMPING STATIONS FOR OIL-BURNING SHIPS

The second method suggested for disposing of oil-contaminated ballast water, by means of facilities provided in port, contemplates the use of “bilge-water” pumping stations.

Such a bilge-water station might be feasible for a small port, but seems impracticable for a large port like New York because of the physical difficulties and the enormous cost of installing a pipeline system along the entire water front. In cold climates the operation of such a pipe line in winter would entail some difficulties. There is also a certain element of risk, for, should the pipe line break, the oil would contaminate surrounding property and cause much damage. A system of this kind, limited in scope, has been patented. It is understood that this system would not extend into all the docks along the water front of a harbor but merely to certain docks favorably situated for oil-burning vessels to discharge oily wastes and take on fuel. The time spent in a port by nearly all cargo, passenger, and oil-carrying ships is short, and it is believed that to have all oil-burning ships go to one place for refueling and the discharge of ballast water would cause too much delay. The system is mentioned here as one of those suggested for dealing with oil pollution.

Description.—The following description is taken from some literature that was furnished the committee:

This plan provides for a quick, efficient, and economical method of discharging bilge water from oil-burning ships. It entails the least possible delay on the ship and enables the oil or sludge to be saved, sold, or utilized. It provides for the discharging of barges should any be employed in connection with the disposition of bilge water and refuse. It must be located in connection with the main channel or channels of a port and be placed as convenient as possible for ships entering or leaving port. Navigation between the discharging points and the shore will not be interfered with. In ports where but few boats bunker with oil two discharging points only need be arranged for. The separation of the sludge from the water in the settling basin is accomplished by running off the water controlled by sluice gates. The basins are of earth and are of inexpensive construction.

Figure 4 is a diagram of the system for disposal of bilge water and recovery of sludge. It is understood that endeavors have been made to have the system installed in certain parts of the United States.

OIL-REFUSE BARGES AND RECLAMATION OF OIL WASTES BY PORT FACILITIES

General Statement.—The use of barges seems the most practical and satisfactory method thus far proposed for the disposal of oil-contaminated ballast water or oily residues by facilities provided in
port. The method requires a number of barges expressly maintained for this service and also the necessary towing facilities and a suitable disposal or reclamation plant. Under the proper conditions such a fleet of barges might be owned and operated by a commercial company organized for that purpose, or by the local municipal government or by port authorities having requisite power. As the investment necessary would be large and the service rendered would be special and of a public character, it seems reasonable that any corporation organized for the purpose should be granted a monopoly in its particular locality by the authority having the proper jurisdiction, provided the schedule of charges, which should permit a fair and adequate return, was subject to the same authority.

Although the committee believes that the most satisfactory solution of the problem under discussion will involve the use of separating apparatus aboard ships, still, in the absence of a fully developed and practicable separator suitable for use on all general cargo and passenger vessels, as well as tankers, it feels that the use of barges in harbors presents the most effective and immediately available method that has so far come to its attention.

The method of protecting the investment in barges and other equipment and of regulating such an enterprise has been mentioned above. In the following analysis an approximate estimate is made for a complete project suitable for the port of New York under
normal shipping activity. The estimate covers the probable maximum daily amount of ballast water to be handled, the number of barges required, the investment for an entire collecting equipment, including a reclamation plant, and all operating and fixed charges. The capacity of the equipment is estimated to be ample to handle satisfactorily the maximum daily amount of oil-contaminated ballast water likely to be brought into New York Harbor during normal shipping activity, all of this water to be discharged into the barges provided for the purpose.

**Barge Project for Port of New York.**—An effort has been made to obtain data on the variation in the activity of oil-burning vessels during a period of years, as well as the seasonal variations, in order to estimate the probable variations in demand for the services of port barge equipment. It seems that statistics covering this point are not readily accessible, and that complete authoritative data could be obtained only by extensive searches of the records and by lengthy computations—a procedure which hardly seemed justified in the preparation of a hypothetical estimate.

Shipping activity in 1924, for the purpose of this discussion, may be regarded as representing normal conditions; in fact, it is said that the number of vessels entering and leaving the port of New York is greater than it normally was before the war. Therefore, it is thought that a barge equipment adequate to handle the maximum daily amount of ballast water likely to arrive in this port under the present conditions of shipping activity would provide a safe basis for estimate.

*Choice of port.*—The port of New York was chosen as representative of the maximum amount of equipment required. This port is typical of greatest density in oil-burning and oil-carrying traffic and presents disposal difficulties somewhat over the average, due to its wide extent and topographical features. It is believed that an estimate based on New York Harbor requirements will give conservative and representative figures and provide a safe guide in general plans for any barge project.

Another reason for selecting the port of New York as the basis for an estimate of the barge project is the complete and readily available data on daily arrivals. These data, for several periods of 26 to 28 days each, were studied to ascertain the tonnage of oil-burning vessels arriving, and thus obtain a basis for estimating the probable maximum daily amount of the oil-contaminated ballast water that might have to be handled.

Official records indicate those vessels arriving “in ballast,” but this designation is of little value in making an estimate of the amount of ballast water to be handled because a vessel so listed
may not have any ballast water aboard, and a vessel not listed as "in ballast" may still have ballast water aboard on account of carrying a comparatively small cargo. The following estimate is not based on the official record of vessels arriving "in ballast," but on an assumed number of vessels actually ballasted. This estimate gives a figure for ballast water that may be regarded as a maximum average under present shipping conditions.

Estimate of ballast water to be handled.—Detailed analyses of lists of arrivals show that during normal activity of shipping about 10 oil-burning vessels of a gross tonnage of approximately 65,000 tons arrive each day in New York Harbor. It is estimated that the ratio of their total ballast space to gross tonnage is 1 to 4. The total ballast space is not available, as some of the tanks contain fuel, but it is believed that 75 per cent of the tanks might be available under certain conditions.

If 75 per cent of the tanks are ballasted and all vessels arrive ballasted, an average of 12,180 long tons, equivalent to 76,000 barrels (of 42 gallons), of ballast water might enter the harbor each day. Since ballasting depends upon load and weather conditions, the foregoing estimate must probably be regarded as representing the maximum condition. Variations in weather and load make an estimate of average conditions difficult; but for the present purpose it is assumed that 50 per cent of the vessels actually are ballasted, and hence carry 38,000 barrels of ballast water. This figure is regarded as representing the maximum average during periods of normal shipping activity.

Although study of the list of arrivals indicates that the tonnage officially listed as arriving "in ballast" would give a considerably smaller figure for ballast water, the official designation "in ballast," as stated before, does not mean much, and the estimate of 38,000 barrels of ballast water a day may be considered a fair gauge of the maximum average amount during a period of normal activity.

Estimated barge requirements.—If 38,000 barrels of ballast water are to be handled daily, it seems necessary to use at least seven or at most eight 5,000-barrel barges, and for each barge to make one trip a day to the nearest point of disposal. Barges with a capacity of 5,000 barrels are suggested as the maximum size that can readily be handled in New York Harbor, because of congestion in the slips. It might seem that by requiring each barge to make more trips in a day a smaller number of barges and a consequently smaller investment would suffice. The more liberal estimate is to be preferred, however, since on some days many more than the assumed average number of vessels may arrive, and for the successful opera-
tion of the barge project enough barges should be available to take care of all vessels as they come into port.

*Method of barge operation.*—To handle efficiently the movements of such a fleet of barges would require a barge dispatcher having a conveniently situated office, who would receive all requests from ships needing barge service and would direct the movements of the barges and tugs.

For the actual operation of the system, two methods are suggested, as follows: (1) Direct collection by 5,000-barrel barges and delivery to the point of disposal by the same barge; and (2) collection by 5,000-barrel barges, transfer to larger receiving barges stationed at convenient points, and transport by these larger barges to final point of disposal.

The first or direct method may be used to advantage in small ports where shipping is less active and the distances within the harbor limits are not great. The second or indirect method is considered better suited for the larger ports, where shipping activity is greatest and the point of final disposal would probably be some distance from the point of collection. A brief account of the two methods will bring out the differences in operation.

First or direct method: The direct method assumes one main headquarters for all barges, and each barge to be of 5,000 barrels capacity. A vessel arriving with oil-contaminated ballast water requests the barge dispatcher to send a collecting barge. A barge leaves the barge station, proceeds to the vessel, collects the ballast water, and, when loaded to capacity, transports its load to the final point of disposal, and returns to the station.

Second or indirect method: The indirect method assumes one or more barge stations at which are stationed large receiving barges of 10,000 barrel capacity. The capacity of each collecting barge is 5,000 barrels. A vessel arriving with oil-contaminated ballast water requests the barge dispatcher to send a collecting barge. A 5,000-barrel barge leaves the nearest station to the vessel, collects the ballast water, carries it to the station, and discharges it into the larger receiving barge. This receiving barge is believed to be large enough to hold at least one day's collections of the several smaller barges assigned to that station. The larger barges when loaded go to the final point of disposal and discharge the residues there. It is suggested that the 10,000-barrel barges be of a self-propelled type like those on the New York State Canal.

*Proposed methods for reducing bulk of material.*—In the lack of any method on board ship for separating oil from oil-water mixtures, it will be advantageous, in order to decrease the cost of handling, to reduce the bulk of the material as soon as possible
after being pumped into the collecting barges. A letter from an oil company that has done much work on the design of separators for shipboard use contains the following statement on the amount of oil in ballast water:

The results of our investigation to date lead us to concur with you in your opinion that the average oil content of ballast water is considerably less than 1 per cent. In fact, we find that it varies between one-tenth and one-half of 1 per cent. We are, however, proceeding under the assumption that 90 per cent of the total amount of ballast water carried by a tank steamer may be discharged overboard without causing any appreciable contamination, and we have therefore designed our separator with a view to extracting all of the oil from the remaining 10 per cent, which means that the separator must handle water containing 1 to 5 per cent of oil.

This statement indicates that disposal of the bulk of the water while the material is being pumped from the vessel into the barge may be possible, particularly in the initial stage of pumping. A still further reduction may perhaps be effected to advantage on the barge itself, where space for an adequate separating device would probably be available. A feasible separation method for use on the collecting barges is highly desirable. Because of the large excess of water over oil, fairly rapid separation of water by settling may be possible in an ordinary barge even without a special separating apparatus. The suggestion is made that the major part of the ballast water as it separates from the oil be discharged overboard while the barge is still receiving ballast water from the ship, and that this may be accomplished by a suitable pumping arrangement mounted on the barge. When time is not the controlling factor and limited pumping capacity will suffice, it has been suggested that either an ejector supplied with air from a compressor driven by a small gasoline engine, or a small centrifugal pump driven by a gasoline engine will furnish a simple and inexpensive pumping outfit.

It is also suggested that the barges be provided with transverse underflow partitions and submerged baffles, such as are found in oil and tar separators on land, thus making the barge a floating "under and over flow" gravity-type separator that can receive the ship's ballast water at one end and discharge clean water at the other. This process of separation can be continued in the larger receiving barges, thus increasing their capacity to take care of a large number of the smaller collecting barges. In addition, it has been suggested that separation of oil from water would be materially aided by having a donkey boiler on each of the receiving barges to supply steam to heating coils in the various separating compartments. When the collecting barges are tied up to the receiving barges this donkey boiler can be used to supply steam to similar heating coils in the collecting barges.
Oil-separating barges.—A number of devices are being developed for separating oil-water mixtures aboard ships, but, as far as the committee has been able to ascertain, none of these have as yet attained wide commercial application. A particular type of ballast-separating barge for handling oil-water mixtures has been developed, however, in England. Two articles quoted at the end of this section describe the barges which are said to be in successful operation on the Tyne and the Thames, separating oil from contaminated ballast water.

Reclamation of refuse oil.—As the oil-water mixture in the barge contains a relatively large amount of water, even after a partial gravity separation may have been effected, further separation must be made. Therefore it seems necessary that this material should be treated at a refinery or at a special reclamation plant. Difficulty may be experienced in getting an oil refinery to take this material, because of the low value of the reclaimed products and the cost of handling them. It may thus be necessary for municipal or especially subsidized privately owned enterprises to construct special reclamation plants, these plants to be like the separating plants now used by practically all oil refineries for treating oil-contaminated plant drainage.

Briefly, a typical plant of this type consists of a power house, storage tanks, a separator, and a skimmed-oil separating tank. This equipment, with suitable piping, should be situated on a waterway where docking facilities for the barges are available and waste waters may be conveniently discharged. Such a plant large enough to reclaim the oil recovered from ballast water and other oil wastes from ships in New York Harbor would require approximately 1 acre of land and a water frontage of 200 feet. Several dehydrating stills may have to be added to this equipment, but they have not been included in the estimate.

The oil-contaminated ballast water remaining after partial separation in the collecting and receiving barges would be transported to the plant wharf and pumped ashore, either temporarily into a main storage tank discharging at a slow rate into the plant separator, or directly into the separator. This separator would be of the "under and over flow" gravity type generally used at refineries. The mixtures skimmed from the plant separator would be discharged into a skimmed-oil separating tank to be kept at as high a temperature as possible without causing the oil-water mixture to foam over. The skimmed mixture while passing slowly through this heated tank would undergo further separation, and the oil rising to the top, comparatively free from water, would go to a storage tank. This reclaimed oil may be suitable for fuel purposes without further treat-
ment, or used for making road oils, or employed by refineries and other plants in their processes.

**Estimated Cost of a Barge and Reclamation Project for the Port of New York.**—The following detailed estimate of approximate cost covers the investment and the annual charges for a complete barge and reclamation project for the port of New York. As previously stated, the investment in barge and towing equipment is based upon the probable maximum daily amount of ballast water likely to be brought into the port.

*Seasonal variation in shipping as affecting barge estimate.*—The demands on the equipment will vary widely. During short periods the equipment may operate at maximum capacity, and during longer periods the greater part of the equipment may be only in partial use. Nevertheless, the equipment, if installed at all, must be adequate to take care of all vessels without undue delay; otherwise congestion of shipping will result, possibly accompanied by the neglect of proper care in preventing pollution.

Although the estimate is approximate, it is considered to be on the safe side in covering an equipment ample for the probable maximum conditions. It is further considered to be on the safe side in having the operating expenses based on a continuous maximum use of the equipment. Some reduction in fuel, maintenance, and supplies probably will be possible during operation over long periods of low shipping activity.

