Pollution of the Sea by Oil

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The problem of preventing pollution of the sea by oil, in so far as it concerns ships which take on water ballast into empty fuel tanks, has been studied in association with the Ministry of Transport and with the co-operation of the Admiralty.

Oil-in-water systems have been subjected to theoretical treatment, and certain of the curves obtained verified practically.

The effectiveness of commercial oily water separators has been assessed theoretically and many oily water separators and their ancillaries installed on ships were examined and tested, and the results are presented graphically. In a number of instances the complete installations were either faulty in design or else were used incorrectly.

Recommendations for improving the performances of separating systems include:

a) The fitting of bellmouths to, or forming sumps at, oil off-take pipes to ensure as complete a removal of the oil and of water as possible.

b) The use of pumps which do not disintegrate the oil in a mixture of oil and water passing through them.

c) The arrangement of pipe layout so that ballast water can be taken in through the separator inlet, and deposits of oil from a previous deballasting can be washed out of the lines back into the tank.

Tests were carried out on various devices incorporated in separators with the object of inducing the coalescence of small oil globules, but results showed that the devices were relatively inefficient.

In practice it was found that some pumps used in separator installations disintegrated the oil to a serious extent, and, as no previous assessments of the effect of pump design on the operation of separators had been made, a test rig was built to investigate this important aspect of the problem. A flotation technique was evolved to ascertain the oil globule size distribution in the mixture in the pump outlet.

Ten different types of pump, normally rated at 10 tons/hr., were tested, and the results presented show the relative degrees of disintegration which were produced with various operating conditions.

The four most suitable designs were those which employed a triple screw, a single vane, a double vane and a rotary gear, but in each case derating by about 50 per cent is advised. The reciprocating and hypocycloidal pumps were not quite satisfactory for deballasting purposes and require modification to reduce the disintegration they produce when pumping oily water mixtures. The diaphragm, centrifugal and flexible vane pumps caused excessive disintegration of the oil, and therefore were unsatisfactory for pumping the contents of ballasted tanks and bilges to separators.

Finally, details are given of the experiments carried out in developing a pebble bed filter unit which will reduce the oil contents in effluents from ships to less than 50 parts per million.

A fluid bed technique, developed for cleaning such filters, is described.

Results from field tests on board ship, and theoretical assessments of the quantity of oil which must be removed by a filter, have been used to design a small 10-tons/hr. separator/filter unit.

The investigations described in Part I of this paper were carried out in 1955 and 1956 on complete installations on board ship. It is desired to emphasize that the results of the investigation should not be directly compared with those of the shore based test prescribed by the Ministry of Transport in connexion with the Regulations which came into force on 1st July 1958.

I. INVESTIGATIONS INTO THE EFFECTIVENESS OF OIL-WATER SEPARATORS FITTED IN DRY CARGO SHIPS

INTRODUCTION

It is surprising that at the present time the world should still be confronted with the problems of pollution of the sea by oil and the consequent fouling of beaches[1], for as long ago as 1922 legislation was passed in the United Kingdom[2] and in 1924 by the United States Government, in attempts to deal with the problem.

Although by this legislation the nuisance was not eliminated, it was apparently reduced for a short period, after which pollution increased in parallel with the rapid increase in the tonnage of oil burning ships and oil tankers; frequent references

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in the daily press to widespread pollution are in support of this.

Excellent papers reviewing the position as related to shipping (1926, 1927) and suggesting preventive measures have been published by Hele-Shaw and Beale[3] and Carland[4]. Since 1930, the American Petroleum Institute has issued Manuals relating to the disposal of refinery waste[5], Volume 1 dealing specifically with waste water. They contain much basic information and are concerned with oil separating plant and techniques applicable at land based oil refineries.

No other publications describing research on the problem have been encountered.

The Ministry of Transport and Civil Aviation, however, has been concerned with the problem for some considerable time, and a report of a special committee studying the subject was published in 1953[6].

In April 1954 an International Conference was held in London at the instance of H.M. Government[7], and drew up the International Convention for the Prevention of Pollution of the Sea by Oil; subsequently, the "Oil in Navigable Waters Bill" was introduced in Parliament[8] in order to give effect to its provisions.

The Bill received Royal assent on 6th May 1955, and was put into operation on 8th September 1956. Briefly, under the Convention the discharge of persistent oil or oily residue whether from tankers or from dry cargo ships is forbidden within certain sea areas, and effluents must not contain more than 100 p.p.m. of oil[9]. Within United Kingdom territorial waters the discharge of any oil continues to be prohibited as under the 1922 Regulations.

Meanwhile, at the request of the Ministry of Transport and Civil Aviation, the Fuel Research Station of the Department of Scientific and Industrial Research agreed to investigate the problem in so far as it applied to cargo and passenger shipping which water ballasted. The Ministry was satisfied that suitable preventive measures were available for oil tankers.

Ships which use their tanks alternatively for oil fuel and water ballast, have, after a certain amount of fuel oil has been used, to take on water into the empty fuel tanks in order to compensate for the consequent lightening of the vessel and so preserve stability. Subsequently this oil contaminated water has to be pumped out of the tanks into the sea. Ships which use bunker fuel tanks in this way for the carriage of ballast water are required by regulations made under the Act of 1955 to be fitted with oily water separators of a type approved by the Minister.

The investigations by the Fuel Research Station were designed to examine all the aspects of the operation of oil-water separators. The main objectives of the work were to establish the degree of pollution that could be reasonably expected in the effluents from separators when operated according to the manufacturers' recommendations, to make suggestions for reducing this pollution, and, if possible, to design a separator that would be more efficient than existing types.

THEORETICAL ASSESSMENT OF FACTORS AFFECTING THE SEPARATION OF OIL IN WATER AND OF LIMITATIONS IN THE DESIGN OF SOME EXISTING SEPARATORS

The principle of separation according to which all commercially available oily water separators function is the gravity differential between oil and water. It is therefore of importance that the basic relationships which exist for oil-in-water systems and their response to certain conditional variations should be considered.

The motive force acting on a sphere of oil moving in water is proportional to the difference in weight between the oil particle and a particle of water of equal volume. The resistance to the movement of the sphere depends on the type of flow, which in turn is related to the size of the globule and the viscosity of the fluid. For small particles moving under streamline conditions, Stokes' Law may be applied, while the flow of larger particles separating under turbulent conditions is determined according to Newton's Law. The change from Stokes' to Newton's Law is not defined precisely, and in practice it may be represented by an Intermediate Law. The limits between which these laws are valid are normally indicated by the Reynolds' Number of the flow as illustrated *in Table I*.

TABLE I.—LIMITS OF APPLICATION OF THE LAWS GOVERNING SEPARATION

Reynolds' Number (*Re*)	Law
0–2	Stokes' Law: $u = g \cdot \frac{(Ds - D)d^2}{18\eta}$
2–500	Intermediate Law: $u = \frac{0{\cdot}153 g^{0{\cdot}71}(Ds - D)^{0{\cdot}71} d^{1{\cdot}14}}{D^{0{\cdot}29} \eta^{0{\cdot}43}}$
500–200,000	Newton's Law: $u = 1{\cdot}74\sqrt{\frac{g\,(Ds - D)d}{D}}$

Where $-Re$ = Reynolds' Number = $\frac{ud}{v}$

u = relative velocity of the particle to the water.
d = diameter of oil particle.
v = kinematic viscosity of the water.
D = density of the water.
Ds = density of oil particle.
η = absolute viscosity of the water.

Fig. 1 shows the general form of graph in which the velocities of separation are plotted in relation to the various sizes of oil particles. The range over which each law is applicable is clearly defined, although, in practice, the change in the general characteristic from Stokes' to Newton's Law will be less pronounced. The conditions associated with systems of oily water separating plant can be represented in most instances in the Stokes' or Intermediate ranges.

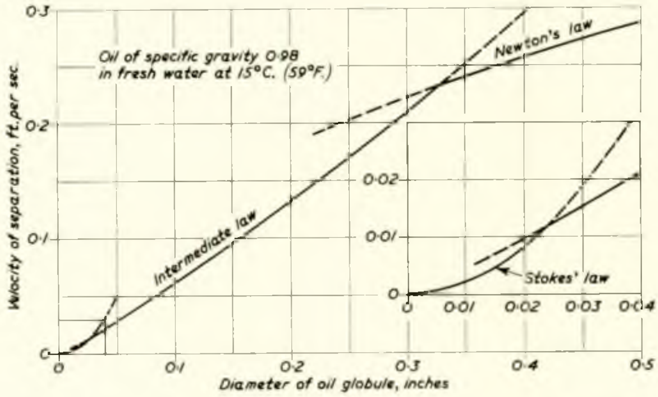


FIG. 1—*General form of curve showing the relationship between the velocity of separation and the diameters of the oil globules*

The graph shown in Fig. 2 shows the effect of changes in the specific gravity of the oil on the velocities of separation of globules of various diameters when moving in fresh and in sea water. Considerable changes in the velocities of separation result from comparatively small variations, of the order of one or two per cent, in the specific gravity of the oils. The rate of separation is greater in sea water (S.G.1·03) than in fresh water (S.G.1·0).

Although the difference between the specific gravities of the oil and the water increases slightly with increasing temperature, the accompanying reduction in the viscosity of the water is considerable, and it is this latter factor which is mainly responsible for the increase in the rate of separation with increasing temperature. The extent to which these increases are effective is shown in Fig. 3, where the velocity of separation in fresh water has been plotted against particle size for

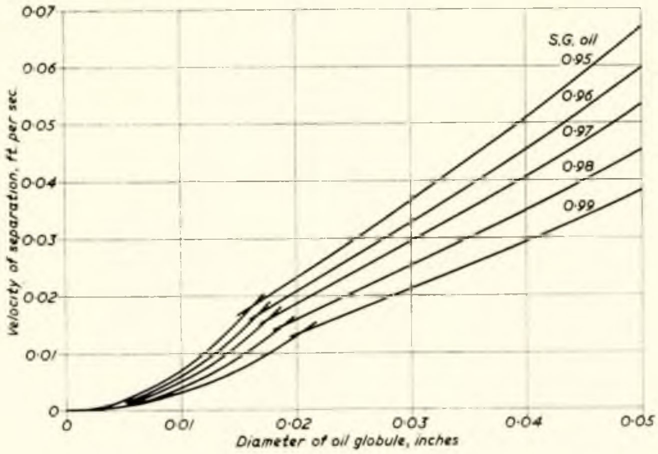


FIG. 2—*Relation between the velocity of separation and the diameter of the oil globules for oils of specific gravity 0·95 to 0·99 in sea water at 15 deg. C. (59 deg. F.)*

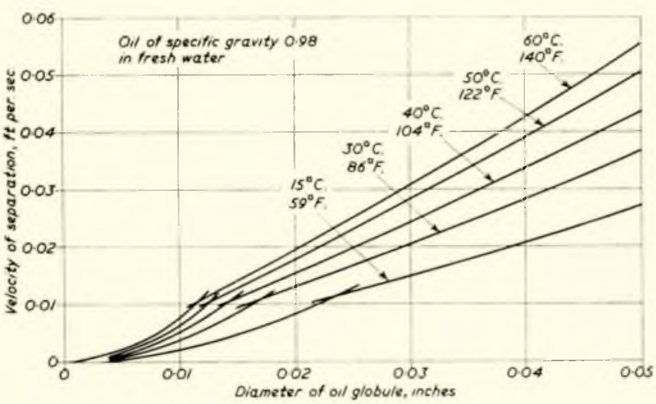


FIG. 3—*Relationship showing the effect of temperature of the system on the rates of separation of oil globules of various diameters*

temperatures ranging from 15 to 60 deg. C. (59 to 140 deg. F.). It is evident that the greatest increases in the velocity of separation for specific temperature changes occur at the lower temperatures.