*Return credit from reclaimed oil.*—The return credit accruing from the value of the reclaimed oil is likely to vary widely. A nominal value of $1 per barrel for reclaimed oil has been assumed, but the value that can be attached to the recovered product is problematic. This value is likely to vary with the character and quality of the oil reclaimed, the uses to which it can be put, and the possibilities of selling it to industries. If the port has no manufacturing or chemical industries or is some distance from industries in which the reclaimed oil can be used, final disposal of this oil may entail still further expenditures.

*Detailed estimate of cost*

<table>
<thead>
<tr>
<th>INVESTMENT EXPENSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collecting equipment:</td>
</tr>
<tr>
<td>8 collecting barges; 5,000-barrel capacity each, equipped with gas-power air compressor and ejectors and heating coils, at $34,000.-------- $272,000</td>
</tr>
<tr>
<td>3 receiving barges; 10,000-barrel capacity each, equipped with self-propelling equipment, donkey boilers, steam pumps, and heating coils, at $100,000.------------------ 300,000</td>
</tr>
<tr>
<td>(Location: 1 at the Battery, 1 at South Brooklyn, 1 at Staten Island.)</td>
</tr>
</tbody>
</table>
Collecting equipment—Continued.
2 towboats, at $85,000........................ $130,000

Total investment for collecting equipment........ $702,000
Add 10 per cent for contingencies.................. 70,200

$772,200

Reclamation equipment:
Land (approximately 1 acre)........................ $10,000
Wharfage.......................................... 15,000
Storage tanks (3)................................. 27,600
Concrete separator................................ 15,000
Boiler house and pump equipment.................... 25,000
Piping................................................ 5,000

97,600
Add 25 per cent for contingencies............. 24,400

Total investment in reclamation equipment........... 122,000
(No dehydrating or chemical treating plant is included. Such equipment would add at least $25,000 to the estimate.)

Total investment:
Collecting equipment................................. 772,200
Reclamation equipment............................... 122,000

Total............................................... 894,200

ANNUAL EXPENSE

Annual fixed charges:
Interest on $894,200, at 6 per cent.................. 53,652
Depreciation, at 5 per cent.......................... 44,710
Insurance, at 1 per cent............................ 8,942
Taxes, at 0.5 per cent................................ 4,471

Total annual fixed charges........................... 111,775

Annual operating expenses:
Collecting equipment expenses—
Towboats—pay roll, water and fuel supplies, and maintenance........ $63,750
Barges—pay roll, water, fuel supplies, and maintenance.............. 84,350

Total.............................................. 148,100

Reclamation equipment—
Pay roll............................................. 16,600
Water................................................ 1,500
Fuel.................................................. 30,000
Supplies............................................ 4,000
Maintenance........................................ 1,500

Total.............................................. 53,600
Salaries—supervision, dispatchers, and other office pay roll........ 10,000

Total annual operating expenses..................... 211,700
Total annual expense, entire project:

Annual fixed charges, collecting and reclaiming equipment........................................ $111,775
Annual operating expenses, collecting and reclaiming equipment.................................. 211,700

Total annual expense........................................................................................................ $323,475

CREDIT

Oil reclaimed on basis of maximum daily amount:
(38,000 barrels of ballast water per day; estimated oil contents, 0.5 per cent. Oil reclaimed equals 190 barrels per day on basis of probable maximum amount, assumed value as fuel oil at $1 per barrel.)
Credit annual value of reclaimed oil (190 barrels a day × 365, at $1 per barrel).......................... 69,350

Net annual expense........................................................................................................ 254,125

(With 10 oil-burning vessels arriving each day, or 3,650 a year, the approximate cost of the barge collection service will be $71 per vessel per call.)

It is understood that during the past year a barge in New York Harbor has been handling ballast water from a few Holland-American liners. According to reports, only about two vessels a month have been served, and the quantity of ballast water removed may average 1,500 to 2,000 tons for each vessel. Figures on the efficiency of operation are not available.

Ballast-Separating Barges for Thames.—In order to prevent pollution by oil and to abide by the provisions of the oil in navigable waters act, effective January 1, 1923, the Smith’s Dock Co., in conjunction with the Anglo-Saxon Petroleum Co., in England, has developed a barge scheme for separating oil from ballast and bilge waters. As a result of successful tests, the port of London has bought two of the barges for use on the Thames.

The following description of the barge scheme has been taken from the Petroleum World (British) February, 1923:

By the provisions of the oil in navigable waters act, 1922, which came into force on January 1, 1923, it became a penal offense to discharge oil, or to allow oil to escape, into the sea within the 3-mile limit from the shore. To avoid the necessity of a vessel having to proceed beyond the 3-mile limit to discharge ballast water from her oil tanks, a scheme has been perfected by Smith’s Dock Co., in conjunction with the Anglo-Saxon Petroleum Co., whereby the oil can be separated from the ballast water.

A specially equipped barge of 250 tons, known as the “ballast separating barge,” is provided, into which the oily ballast water is discharged. This barge operates on the well-known principle of surface separation of liquids of different specific gravities, the lighter liquid rising to the surface. The barge has been designed from the experience gained by a considerable number of experiments on the separation of scum from ballast water at the com-
pany's works. The barge is subdivided into a number of compartments by transverse bulkheads, the first being provided with a series of cones and baffles, while the bulkheads between the other compartments are arranged to form a cascade filter. From these filters the water passes overboard. The cascade-filter compartments are made up of a number of transverse bulkheads extending from side to side of the barge, each having a horizontal slot at the top and at the bottom alternately, these slots being the full breadth of the bulkheads. These filter compartments are partially closed at the top by a sloping plate so that any scum which comes to the top is accumulated on a relatively small area instead of a large one. By this arrangement the thickness of the scum on the surface of the water is increased and rendered more easily removed.

The barge is fitted with a pump which is capable of drawing from the river, from the filter compartments, or from the scum-storage tank, and delivering to deck, where there are two branches—one leading to the filter compartments and the other delivering ashore.

A delivery pipe from the ship is led into the open top of a receiving compartment, the function of which is to prevent the pulsation of the pump affecting the operation of the cone separator, which requires a steady flow.

The oily mixture is pumped into the cone separator compartment, where practically all the scum in the water is trapped. This compartment contains a number of superimposed cones terminating in the form of a bottle neck, the function of which is to reduce the free area of the scum, which rises to the surface. When the scum accumulates in sufficient quantities in this bottle neck it overflows into scum trays surrounding the filter cone top and drains from there into the scum-storage tank. The remainder of the ballast water passes from the cone separator through the cascade-filter compartments, and means are there provided for draining any remaining scum into the storage tank.

The ballast water passing through the cascade filters is discharged through a valve on the ship's side, which is just above the river water level and under the observation of the operator. This valve is open and set by trial to maintain just the proper working level of the water in cascade, and when the ship is pumping steadily the valve requires little attention until the bottom drainings of the tank are pumped through, when the flow from the ship becomes erratic. It is necessary when scum alone is being pumped from the vessel to see that a reasonable cushion of water is always in the cone separator. This is attained by means of the barge's pump drawing water from the sea and delivering it into the bottom of the cone separator. It is found that scum did not seriously extend beyond the fourth cascade opening, and this scum can be dealt with by hand. Heating coils are fitted in the storage tank, so that the scum can be heated and settled. The water thus separated is pumped out through the cone filter until practically nothing but pure oil remains in the storage tank. This oil can be delivered back to the ship or ashore as desired. An extensive system of heating coils is provided in the filtering compartments on top of the floors and underneath the deck. When the pumping operations from the ship are finished the oily ballast water in the barge is heated and an absolute separation of the scum from the ballast water is effected, so that any remaining scum may be removed. The barge is then ready to commence working on another ship. The steam for heating is derived from the vessel using the craft. The barge is capable of dealing with 180 to 200 tons of ballast water per hour.
Official tests were recently carried out under actual working conditions on a tank steamer which had carried Mexican crude oil following on a cargo of creosote. Approximately 2,000 tons of oil ballast were pumped through the barge without the discharge water showing any trace of oil whatever, and about 60 tons of oil were retained in the barge. These tests were witnessed by all the principal dock and harbor authorities, together with representatives of the oil and liner companies, and they were greatly impressed with the results obtained. It may be added that following these trials the port of London ordered two barges equipped with this system from Messrs. Smith's Dock Co.

Attention is also called to an article entitled "Oil in navigable waters," in Shipbuilding and Shipping Record, London, January 11, 1923, pages 36 to 39. This article describes the new ballast-separating barges to be supplied to the port of London authority by Smith's Dock Co. (Ltd.), and gives drawings that show the method of operating. It is reported that other foreign concerns are interested in the development of barges for handling ballast water.

**AIR-EMULSION METHOD**

Ship contractors and salvage companies in various ports operate barges in connection with their business but use them mainly for cleaning out tanks and handling oily refuse and residues rather than oil-contaminated ballast and bilge waters.

The apparatus considered here has been developed for cleaning the tanks of ships and may be regarded as a barge method of limited scope, rendering a special service. When this process was seen in operation, the barges were not big enough or were they equipped to handle large quantities of ballast water in a short period of time. The apparatus is used mainly for removing oil from tanks before repairs, for disposing of heavy oils, sludges, and refuse, and for cleaning out large quantities of oil from bilges.

The committee saw this process in operation while it was being used to clean one of the bilge compartments of the Shipping Board's steamship *West Saginaw*, which had a leak in one of the fuel tanks. About one-half hour is required for the crew to get the apparatus working after the barge is brought alongside the ship. It is essentially a vacuum apparatus. Steam or air can be admitted to the special nozzle on the suction hose used, but in this case steam was used in order to make the heavy oil flow more readily and to break up the large particles. The nozzle was placed in the bilge compartment and the heavy viscous oil was drawn up in a manner similar to that of a vacuum cleaner taking up dust.

It is claimed that one of the essential features of this system is the intimate mixing of air or steam with the material being removed
and the formation of a mixture which is readily handled by the rapidly moving air and steam.

The committee was unable to board the barge, and so did not inspect the working of the pump and settling tanks. The apparatus does away with the tedious hand method of cleaning very heavy oils from tanks and bilges and is said to take care of sludges and very heavy oil wastes and sediment. It apparently works very well and is the only apparatus the committee has seen that can handle this kind of work. After all of the movable waste is taken from the tank, sawdust is used to absorb the oil adhering to the sides and braces. The oily sawdust is then removed through the suction hose, discharged into a separate tank from the other oily wastes, and later is used as fuel. The operator passes the nozzle over the rivets and along the seams of the tank, and in this way can remove a large portion of the sludge clinging to the sides. It is claimed that a tank cleaned by this method does not need to be steamed and ventilated before the workmen enter it for repairs.

Several other salvage companies are said to operate salvage barges which perform a service similar to that offered by the proprietors of the air emulsion method.

Although this method appears to be successfully used in port for removing heavy oils and sludges from tanks, the advantage in using it to handle ballast or bilge waters is not evident.

Certain advertising literature of the company stresses the practicability and efficiency of the apparatus and compares the process of tank cleaning by hand and by the air emulsion method. It is indicated that in cleaning the fuel-oil tanks of a vessel by the older method about 118 men would be required to do the work of one tank-cleaning outfit. Inasmuch as only 20 men can be employed efficiently on a tank-cleaning job, it is pointed out that cleaning by hand would take five or six times as long as by the air emulsion method. It is stated that the oil residue is burned under the boilers on the barge.

*Tank cleaning by hand compared with the "air emulsion" method.*—Tank cleaning by hand is done by a gang of men, usually 20 in number. One man is stationed in each frame space of the double bottom and the material is passed along in buckets through the lighting holes, and the buckets are emptied into a barrel which is hoisted up and swung over the ship side, from where it is taken away by a wagon or other convenient means of transportation. It has been found that one man is able to clean out four barrels in eight hours, or half a barrel in an hour. As one barrel weighs 340 pounds, the capacity of one man is 170 pounds per hour, and 118 men would be required to do the work of one ——— tank cleaning outfit.

Tank men are paid from 75 cents to $1 an hour, and the cost would then be one-half cent per pound of sludge, to which the cost of final removal has to be added; but inasmuch as only 20 men can be efficiently employed on a
tank-cleaning job, the cleaning by hand would take five times as long as the cleaning by the ——— outfit.

Time is often an all-deciding factor where ship repairs are concerned, and as two pumping outfits very well can be placed on one barge, such a barge would clean a tank in one-tenth the time the bucket gang would take.

Instead of tying up the vessel for weeks and paying men for night work, a couple of days is all the ——— cleaning outfits require in order to do an efficient job, and repair men can enter the tanks right away, as the tank has been efficiently ventilated.

One ——— outfit employs five men, and in case of two outfits on a barge, 8 men, and the cost would be 0.02125 cent and 0.0165 cent per pound, respectively, or 23 and 31 times cheaper.

No fuel cost is to be added to the ——— outfits, as the oil residue is afterwards burnt under the boilers on board the barge.

Towing charge has, of course, to be added, and this charge is about equal to the transportation charge in the hand cleaning method.

This charge disappears where the pumping barge is made self-propelling, as the reclaimed oil sludge furnishes the driving power.

*Essential features of the ——— Salvage Co.'s vacuum oil tank cleaning apparatus, patented.—It is a very simple and strong apparatus. There is nothing to get out of order.

It consists of standard equipment throughout and which can be purchased in any country.

It does the work in at least one-quarter the time and for one-quarter the cost of the hand method.

It eliminates all steaming for gas removal because, being a vacuum system, the gas is automatically removed with the oil residue and dirt.

It makes the vessel safe against explosion because once the tanks are cleaned by the ——— vacuum method there is no gas left.

It will handle, without any difficulty whatever, all muck, sand, bolts, nuts, rivets, etc., that happen to be in the oil residue.

No ship is too big, no job too tough. The steamships *Resolute*, *Reliance*, and *President Monroe* are among the ships recently cleaned.

Picture in your mind which is the better method—a gang of laborers with shovels and buckets working through a small manhole cleaning a ship's double-bottom fuel-oil tanks, or a 4-inch flexible steel hose rapidly drawing oil sludge, no matter how thick, and any foreign matter which might be in the residue, over the side of the ship under the impulse of a powerful vacuum pump. The latter is the ——— system.

This system, which automatically changes the air in the tanks, removing all gas pockets and sickening combustible vapors, is considered the greatest safeguard against explosion and fires.

Last, but not least, cleaning by the ——— system makes it possible to burn the residue under the boilers as fuel instead of dumping, as heretofore, in the harbor waters, causing the pollution about which there is now so much trouble and legislation.

On our steam outfit, which is the latest, we have not bought 1 pound of fuel since commencement of its operation.

We are ready to substantiate all these claims by practical demonstration on our outfits in New York Harbor.

——— Salvage Co. (Inc.).
SUMMARY

Of the three methods for disposing of oil wastes from ships by means of facilities provided in port, petroleum harbors seem impractical because of delays to shipping and the consequent decrease in earnings, and bilge-water pumping stations seem impractical in large ports because of the enormous cost of installation. The use of collecting barges, as already described under "Barge project for port of New York," appears to be the only feasible and practical method for all ports.

DISPOSAL OF BALLAST WATER AND OILY WASTES ON SHIPBOARD

The committee finds that a few of the more progressive ship operators and oil companies are using, to a very small extent, a method developed by them for minimizing pollution by oil from the pumping out of ballast water and the cleaning tanks. This method consists of the use of a spare tank on board ship to receive the residue oils from ballast water and tank cleanings and permits this material to be retained on board until a further partial separation of the oil and water is effected. As far as general cargo-carrying ships are concerned, this method seems practicable only on vessels that have empty tanks available, such as one of the peak tanks, and apparently is used only on a few vessels employed in certain classes of service. For instance, one company now uses this method on its ships in trans-Atlantic trade. Should the same company run these steamers through the Panama Canal, this practice under existing toll regulations would result in a larger toll charge because of the peak tanks being used for other than trimming purposes. Thus the company would penalize itself without evident justification.

When oil-cargo vessels clean their tanks at sea, they sometimes pump the residues into a spare tank where a rough separation may be carried out. The final residues are pumped ashore into the refinery separator after the vessel is berthed at a refinery dock.

These methods are not applicable to all oil-burning vessels unless definite provisions are made for having storage specially set aside on board these ships to receive such residues and to effect the partial separation described above. The committee regards these methods as only a step in the solution of the problem, since further means must be devised for handling the residues after the ships arrive in port. It is extremely unlikely that such rough separation with the crude means furnished by a plain tank used as a separator would result in reclaiming an oil sufficiently free from water to permit use directly as fuel, even when mixed with clean oil. Any method that
leaves much to the personal equation in its application introduces uncertainty. The improvements to be sought are those which will eliminate this uncertainty as far as possible.

CHEMICAL METHODS

General Statement.—Chemical demulsifying agents and coagulant methods have been suggested for shipboard use in separating oil from bilge and ballast water. These methods may work satisfactorily on land, but as far as can be ascertained, difficulty is likely to be encountered in treating the oil-water mixtures formed by water ballast in the fuel or cargo tanks of oil-burning ships. Although chemical agents may be effective in separating the oil and water, a method for satisfactory mechanical separation of the oil and water still remains to be devised.

The oil-water mixtures found on shipboard probably differ widely with the varying degrees and types of emulsification, nature of the oil, presence of large lumps, etc. As the effective use of chemical demulsifying reagents depends upon definite information regarding the mixtures being treated, it does not seem likely that any set method will prove applicable to all the mixtures found.

One company that manufactures a demulsifying agent suggests that it be added to the ballasted tank, and after a separation has taken place the oil-free water may be pumped out, leaving clean oil suitable for fuel. The committee believes that under sea conditions the rolling of the ship may prevent good separation of oil and water, and thus hinder the effectiveness of chemical methods.

Should the chemical coagulant be applied in the ballast-water discharge line, as suggested by one of the companies manufacturing it, an oil trap and a filtering device of some kind would have to be employed. Since some of the coagulants react only with emulsified oil, the oil trap would be needed to remove the free oil and lumps of sludge before the chemical is introduced into the ballast water being discharged. The use of the oil trap brings up a problem regarding its size, for in all essential details it would be equivalent to a ship separator and would have to be of equal capacity. The filter is needed to remove the coagulated sludge from the discharge water.

The problem of disposing of the coagulated sludge also arises, for it is said that it can not be burned as fuel. The cost of the chemical coagulant may make its use in large quantities practically prohibitive, should the resulting by-product have no commercial value. Moreover, the storage of the chemicals on shipboard would occupy much valuable cargo space. Information regarding one of the chemical demulsifying agents indicates that about 300 pounds are required to treat 1,000 barrels of oil-water mixture. This amount of
reagent might represent a nominal cost when applied to an oil-field emulsion containing a fairly high percentage of oil; but it becomes an important item of expense in treating ballast water which probably averages not over 1 per cent of oil.

The use of the chemical method by itself, therefore, does not appear advantageous, although limited application of a chemical demulsifying agent may be of assistance in the treatment of intimate oil-water mixtures or emulsions on shipboard when a gravity-type separator is being used for the bulk separation. The principal disadvantages are the use of an oil trap equivalent to a full-size ballast-water separator, the installation of a filter, the occupation of valuable cargo space, and the cost of the chemicals. Moreover, the chemical method would probably require additional supervision of a type not generally available on shipboard.

Two substances proposed for use in the chemical treatment of oily bilge and ballast water have been brought to the attention of the committee. Both would probably be open to the general objections outlined above. In the absence of a suitable oil separator on board ship, the skill and watchfulness of the pump operator must be depended upon entirely to avoid pollution of navigable waters while ballast water is being discharged.

**COLLOIDAL COAGULANT**

One company prepares a colloidal coagulant which is designed primarily for use in water purification and sewage disposal. A pamphlet issued by the company describes the use of the coagulant for the purification of water in sewage disposal and in treating factory wastes. The application of this substance to the separation of oil-water emulsions is a new development, which at the time of the committee's visit in December, 1922, had apparently not been carried beyond the laboratory stage.

With regard to the handling of oil wastes, the pamphlet makes these claims:

Ships that either burn or transport oil are obliged to fill the compartments that held oil with sea water as soon as the compartments are emptied of their oil content. This is necessary to preserve the stability of the ship.

When a ship enters port where it can safely discharge such salt-water ballast, it is pumped out into the harbor or river in which the ship is located.

The residue oil that was left in the emptied compartments has become for the most part very finely emulsified in the sea-water ballast, so when this ballast is discharged many barrels of oil pollute the navigable waters frequented by oil-burning vessels or oil-tank ships.

Since, as just stated, the oil as discharged is in a very finely divided form ordinary methods of oil separation such as centrifugation, the use of oil traps, etc., fail.
Colloidal coagulant, on the other hand, instantly absorbs the emulsified oil droplets and carries them to the bottom of the waterway, where current and tide carry the material out to sea. And the finer the oil is emulsified the better colloidal coagulant acts. In this way, by using an oil trap to catch the nonemulsified oil and the colloidal coagulant for the emulsified quota, a solution of oil pollution by ships is obtained.

The above description does not include details indicating how the coagulant shall be used in separating mixtures of oil and water. In an interview with a representative of the company, the following procedure was outlined for use of the coagulant on shipboard: The bilge or ballast water will first be passed through an oil trap to remove any free oil. This is necessary because the coagulant will not take care of large lumps or globules of oil. On the other hand, the coagulant reacts readily on oil which is finely emulsified. The discharge pipe from the oil trap is fitted with a small mixing chamber into which the coagulant is fed, and here the coagulating action can take place. From this chamber the mixtures will pass through porous coal dust or some other filtering medium, in which operation the coagulant sludge is retained in the filter while the purified water is discharged. The coal-dust filtering medium can be held either in a tank located on the ship or in a bucket swung at the side of the vessel by a crane.

The coagulant reacts readily with emulsions of heavy oils, but it is understood that some trouble is encountered with lighter oils and gasoline. The coagulant mixture of oil and chemical is a soft sludge of butterlike consistence, and apparently a satisfactory means for disposing of this sludge has not yet been found. It is understood that the coal dust mixed with coagulant sludge can be briquetted and may possibly be used as a fuel. Several demonstrations were made on a very small scale in the laboratory, but so far as could be ascertained the process had not been applied to the separation of oil-water mixtures on a large scale.

In order to learn of later developments in the application of this substance to the handling of oily wastes, the committee wrote to the company on February 9, 1923, requesting information. The company's reply follows:

We are glad to advise you that we have progressed considerably in this connection.

We are able to produce the coagulant in a solid form, thereby lowering its shipping weight, which is a desirable feature in vessels. Furthermore, we have made considerable experiments on a semicommercial scale with very heavy oils and very light oils. In all cases our process has completely absorbed the finely emulsified oil globules and has held them successfully on various types of filters.

On account of the fact that shipping people throughout this district seem to be holding off, awaiting Federal action upon the oily pollution of navigable
waters, none are willing to make extensive experimental runs on the coagulant until compelled to do so by the activities of your department. For this reason, although we have the best grounds for believing that we can overcome this sanitary problem, we have not been able to have very extensive tests made.

Again, on October 1, 1923, the committee wrote to the ——— Chemical Co. requesting information regarding still further developments in the application of the ——— chemical coagulant. The company replied as follows:

We regret to advise that we have not conducted any extensive engineering experiments, because our force has been occupied in other developments, but we shall be pleased to cooperate with your department, or possibly with the American Steamship Owners Association, in the application of (our coagulant) to the treatment of oily wastes.

You may be interested to know that we are now selling (our coagulant) in a dry and more permanent form, but are continuing our experiments so as to produce the material on a more economical basis.

The company held a demonstration on a small laboratory scale fairly recently and apparently was unprepared to advise, except in a most general way, what auxiliary apparatus would have to be developed to make the coagulant practicable for shipboard use. It is understood that no further progress has been made with this method. this coagulant, therefore, seems little likely to solve the problem of preventing oil pollution from oil-burning ships.

OIL-WATER SEPARATORS FOR SHIPBOARD USE

General Discussion.—When the various methods proposed for shipboard use are compared, it appears that setting aside storage for oily residues on shipboard, as a few companies do, still leaves the problem of the disposal of the material after the ship arrives in port. Chemical coagulant is likely to be expensive, as the cost of the chemicals themselves and the valuable cargo space taken by their storage both demand consideration. Moreover, these methods also leave unsolved the problem of disposal of the coagulated oil.

The committee looks far more hopefully to the development of suitable separators which can be used on shipboard and which may give a reclaimed oil suitable for use as a fuel directly or after mixing with clean fuel oil. A separating installation on shipboard would cope with the situation before it becomes a pollution problem.

Study of the separators successfully used on land indicates that a great surface area, a large depth of water, and a slow rate of flow are desirable. Even in the most congested plants on land, enough space can usually be found for construction of an adequate separator, although the rate of handling water through such apparatus is many times greater than that at which ship's ballast water would be pumped. For use on land a typical separator handling water at
about 600 tons per hour is 150 feet long, 55 feet wide, and 12 feet deep. These dimensions evidently are altogether impracticable for shipboard application.

The limitations of ship design require that an apparatus for separating oil and water on vessels must be comparatively small and compact; at the same time it should preferably be capable of handling 100 to 200 tons of oil-water mixtures per hour, depending upon the amount of such mixtures on board, the time available for disposal, and the capacity of the pumps. Considered from this point of view, many installations which might be entirely practicable ashore and which might show vast improvement in space economy over present land practice would still be impossible for installation aboard ship.

Furthermore, before vessels in commercial service are equipped with any sort of apparatus, the apparatus must be shown to be suitable for performing the work for which it is designed. This principle applies to all marine devices, including those intended to separate oil-water mixtures. Apparatus for installation on board ship, which can not perform the duties required of it may be a heavy financial burden and may cause trouble that will endanger the safety of the vessel.

Qualifications for oil-water separator.—An oil-water separator for shipboard use should be reasonable in cost, and its installation and use should not impose undue or unreasonable demands or hardships upon the ship operator. One device proposed for ship installation and said to be capable of handling 200 tons per hour is quoted as costing about $6,500. Another apparatus of approximately the same rating, which is now being developed, may cost approximately $4,500, not including installation. Economy of operation and maintenance must also be considered. Should such a device require a large amount of steam or any additional members of the crew for operating it, the operating burden on the ships would be increased. However, a satisfactory device which can be operated by the engineers or assistants in conjunction with their regular duties can probably be developed for floating craft. It should be emphasized that in the present design of ships the amount of space available for the installation of separators is limited. The engine room is usually crowded with the machinery necessary for the operation of the ship, and other parts which might be thought suitable for the installation of a separator are similarly congested. Any additional installations would have to be of comparatively small dimensions. To place an oil-water separator in the valuable cargo space would entail a loss of operating revenues which would have to be overcome by increased freight rates.
For example, should the apparatus weigh 10 tons empty or occupy a volume, calculated by the usual rules, equivalent to the space occupied by 10 cargo tons, the paying cargo being carried would be reduced by an equal figure. If the ship makes 10 passages a year and the average cost of carrying a 1-ton cargo is assumed to be $6 per passage, the reduction in operating revenues would be $600 per year. If a ship owner has 10 vessels, and the separators could be installed for $6,000 each, his initial investment would be $60,000 and the cost of carrying these separators, excluding fixed charges, operation, and upkeep would be at least $6,000 per year. It is evident that placing separators in the cargo space entails considerable financial burden. Another reason why it would not be good practice to install a separator in cargo space is the possibility of leakage and the subsequent damage of cargo and the probable difficulty of obtaining insurance on cargo that may be carried in the same compartment with the separator.

Mainly because of the lack of available space and the inconvenience of operation, it is believed to be impracticable to place a separator on the upper deck of a general cargo or passenger vessel, although this situation may be feasible on a tank steamer. Furthermore, to place an apparatus on an upper deck, would necessitate piercing of the decks for piping and other accessories and would thus weaken construction. Good practice calls for as few openings through the decks as possible.

Although space could undoubtedly be found for the installation of a separator if it becomes absolutely necessary for some such device to be placed on oil-burning vessels already in service, it would probably entail some difficulties in ship operation as vessels are now constructed. When new ships are being built, it is thought feasible to make proper provision for the installation of separating equipment in the most favorable location.

**Advantages of Separator on Shipboard.**—If a separator satisfactory for use on board ship can be found or developed, the cost in operating charges and delays may be less, and its use may entail less inconvenience to the shipping industry than would the operation by port authorities of a large fleet of barges or the construction of petroleum harbors. Moreover, many ports might not be equipped with barges or other means of caring for refuse oil, whereas an apparatus on each ship would handle the problem under any conditions.