This theoretical consideration immediately brings to light the significance of the important factors which are acting simultaneously during the separation of oil globules from water under gravity, and it also shows quantitatively the effects of certain variations in the conditions. Under static conditions a high rate of separation is favoured by a large size of oil globule, elevated temperature of the system, low density of the oil, and the use of sea water as compared with fresh water. Obviously, indiscriminate turbulence or agitation will interfere with the separation.

The laws presented here have been employed to assess the limitations in the performance of a number of designs of separator which are marketed in this country. For this theoretical assessment the maximum possible residence time of the oily water mixture passing through a particular equipment can be calculated from the manufacturer's throughput rating and the dimensions of the plant. With the knowledge of this, the separator design, the data relating the velocity of separation and the size of oil globules, the oil density, and the water temperature, it was possible to calculate the minimum size of oil globule with which a particular separator is able to deal at a given rate of operation.

In all but one design the flow was turbulent, with Reynolds' Numbers exceeding 11,000. However, assuming that free settling rates occurred in all cases, the minimum size of globule which could be extracted varied according to design between 0·006-in. and 0·05-in. diameter. Even with the more efficient designs globules smaller than about 0·010-in. diameter would be expected to pass out in the effluents.

COALESCING DEVICES

From theoretical considerations it is clear that oily water separators will not arrest globules of oil much smaller than 0·01-in. diameter and this limitation has been realized by most of the manufacturers of these equipments. Numerous variations in design have been made in attempts to induce the coalescence of small oil globules into larger and more easily separable ones. The methods most commonly employed rely upon impingement, compacting and swirl devices. Clearly

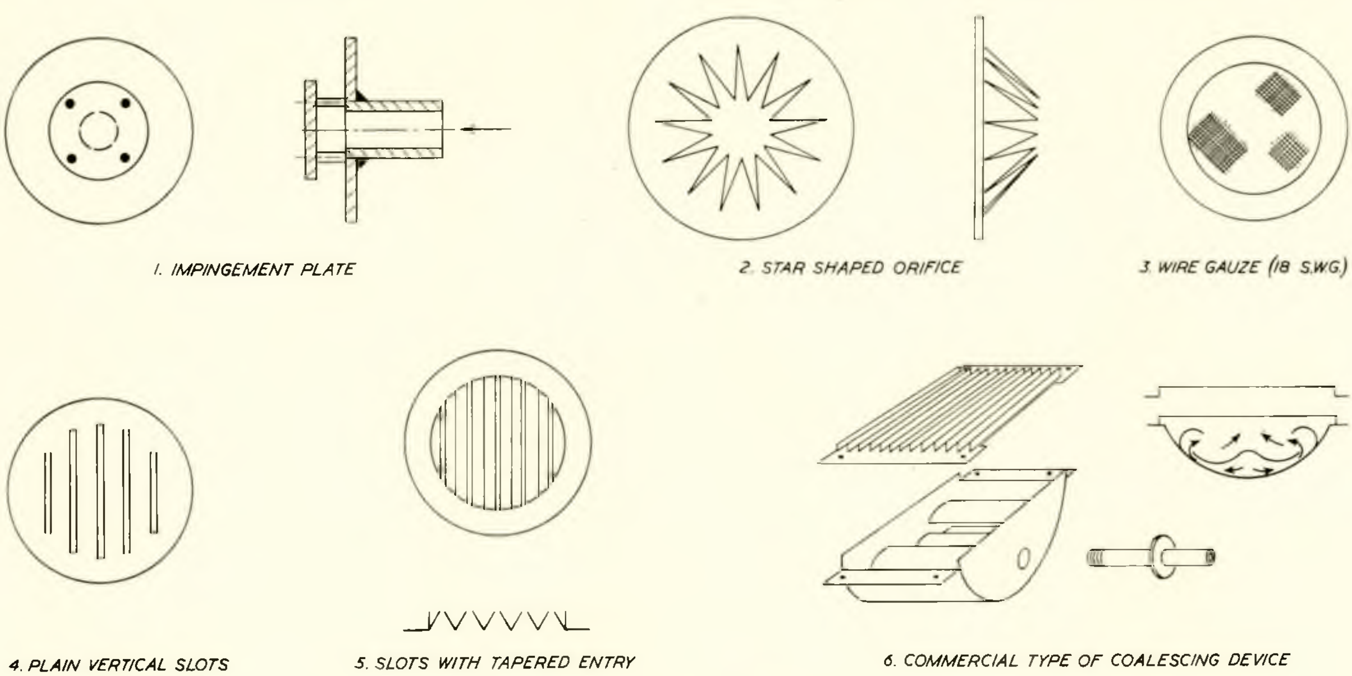


FIG. 4—*Coalescing devices*

there was a need for tests to be carried out in order to establish which method was the most satisfactory.

Two basic requirements before an investigation can be made on the relative efficiencies of the above methods are the ability to produce a standard oil/water mixture throughout the entire course of the work, and the ability to measure the particle size distribution of oil in water systems.

Equipments were developed for these purposes and the coalescing devices listed below and illustrated in Fig. 4 were tested under similar experimental conditions.

1) Impingement plate
2) Star shaped orifice
3) Gauze
4) Vertical slots, plain
5) Vertical slots, tapered entry
6) Commercial type of swirling device

The results obtained are shown graphically in Fig. 5, where the particle size distributions of the oil globules in the mixtures leaving the various devices are compared with those obtained when the devices were not used.

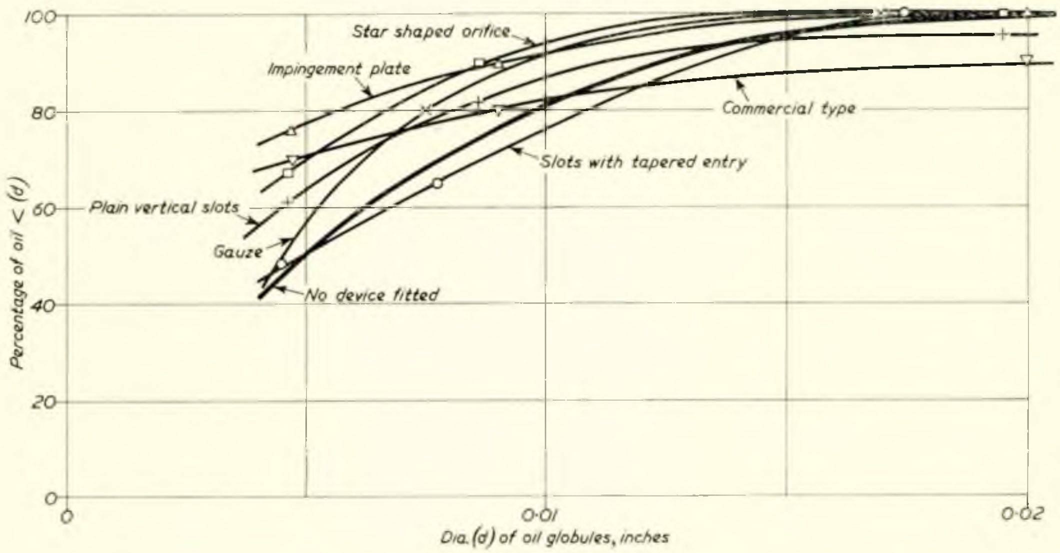


FIG. 5—*Particle size distribution of oil in mixtures from compacting devices*

With the methods of sampling employed, errors as high as 20 per cent were encountered, so that the results are only approximate. However, even when allowances are made for these errors, it would appear that no noticeable advantage occurred by using the compactors.

Oil deposits built up on all devices except the impingement plate and the vertical slots with tapered entry, and it is considered that, in practice, such devices may well provide additional surfaces where heavy deposits of oil might form at the end of a deballasting schedule. In consequence, these deposits would almost certainly be stripped off during the early stages of a subsequent deballasting in the form of very small globules which would pass through a separator.

Test of Cyclone Type of Flow

It emerged during discussions that certain oily water separator manufacturers and some shipowners seriously advocated the introduction of cyclone type of flow in oily water separating installations.

Consequently, it was important that this matter should be investigated, for theoretical considerations suggest that, by subjecting an oil-in-water mixture to a cyclone type of flow in which the magnitude of the centripetal force acting on the oil globules will be governed by the circumferential velocities within the system, the rate of separation of the globules would be greater than that which would occur in still water.

A simple laboratory plant was constructed and used to explore the velocity distribution and flow patterns within a cyclone. These tests showed that the theoretical advantages of a simple cyclone type of separator were not achieved in the design tested, being more than offset by turbulence and short circuiting of the flow.

Tests Carried Out on Oily Water Separating Installations

Having examined many theoretical aspects of the problems involved in separating oil from ballast water, practical tests were carried out on separators and installations on board ships.

In broad terms the objects of the tests were:

a) To ascertain the characteristics of the oily water systems normally occurring on shipboard.
b) To determine the effectiveness of oily water separating plants under normal operating conditions.
c) To gain information regarding the disposition of separating plants on shipboard (tanks, pipework, pumps).
d) To examine the ballasting/deballasting schedules commonly followed.

Test Procedure

The installations tested were invariably identical in so far as they included a dual purpose tank, a deballasting pump and an oily water separator. However, the layout of the installations and the connecting lines were varied and often complicated. The test procedure adopted followed a fixed pattern and was devised after a number of plants had been inspected.

In every test, samples of the mixtures being separated were taken from various points along the system. In particular, related samples were obtained from the inlet and outlet lines of the separator after allowance had been made for the residence time. Where possible, the mixtures in the tank and those entering the pump were also examined.

The duration of the tests varied, depending on the quantity of ballast water to be discharged and also on the rate of throughput of the separator. Sampling commenced after an initial settling down period and continued at regular intervals until the final stages of the test, when the periods between taking samples were decreased in relation to the rapidly changing oil/water ratios in the mixture at the separator inlet.

Immediately a sample was taken it was inspected, using a pocket microscope, and an estimation made of the sizes of the oil globules. The results by this method are only approximate, for frequently the larger globules of oil separated to the top before readings could be made.

The oil contents of the samples were determined gravi-

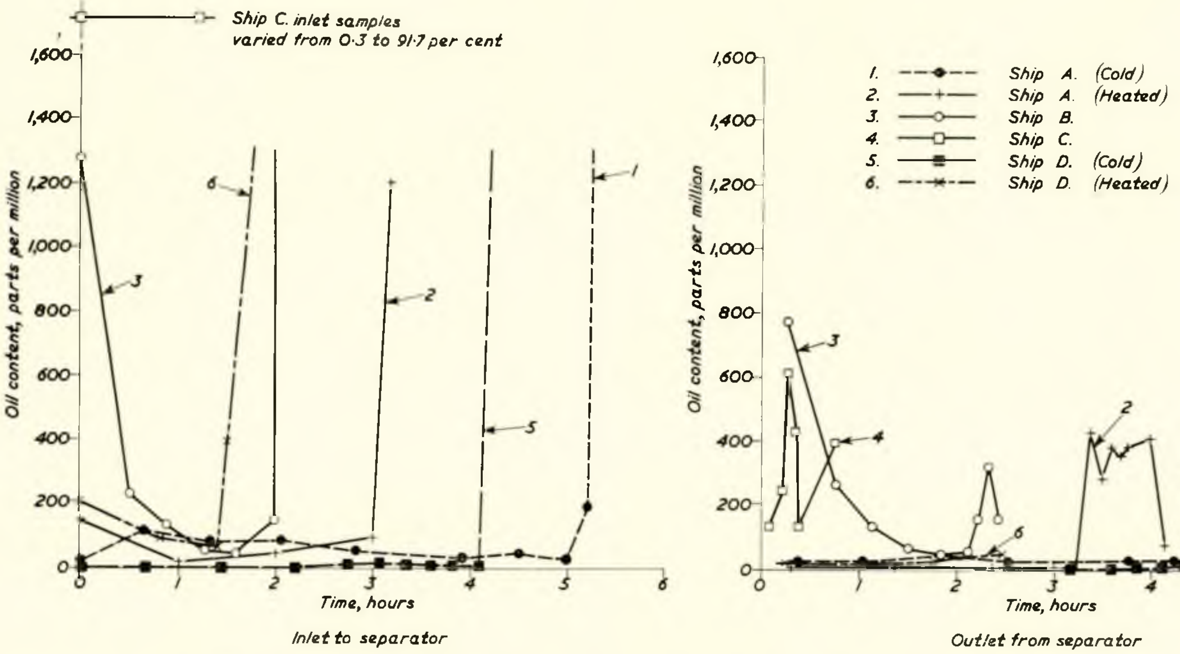


FIG. 6—*Oil content of the mixtures from the inlets and outlets of oily water separators*

metrically by extracting the oil with benzene, evaporating the benzene, and weighing the remaining oil. For oil contents up to 500 p.p.m. the accuracy of this method is of the order of ±1 per cent.

Test Results

A considerable amount of data is available from these tests, but to report upon each one in detail would be tedious and probably confusing, for an overall picture of the position is required rather than details relating to the vagaries of a particular installation.

The curves given in Figs. 6 and 7, showing the oil contents of samples taken at inlets and at the outlets of the separators throughout the deballasting period, do give such a picture. They show that when deballasting is performed according to normal procedure there is a definite and consistent trend in the oil content of the water entering and leaving the separator.

At the start of deballasting, relatively large quantities of oil occur at the separator inlet; subsequently they decrease, but rise steeply towards the end of the operations when the oil/water interface is encountered. The corresponding pattern at the outlet of the separator is similar to that at the inlet, although the oil concentrations are considerably smaller, reaching a maximum of 400 to 600 p.p.m. in the final stages of deballasting. In three tests only (Ships A and D and one other not shown) did the separators operate to give an effluent less than 100 p.p.m. of oil during the final stages. In addition, it was noted throughout these tests, that, although the sizes of the oil globules in the mixtures at the inlets to the separators varied considerably, those examined in the effluents were in most cases smaller than 0·01-in. diameter, although in one or two instances particles as large as 0·032-in. diameter were encountered and in one test a 1/16-in. diameter globule was observed.

With regard to the effect of temperature, comparative tests were carried out on Ship D, when it was found that the maximum oil content of the water discharged when the ballast was at 16 deg. C. (60·8 deg. F.) was 300 p.p.m. as compared with 51 p.p.m. after the ballast had been heated to 52 deg. C.

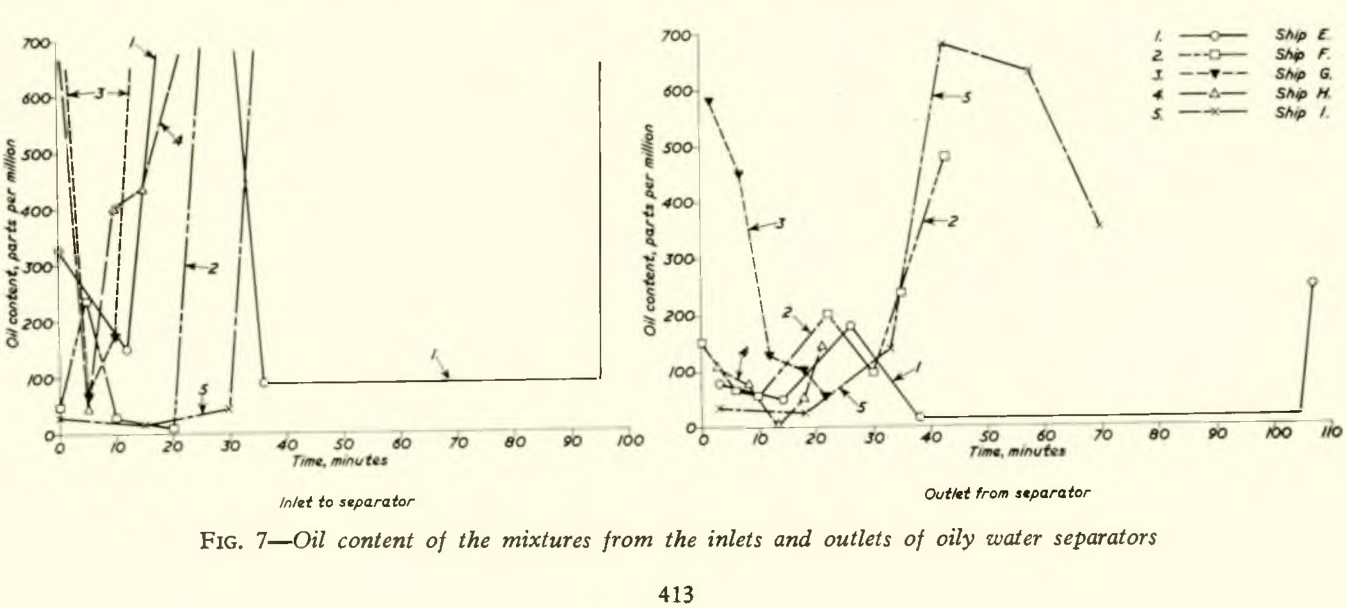


FIG. 7—*Oil content of the mixtures from the inlets and outlets of oily water separators*

(126 deg. F.). In this test the ballast was heated in the tank, although it may be preferable not to raise the temperature of the mixture until it has passed through the pump, so that disintegration of the oil can be kept to a minimum.

The best way of interpreting the curves is to describe in detail the complete sequence of a typical ballasting/deballasting operation, and to introduce at appropriate stages results obtained during the tests to support the observations made. When a fuel tank is emptied, the amount of oil remaining is determined by the design of the tank and the height of the end of the oil off-take pipe above the bottom. Obviously the trim of the vessel is involved in so far that a list or "down by head or stern" may result in a pocket of oil being left in the tank, and also, however efficient the removal may be, some oil will always be left adhering to the sides and strengthening members of the tank.

It is evident that the more oil that can be removed from the tank, the smaller will be the likely degree of the pollution hazard. Therefore, the end of the oil suction pipe should be placed as low as possible, either by placing in a sump, or else by fitting a bell mouth. Stripping lines would also be of great assistance here.

Tests carried out on Ship J are in support of this, for in one fuel tank a rubber bell mouth was fitted and in the other a sump was formed, in order that as complete a removal of the oil as possible could be effected. Twelve hours after ballasting these tanks with water, the layer of oil on the surface was less than 1/16-in. thick.

Further, after this period, an extensive exploration was carried out from the bottom of a tank, at 6-in. intervals, to within 3in. of the surface, and the maximum oil content observed was 8 p.p.m. Similar tests on Ship A showed oil concentrations of 23, 21, 61 and 31 p.p.m. and on Ship B, 19 p.p.m., and considering all the tests which have been carried out on deep tanks, it would appear that a typical ballast water may contain less than 100 p.p.m. of oil.

In addition to the oil left in the tank, a considerable quantity will be contained in the pipe lines, where it will remain during ballasting.

When deballasting commences, the relatively oil free ballast water passes through the suction lines to the pump and then to the separator. A large proportion of any oil lying in these sections of the deballasting system becomes entrained by the water as globules of various sizes and is carried forward. This explains the high oil content of the initial inlet samples in many of the tests (Ships B, E, G and H). As the operation proceeds, the oil deposited in lines and on pump surfaces or in pockets, and in some cases on surfaces inside the separator, is progressively stripped and the oil content of inlet samples decreases until the oil/water interface is reached. At this point in the final stages of deballasting, the mixture will contain a high proportion of oil, and, if an unsuitable type of pump is used, disintegration of the oil into small globules may take place in passing through the pump. If this occurs, the normal separator working at its rated throughput will fail to achieve satisfactory separation.

In support of this, the results obtained on a test rig using a disc and shoe type of pump are quoted: Samples taken at the inlet to the pump contained very coarse mixtures of oil and water which separated even while sampling. After passing through the pump the oil in the mixture was so disintegrated that samples appeared like ink, and separation could not be detected for at least 20 minutes after the samples had been taken. This mixture passed straight through the separator and one outlet sample contained 15,500 p.p.m. of oil.

On the ships' installations that were tested, it was observed that various types of pump were employed and that frequently any pump readily available in the engine room was used. In one instance the discharge from a centrifugal pump, with a rating above that of the separator, was throttled down to give the desired rating. Such a procedure is fatal. It is imperative to use the correct type and size of pump and this will be considered in detail in Part II of this paper.

Now, concluding the deballasting cycle, at this stage the suction lines, pumps, and certain parts of the separator can become heavily contaminated with oil, especially when the suction becomes exposed and the pump is shut down. These oil deposits usually remain in the lines and ancillaries between the tank and the separator, until the next deballasting operation, when they reappear to varying degrees as free oil in the inlet and outlet branches of the separator.

From the foregoing account it is apparent that the danger of causing pollution is greatest at the start and at the finish of the deballasting operation, and originates from the oil which has been trapped from a previous operation in the pump and lines, and from the bulk oil when the oil/water interface is reached.

Methods of Improving Separation Efficiencies

Commenting upon the ballasting/deballasting sequence just described, the first source of pollution mentioned can be eliminated by introducing a scheme whereby the ballasting and deballasting can be carried out entirely through the same system. This procedure provides a means of cleaning the pipe work and equipment between the separator and the fuel tank, any oil deposits being flushed back during ballasting into the tank, where they have ample time to separate before deballasting commences. During the initial stages of this operation the water should be introduced slowly until the pipe inlet in the tank becomes immersed, thus preventing any break-up of the oil caused by an exposed jet of water breaking through its surface.

Further, tanks and off-takes should be designed so that vortexing, and weiring over internal structures, does not occur, for this will cause break-up of the oil layer when the oil/water interface is approached. Also, where possible tanks should be pressed up in order to reduce the free space and so minimize the agitation, during rough weather, of any oil separating to the top.

The ease with which a separator will extract oil is governed directly by the size of the globules contained in the inlet mixtures. Consequently, it is of fundamental importance that suitable pumps should be employed, in conjunction with correctly designed pipe lines, to ensure that the disintegration of the oil in the system is reduced to a minimum.

Elevated temperatures increase the velocity of separation of globules of oil in water and may also be employed to improve the performance of separating systems. Obviously the economics of such a system would have to be considered.

CONCLUSIONS

The use of elevated temperatures and the production of large sized oil globules are both contributory factors in improving the operating of oily water separators.

Limitations in the operation of existing designs of equipment have been assessed theoretically and by practical observation; it would be unreasonable to expect particles smaller than 0·01-in. diameter to be arrested in a separator operating at its rated capacity, and the extent of pollution in the effluents when a large proportion of small globules was present frequently fell within a range of 400—600 p.p.m.

The degree of contamination of ballast water by oil varies throughout a deballasting cycle; it originates from deposits in pipelines and on the internal surfaces of pumps and separators, from residual suspensions of small globules, usually in concentrations less than 100 p.p.m. in the bulk of the ballast, and finally from the contamination at the interface between the water and the floating oil layer.