A device installed on shipboard permits greater freedom in the ship's movements, and less time would be lost than in the disposal of large quantities of ballast water by facilities provided in
port. When a vessel docks, it is necessary to discharge cargo, load, make necessary repairs, and get under way as quickly as possible. Anything which requires additional movements of the vessel means costly delays, and such delays must be avoided as far as possible. The pumping out of large quantities of oil-contaminated bilge and ballast water into barges, the movement of the vessel to special places for refueling, and the compulsory use of oil harbors might entail delays which should be eliminated as far as practicable.

In their present stage of development (1925), none of the devices and methods proposed for separating oil and water can be unreservedly recommended by the committee as commercially practicable for use aboard ship. The various types of separators investigated by the committee may be classified under gravity, centrifugal, filtration, and miscellaneous types.

![Diagram](image)

**FIGURE 5.—Battery of four "gravity" separating units**

The gravity-type separator seems to offer the best possibilities for development in handling oil-contaminated ballast water aboard ship. It is believed possible to construct a separator of practicable dimensions of this type that will successfully handle large quantities of mixtures within the required time limitations.

"Gravity" Separating Devices.—"Gravity" separating devices are, of those seen, perhaps the most promising for handling oil-water mixtures on shipboard. One device of this sort consists of a series of baffled tanks through which the oil and water flow and are separated by gravity.

Description.—The accompanying drawings (figs. 5, 6, and 7) and general description of the separator are from the literature issued by the company; they give a general idea of the apparatus, its opera-
tion, and the proposed method of installing it in the regular ballast-discharge system of a vessel:

The battery, as shown, is a preferred form, although separators can be used singly, in series, parallel, or superimposed, as may be required.

The separator is adapted to receive, and contains therein at all times, a full charge of water into which the fluid to be filtered is discharged continuously under a definite pressure. The top of the separator itself functions as a sort of hood or collector for the oil, and it will be noted that the passage of the material to be filtered through the separator causes it to be affected by a system of guiding plates and hoods or collectors beneath which these enlarged chambers or so-called neutral zones are formed during the flow of the liquid to allow for the separation of the oil from the water and to allow for an overflow of such oil to the upper portion of the separator to be taken off.

* * *

**Figure 6.—Battery of separating units for installation on land**

The relation of the size and proportion of the various passages and chambers through which the fluid is forced to pass is determined in accordance with the pressure used and the speed of flow desired.

The operation of the apparatus is as follows: The mixture flows into $a$ through $b$ and past the collectors $f$, $g$, and $h$; the oil separating flows through the oil line $d$ to tank $j$ and the water through outflow $c$.

*Tests of model.—* The committee witnessed a demonstration of a small experimental model which had the same general construction as that shown in Figure 5 and was handling a mixture of heavy oil and water. The apparatus had a total volume of $2\frac{3}{4}$ gallons and handled 1 gallon of liquid per minute. The ratio of the volume of the model to the amount of oil-water mixture passed through it in 1 minute is almost 3 to 1. There seems to be some doubt whether this ratio is followed in the larger apparatus. The separation effected by the experimental model was satisfactory, but it is to be noted that the oil-water mixtures formed in a ship's ballast tanks may differ widely from the mixture used in this demonstration. Apparently the mixtures that may be formed by fuel oil and water have not been
thoroughly investigated and, if such mixtures are similar to the emulsions that are sometimes found in oil-field practice, separation of the components by gravity alone would probably be impossible.

In the experimental model that the committee saw in operation, about 96 to 97 per cent of the oil was removed in the first compartment, and it is reasonable to suppose that this percentage may be attained in commercial practice.

![Figure 7](image)

**Figure 7.**—Proposed method of installing one type of "gravity" separator aboard ship

Representatives of the company estimate that the amount of oil in the discharge water is virtually nil. When the apparatus is operating properly, the oil recovered is said to contain not over 2 per cent of water. In general, this proportion of water in an oil does not prevent the use of the oil as a fuel. However, one should note that this device is intended principally to separate from water oil that is appreciably lighter, and it does not seem to be suitable for handling heavy sludges which presumably must be cleaned out of ship tanks by the usual methods.
This apparatus may be installed in sections in different parts of the vessel, if that arrangement should prove advantageous, in order to utilize space more economically or to distribute weight satisfactorily. Compact construction seems possible, an important feature that would favor the possibility of installing the apparatus on shipboard.

An apparatus to handle 200 tons of ballast water was designed for a French steamer, and it is understood the company estimated the cost at about $6,200, installed. It was planned to make the apparatus approximately 19 feet long, 6 feet high, and 4 feet 3 inches wide. The installed weight, with tanks full, would be about 19 tons; with tanks empty, about 6 tons.

The committee is informed that a similar separating unit, capable of handling 75 tons per hour, was formerly in operation in Brooklyn. It is understood that this plant was dismantled because of the expense of continual demonstration.

Tests of separator.—In a test made with this type of separator at Pier No. 30, Brooklyn, on June 21, 1922, about 135 tons of oil-water mixture were pumped through the apparatus in 3½ hours. Apparently the discharge water was not entirely free from oil during this whole period, but for at least 1 hour there was a continuous flow of clean water overboard without any visible trace of oil.

The following letter from the company to the Commissioner of Docks, New York City, gives a description of the above test:

In compliance with your written request, dated August 10, for statistics and costs of operating our separator— at Pier No. 30, Brooklyn, on June 21, 1922, we are pleased to make the following report:

Separator was fitted up on the south side of the dock, abeam of engine room of steamship ——.

Connection was made to oil-filling line at ship's side with 20 feet of 4-inch flexible hose and 20 feet of 4-inch galvanized pipe.

At the pump room a section of pipe was removed and 125 feet of 4-inch galvanized pipe was fitted temporarily to run from pump room to engine room. This piping was connected to ballast pump size 10 by 8 by 14 inches and a 6-inch discharge line of about 80 tons capacity per hour.

The mixture was first pumped from boiler room (bilge?) through separating apparatus at 1 p. m.; the liquid discharged overboard was very much discolored on account of washing out boilers.

A slight film of oil was seen on the surface of the water, which was the result of getting an air lock in the apparatus; this has since been remedied by extending the vents.

At 2 p. m. the engineer changed over to the pump-room bilges, from which the mixture contained more oil than that from the boiler room; at this time we estimated the flow to contain about 6 per cent oil; the separator handled this mixture very nicely, working smoothly and effectively.

For about one hour there was a continuous flow of clean water overboard without any trace of oil film and a slow continuous discharge of good oil free of any water.
About 135 tons of mixture was pumped through the separator between the hours of 1 p. m. and 4.30 p. m. A great part of this time the pump was pumping from empty bilges; at such times the apparatus required careful handling and attention to prevent same becoming air locked.

The percentage of oil in the mixture at times was approximately 10 per cent. There were two tons of oil salvaged at the demonstration.

The entire cost of this test, which includes the cost of trucking, rigging up apparatus, connecting and running pipe lines in bottom of ship, dismantling, several slight alterations, returning apparatus to New York, and storage was $511.

The American Bureau of Shipping has approved this device for installation, subject to the general piping requirements of the bureau, on vessels classed with that bureau.

The company claims that the separator can be used to handle oil-water mixtures from industrial plants. The cost of a land installation is said to be approximately one-third of the cost of that for shipboard use. Installations projected for industrial plants are intended to handle both mineral and vegetable oils. A land installation designed for a capacity of 50 tons per hour is said to cost approximately $1,800.

In order that the committee might have information relative to later developments of this process, the following letter was written to the company on February 1, 1923:

I * * * should be glad to know whether there have been any new developments in your process since we saw your experimental device in operation in November. I should be particularly interested to have information relative to the installation which was being built for the ——, and to know whether you have built any other units for commercial application. * * *.

I should be glad to have information on the following points: (1) How does the mean velocity of the liquid through the experimental apparatus, which we saw in operation in your laboratory, compare with the mean velocity through the larger units which you have designed for commercial use? (2) Have you attempted to separate anything except such mixtures of heavy oil and water as we saw when in New York? What is the gravity of this oil, and what proportions of the oil and water have you handled successfully? (3) Have you emulsified lighter oils with water by mechanical means and attempted to separate these with your devices? If so, what method was used in making the emulsion? (4) How much oil would you say is present in the average ballast water, and how much in bilge water?'

The company’s reply was as follows:

In reply to yours of February 1, 1923, asking for information relative to our separator and oil contained in ballast and bilge waters, I will try to answer your questions in detail as given in your letter.

The installation of the steamer ——— is still held in abeyance, the owners having made the proposal to build this apparatus and install same in their own yard in Havre, France, which they figure they can do at half the cost, or about $3,400.

No shipowners will consider any installation at this time; they are awaiting the result of the investigations by your committee, so I am informed; consequently, there are no negotiations for any installation at present,
1. The velocity of actual flow is at the point of expansions, where separation of oils takes place, in the separator and is slightly less in the full-size commercial apparatus. The mean velocity of flow through the system, as a whole, seems to have no relation and varies with the mode of assembly of the compartments in relation to flow. In series, parallel, or series parallel, which are all governed by the particular requirement of the ship.

2. We have not experimented with any other oils except those encountered on a ship; viz, engine and fuel oils in all grades and of all gravities—all of which we have successfully separated, the mixtures being of all percentages of both oils and water and in any combination.

3. No; except as above, we have tried to produce the worst condition that could prevail, artificially by mechanical means of agitation.

4. Anywhere from $1\frac{1}{2}$ to 7 per cent in ballast and one-half to 3 per cent in bilge waters. This is from data obtained by us during tests under actual working conditions by a full-size apparatus of 100 tons' capacity and which is verified by shiip companies submitting inquiries for separators to handle mixtures of this description.

The United States Navy, with the cooperation of this company, made a series of tests of a separator of this type at the Navy experimental station at Annapolis, Md., during the latter part of February and the first part of March, 1928.

Efficiency of separator.—

A more recent communication from the corporation includes data on the efficiency of the separator. These data are appended (Table 1). The company developed an automatic indicator and oil-control system, as well as a direct-acting automatic oil-check system. The purpose of these systems is automatically to prevent the oils in water ballast from being pumped overboard by oversight. Installations of this device were designed for two French steamers, but it is understood that the installation of this apparatus has been held up indefinitely on both steamers.

The corporation that developed this separator has said that a large shipbuilding corporation has taken over all the United States rights for the manufacture and sale of this device. It is understood that the shipbuilding corporation has modified the separator considerably, as indicated in Figure 8. In January, 1925, three 25-ton units of the newer type in conjunction with a filter were in-
stalled on a vessel in the North Atlantic service. Results were reported as rather unsatisfactory, but changes that are said to have effected an improvement were made later.

**Table 1.—Efficiency of separator**

(Data and note supplied by the manufacturer)

<table>
<thead>
<tr>
<th>Oil in mixture (per cent)</th>
<th>Oil in water discharge (per cent)</th>
<th>Oil in mixture (per cent)</th>
<th>Oil in water discharge (per cent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>While operating at total capacity:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>0.015</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>0.017</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>0.022</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>0.042</td>
<td></td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>0.015</td>
<td></td>
<td></td>
</tr>
<tr>
<td>75</td>
<td>0.014</td>
<td></td>
<td></td>
</tr>
<tr>
<td>85</td>
<td>0.001</td>
<td></td>
<td></td>
</tr>
<tr>
<td>95</td>
<td>0.004</td>
<td></td>
<td></td>
</tr>
<tr>
<td>While operating at 33 1/3 per cent overload:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>0.008</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>0.010</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>0.005</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>0.013</td>
<td></td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>0.005</td>
<td></td>
<td></td>
</tr>
<tr>
<td>While operating at 66 2/3 per cent overload:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>0.031</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>0.013</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>0.033</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>0.084</td>
<td></td>
<td></td>
</tr>
<tr>
<td>While operating at 100 per cent overload:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>0.056</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>0.156</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>0.208</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Note.**—From analysis of water after passing through the separator at a recent test under continuous operation lasting over a period of 7 weeks with a continuous mixture flowing through the separator at all times. During this period a machine with 4 stages in operation and the mixture varied as above, at different periods of time, the oils were found to be discharged free of all grit, cement, sand, and other foreign matter, and the oil at all times was fit for direct use in furnaces, with perfect combustion. Percentage of moisture in oil in a suspended form, 0.5 to 5 per cent, at varying speeds and percentages of mixtures.

**Oil-water separator for tankers.**—For some time a prominent oil company that operates a large fleet of tankers has been working upon the problem of devising a separator for use aboard tankers and oil-burning vessels. Oil-contaminated bilge and ballast water were to be passed through this apparatus to avoid polluting waters with refuse oil. Over two years ago the company built and installed upon one of its tankers a commercial-size apparatus large enough for test under actual working conditions.

The company consented to demonstrate this apparatus for the committee. A mixture of fuel oil and sea water was prepared in one of the summer tanks under conditions believed to be as severe, or even more severe, than those attending the discharge of ballast from a fuel or cargo tank. This mixture consisted approximately of 60 barrels of fuel oil of 17° B. gravity and 600 barrels of salt water—approximately a 10 per cent oil mixture—which is regarded as representing an extreme condition.

Before the mixture had time to separate in the tank it was pumped through the separating apparatus, the water being discharged directly overboard and the separated oil delivered to a spare tank. One man of the regular crew attended to all details of separator operation. The discharge seemed very clean throughout the entire demonstration and the apparatus seemed to work satisfactorily. A small
amount of drifting oil scum, and the discoloration of the surface of the water around the tanker before and during the test, unfortunately prevented the committee from being definitely certain that no discoloration was passing through the separator discharge. However, even if the small amount of discoloration noticed on the water about the tanker had come through the separator, the committee’s opinion is that the separator was functioning satisfactorily. It was felt at the time that this apparatus offered promise as a possible solution of the pollution problem as far as tankers were concerned and might be capable of development for use on oil-burning general cargo vessels. So far as the committee was aware, this was the only apparatus of commercial capacity which, up to that time, had been constructed and operated under conditions approaching normal marine practice.

The company in question has since made additional developments in somewhat different directions. Cofferdam No. 2 of one of its tankers has been converted into a separating compartment. This method of handling oil-contaminated water has the great advantage over the former installation of affording much more room for settling purposes. Moreover, installation of the separating device
in the structure of the vessel obviates the additional maintenance cost of a separator installed independently on or below decks. Figure 9 shows the method of adapting cofferdam No. 2 for use as a separating tank.

A 6-inch pipe admits the oily water to the starboard side of the cofferdam. The water flows in a general downward direction to the bottom, where it passes through limber holes in the center-line bulkhead and travels across the port side of the compartment and into an 8-inch outlet pipe, which discharges it overboard 4 feet 6 inches below the shelter deck. This method of operation insures against pressure being built up on the deck.

A large part of the oil content of the ballast water collects at the surface on the starboard side, but oil-discharge standpipes have been provided in either side to skim the oil from the surface and store it in summer tank No. 3. The removal of the oil is intended to be intermittent and is regulated by valves having remote control on the shelter deck.

When 1,000 barrels are handled per hour, the average downward velocity of the water through the starboard side will approximate 0.85 foot per minute; at this rate a given particle of oily water will pass through the cofferdam in about 45 minutes.

Oil that is trapped at the surface of the two compartments of the cofferdam is skimmed from the top by means of funnels situated 3 feet 6 inches above the level of the overboard discharge orifice, and is piped to the starboard side of No. 3 summer tank.

The installation readily handles 1,000 barrels per hour, and a number of trials made under the conditions of marine practice show that the oil content of the effluent is exceedingly small. There are, however, a number of features that still remain to be worked out; but, considered as a whole, the device is probably the most promising of this type that has been developed. The company is completing similar installations on several of its tankers.

Separator consisting of three concentric vertical cylinders.—Another type of “gravity” separator consists of three concentric vertical cylinders. (Fig. 10.) An adjustable sleeve at the top of the inner cylinder permits variation of the head in the separator. In the 6-inch space between the outer two cylinders is a spiral baffle. Between the mixture inlet and the oil discharge this 6-inch space is restricted, and steam coils have been installed.

The mixture enters the separator radially and flows down the spiral passage counterclockwise. Oil is free to rise as soon as the mixture enters the separator. After the flow through the separator
is established, the sleeve on the inner cylinder is set just below the level of the oil outlet.

During the passage of oil-water mixtures downward in the spiral passage the rising oil may collect on the underside of the spiral baffle and creep back up against the flow of water, finally rising to the heating coils. When the fluid passes through the ports at the bottom of the intermediate cylinder, all separation ceases.

This separator has been used at sea under adverse conditions. It was run at capacities ranging from about 30 to 72 tons per hour, and the mixture entering the separator contained less than 1 per cent of oil. The discharge water contained on an average less than 0.002
per cent of oil. There seem to be some defects in the separator, and additional tests will be required before definite conclusions can be drawn. The results, however, are considered promising.

*Gravity separators made abroad.*—During the past two years a number of "gravity" separating devices have been developed abroad. Figure 11 is a sketch of one of them. Its operation is briefly described by the manufacturer, as follows:

![Diagram](image)

**Figure 11.**—One type of "gravity" separator developed abroad

1. Oily ballast to be treated is delivered at A and passes to the main conical chamber B, where 90 per cent of the separation is effected.

2. Oil rises to the seal and heating chamber C, while water passes into compartment E. When C is filled with oil, the overflow, if any, passes by pipe D to storage, or as desired.

3. Further separation having taken place in E, any remaining oil rises to cone F, while water passes via conduit G into compartment H, where practically all remaining oil is caught.

4. To effect complete separation, water now passes into scrubber J for final purification and is then discharged at K. A temperature-control device is fitted at L.

**Note.**—It is essential to maintain an even temperature in the oil seal no matter how widely different are the percentages of oil in the mixture being fed to the separator.

At M is an air pipe under the scrubber J. This provides for efficient cleansing without any dismantling of the apparatus.

The manufacturers claim that this device is entirely automatic and requires no skilled attention; it takes up a minimum of space
and can be used at sea; it can be installed in a vessel without interfering with the existing piping system and requires no power except that necessary for driving the ship’s pumps. The manufacturers also claim that the device operates at any rate up to 200 tons per hour and that it automatically adjusts itself to changes in composition of the mixture being handled.

The dimensions for standard units are given as follows:

**Dimensions of standard units**

<table>
<thead>
<tr>
<th>Capacity, tons per hour</th>
<th>Diameter, inches</th>
<th>Height, inches</th>
<th>Capacity, tons per hour</th>
<th>Diameter, inches</th>
<th>Height, inches</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>51</td>
<td>50</td>
<td>50</td>
<td>105</td>
<td>85</td>
</tr>
<tr>
<td>10</td>
<td>63</td>
<td>58</td>
<td>75</td>
<td>118</td>
<td>93</td>
</tr>
<tr>
<td>15</td>
<td>71</td>
<td>64</td>
<td>100</td>
<td>129</td>
<td>101</td>
</tr>
<tr>
<td>20</td>
<td>78</td>
<td>68</td>
<td>150</td>
<td>148</td>
<td>114</td>
</tr>
<tr>
<td>30</td>
<td>89</td>
<td>75</td>
<td>200</td>
<td>162</td>
<td>123</td>
</tr>
</tbody>
</table>

Certain land tests of this apparatus show it to be very effective within and slightly above its rated capacity. Table 2 gives the results of a series of authentic tests made on a separator of this type having a capacity of 50 tons per hour. The oil used in the tests was “bunker fuel oil A” (Federal specifications) of approximately 22° B. The oil and water were thoroughly mixed but not emulsified. Attention is called to the very small quantity of oil found in the discharge water. The separated oil showed a large percentage of entrained water which gradually increased during the tests. This water was probably due to the continued recirculation of the oil through the separator. The glazed pieces of crockery in compartment J are fairly effective in removing the small quantity of oil remaining in the water as it leaves compartment H. The “pottery filter” may be cleansed by “scrubbing” with steam. The flow through the apparatus is entirely by gravity. The amount of steam supplied to the heating coils varies with atmospheric conditions and the oil to be separated.

Although the separator under consideration has been demonstrated apparently with success, both abroad and in this country, the reader should remember that satisfactory operation of a separator at the dock or on land does not guarantee the proper functioning at sea under prevailing conditions on the average general cargo vessel. It is felt that the bulky proportions and the weir construction of this separator make its successful operation at sea doubtful. Thorough tests under the conditions prevailing in marine practice are therefore necessary, and it is understood that plans are now being made to do this (1925).
<table>
<thead>
<tr>
<th>Run number</th>
<th>Date, 1924</th>
<th>Duration of run, minutes</th>
<th>Temperature of oil mixture, degrees Fahrenheit</th>
<th>Temperature of inlet gas, degrees Fahrenheit</th>
<th>Temperature of outlet gas, degrees Fahrenheit</th>
<th>Gallons of oil injected during run</th>
<th>Rate of oil injection (gallons per hour)</th>
<th>Rate of oil injection entering separator (gallons per hour)</th>
<th>Rate of mixture entering separator (gallons per hour)</th>
<th>Oil in mixture (per cent)</th>
<th>Water in separator oil (per cent)</th>
<th>Water in separator oil (per cent)</th>
<th>Parts of oil per million (per cent)</th>
<th>Oil discharged with separated water (pounds per hour)</th>
<th>Water delivered with separated oil (pounds per hour)</th>
<th>Net amount of oil delivered to oil separator per hour (tons per hour)</th>
<th>Net amount of oil delivered to oil separator per hour (tons per hour)</th>
<th>Real rate of mixture entering separator per hour (tons per hour)</th>
<th>Actual oil in mixture (per cent)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Aug. 2</td>
<td>45.12</td>
<td>77.9</td>
<td>77.8</td>
<td>0.0</td>
<td>30.40</td>
<td>131.0</td>
<td>174.2</td>
<td>6.1</td>
<td>50.67</td>
<td>6.5</td>
<td>50.75</td>
<td>6.3</td>
<td>12.0</td>
<td>4.5</td>
<td>14</td>
<td>4.0</td>
<td>0.65</td>
<td>0.03</td>
<td>0.57</td>
</tr>
<tr>
<td>2</td>
<td>Aug. 4</td>
<td>30.00</td>
<td>77.9</td>
<td>79.2</td>
<td>1.3</td>
<td>48.46</td>
<td>230.0</td>
<td>660.0</td>
<td>2.29</td>
<td>50.75</td>
<td>8.6</td>
<td>50.75</td>
<td>6.3</td>
<td>12.0</td>
<td>4.5</td>
<td>14</td>
<td>11</td>
<td>1.19</td>
<td>0.29</td>
<td>2.019</td>
</tr>
<tr>
<td>3</td>
<td>do</td>
<td>30.00</td>
<td>80.8</td>
<td>82.0</td>
<td>1.2</td>
<td>47.52</td>
<td>760.0</td>
<td>1365.5</td>
<td>5.34</td>
<td>52.86</td>
<td>10.1</td>
<td>52.86</td>
<td>6.3</td>
<td>12.0</td>
<td>4.5</td>
<td>14</td>
<td>32</td>
<td>3.41</td>
<td>1.373</td>
<td>4.068</td>
</tr>
<tr>
<td>4</td>
<td>do</td>
<td>30.00</td>
<td>81.8</td>
<td>83.0</td>
<td>1.2</td>
<td>24.04</td>
<td>361.0</td>
<td>722.0</td>
<td>2.51</td>
<td>26.55</td>
<td>9.4</td>
<td>26.55</td>
<td>6.3</td>
<td>12.0</td>
<td>4.5</td>
<td>14</td>
<td>9.6</td>
<td>0.48</td>
<td>0.806</td>
<td>1.756</td>
</tr>
<tr>
<td>5</td>
<td>Aug. 5</td>
<td>30.00</td>
<td>78.9</td>
<td>78.8</td>
<td>0.9</td>
<td>24.04</td>
<td>186.0</td>
<td>372.0</td>
<td>1.29</td>
<td>25.33</td>
<td>5.9</td>
<td>25.33</td>
<td>6.3</td>
<td>12.0</td>
<td>4.5</td>
<td>14</td>
<td>6.3</td>
<td>0.32</td>
<td>0.415</td>
<td>0.905</td>
</tr>
<tr>
<td>6</td>
<td>do</td>
<td>30.13</td>
<td>79.3</td>
<td>79.8</td>
<td>0.5</td>
<td>25.11</td>
<td>71.0</td>
<td>141.4</td>
<td>0.49</td>
<td>25.60</td>
<td>1.9</td>
<td>25.60</td>
<td>6.3</td>
<td>12.0</td>
<td>4.5</td>
<td>14</td>
<td>5.6</td>
<td>0.28</td>
<td>0.163</td>
<td>0.339</td>
</tr>
<tr>
<td>7</td>
<td>do</td>
<td>30.25</td>
<td>83.2</td>
<td>83.2</td>
<td>0.0</td>
<td>4.67</td>
<td>72.0</td>
<td>142.8</td>
<td>0.30</td>
<td>5.37</td>
<td>9.3</td>
<td>5.37</td>
<td>6.3</td>
<td>12.0</td>
<td>4.5</td>
<td>14</td>
<td>6.6</td>
<td>0.07</td>
<td>0.093</td>
<td>0.251</td>
</tr>
<tr>
<td>8</td>
<td>do</td>
<td>30.27</td>
<td>83.8</td>
<td>84.4</td>
<td>1.1</td>
<td>5.23</td>
<td>45.0</td>
<td>89.3</td>
<td>0.31</td>
<td>5.50</td>
<td>5.6</td>
<td>5.50</td>
<td>6.3</td>
<td>12.0</td>
<td>4.5</td>
<td>14</td>
<td>8.9</td>
<td>0.08</td>
<td>0.099</td>
<td>0.077</td>
</tr>
<tr>
<td>9</td>
<td>Aug. 6</td>
<td>30.00</td>
<td>83.8</td>
<td>86.4</td>
<td>3.1</td>
<td>4.34</td>
<td>15.0</td>
<td>30.0</td>
<td>0.10</td>
<td>8.44</td>
<td>2.2</td>
<td>8.44</td>
<td>6.3</td>
<td>12.0</td>
<td>4.5</td>
<td>14</td>
<td>8.9</td>
<td>0.05</td>
<td>0.093</td>
<td>0.251</td>
</tr>
<tr>
<td>10</td>
<td>do</td>
<td>15.08</td>
<td>85.3</td>
<td>85.9</td>
<td>0.6</td>
<td>49.29</td>
<td>72.0</td>
<td>287.0</td>
<td>1.00</td>
<td>50.29</td>
<td>1.9</td>
<td>50.29</td>
<td>6.3</td>
<td>12.0</td>
<td>4.5</td>
<td>14</td>
<td>5.5</td>
<td>0.28</td>
<td>0.299</td>
<td>0.718</td>
</tr>
<tr>
<td>11</td>
<td>Aug. 7</td>
<td>30.05</td>
<td>83.3</td>
<td>83.4</td>
<td>1.8</td>
<td>48.07</td>
<td>344.0</td>
<td>688.9</td>
<td>2.39</td>
<td>50.46</td>
<td>4.7</td>
<td>50.46</td>
<td>6.3</td>
<td>12.0</td>
<td>4.5</td>
<td>14</td>
<td>4.3</td>
<td>0.43</td>
<td>0.714</td>
<td>1.719</td>
</tr>
<tr>
<td>12</td>
<td>Aug. 8</td>
<td>30.00</td>
<td>81.8</td>
<td>83.0</td>
<td>1.2</td>
<td>60.03</td>
<td>452.5</td>
<td>955.0</td>
<td>3.15</td>
<td>63.18</td>
<td>4.9</td>
<td>63.18</td>
<td>6.3</td>
<td>12.0</td>
<td>4.5</td>
<td>14</td>
<td>6.6</td>
<td>0.81</td>
<td>1.145</td>
<td>2.078</td>
</tr>
<tr>
<td>13</td>
<td>do</td>
<td>30.00</td>
<td>84.1</td>
<td>84.7</td>
<td>0.6</td>
<td>48.06</td>
<td>352.0</td>
<td>794.0</td>
<td>2.44</td>
<td>50.00</td>
<td>4.5</td>
<td>50.00</td>
<td>6.3</td>
<td>12.0</td>
<td>4.5</td>
<td>14</td>
<td>22.8</td>
<td>2.48</td>
<td>0.943</td>
<td>1.566</td>
</tr>
<tr>
<td>14</td>
<td>Aug. 18</td>
<td>30.00</td>
<td>78.9</td>
<td>81.3</td>
<td>2.4</td>
<td>5.64</td>
<td>43.0</td>
<td>86.0</td>
<td>0.30</td>
<td>5.94</td>
<td>5.0</td>
<td>5.94</td>
<td>6.3</td>
<td>12.0</td>
<td>4.5</td>
<td>14</td>
<td>6.6</td>
<td>0.68</td>
<td>0.112</td>
<td>0.194</td>
</tr>
<tr>
<td>15</td>
<td>do</td>
<td>15.00</td>
<td>78.4</td>
<td>78.7</td>
<td>0.3</td>
<td>43.88</td>
<td>189.0</td>
<td>636.0</td>
<td>2.21</td>
<td>46.09</td>
<td>4.7</td>
<td>46.09</td>
<td>6.3</td>
<td>12.0</td>
<td>4.5</td>
<td>14</td>
<td>6.6</td>
<td>0.59</td>
<td>0.108</td>
<td>1.260</td>
</tr>
</tbody>
</table>
Another gravity device of foreign manufacture has been mentioned as promising. This separator is said to have been originally designed for incorporation in part of the cellular double bottom of the vessel, but it may be installed elsewhere if necessary. It employs the “gravity” principle and is stated to be entirely automatic in action. The manufacturers are said to have acquired several barges into which they are fitting oil separators to treat oily water from ships’ tanks. According to available information the company guarantees to discharge water free from oil into the sea and return virtually water-free oil to the ship’s storage tanks. It plans to do this, according to report, by running the separator in conjunction with a filter of its own design and a supplementary device for the removal of water from the recovered oil. The separator is also said to be a valuable adjunct at land plants where oils, fats, or grease have to be separated from water. This separator is reported installed in at least one vessel, and the company is said to have contracts for other installations (1925).