Pumps and other ancillaries may disintegrate the oil and so impair the effectiveness of the separator; further work is required to determine the most suitable types of ancillary equipment and the most effective methods of operation.

The series of field tests has given a broad picture of the position as it exists at present. The factors which must receive proper consideration when installing oily water separating plant are summarized below.

From design aspects, attention must be given to:

a) Means for removing as much oil as possible from tanks, by reducing the distance between the suction of the oil off-take pipe and the tank bottom, by fitting bell mouths to, or forming sumps at, oil off-takes.

b) The use of pumps which do not disintegrate the oil in a mixture of oil and water passing through them.

c) The advantages to be gained if the ballast could be heated economically, downstream of the pump, before it enters the separator.

d) A layout designed so that "back-ballasting" or ballasting through the separator can be carried out.

II. THE DISINTEGRATION EFFECT OF PUMPS ON MIXTURES OF OIL AND WATER

INTRODUCTION

From practical investigations carried out on oily water separating installations on shipboard, several factors which influence the satisfactory deballasting of ships were noted. In particular it was realized that the type of pump used for handling oily water had a direct influence on the efficiency with which the operation was carried out and therefore the choice of the most suitable equipment is of utmost importance.

Centrifugal and reciprocating pumps are in common use on shipboard, being used for many purposes, including the handling of bilge and ballast water. For the latter operations no special precautions are taken in the method of using pumps, and frequently any pump that is readily available is put into service. Often a small pump may be run at high speed in order to achieve a desired output, and conversely, a large pump, such as a centrifugal pump giving too high an output, may be throttled down on the discharge side. Such procedures can seriously increase the difficulties of removing oil from oily water.

The various types of commercially available oily water separators working at their rated throughput cannot deal with oil particles smaller than about 0·01-in. diameter. Thus it is possible that a mixture of oil and water, containing large oil globules that would easily be removed by an oily water separating installation, could be so disintegrated by passage through a pump that the oil globules would be below the critical size, and so be too small to be removed.

As the result of extensive enquiries it would appear that no work had been carried out, nor is any reliable information available, concerning the comparative disintegrating effects of various types of pump. Thus it was decided to investigate this problem. This entailed the design and construction of a special test rig, and also the adoption of particular methods to give an accurate determination of the size distribution of the oil globules in the water discharge.

Work was carried out in consultation with the manufacturers of the various types of pump being tested, so that all information concerning any pump would be available, and, further, it was arranged that a manufacturer's representative could always be present during a test, so that there was mutual assurance that the pump installation was satisfactory.

THE TEST PLANT AND PROCEDURE

Since full-scale tests on large equipments would involve very large storage tanks and supplies of large quantities of oil and water, and since the disposal of the oil/water mixtures would promote many difficulties, it was decided to work with pumps having a normal rated output of 10 tons/hr. A tank of 10-tons capacity was installed so that, if it should prove necessary, a run of one hour's duration could be undertaken or else a large number of short runs could be carried out in a day. Owing to the location of the Fuel Research Station, mains water was used instead of sea water, for the quantities involved were too large for regular transport.

A diagrammatic layout of the plant that was erected for carrying out the tests is shown in Fig. 8, and a photograph in

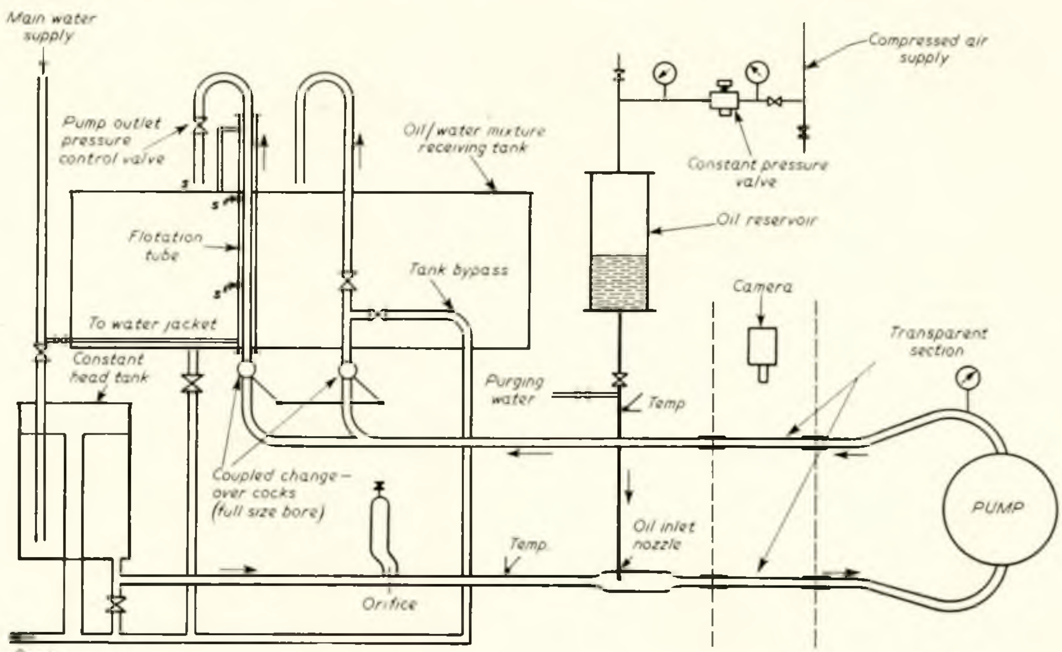


FIG. 8—*Diagrammatic arrangement of the pump testing plant*

FIG. 9—*Test plant*

Fig. 9, the tank, flotation tube, electric motor and ancillary equipment being set up permanently on a concrete base with facilities for coupling-up each pump to be tested.

Considerable attention was given to the layout of the pipework to ensure that disintegration of the oil was not caused by high flow velocities, sharp bends, or obstructions introduced by the installation of valves of an unsuitable design.

A system of valves was fitted so that the discharge from the pump could be piped directly into the reception tank or *via* a "Perspex" flotation tube, in which the particle size distribution of the oil could be determined. When no oil was present the water could be bypassed to the drain.

The oil was contained in an electrically heated cylindrical reservoir, and was introduced through a nozzle into the suction line; the rate of introduction was governed, knowing the temperature of the oil, by controlling the air pressure above the oil.

Horizontal sections of transparent Perspex piping connected to the inlet and from the outlet of the pump were arranged adjacent to each other, so that visual comparisons of the inlet and outlet mixtures could be made immediately and also recorded by still and cine photography.

Typical conditions are illustrated in Fig. 10, showing the oil entering the pump in the form of a continuous, slightly undulating rod about 5/16-in. diameter, moving with the water in the pipe, and leaving the pump as a disintegrated mixture.

In order to determine the size distribution of the oil globules in the mixture issuing from the pump, a section of the outlet mixture was isolated in the flotation tube by means of an interconnected valve system, and a flotation technique was applied. The pressure control valve in the line containing the flotation tube was fitted downstream of the tube, and had no effect on the break-up of the oil in the mixture of this section. Two sampling cocks were positioned at 26in. and 47in. above the bottom of the tube, which was 2-in. diameter and 66-in. long. A Perspex water jacket was built around the tube in order to prevent variations in the temperature of the contained liquid and so reduce any recirculating currents which would lead to inaccurate results.

The formulation of the flotation techniques and the establishment of the required sampling times are based on the fact that the velocities with which the globules of oil rise in water depend on their sizes. These velocities may be calculated, from well established formulæ, and used to establish a time schedule for taking samples from a point a known distance above the bottom of the flotation tube. Thus the oil in the samples taken will consist of globules of known upper size limit. By determining the amount of oil in each sample by extraction with benzene, evaporating the benzene and weighing, and substracting one from another in sequence, the amount of oil present within previously determined size ranges can be obtained.

The range of pumps selected for these tests includes widely varying designs in common use. Details of the pumps showing the conditions of operation at rated outputs, are given in Table II, and photographs, showing the construction of each equipment, can be seen in Figs. 11(a)—(j).

TABLE II.—DETAILS OF OPERATION OF THE PUMPS—DISCHARGE PRESSURES CONSTANT (15 LB. PER SQ. IN. GAUGE)

Type	Rate, tons/hr.	Speed, r.p.m.
a) Hypocycloidal	10	1,000
b) Centrifugal	10	1,050
c) Flexible vane	4·5	1,180
d) Disc and shoe	10	540
e) Diaphragm	6	60
f) Reciprocating	10	44 ds/m
g) Triple screw	10	960
h) Single vane	6·6	85
i) Double vane	10	315
j) Rotary gear	10	500

Each pump was allowed to run for a short period in order to expel air from the system and also to purge oil from the lines and test cocks. Performance characteristics were then obtained by varying the speed of the pump and observing the corresponding rates of delivery against a constant discharge pressure of 15lb. per sq. in. gauge. The effects on output were also noted for constant speed operation at various discharge pressures.

When preparing to carry out a test to determine the disintegration of the oil, simultaneous adjustments were made to

Oil in outlet from pump

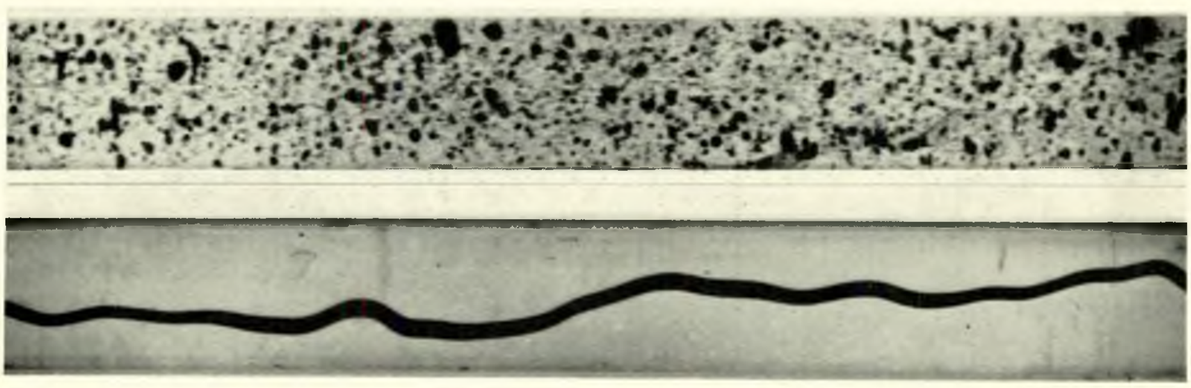
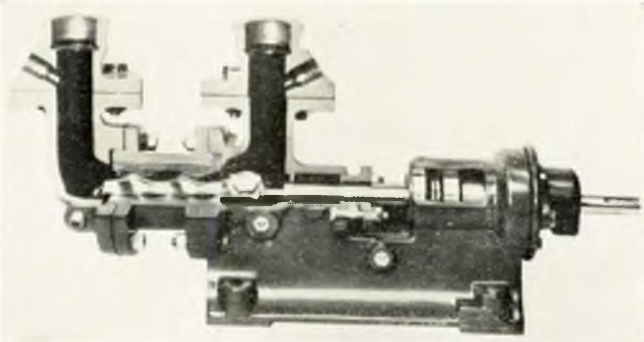
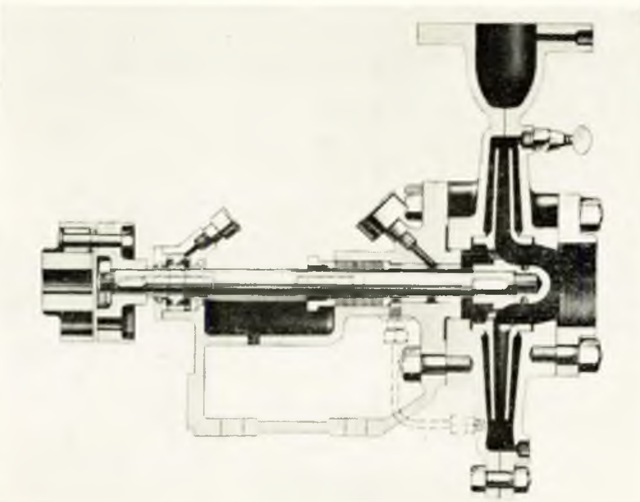