**Gravity separator of U-tube type.**—Figure 12 shows a “gravity” separator of the U-tube type. The general method of operation will be evident in the light of the preceding discussions of other gravity separators. Several ships are said to have been equipped with these devices, but no information is at hand regarding the efficiency or effectiveness of operation.

**Centrifugal Separators.**—Centrifugal devices as now developed (1925) do not seem capable of handling the large volume of oil-contaminated ballast water on shipboard in the short time available. Under normal conditions a centrifugal machine usually handles 150 to 300 gallons of emulsion per hour. To treat ballast water, it would have
to handle 100 to 200 tons of mixture per hour. The capacity of the centrifugal equipment could, of course, be increased by additional units, but the number of machines that could be used aboard ship is limited by the small space available. About 165 centrifugal machines, each handling 300 gallons per hour, would be needed to treat 200 tons of oil-contaminated ballast water per hour, and installation of that size is obviously impracticable. Furthermore, it seems doubtful whether centrifugal separators will separate effectively such oil-water mixtures as bilge water and water from ballast tanks.

Centrifugal machines are peculiarly liable to clog with the dirt, silt, and lumps of sludge found in oil-contaminated ballast water. This foreign matter adds greatly to the difficulty of separation, so that the problem becomes somewhat different from the ordinary separation of oil and water.

A particularly difficult mechanical problem is involved in the use of centrifugal separators for the separation of oil from bilge and ballast water, because these mixtures are not homogeneous, and in consequence the great strains set up in the machines may render operation dangerous.

In order that centrifugal machines may handle oil-contaminated ballast water most efficiently, heating is necessary so that the heavy oil may flow more easily and pass through the machine. It is not always possible or economical to heat the large volume of material that might be carried as ballast for a vessel.

Use of centrifugal machines for handling bilge water may be possible, for the quantity of this material is seldom great, nor does it contain as much heavy fuel oil as ballast water. Bilge waters are more apt to contain dirt, pieces of waste, and similar refuse than are ballast waters from fuel tanks; but these materials could be removed with a strainer.

Some time ago, after much study of the problem, one large oil company tested a centrifugal apparatus quite thoroughly, with the following results:

1. The centrifugal machine is not capable of handling large quantities of bilge water and oil in either double-bottom cargo ships or from the tanks of tank steamers.
2. The centrifugal separator would not handle the heavier oils, as in mixtures with water heavy oil forms large, hard globules which would not pass through the machine.
3. While the separation gave oil practically free from water, it did not give water even comparatively free from oil.

One company that manufactures a centrifugal separator has been working on the problem for some time. The company conducted some tests for the Navy at Annapolis, using bunker fuel oil "C"
mixed both with fresh water and sea water. The oil used in the tests was about 14.5° B., and the mixture handled contained about 54 per cent water. The separator received 150 gallons of the mixture per hour. This rate of operation, even with entirely satisfactory separation, is evidently inadequate for handling oily wastes from ships.

At the time that representatives of the company were interviewed by the committee, they did not think pumping all the ballast water through a centrifugal apparatus on the vessel would be practicable, and suggested barges to hold the mixture temporarily until it could be separated. They felt confident that they could handle the bilge water successfully.

Another company manufactures a centrifugal machine that has also been considered to offer a possible solution for the handling of oil-water mixtures on shipboard. Although it is claimed that this separator has been successfully used in handling the tar and water mixtures formed in the manufacture of water gas, there is doubt as to whether this apparatus can be successfully used to treat ballast water. Like other machines of this type, it does not handle, within the required time limit, the large volumes of mixture to be separated.

The manufacturers of centrifugal apparatus seem to feel that the solution of this problem with their devices depends upon separating the large bulk of oil and water by a preliminary settling, after which the oil, containing some water, would be put through the centrifuge. Developments along these lines are understood to be in progress, and one installation aboard ship is now reported to be on trial. Of much interest is the reported attainment of 5 tons per hour capacity on ballast water by a regular stock centrifuge. Further details are not available at present (1925).

Filtration Methods.—Some of the filters brought to the committee’s attention seem admirably adapted for the purpose for which they are built—that is, for filtering feed waters for boilers. It is virtually certain that they can not take care of the large amount of oil contained in bilge or ballast water. Information was also obtained regarding other filters, some of which were designed or are being developed for bilge and ballast water; but it is believed that these will be subject to the same limitations as feed-water filters.

Unless filtering areas approximating 500 or 600 square feet are provided, the use of filters for eliminating oil from bilge or ballast water appears to be much too slow, even under the best conditions. When the surface of the filtering medium becomes coated with oil or residue, effective filtration is materially decreased. To clean and recharge the filter would probably entail more work than would
be involved in other proposed methods for handling oil-water mixtures aboard ship. Storage of the filtering material would take up valuable space. The problem of properly disposing of large amounts of oil-contaminated filtering medium would also have to be considered.

*Vegetable carbon filter.*—One filtration method utilizes the property of a particular grade of vegetable carbon, highly activated and finely pulverized, to separate emulsified oil and water completely. The form of filtering apparatus to be used had not been designed at the time of the committee's visit, but it is thought that the ordinary filter press could be employed successfully. The carbon mixed with water is placed on the plates of the filter press, and when the oil-water mixture to be separated is pumped into the press the water passes through the carbon medium and the oil is retained to be drawn off into a receiving tank placed above the apparatus. It was suggested that a filter press of suitable size for this work would be 5 or 6 feet long and 24 inches square, or about 8 feet long and 36 inches square. The press may be set in a tank receiving the clean waste water, which is discharged as desired.

The committee was informed that calculations showed that an equipment of this kind for the steamship *Manchuria*, of 13,638 gross tons, can filter in 24 hours all the ballast that the ship carries. The following description, with the accompanying sketch (Figure 13), has been supplied by the promoter of this filter:

The apparatus described and shown is arranged to superimpose a film of this carbon between bilge or ballast pump and overboard discharge, thus causing separation of oil and water, discharging the water, and salvaging the oil. The method of operation is as follows:

The pump, taking its suction from manifold, discharges oil and water through discharge line to separating tank. This tank is provided with suitable hoppers, as shown, for removal of any heavy solids. The oil and water is partly separated in tank by gravity and such water still containing oil is passed through interconnecting pipes A to filter chambers. The water is then filtered through carbon deposited on plates B and shown cross-hatched. Here complete separation takes place, water passing freely through carbon and oil held back in frames C where accumulation of oil passes through inner pipes D to top of separating tank. The separating tank is blown down as oil accumulates through discharge line to bottoms.

As the carbon fouls and becomes inoperative, the pressure on pump discharge will increase, which increases in pressure will be a warning to the operator to recharge the filter. This will be accomplished as follows:

First empty separating tank of all oil. Shut down pump and close discharge valve. Close overboard discharge valve. Open live-steam valve E; this valve admits steam to the interior of the plate, blowing steam through carbon in reverse direction of filtration. Open valve F; the carbon, oil, condensed steam and water are thus forced through filter in a reverse direction and collected in a blow-down tank. A new charge of carbon may then be
fed to press by means of filling carbon-charging pot with proper amount of carbon and sealing same. This pot is provided with a stirring device. When pot is charged and closed, open sea valve and open stirring device. After carbon is thoroughly mixed open pump discharge, manipulate all valves to again put filter in operating condition, and run pump slowly. Water and carbon will be sent directly through pump and carbon deposited on plates. The apparatus is then in shape for continued pumping.

![Diagram of handling oily water from ships and plants]

**Figure 13.—Proposed method of separating oil from bilge or ballast water by filtration through carbon**

Additional steaming lines and sea-water lines are provided, as shown, for complete cleansing of entire apparatus. A steam coil is provided in separating tank for heating oil during operation to cause same to flow freely.

If a further cleansing of oil is desired, a second filter may be installed in the oil-discharge line and charged with carbon saturated with fuel oil instead of water. This filter will deliver pure oil with all suspended matter and water removed. * * *

The committee witnessed several simple laboratory experiments on the use of this carbon as a filtering medium for oil-water emulsions. The oil was held on the carbon and the separation was good.
It was understood that the scheme was being tested on one of the ships of the Booth Line, but a later communication relative to this test leaves some doubt as to the success of the experiment.

More recently the committee requested information regarding later developments in this process, but found that it is now owned by another company, and doubts whether appreciable progress has been made in adapting the process to shipboard use.

Two other companies are said to have been interested in the possibilities of developing filters for the removal of the last traces of oil in the effluent from separators of the gravity type, but the work seems to be in the experimental stages. A third company made certain tests along similar lines, but it was said that the cost of using a filter in this way would be unreasonably high.

Other filter methods.—A number of other methods were investigated, but none of them seemed at all adapted to the handling of oily ballast water. All were in the early experimental stages so far as treatment of ballast water was concerned.

RECLAMATION SYSTEMS USED BY SHIP-REPAIR YARDS

Ship-repair yards often handle large quantities of oil, oil refuse, and oil sludge from the tanks of oil-burning vessels and tankers undergoing repairs. Some of the yards that have not provided means for reclaiming the oil haul this refuse out to sea and dump it, deposit it on swampy land, or endeavor to burn it at some convenient place. Other yards that do considerable repair work on oil-burning steamers have systems for the reclamation and disposal of the oily material. These systems are more or less elaborate, depending upon the quantities of waste to be handled, and the apparatus is usually built by the personnel of the yard. The value of the reclaimed oil may, to some extent, balance the operating cost, and such reclamation methods would seem more economical than the expensive expedient of transporting the oil to a satisfactory dumping place, a method of disposition which may cost as much as $2 per barrel.

DESCRIPTION OF ONE RECLAMATION SYSTEM

One of the ship-repair yards visited by the committee has installed a system that utilizes separating tanks for reclaiming oil from oil-water mixtures. The mixtures handled are mostly from tanks of ships under repair in the yard, although some refuse oil is obtained from other ship-repair yards in the district and from salvage companies and ship contractors. The waste oil is first received in an oil barge equipped with steam coils, which was built in the company’s own yard and has a capacity of about 30,000 gallons. Pre-
liminary settling takes place on this barge. The emulsion is then pumped into settling tanks on shore, which also are equipped with steam coils. Here the oil-water mixture is heated for 6 to 20 hours, the time depending on the nature of the emulsion. The water is drawn off from the bottom of the tanks and the reclaimed oil is transferred to storage tanks. Periodically, manhole plates in the sides of the settling tanks are removed and the settled residue and heavy sludge are cleaned out. This material is mixed with coal and used as fuel. The company has settling tanks of a total capacity of 150,000 gallons but lacks fuel-oil storage tanks to receive large quantities of the reclaimed oil. The engineer in charge of the reclamation plant estimated that it would take about 24 hours to handle 120,000 gallons of emulsion. This time limit, of course, is controlled by the nature of the oil-water mixtures being treated.

At the time of the committee’s visit only two settling tanks or separators were in operation; one separator had a capacity of 20,000 gallons and the other of 40,000 gallons. The oil reclaimed by the system is used as fuel in the company’s power plant.

OTHER RECLAMATION SYSTEMS

Another company has installed a separating system that consists of two cylindrical steel tanks in a concrete basin. These tanks hold about 800 barrels and are equipped with steam coils. All the oily mixtures, emulsions, and sludges taken from ships under repair are sent to these tanks and heated until satisfactory separation takes place. Oil so reclaimed is burned under boilers.

A third repair yard visited by the committee has a system for reclaiming all waste oils from ships undergoing repairs. The apparatus was built in the company’s yard and, although crude, is working satisfactorily. All the waste oils and oil-water mixtures taken from the ships are stored in earthen reservoirs until they can go to the separator. In the reservoirs partial separation of water takes place. The oil is pumped from the reservoir into a tank car, equipped with steam coils, which transports the emulsions to the separating tank. The settling tank also has steam coils and in it the oil-water mixtures are heated to about 250° F. until free of water. Approximately 1,000 gallons of oil are recovered daily in this way. The reclaimed oil has a gravity of about 12° B. and is mixed with a gas oil of about 40° B., producing a fuel oil of about 26° B. gravity. An oil of this gravity is much easier to handle and use throughout the plant. The fuel-oil storage tank used for the reclaimed oil mixture has a capacity of 80,000 gallons. The oil reclaimed in the separator pays for operating the system.
At a repair yard on the Gulf coast, the oily wastes taken from tanks of vessels under repair is put in barrels or in a refuse barge, and is then pumped through a pipe line to a cylindrical tank of about 3,500 barrels capacity, situated back from the water front. Here the emulsions are heated with steam coils and the water is drained off at the bottom of the tank. The reclaimed oil is used for fuel in the plant.