FIG. 10—*"Perspex" inspection tubes*

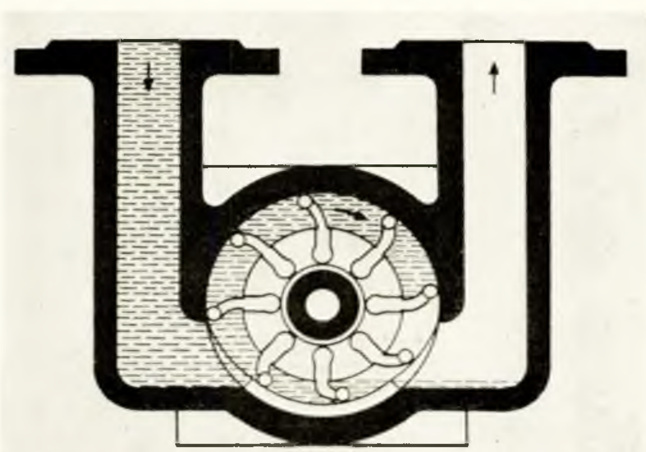
Oil in inlet to pump



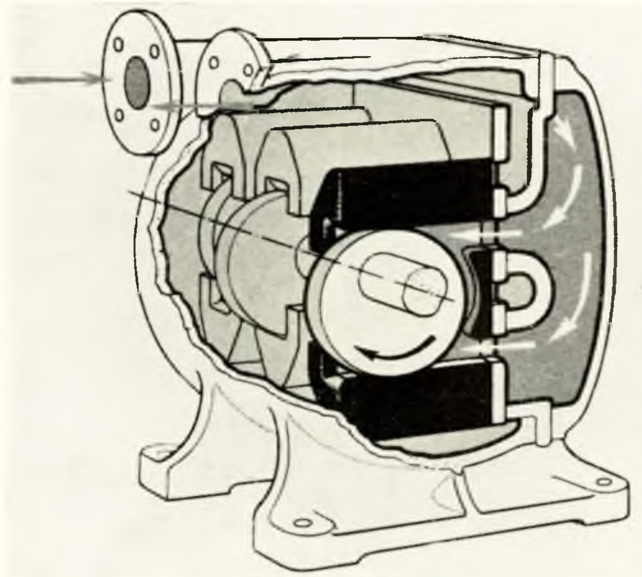
(a) Hypocycloidal



(b) Centrifugal



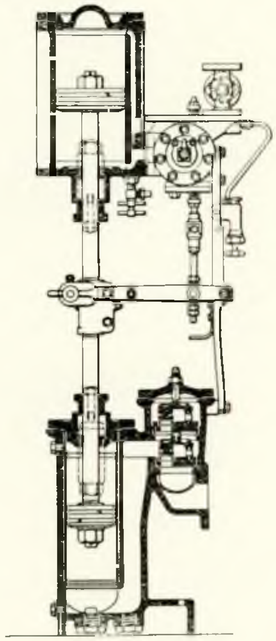
(c) Flexible vane



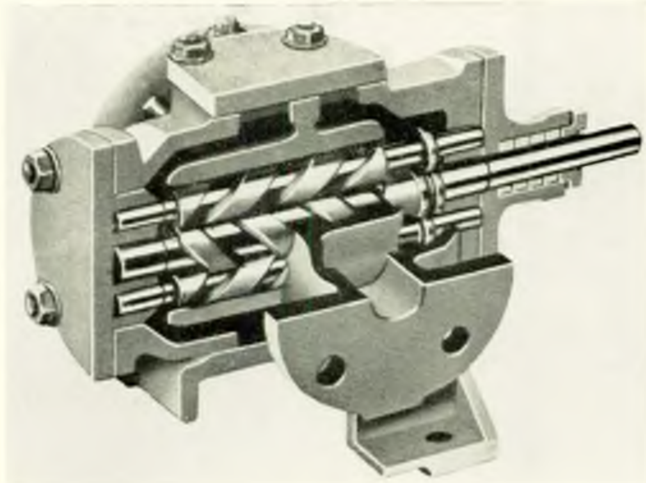
(d) Disc and shoe

(e) Diaphragm

Figs. 11(*a*)—(*e*)

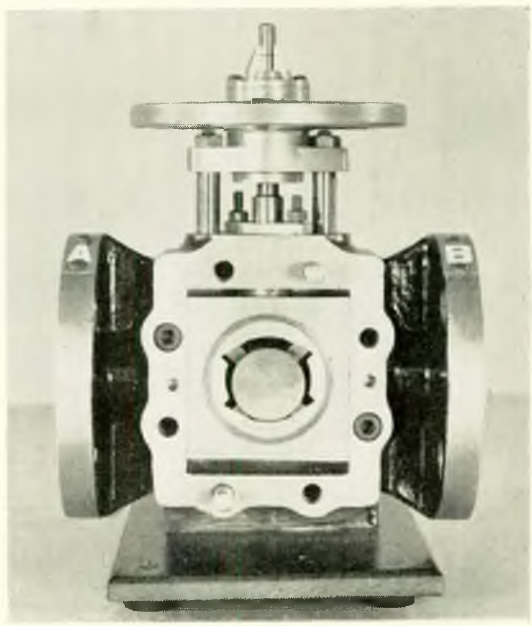


(f) Reciprocating



(g) Triple screw

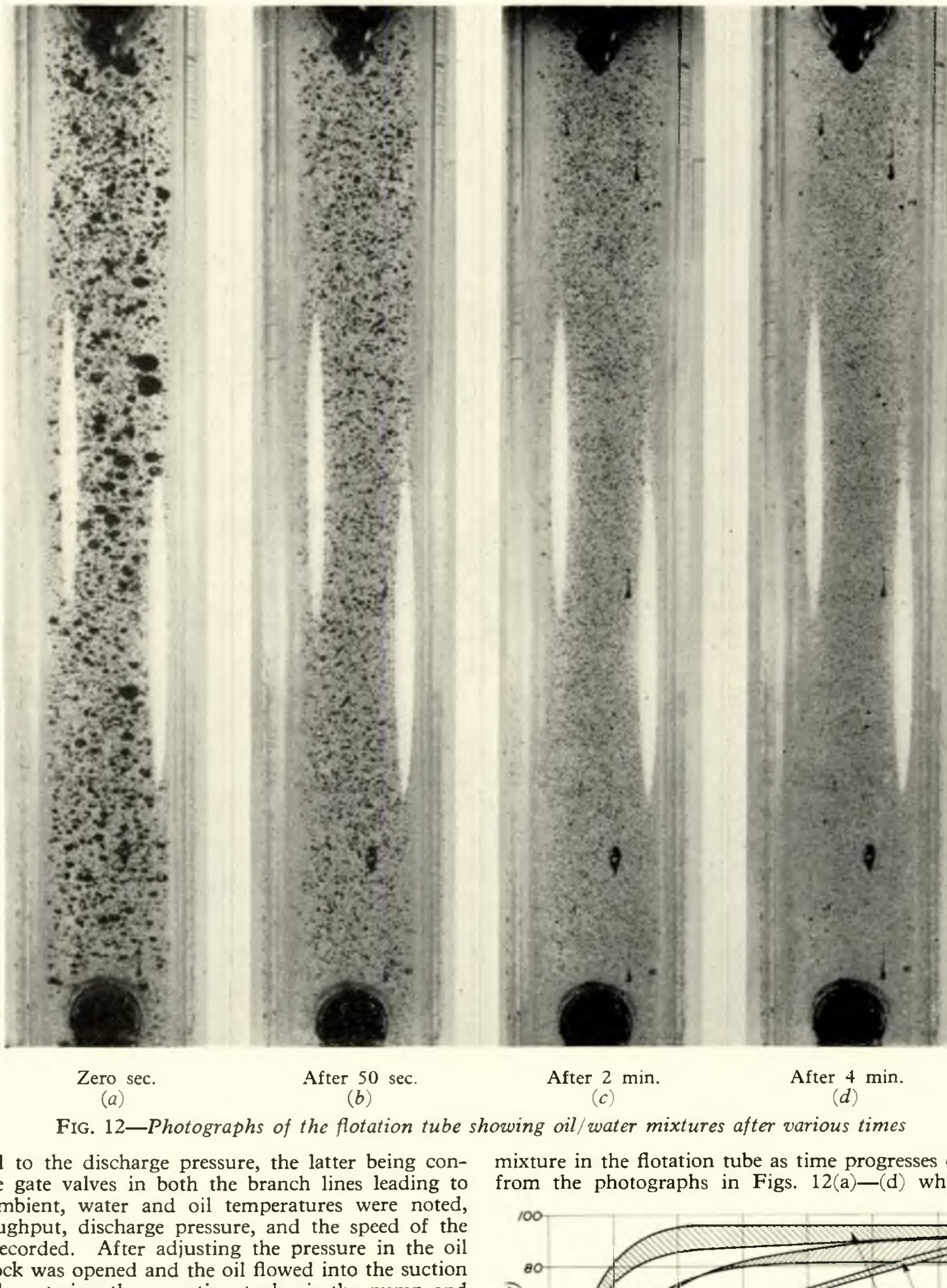
(h) Single vane



(i) Double vane

(j) Rotary gear

Figs. 11(*f*)—(*j*)



Zero sec. (*a*) — After 50 sec. (*b*) — After 2 min. (*c*) — After 4 min. (*d*)

FIG. 12—*Photographs of the flotation tube showing oil/water mixtures after various times*

the speed and to the discharge pressure, the latter being controlled by the gate valves in both the branch lines leading to the tank. Ambient, water and oil temperatures were noted, and the throughput, discharge pressure, and the speed of the pump were recorded. After adjusting the pressure in the oil container a cock was opened and the oil flowed into the suction line, eventually entering the reception tank *via* the pump and the flotation tube.

When steady conditions were attained and the composition of the mixtures flowing through the Perspex inspection tubes appeared to be consistent, a sample was collected at the discharge from the flotation tube. Immediately following this operation the bypass valve, cutting off the flow to the flotation tube, was operated and a stop watch started. The globules of oil in the mixture trapped in the flotation tube began to separate at once, with velocities depending on their size. Samples of the mixtures were taken from the upper test cock after periods of 35 sec., 1 min. 20 sec., and 7 min., and a final sample taken from the lower test cock after 20 minutes.

An impression of the changes in the composition of the mixture in the flotation tube as time progresses can be obtained from the photographs in Figs. 12(a)—(d) which were taken

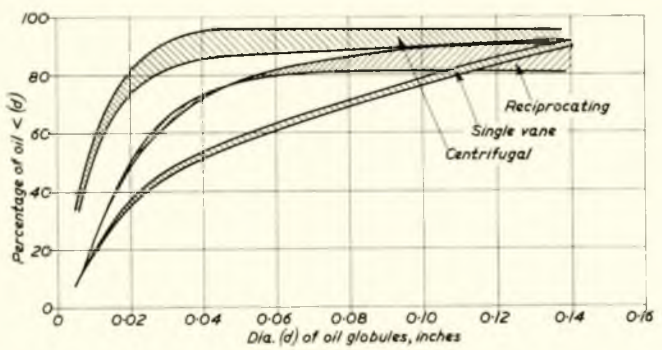


FIG 13—*Size distribution curves illustrating reproducibility of results*

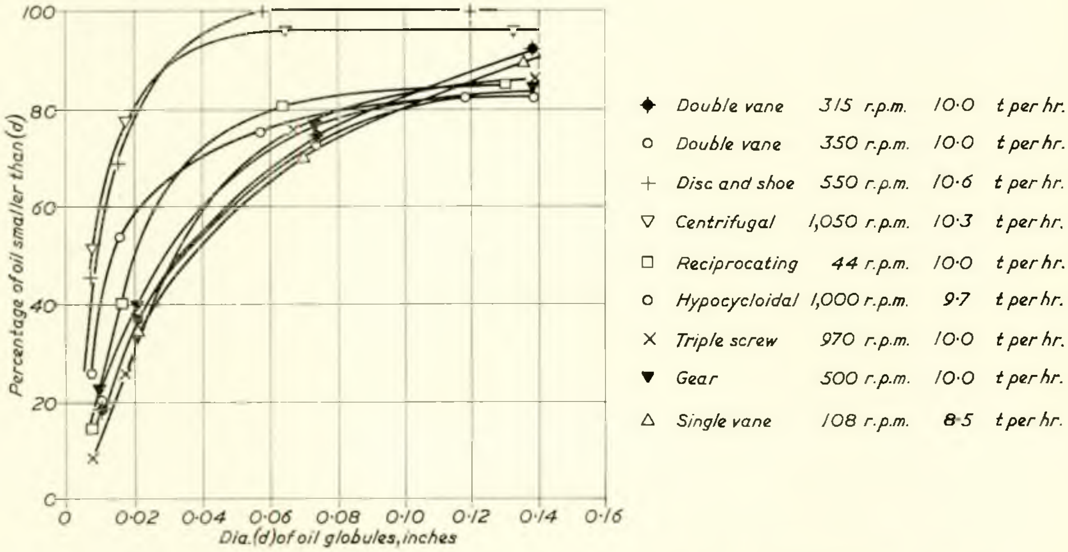


FIG. 14—*Comparative size distribution curves for the oil in the discharged mixtures from pumps operating at rated loads (discharge pressure 15lb./sq. in.)*

0 secs., 50sec., 2 min., and 4 min. respectively after operating the changeover valve.

Each pump was tested in the manner described, and repeat tests were carried out, in order to determine the accuracy of the methods employed.

The results from these tests have been expressed graphically to indicate the globule size distribution of the oil in the mixtures discharged from the pumps. In each case the curves were reasonably consistent and the results of three sets of duplicate determinations are shown in Fig. 13, where the limits of accuracy lie within the shaded portions. Similar accuracies were obtained in tests on the other pumps.

DISCUSSION OF RESULTS

Many factors are involved in the break-up of the oil in mixtures as they pass through pumps. Excessive velocities and accelerations, caused by restricted ducts and rapid changes in direction, or by inadequate cut-off areas through valves, are responsible for much of the disintegration. In particular, tests which have been carried out on a single valve from a reciprocating pump have shown that a major portion of the disintegration in this pump is caused as the mixture flows through this part of the equipment. Similarly, the reduced area of the discharge valve and the "chopping" action of this valve in the "disc and shoe" pump is held responsible for the considerable break-up of the oil which occurred.

With most of the pumps tested a certain amount of "slip" or leakage, dependent on the pressure differential, occurred between the discharge and suction branches. The degree of "slip" was determined for each pump under all test conditions, but specific tests to determine its effect on the disintegration of the oil were not undertaken.

With the double-vane type of pump the throughput could be controlled by varying the eccentricity of the rotor. Tests have shown that this method of control is inadvisable and better performances may be obtained by speed control with the rotor set at maximum eccentricity.

The effects of varying speeds and discharge pressures could not be investigated on the diaphragm pump because of limitations imposed by the strength of its casing. However, the limited results obtained indicate its unsuitability for use in deballasting operations.

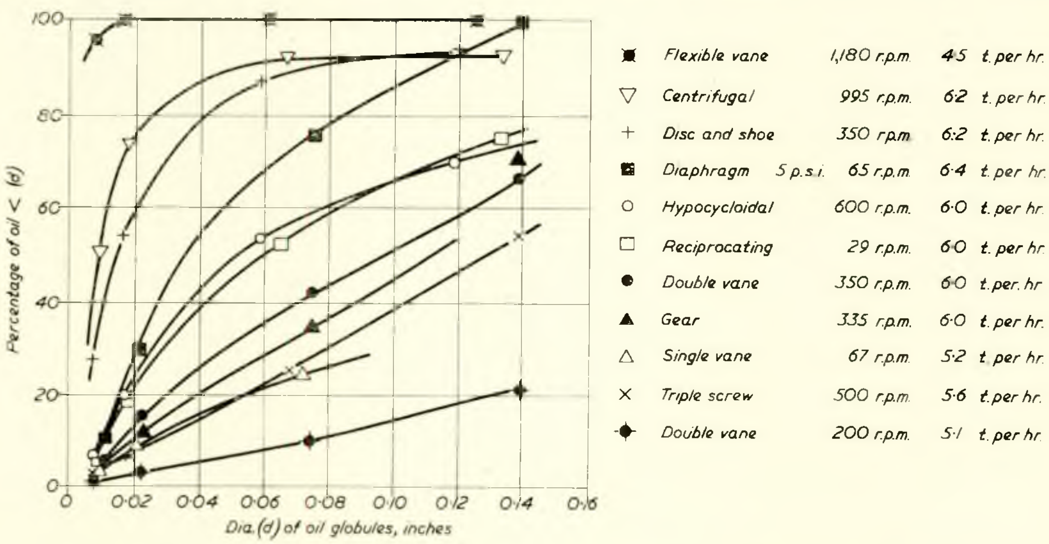


FIG. 15—*Comparative size distribution curves for the oil in the discharged mixtures from pumps, operating at reduced loads (discharge pressure 15lb./sq. in.)*

Apart from a few unavoidable exceptions, the pumps tested were rated to discharge 10 tons/hr. of water against nominal pressures varying between 15 and 30lb. per sq. in. gauge. The first results to be examined, therefore, will be those obtained at this throughput and a common discharge pressure of 15lb. per sq. in. gauge.

The size distribution curves of the oil globules in the resulting mixtures from the pump outlets are shown in Fig. 14, where the coarser and more acceptable mixtures are represented by the lower curves.

It is considered that the critical size range of oil globules adversely affecting oily water separator performance lies between 0 and 0·01-in. diameter. By examining these curves within this range, the pumps may be placed in order of increasing disintegrating tendency.

The discharge from the screw pump contained the coarsest size distribution, in which as little as 12 per cent of the oil appeared as globules smaller than 0·01-in. diameter. By comparison, the single-vane type produced 20 per cent, the double-vane 21 per cent, the rotary gear 22 per cent, the reciprocating 24 per cent, the hypocycloidal 40 per cent, and the disc and shoe and centrifugal pumps each discharged 56 per cent of the oil as globules smaller than 0·01-in. diameter.

Comparable conditions could not be achieved in this series of tests with the flexible vane and the diaphragm pumps, owing to limitations imposed by their design; however, these pumps will be considered later when derated conditions are discussed.

Although the performance of the vane, screw and rotary gear types of pump were comparatively good, it is considered that better results are required, and these could be achieved by derating each pump. Consequently, further comparisons at flow rates of 6 tons/hr. are presented in Fig. 15.

Here the order of efficiency is similar to that indicated previously for nominal flow rates of 10 tons/hr., although the single, double-vane and screw types have changed their relative positions.

For greater clearness the results for the two rates of discharge are presented in Table III.

TABLE III

Pump	Percentage of oil as globules smaller than 0·010-in. diameter	
	Rate, 10 tons/hr.	Rate, 6 tons/hr.
Triple screw	12	3
Single vane	20	4
Double vane	21	1
Rotary gear	22	5
Reciprocating	24	9
Hypocycloidal	40	11
Diaphragm	—	12
Disc and shoe	56	36
Centrifugal	56	56
Flexible vane	—	98

The percentage of oil appearing as globules smaller than 0·01-in. diameter in the discharges from each pump, when operating at various speeds, is shown in Fig. 16. These curves have been plotted in order to present a continuous record of the relative disintegrating effects of each pump, and although true comparisons can be made within the range of these tests, extrapolations beyond these limits cannot be carried out with confidence.

Without exception, with each pump there was less disintegration of the oil at lower speeds and consequently with lower throughputs.

The effects of increases in discharge pressure on the disintegration of the oil were not generally consistent. In tests on the disc and shoe, the centrifugal and the double-vane pumps, definite increases in the disintegration of the oil were recorded as the discharge pressure was increased. The trends in the results from the remaining pumps (excluding the reciprocating pump) were not positive and it is considered that in

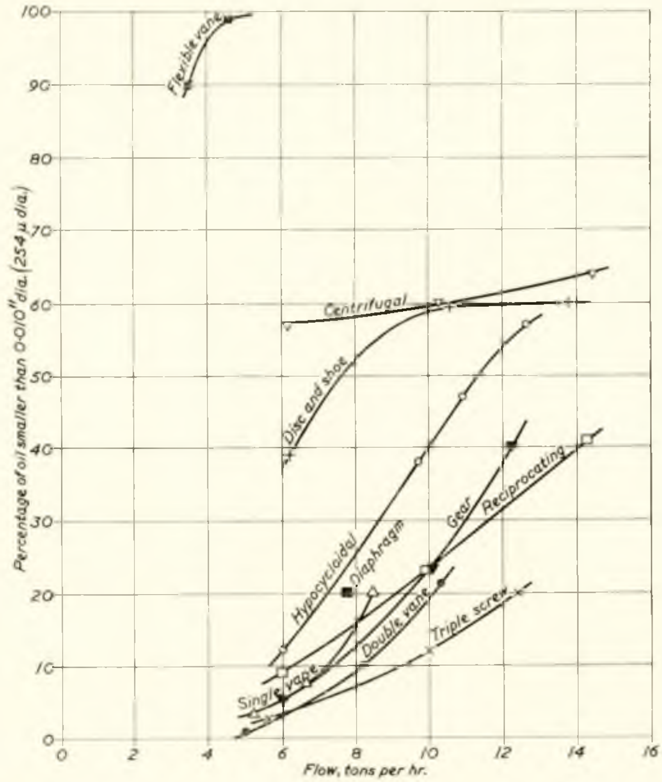


FIG. 16—*The effect of varying speed and throughput on the disintegration of the oil in the mixtures discharged*

these cases, the disintegration caused by the speed of the pumps obscured any effects resulting from changes in discharge pressure. However, it would be reasonable to expect more pronounced trends from pressure variations when lower operating speeds are employed and to suggest that these would follow the patterns already indicated in the results from the other equipments, i.e. the disintegration would increase as the discharge pressure is increased.

The converse was found to be true with the reciprocating pump, which gave better performances at higher discharge pressures; the more positive action of the valves was thought to be responsible for these results.

The figures shown in Table III and the curves reproduced in Figs. 14, 15 and 16 show the superiority of the single and double-vane, the rotary gear and the triple-screw pumps as compared with the remainder.

Although the performances of the hypocycloidal and the reciprocating pumps were inferior in comparison with the above, with modifications they may produce acceptable results. For instance, modifications to the valve gear would most certainly improve the reciprocating pump, while an acceptable performance may be achieved with the hypocycloidal type if the flow paths are streamlined and larger pockets provided between rotor and stator, and reduced rotor speeds are employed.