The methods of disposing of oil and refuse sludge in 17 dry-dock, shipbuilding, and ship-repair yards have already been indicated in a publication by the Bureau of Mines.8

REFINERY AND GAS-PLANT SEPARATORS

The commercial handling and utilization of all commodities almost invariably involve some unavoidable loss. This fact holds true in oil refineries, gas works, and other oil-using plants; therefore such plants have been quite generally regarded as sources of oil pollution. Refineries and gas plants in particular are popularly believed to be sources of serious oil or tar pollution, and it is therefore interesting to consider what these industries are actually doing toward preventing the escape of oil into the waters near their plants.

In general, refineries and gas plants recognize the practical impossibility of conducting operations without some slight leakage or spilling of oil during the various processes, and primarily as a measure to prevent industrial waste have developed and installed in their plants separators through which all liquid wastes must pass for treatment before final discharge into the nearest river or other waterway. Although the spillage and escape of oil in each of the multitude of manufacturing processes in a modern refinery is reduced to a minimum, the daily waste from the aggregate of the losses would be considerable unless some means of recovery was provided.

Some plants in the United States that are refining as much as 4,000,000 gallons of crude oil a day require more than 20,000,000 gallons of water a day for condensing, treating, and washing. In many of the larger plants two hundred to several thousand barrels of oil-water mixtures, which may contain as high as 60 per cent of water, are skimmed from the separators daily. The oil recovered from the oil-water mixtures may represent an amount ranging from a fraction of 1 per cent to as high as 2 per cent and over of the crude oil charged to the stills.

As mentioned above, waste waters from refineries and gas plants are passed through separators that permit separation of the waste oils by gravity. Most petroleum products are lighter than water;

---

8 Pollution by Oil of the Coast Waters of the United States; preliminary report, p. 110.
accordingly, the waste oil from refineries is recovered from the surface, although the quantities of heavy sludge that settle to the bottom of the separator necessitate periodical cleaning out. Some emulsions, particularly those from Mexican crudes, in which the oils are of almost the same specific gravity as water, are extremely difficult to separate; as would be expected, emulsions containing light oils separate far more readily. Some plants that have to handle stubborn oil-water mixtures have built large auxiliary basins into which the mixtures are discharged and allowed to settle for long periods.

Most of the tar oils in the manufacture of water gas have a greater specific gravity than water; therefore, in gas-plant separators particular attention is paid to accumulating and reclaiming the waste tar oils from the bottom of the separator compartments; lighter oils and oil emulsions, however, are also met. Gas-plant emulsions that are too refractory for treatment in the separator may be treated in tar-dehydrating stills.

Because the oil-water mixtures handled are of different types, and because the amount of gas-plant wastes is small in comparison with that met in refineries, the two types of separators show some differences.

**REFINERY SEPARATORS**

In general the separators consist of large open basins, usually of concrete or wood, through which all the plant oil and water wastes flow at greatly reduced velocity. The basins are large enough to permit a lapse of 1 to 20 hours between the time the mixture enters and that at which it leaves, thus allowing an ample period for the separation of the oil and water. Separators that handle chiefly light or refined oils may have removable slab covers provided with vents, and also steam lines in each compartment for combating fires.

As the capacities of crude-oil refineries range from a few hundred to over 85,000 barrels a day, and as the plants differ in type, ranging from asphalt and terminal plants to complete refineries, an equally wide range of separator sizes and capacities is in use. For example, asphalt and oil terminal plants require a comparatively small amount of water; the ratio of gallons of water to barrels of oil handled is about 30 to 60 to 1. Skimming and lubricating oil plants may work on a ratio of 60 to 100 to 1, and complete refineries may require as much as 600 or 800 gallons of water for each barrel of crude oil. In large refineries the practice is to install separators at those places where the chief losses and wastes occur. This practice is particularly advantageous in the refined-oil departments, where the oils to be reclaimed are comparatively light and easily separated and can be
charged back into the refined-oil stills. Some of the larger plants visited have at different places in the works as many as seven to nine separators so arranged that the smaller separators finally discharge through one or two large main separators.

DESCRIPTION

The following description of a separator is necessarily general. A separator typical of those in use in refineries of moderate size may be 150 to 200 feet long, 50 to 60 feet wide, and 10 to 12 feet deep. There may be two or more parallel circuits and about six skimming compartments in series in each circuit. A continuous longitudinal partition wall or walls divides the separator into two or more independent parallel circuits. Suitable control gates at the inlet, and in some separators at the outlet, permit isolation of each circuit for cleaning or repairs while the total flow goes through the other circuit or circuits. Each circuit thus constitutes a separating unit that can operate independently of the others. For small plants a single circuit may suffice, but the general practice is to have two circuits, and occasionally three are used.

The cross or transverse partition walls separating the compartments generally extend from the top down to within about 2 feet of the separator bottom, thus providing a submerged aperture through which water flows from one compartment to the next. In order to prevent a direct short-circuiting of the water stream along the bottom of the separator, so-called “knee walls” or submerged baffle walls are provided. These are generally placed transversely, midway between the compartment partition walls and are 2 to 4 feet high, according to the depth of the water. Besides preventing direct short-circuiting of the water, these baffle walls, by causing gentle vertical displacement of the main stream, serve to bring the oil to the surface without turbulent flow and thus facilitate gravity separation. It is important, therefore, that the velocity of the stream passing over a baffle wall and the downward velocity near a submerged aperture be very small in order to prevent oil on the surface from being dragged into the next compartment. Another function of the submerged baffles is to prevent the accumulated sludge from being carried out with the discharge waters.

In general, the cycle of operations through the separator is as follows: The liquids enter the first compartment, thence go over the first baffle, under the first partition wall, into the second compartment, and so on through all compartments, through the outlet gate, thence to the discharge sewer. The oil and water separate during passage through the separator at an average horizontal velocity of
about 1 to 1½ feet per minute. In the separators and settling basins, time is a factor of great importance. Oil in contact with solid matter may be carried in suspension for a long time, finally separating and rising to the surface. It is believed that separation of the oil from the solid matter and water is essentially complete after five hours.

The oil that collects on the surface and is retained between the partition walls is periodically skimmed off in each compartment by specially designed suction strainers connected through adequate piping to a suction pump. Skimming necessarily removes much water as well as oil, and the mixture removed goes to settling tanks provided with heating coils, where further separation takes place. The reclaimed oil is returned to the refinery stills or burned under the boilers; the water that separates in the settling tank is returned to the separator. In one plant the committee visited, separation is aided by mixing the reclaimed oil with naphtha bottoms; the mixture is said to be ideal for further distilling.

EFFICIENCY

The greater part of the waste oil is generally reclaimed in the first two or three compartments of the separator, and very little of it should ever reach the final compartments; therefore, unless the separator is overloaded, poorly operated, or poorly designed, the final discharge water should show very slight, if any, traces of oil. Usually the only evidence of contamination by oil is an occasional small iridescent patch on the surface of the discharge waters, or more rarely a film of limited extent. Such patches and films represent only the slightest trace of oil, and usually disappear entirely at no great distance from the point of discharge into the river. It is practically impossible to remove this iridescence from the water even by filtration, although some separator discharges have been seen which are almost free even from this trace of contamination. If the separator is of good design and efficiently operated, appreciable quantities of oil are likely to pass through it only when circumstances are beyond the control of the operators. This condition exists when the separating system is flooded during or after an unusually heavy rainstorm; or when, if the separator is on low ground near tidal waters, high tides cause overflow; or when the separator is flooded by the bursting of a pipe or storage tank. By an overflow of the separator or the increased velocity of flow the efficiency of the separation is temporarily reduced. Fortunately, such conditions arise infrequently and, in the more efficient plants,
the damage from such an emergency is minimized by instructing
the operator at the separators to speed up the skimming pumps and
have them going full speed while the flood of oil or water is pass-
ing.

**FUNDAMENTAL FACTORS**

Some fundamental factors of an efficiently designed petroleum
refinery separator are:

1. Large enough volumetric capacity and cross-sectional area to
handle the entire volume of wastes at a rate of flow slow enough to
effect good separation. The volumetric capacity, sometimes referred
to as the "static" capacity, should permit a lapse of time between in-
let and outlet of at least 2½ hours, preferably more. The cross-
sectional area should preferably be such that the average horizontal
velocity will not exceed 1 to 1½ feet per minute. The depth of
liquid in the separator should be at least 6 feet, and 8 feet, or even
more, would be better.

2. There should be at least 4 compartments, and preferably 6
to 10. Baffle walls should usually be placed midway between parti-
tion walls to prevent direct flow through the submerged apertures
and to divert the oil to the surface. Under normal conditions it is
desirable that the greater part of the oil be trapped in the initial
compartments. The final compartments remove the last traces of
oil and provide reserve capacity for emergencies.

3. Liberal area should be allowed in openings under partition
walls and over baffle walls in order to prevent too great an in-
crease of velocity when the liquid passes from one compartment to
another or over the baffles. The bottom openings should preferably
be 1½ to 2 feet vertically, and the discharge areas over baffles should
be at least 2 feet vertically and should extend the full width of the
separator.

4. The inlet water should enter with as little turbulence as pos-
sible in order to avoid creating high-velocity eddies and whirls
which keep the oil-water mixtures in violent motion and retard
separation. It is suggested that this water be introduced as far
below the surface of the liquid as practicable. In most of the sepa-
rators investigated, it is introduced at approximately the height of
the liquid level in the separator. At a few plants the waste water is
introduced above the liquid level and allowed to splash into the
first compartment, thus creating considerable disturbance and ren-
dering the compartment ineffective. The outlet should always be
submerged, and the outlet area should be so large that the velocity
of the water approaching the outlet in the last compartment will
Figure 14.—Typical refinery separator; approximate capacity, 4,000,000 gallons in 24 hours
be slow enough to avoid sludge sediment being carried from the bottom. It is suggested that this area be such that the velocity of the outgoing water at the point where it leaves the separator does not exceed 40 feet per minute and is preferably about 25 feet per minute. Velocities of 40 feet per minute and upward in the inlet and outlet conduits are quite general.

A prime factor contributing to cleanliness of the discharged water is frequent skimming of the compartments, at least once every 24 hours, and preferably every 8 hours. Local conditions will determine whether more or less frequent skimmings are necessary. Another factor of prime importance is keeping the bottom of the separator clean—that is, periodical removal of the B. S. If cleaning is neglected, sediment passes off in suspension in the discharge water.

Table 3 gives the main characteristics of typical separators seen in operation at various petroleum refineries. Figure 14 is a sketch of a refinery separator typical of good practice for a capacity of 4,000,000 gallons a day.
### Table 3.—Separator characteristics at oil refineries

<table>
<thead>
<tr>
<th>Plant</th>
<th>Rated capacity of crude per day</th>
<th>Type of plant</th>
<th>Total water per day</th>
<th>Ratio of gallons of water to barrels of crude being run</th>
<th>Parallel or series</th>
<th>Number of compartments per circuit</th>
<th>Linear dimensions in feet</th>
<th>Area</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Gallons</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Ft. in.</td>
<td>Ft. in.</td>
</tr>
<tr>
<td>1</td>
<td>50,000</td>
<td>Complete</td>
<td>5,000,000</td>
<td>584:1</td>
<td>All series</td>
<td>5 (80 x 50 ft.)</td>
<td>400</td>
<td>50</td>
</tr>
<tr>
<td>2</td>
<td>2,500</td>
<td>Lubricants</td>
<td>1,500,000</td>
<td>200:1</td>
<td>All series</td>
<td>3 (25 x 30 ft.)</td>
<td>75</td>
<td>30</td>
</tr>
<tr>
<td>3</td>
<td>20,000</td>
<td>Skim and asphalt</td>
<td>500,000</td>
<td>141:1</td>
<td>No parallel</td>
<td>4 (50 x 50 ft.)</td>
<td>200</td>
<td>50</td>
</tr>
<tr>
<td>4</td>
<td>6,000</td>
<td>Complete</td>
<td>4,750,000</td>
<td>179:1</td>
<td>Two paralleled</td>
<td>8 (17½ x 27½ ft.)</td>
<td>149</td>
<td>55</td>
</tr>
<tr>
<td>5</td>
<td>10,000</td>
<td>Skim</td>
<td>10,000</td>
<td>166:2</td>
<td>No parallel</td>
<td>4 (50 x 40 ft.)</td>
<td>200</td>
<td>80</td>
</tr>
<tr>
<td>6</td>
<td>14,000</td>
<td>Complete</td>
<td>12,000</td>
<td>180:1</td>
<td>All series</td>
<td>20 (30 x 30 ft.)</td>
<td>300</td>
<td>60</td>
</tr>
<tr>
<td>7</td>
<td>10,000</td>
<td>Skim</td>
<td>7,000</td>
<td>166:1</td>
<td>No parallel</td>
<td>24 (50 x 50 ft.)</td>
<td>400</td>
<td>150</td>
</tr>
<tr>
<td>8</td>
<td>5,000</td>
<td>Asphalt</td>
<td>300,000</td>
<td>101:1</td>
<td>No parallel</td>
<td>12 (12 x 12 ft.)</td>
<td>300</td>
<td>60</td>
</tr>
<tr>
<td>9</td>
<td>5,000</td>
<td>Complete</td>
<td>6,000</td>
<td>601:1</td>
<td>Two paralleled</td>
<td>7 (20 x 20 ft.)</td>
<td>140</td>
<td>40</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Plant</th>
<th>Cubic contents of separator</th>
<th>Ratio of 24-hour flow to volumetric capacity</th>
<th>Velocities</th>
<th>Time</th>
<th>Appearance of water discharge</th>
<th>Oil reclaimed per day</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Gallons</td>
<td>Inlet</td>
<td>Under partition wall</td>
<td>Over submerged baffles</td>
<td>Average horizontal cross sectional</td>
<td>Average vertical cross sectional</td>
<td>Between compartment partition walls</td>
</tr>
<tr>
<td>1</td>
<td>900,000</td>
<td>5.58:1</td>
<td>0.86</td>
<td>0.56</td>
<td>0.028</td>
<td>0.028</td>
<td>0.86</td>
</tr>
<tr>
<td>2</td>
<td>101,000</td>
<td>4.98:1</td>
<td>4.00</td>
<td>.031</td>
<td>.004</td>
<td>.004</td>
<td>.45</td>
</tr>
<tr>
<td>3</td>
<td>450,000</td>
<td>8.9</td>
<td>.31</td>
<td>.25</td>
<td>.02</td>
<td>2.0</td>
<td>.67</td>
</tr>
<tr>
<td>4</td>
<td>522,000</td>
<td>9.1</td>
<td>.14</td>
<td>.024</td>
<td>.016</td>
<td>(up)</td>
<td>.9</td>
</tr>
<tr>
<td>5</td>
<td>600,000</td>
<td>16.6</td>
<td>.32</td>
<td>.15</td>
<td>.039</td>
<td>(?)</td>
<td>.65</td>
</tr>
<tr>
<td>6</td>
<td>640,000</td>
<td>18.7</td>
<td>.15</td>
<td>.28</td>
<td>.25</td>
<td>.13</td>
<td>.04</td>
</tr>
<tr>
<td>7</td>
<td>(4, 500,000</td>
<td>15.5</td>
<td>.87</td>
<td>.087</td>
<td>.044</td>
<td>(up)</td>
<td>.022</td>
</tr>
<tr>
<td>8</td>
<td>1,375,000</td>
<td>5.1</td>
<td>.54</td>
<td>.185</td>
<td>.06</td>
<td>.037</td>
<td>(up)</td>
</tr>
<tr>
<td>9</td>
<td>68,000</td>
<td>4.4</td>
<td>.3</td>
<td>.03</td>
<td>None.</td>
<td>.0077</td>
<td>None.</td>
</tr>
<tr>
<td>10</td>
<td>105,000</td>
<td>2.9</td>
<td>.58</td>
<td>.073</td>
<td>.0095</td>
<td>.0065</td>
<td>.0065</td>
</tr>
<tr>
<td>10</td>
<td>235,000</td>
<td>23.8</td>
<td>.67</td>
<td>.23</td>
<td>.23</td>
<td>.039</td>
<td>.023</td>
</tr>
</tbody>
</table>

Has two separators; data apply to new separator which receives discharge from old separator; plant clean; wharves clean.