The remaining pumps caused excessive disintegration of the oil and so cannot be recommended in their present form for pumping oily ballast to oily water separators.

CONCLUSIONS

The flotation method developed for the determination of the size distribution of globules of oil in water proved to be satisfactory for enabling assessments to be made regarding the disintegrating effect of various types of pump.

Invariably the efficiencies of the pumps tested were related to the speed of operation, other conditions being constant, and the degree of disintegration of the oil decreased with the speed, and consequently with the output of the pump. It was not possible to separate the effects of these two variables (speed and output), although the results from the tests on the double-vane pump indicated that both factors were responsible to a similar degree for the disintegration of the oil.

To some extent, the results indicate that higher discharge pressures tend to produce more slip and greater disintegration of the oil, therefore the layout of deballasting installations should be arranged so that the discharge pressure is reduced to a minimum. Low speed pumps of ample dimensions, having smooth flow paths free from obstructions, must be employed, if the break-up of oil contained in oily ballast water is to be reduced to a minimum.

Considerable attention must be paid to the design of valves, for they can cause extensive disintegration of oil in oil/water mixtures flowing through them.

None of the pumps, operating at their normal rated capacities, was considered suitable for pumping oily water mixtures to separators, although their performances could be assessed relatively and the most satisfactory types noted. However,

TABLE IV

Order	Type	Remarks
1	Double vane	Satisfactory at 50 per cent derating
2	Triple screw	Satisfactory at 50 per cent derating
3	Single vane	Satisfactory at 50 per cent derating
4	Rotary gear	Satisfactory at 50 per cent derating
5	Reciprocating	Not satisfactory: modifications may improve efficiencies to "Satisfactory" level
6	Hypocycloidal	
7	Diaphragm	Unsatisfactory
8	Disc and shoe	
9	Centrifugal	
10	Flexible vane	

with lower speeds and with reduced outputs, the performances of all the pumps were improved. Further, the performances of the most satisfactory types fell within acceptable limits when pumping at 50 per cent of their rated capacities, and consequently these pumps operating under a 50 per cent derating factor have been recommended.

The pumps tested are listed in Table IV and classified in order of suitability.

RECOMMENDATIONS

From the experience gained in carrying out this work and from the assessment of the results, certain requirements for the design of a deballasting pump have been noted.

It is desirable to employ a low speed, positive displacement pump, dimensioned to reduce the velocity of flow to a minimum, particularly at points of cut-off, and designed to promote streamlined flow in all sections.

Valves provide sources of turbulence and faces to which oil may adhere and should be excluded if possible. When valves are incorporated in a system, extreme care must be taken in providing a design which does not promote the break-up of the oil.

Smooth continuous flows should be achieved, as they reduce the maximum velocities and accelerations, and consequently the forces and vibrations set up in the pump and pipe lines.

Further, considerable attention must be devoted to the installation of a pump, for although the design of pipe work is outside the intended scope of this paper, other tests have shown that the degree of disintegration of the oil may be affected by high flow velocities and the types of bends employed. The valves installed should be of the full bore type, and should be operated in the fully open or fully closed positions only. They should not be employed as regulators.

III. INVESTIGATIONS LEADING TO THE DESIGN OF AN OILY WATER SEPARATOR/FILTER UNIT FOR INSTALLATION IN CARGO AND PASSENGER SHIPS

INTRODUCTION

The majority of separators, fitted in cargo vessels, depend entirely upon the difference between the specific gravity of the oil globules and of the contaminated water for the efficient separation of these two liquid phases. In practice this difference is relatively small, being normally of the order of 0·06, and in extreme cases, when exceptionally heavy oils are encountered, it could be as low as 0·03. It is certain that, under such conditions, the forces effecting separation are by no means positive and only slight changes in operating conditions will adversely affect the performance of these equipments. This is true, especially when small globules of oil are produced in the mixtures to be cleaned.

Tests carried out on shipboard installations have confirmed these observations and it has been shown that effluents from oily water separators, operating under practical conditions, may contain as much as 400 p.p.m. of oil. Consequently, other more positive methods of separating oil from ballast water have been examined.

Filtration is a commonly accepted method for the efficient removal of particles from fluids. However, with certain types of pollution and filter materials, difficulties are often encountered when the filter has to be cleaned. For example, a polluted filter cloth cannot always be cleaned successfully by "blowing back" or "back steaming", especially when uneven displacement of the pollutant occurs, and the cleaning fluid breaks through one localized area only.

Filter beds of granular materials are highly efficient, and are commonly used in land based filter units; but, again, the bed eventually becomes impregnated with the extracted material and often has to be dug out and renewed. This operation is arduous and detracts from the advantage of the highly efficient filtering action of the medium; an added problem arises in disposing of the fouled material.

If a suitable method of cleaning a pebble bed filter could be evolved, its use for the separation of oil/water mixtures has many advantages; the material is cheap and readily available; it is extremely efficient as a filter; and can be employed in depth without excessive pressure drop and with a corresponding increase in efficiency; it is strong and it is not easily disintegrated, and would therefore have a long life.

With these aspects in view it was decided to examine a fluidized bed technique for cleaning such a filter, and to determine its performance under varying conditions of operation.

LABORATORY TESTS AND INVESTIGATIONS

Initially, a suitable design of separating plant, incorporating the filter, had to be envisaged and a practical operating schedule proposed as a basis upon which the laboratory test work could be carried out.

For shipboard applications the separator should be simple

N.B. The method of cleaning the filter is the subject of a Provisional Patent Specification.

and easy to manufacture, and its size should be similar to, or smaller than, equivalent units already in use. It was decided to consider an equipment comprising two major sections; a settling chamber, in which the larger globules of oil would have an opportunity to settle out, and a pebble bed filter section, in which the smaller particles would be extracted before the effluent is discharged.

The size of the filter should be sufficient to contain at least as much oil as would be discharged in one cycle without promoting excessive back pressures. Consequently, a convenient procedure for cleaning the filter after each operation must be developed.

The layout of the separator/filter unit proposed and the method of cleaning the filter are described below. The unit comprises two sections; a settling chamber into which the oil/water mixture is introduced, and where the larger oil particles separate under gravity, followed in series by a filter section where the particles of oil remaining in the water are extracted. Both sections are contained in a common shell.

Proposed Procedure for Cleaning Filter

The six stages involved in cleaning the filter are described below and are illustrated in Figs. 17(a)—(f).

a) Transfer oil from the settling chamber to an oil reception tank.

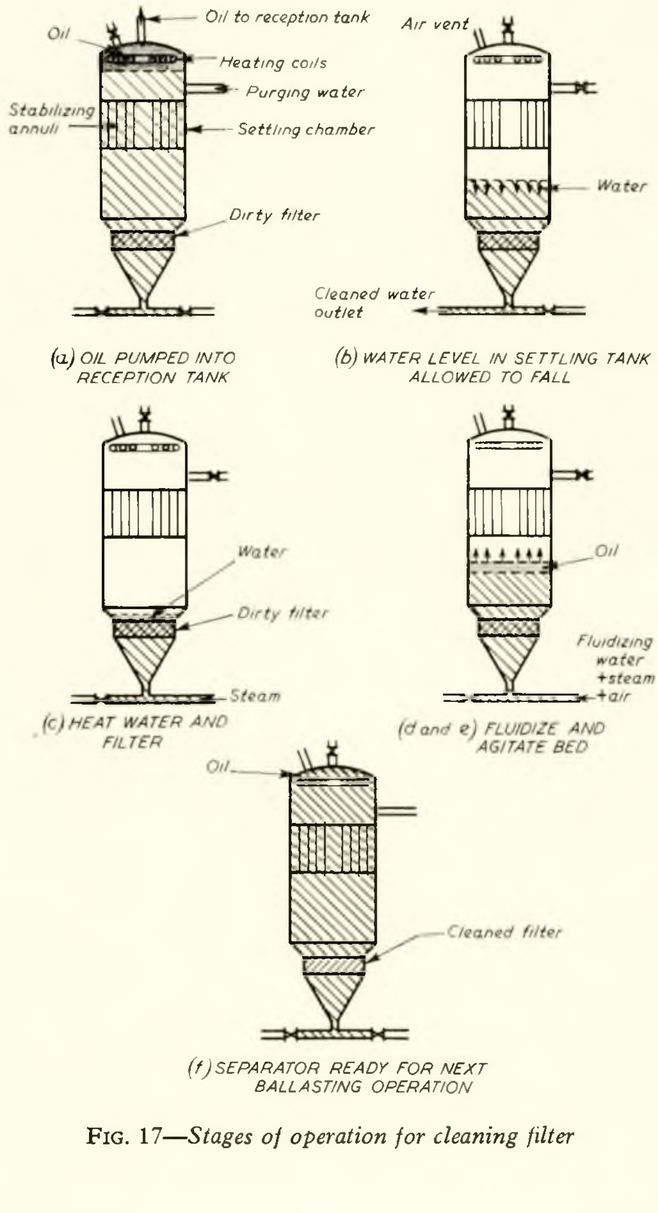


FIG. 17—*Stages of operation for cleaning filter*

b) Allow the level of water in the settling chamber to fall down to within 1 or 2in. of the filter bed, the water being run off through the filter.

c) Close the clean water outlet valve, and introduce steam into the exhaust side of the filter until the water and the filter are sufficiently heated.

d) Introduce hot water (water and steam) from the exhaust side of the filter into the settling chamber. The quantity of water should be sufficient to fluidize the pebble bed, thereby freeing any trapped oil.

e) Pass air through the fluidized hot filter bed to increase the agitation until all the oil is liberated into the settling chamber.

f) Refill the separator with water in preparation for the next deballasting operation.

Before this procedure could be adopted, many variables were investigated to determine its practicability and also to obtain data for design purposes. Such factors as size of pebble, depth of bed, back pressure set-up by the bed, capacity of the bed for retaining oil, quantity of water required for fluidizing, the amount of agitation required for cleaning, and the effectiveness of cleaning techniques, all required investigation.

Qualitative Tests on a Pebble Bed Filter, 2-in. Diameter and 12-in. Long

Before embarking on an extensive series of tests, initial qualitative investigations were made to prove the practicability of the proposed fluidized bed technique for cleaning a pebble bed.

Attention was first given to the particle size of the medium to be used. A small-grained bed would provide efficient filtration and would be fluidized by small mass flows of water, but when impregnated with oil the combined specific gravity might fall below unity, and a considerable quantity of the filter material might float off with the oil. Conversely, with coarse material, the filtration efficiency would decrease; also, comparatively large quantities of water would be required to fluidize such a bed. This factor would impose severe limitations on the design of the settling chamber, which must be proportioned to contain all the contaminated fluidizing liquid, as well as providing efficient settling conditions in the deballasting stage of the operations. After due consideration, pebbles ranging in size from 1/8in. to 1/16in. were chosen, and a bed of this material was contained to a depth of 1ft. in a vertical tube of 2-in. diameter × 3-ft. long.

An apparatus, designed to supply oil/water mixtures consistent in particle size distribution and composition, was employed to provide mixtures for all the laboratory tests. The particle size distribution of the oil in the test mixtures produced throughout these investigations is indicated in Fig. 18. It will

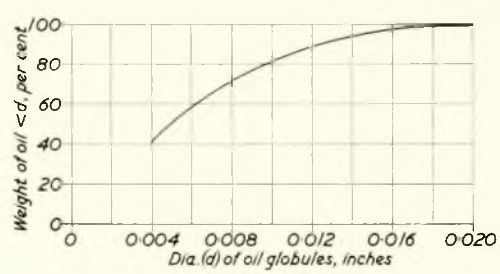


FIG. 18—*Particle size distribution of oil in test mixtures*

be realized on examining this graph that extremely fine oil particles were produced and that conditions in the tests were severe compared with those in practice, where coarser particle size distributions are encountered.