Separator discharges over pile of bricks before entering bay; bricks coated with marine growth; plant very clean; wharf very clean.

Gates at outlet located at water level, last compartment ineffective; plant clean; wharf clean; (waffle in first compartment, immediately before opening in partition, wall extends across 86 per cent of width, with open end).

Plant clean; wharf fair.

No. 1 separator discharges into No. 2 separator; plant very clean; wharf very clean.

Has two excelsior filters in separator and coke filter interposed between separator and river; plant very clean; wharf clean.

Has two excelsior filters in separator; marine growth on stones at separator outlet; plant clean; wharf very clean.

Separator discharges into a pond, 500 feet in diameter, before finally passing into river; contemplate construction of two new separators; plant clean; wharf fair.

---

1 Computations in this table are approximate.
2 This represents only the water passing through one separator. Total water for plant is 2,300,000 gallons per day.
3 Skimming baffle has nine 12-inch square holes, submerged top of opening 4 feet below dead water line, spaced 5 feet between centers.
4 Flush with bottom.
5 Above surface.
6 Siphon.
7 First compartment only
8 One baffle only.
GAS-PLANT SEPARATORS

In general, the problem of waste disposal is more complex at gas-manufacturing plants than at petroleum refineries because the oils recovered have a greater range of gravity. Some are lighter and some heavier than water. The latter constitute by far the greater proportion and represent the larger value when recovered. Under certain conditions of operation, exceedingly refractory emulsions are encountered at gas plants; but, on the other hand, the problem for the average gas-manufacturing plant is easier because of the comparatively small quantity of wastes to be treated. With the exception of certain minor details and much smaller size, the main details of a gas-plant separator are similar to those of separators used in oil refineries. A separator consists of the usual basin subdivided into a number of compartments, and has the usual baffle walls, oil-tar draw-off, piping, etc.

COMPARISON WITH REFINERY SEPARATORS

Some of the details in which gas-plant separators differ from refinery separators are as follows:

1. The water entering the first compartment is allowed to drop on a splash board which, according to engineers who have made a study of gas-plant separators, assists in breaking up the mixture of the tar and water.

2. Baffle walls are carried higher and closer to the liquid level; this is possible because of the comparatively small volumes handled.

3. Steam coils are used to heat the tar-water mixtures in order to facilitate separation, especially during cold weather.

4. The separator is entirely covered, and a suitable vent pipe carries off the steam vapors.

5. A "recirculating" chamber at the outlet end forms an integral part of the separator. This chamber serves to collect the comparatively clean water, which is recirculated through the various processes in the plant.

6. At many plants a coke, charcoal, sand, gravel, or wood-shaving filter is placed between the separator outlet and the final point of discharge; this filter retains fine particles of oil, tar, or coke held in suspension after the water has passed through the separator.

7. Suction pipes for reclaimed tar oil are carried to the bottom of the separator.

The cycle of operations is similar to that of a refinery separator, except that the most valuable material is reclaimed from the bottom. If lighter oil accumulates on the surface, it is usually skimmed off by hand.
Sometimes an emulsion of tar and water or oil and water, or both, is formed which contains 75 per cent, or even more, water. This emulsion passes through the tar separators and fouls the coke in the coke filter or the sand in the sand filters so quickly that the effective capacity is greatly reduced. Such an emulsion can be handled by means of a tar-dehydrating still which not only breaks up the emulsion, but also reduces the water content of the tar itself and thereby renders it more marketable. In a continuous-type still, particularly suited for handling emulsions, it is possible after the charge has been thoroughly heated to skim off most of the water with a skimmer; there is also less danger of foaming. The disadvantage is that more attention is required, and there is difficulty in regulating the feed to obtain a product uniformly low in water. For most installations an intermittent still equipped with a skimmer is preferable; it has been successfully used with tar containing a high percentage of water.

At one big gas plant visited by the committee a large auxiliary tank is used as an emergency receptacle for waste liquids in the event of an accident to the separator.

Another gas company is said to use coke filters in addition to the ordinary separators. The committee is informed that a number of these coke filters are used in series, and that they recover appreciable amounts of oil. Both the separated oil and water are returned to the process. Such coke filters are in use by several other gas companies.

As to the size of the separator, the general practice in gas plants seems to be to provide 6 gallons capacity per thousand cubic feet of gas produced per day. The overall dimensions of an average separator for this industry are about as follows: Length, 28 to 30 feet; width, 15 to 18 feet; and depth, 8 to 10 feet. Such a separator of the three-circuit or three-unit type, with three compartments per circuit and a single recirculating chamber common to all three units, has been recommended by a committee on disposal of gas wastes of the American Gas Association as suitable for a gas plant making 2,000,000 cubic feet of gas a day. Figure 15 gives the elevation of a typical gas-plant separator.

**ADDITIONAL INFORMATION**

Most gas-plant separators are entirely inclosed, and it is therefore difficult to obtain a general idea of their details from casual observation. For further details and figures, reference should be made to the 1920 and 1921 reports of the chairman of the American Gas Association convention committee on disposal of waste from gas plants, which are reprinted, respectively, in the November 10, 1920, and in the November 5, 1921, issues of the Gas-Age Record.
FUTURE DEVELOPMENTS IN LAND SEPARATORS

It is not unlikely that extended study of separator design would indicate the possibility of a great reduction in the size and cost of oil separators without any decrease in separating efficiency. More frequent skimming and cleaning may make possible a material reduction in the number of compartments and the total time between inlet and outlet. Development of automatic or self-skimming separators would seem to be an attractive field for further investigation. The present study has shown that few or no reliable data on designs are available for determining the size, shape, and arrangement of separators. One separator that the committee saw in operation had essentially the dimensions shown in the sketch of a typical refinery separator (fig. 15). The excellent results obtained lead to the belief that the general proportions and characteristics incorporated in this design are essentially correct.

In view of the present practice of heating oil-water mixtures in "slop" tanks, it seems probable that more rapid and perhaps more efficient separation, especially of stubborn emulsions, can be accomplished by mixing with naphtha bottoms or other intermediate refinery by-products.

Some separators have coke, gravel, sand, or excelsior filters in the outlet passage. Further study should be given the actual benefit derived by adding these filters and the possibility of extending further the use of such auxiliaries with a view to decreasing materially the size and cost of the primary separator.

MISCELLANEOUS DEVICES OF MINOR IMPORTANCE

Inquiries were sent to a rather large number of other companies in an endeavor to determine whether the apparatus they sold would
be capable of handling oily ballast water. None appeared to be suitable for the purpose or likely to offer any promise for future development.

SUMMARY AND CONCLUSIONS

The committee believes that, even with the present entirely inadequate means for properly handling oil-water mixtures on shipboard, much can be done by more careful instruction and training of ships’ crews in the proper and efficient handling of oil to reduce the pollution from this source. Workmen on docks and in land plants should receive appropriate instruction on the same subject. Much has been done in this direction, but the possibilities are by no means exhausted.

Oil-contaminated ballast water, tank cleanings, and bilge water constitute the chief items of the problem of handling oily waste discharged from ships. Of these the disposal of bilge water is probably least difficult.

Since the total bilge volume is comparatively small, bilge water probably can be treated at a reasonable cost by installing a small pump that has a flexible hose suction and discharges into a conveniently placed settling tank. The oil that separates on the surface of the water in the tank is skimmed off at suitable intervals and is returned to the fuel storage tanks; the water is drained back into the bilge.

The proper disposal of ballast water and tank cleanings from vessels presents much greater difficulties. This subject was considered under two main divisions: (1) Methods that contemplate disposal of the material by use of port or harbor facilities, and (2) methods that contemplate disposal by use of apparatus to be installed on shipboard.

DISPOSAL BY PORT OR HARBOR FACILITIES

Where disposal is made after arrival in port, it is likely that ships must (1) proceed to a definite disposal point similar to a petroleum harbor and discharge the oil-contaminated water, (2) utilize pipe lines connected to a waste reservoir on land at the individual docks, or (3) discharge the oil-contaminated wastes into collecting barges brought alongside while the ship is at the dock. Methods (1) and (2) are believed to be generally unsuitable or impracticable for conditions at American ports, or their application is limited by the size of the port.

Of the methods that propose the use of port or harbor facilities, the disposal of oil-contaminated ballast and oil refuse by collecting barges seems to be the most immediately available, practical, and satisfactory. The system requires a number of barges maintained expressly for this service, and also the necessary towing and suitable
reclaiming or disposal facilities. It has been suggested that the fleet of barges might be owned and operated by a commercial company or by the local municipal government or port authorities. On account of the low value of the recovered material, it is problematical whether such an enterprise could be made self-supporting, particularly in the initial stages, without some form of assistance or protection against loss.

The barge method has been carefully studied, and an estimate for its application to the port of New York over a period of normal shipping activity has been made. This estimate is based upon what may be considered the maximum average amount of oil-contaminated waste that would have to be handled in the harbor in any one day. It is assumed that no ballast water would be discharged save into the barges provided for that purpose. The initial investment is estimated at approximately $900,000, and the approximate net annual expense about $255,000. This corresponds to a total cost for this service of about $70 per vessel per call.

Ship contractors and salvage companies in various ports operate barges in connection with their business, but use them mainly for cleaning out tanks and handling oil refuse and bilge residues rather than for the collection and disposal of the vastly greater bulk of oil-contaminated ballast water.

DISPOSAL BY APPARATUS ON SHIPBOARD

So far as oil-burning ships are concerned, it is believed that the most satisfactory ultimate solution will involve the use of a separating device on each individual ship and provision of facilities in harbors for the collection and proper disposal of heavy sludges and any other oily wastes that the separator will not handle. After careful consideration, the committee believes that an oil-water separator for shipboard use can be developed which will satisfactorily separate the oil and water and yield a reclaimed oil suitable for use as a fuel without further treatment. Use of such a device would make vessels self-contained and independent to the maximum extent, thus reducing the time of their turn-around period in port and lessening pilotage and port charges.

Of the devices proposed and now under development for eliminating pollution of water by oil-burning ships, none have been seen that can be unreservedly commended for use on general cargo vessels (1925). One or two of these devices are promising, but more experimental work is necessary before any can be definitely recommended. It is highly desirable that the shipping interests give active encourage-

---

*It is understood that the more recent work on this problem by the United States Bureau of Standards has resulted in much progress in this direction.*
ment and constructive criticism in the development of such methods and devices.

If a completely successful device for separating ballast water and oil on general cargo vessels can not be readily developed and applied, a separator that would satisfactorily reduce the bulk of the oil-water mixtures would be valuable. A great reduction of bulk would much facilitate the collection, by barges, of residual mixtures that the separators will not handle. In fact, as indicated above, it seems probable that, in addition to any oil-water separating device, however effective, which may be installed on vessels, methods for collecting and properly disposing of tank sludge and certain other oily refuse will have to be generally available in port if oil pollution from vessels is to be avoided.

The limitations of ship design require that an apparatus intended for separating oil and water on vessels must be comparatively small and compact, and yet preferably capable of handling 100 to 200 tons of oil-water mixtures per hour. Space is one of the most important considerations in the installation of any apparatus aboard ship. Although room could undoubtedly be found for a separator if the use of some such device on oil-burning vessels already in service becomes necessary, it would very likely entail some difficulties in ship operation under the prevailing conditions in vessels as now constructed. When new ships are being built, it should be feasible, without imposing serious hardships, to make special provision for the installation of separating equipment in the most favorable place. Separators for duty on shipboard should be reasonable in cost, and their installation and use should not impose undue or unreasonable demands or hardships on the ship operator.

None of the devices and methods proposed for separating oil and water on board ships—gravity, centrifugal, filtration, and miscellaneous—seem to have been applied to commercial shipping with entire success (1925). The gravity type is, however, believed to offer the best possibilities for future development. Judged from their operation in the present stage of development, the other types seem to be definitely limited by a number of factors, such as prohibitive cost, excessive weight, and lack of capacity; moreover, their use probably would involve new and additional problems of waste disposal.

The operators of a large fleet of tankers have developed a gravity-type separator which seems to offer promise as a solution of the problem so far as oil-cargo vessels are concerned.

In addition to equipping oil-burning vessels with oil-water separators and providing barges in harbors, it would be advisable to have apparatus for skimming and collecting from the surface of
the water the patches of free oil that sometimes result from accidents in spite of all precautions. Such apparatus should prove valuable in slips and quiet pockets where spilled oil accumulates.

It is believed that the apparatus now available for handling oil-water wastes from land plants are adequate, when properly installed and used, largely to eliminate oil pollution from such establishments—with the possible exception of ship-repair yards, where the normal conditions of operation are such that the control and proper disposal of oil refuse and oil wastes are very difficult. Ship-repair yards will require the further development of means for coping effectively with this situation.