An oil/water mixture was introduced into the top of the tube, the oil being retained in the filter and the cleaned effluent passing from the bottom of the bed.

The contamination gradually extended evenly from the top of the bed down its length, and was easily discerned by a clearly defined line which extended across the section of the bed between the contaminated pebbles and the clean pebbles. Subsequent examinations showed that more than 95 per cent of the extracted oil was contained, and evenly distributed, in the visibly polluted band in the top section of the bed.

The water leaving the apparatus was extremely clear and no traces of oil could be seen, although its presence could be detected by smell.

Following the predetermined cleaning procedure, the water in the tube was allowed to fall to a level just above the top of the pebble bed, and steam, introduced from the clean water side, was passed into the bed to raise its temperature. At a temperature of approximately 70 deg. C., quantities of oil in the form of globules, measuring up to ½-in. diameter, left the bed and floated to the surface of the water. Subsequently water was introduced with the steam when the bed became fluid and further quantities of oil were released. Finally, air was passed upwards through the bed to agitate it and complete the cleaning of the material and the sides of the container, so that all traces of oil were removed from the filter.

The high efficiency with which the filter extracted the fine globules of oil, and the comparative ease with which the oil coalesced and was subsequently completely released by the fluid bed technique, indicated the practicability of the method, and so tests of a more quantitative nature were considered worth while.

Filtration Tests

Initially the quantitative tests were carried out on a 2-in. diameter bed to determine the pressure drops, flow quantities, and the optimum conditions required to operate a pebble bed filter. Subsequently, further tests on an 8-in. diameter bed were undertaken, as an intermediate stage, to indicate the effects on performance of "scaling up" prior to building and testing a practical separator unit.

The results from these two units will be reported simultaneously to assess comparisons and to eliminate repetition.

Fig. 19 shows the diagrammatic layout of the test equipment.

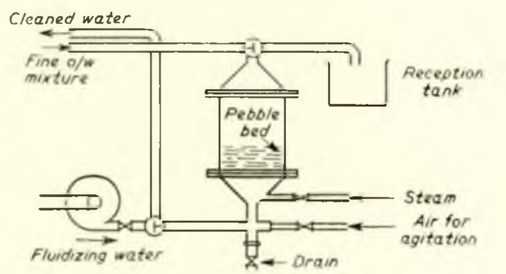


FIG. 19—*Apparatus for filtration and fluidization tests*

Rate of Penetration of Oil through the Bed

The speed with which the oil penetrates the filter medium is indicated in Fig. 20, where the visible thickness of the oil band has been plotted at various time intervals for a 2-in. diameter and an 8-in. diameter bed.

The conditions in each case are similar and are indicated on the graph. The rates of growth of the oil bands are almost identical. The slightly smaller gradient of the line relating to the 2-in. diameter bed may be attributed to the slightly lower rates of flow.

These results indicate that the rate of penetration of oil through a pebble filter is constant, and apparently is independent of the filter diameter. Further, under the conditions of these tests, the 8-in. diameter and 2-in. diameter filters retained 0·0062 and 0·0063lb. of oil/cu. in. of contaminated filter respectively—the pollution in the effluent being 19—20 p.p.m.

In most cases the initial rate of penetration was slightly higher than the average rate; this is attributed to the fact that filtration improves after a layer of compacted oil has been

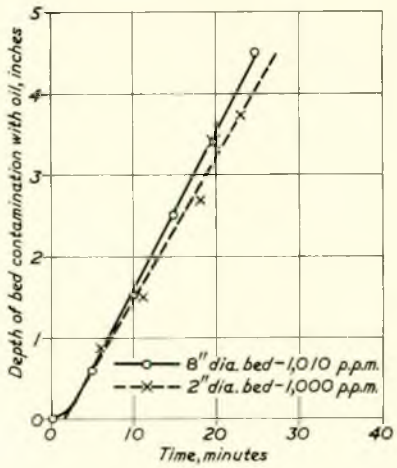


FIG. 20—*Rate of increase in the depth of contamination in 2-in. and 8-in. diameter pebble beds*

deposited in the bed; thereafter, globules of oil have less freedom, and immediately on entering the bed they combine with the oil mass and lose their identity as single particles.

Pressure Drops across Oil Contaminated Beds

The pressure drops across the 8-in. diameter and 2-in. diameter filters were taken at intervals during tests in which equal flow velocities were employed. The results have been plotted in Fig. 21. From the relative disposition of the result-

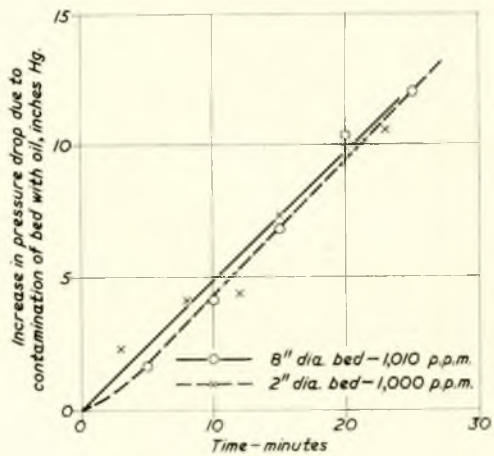


FIG. 21—*Increases in pressure drops due to oil contamination of 2-in. and 8-in. diameter pebble beds*

ing straight line graphs, it is seen that the rate of increase in pressure drop is constant at about 0·5-in. Hg./min. and is independent of the diameter of the filters.

Normally, pressures up to 15lb. per sq. in. gauge (30in. Hg.) are employed in separating tanks, and therefore, the inclusion of a filter would not impose additional strains or power requirements on existing systems.

Effect of Flow Rate and Oil Content of the Mixtures on the Rates of Penetration of Oil through the Filter Bed

In Fig. 22 the product of oil content (p.p.m.) in the mixture and the flow rate (cu. ft./hr.) has been compared with the linear rate of growth (in./min.) of the visible oil band at the top of the pebble bed. A certain amount of scatter of the plotted points has resulted, but nevertheless a linear relationship is apparent and indicates that the rate of oil supply is directly responsible for the rate at which the oil penetrates the bed.

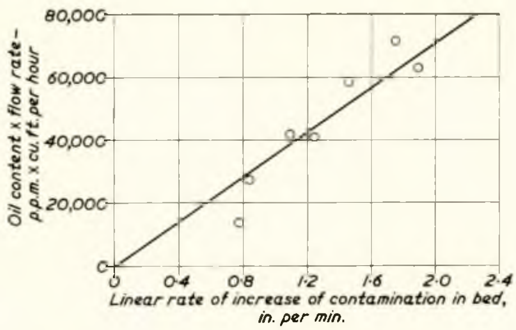


FIG. 22—*Increase in depth of contamination of pebble beds with varying rates of oil supply*

Effect of Pebble Size on the Efficiency of Filtration

The size of pebbles used for these initial tests varied between 1/16in. and 1/8in.; this range was chosen arbitrarily and gave satisfactory results when dealing with mixtures containing up to 1,000 p.p.m. of finely divided globules of oil. The results of further investigations are shown in Table V. Here the contamination in the effluents from three beds, each fed with similar mixtures but each comprising a different pebble size, are tabulated. The efficiency of extraction can be seen to improve with decreasing size of pebbles. However, when other factors, such as pressure drop and the retention of the bed within the system, are considered, the size range 1/8in. to 1/16in. appears to be the most satisfactory, although more extensive tests may indicate a slightly different optimum size.

TABLE V.—EFFECT OF PEBBLE SIZE ON FILTRATION EFFICIENCY

Size of pebbles, in.	Oil content of inlet mixture, p.p.m.	Oil content of effluent, p.p.m.
1/32—1/16	810	4
1/16—1/8	1,025	21
1/8 —1/4	1,200	280

Effect of the Size of Oil Globules on Efficiency of Filtration

Mixtures containing similar amounts of oil but having different globule size distributions were fed at similar rates through a 1/16-in.—1/8-in. pebble bed filter. When 80 per cent of the oil in the mixture was introduced as globules smaller than 0·01-in. diameter and in concentrations of approximately 1,000 p.p.m., the maximum pollution in the effluents in a number of tests ranged from 13 to 29 p.p.m.

No pollution was detected in the effluent when a coarser mixture (10 per cent of the oil as globules smaller than 0·01-in. diameter) was introduced into the equipment.

It would appear therefore that the efficiency of operation of the filter bed is dependent on the size of oil globule presented, but that even under extreme conditions, when finely divided mixtures are formed, the pollution in the effluent would not be expected to exceed 30 p.p.m.

Effect of Depth of Filter Bed

Most of the oil extracted by the filter collects in the top section, its density of distribution being 0·006 to 0·007lb./cu. in. of filter. Consequently, assuming the volume of the bed sufficient to contain the extracted oil, further increases in the depth of the bed provides comparatively slight improvement in filtration efficiency.

Obviously the pressure drop across the filter bed will be influenced directly by its depth, but, within practical limits, it will be small compared with the resistance set up by the contained oil, and with the resistance automatically imposed on the separator by control valves.

Fluidization and Cleaning Tests

The fluidized bed technique has already been demonstrated as a satisfactory method of freeing oil from a pebble bed filter. For the best results it is necessary to employ a system which promotes an evenly fluidized bed. A number of variations were investigated and these are illustrated in Figs. 23(a)—(d).

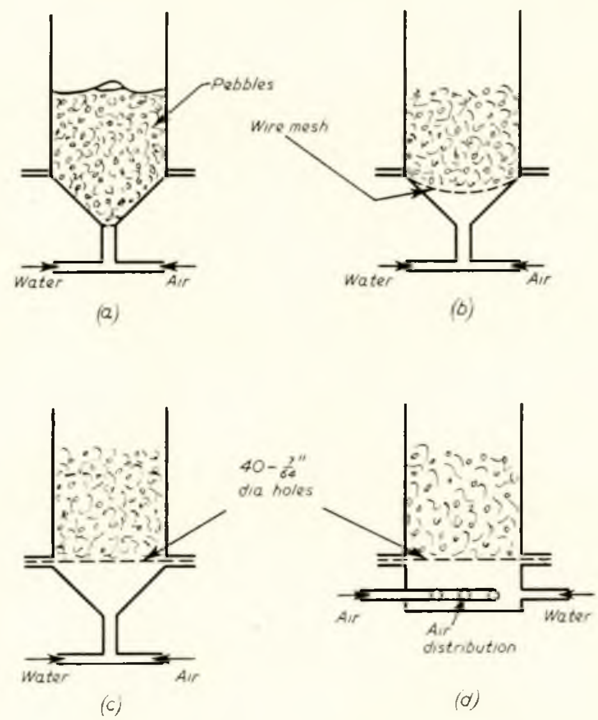


FIG. 23—*Methods of supporting pebble bed*

The system shown in Fig. 23(a) promoted uneven flows, most of the bed being in a semi-fluid state with a highly fluidized mobile column moving through it.

The curvature of the supporting wire mesh in the arrangement shown in Fig. 23(b) caused uneven water distributions, and only local fluidization could be achieved at the sides of the tube. Fig. 23(c) illustrated a most suitable arrangement which, with correctly positioned holes in the perforated plate, provides an evenly distributed fluid bed.

In practice, due to space limitations, it would be advantageous to replace the conical entry with a less bulky type and so the system indicated in Fig. 23(d) was tested. In this case the flow patterns were not so evenly distributed as those produced by the cone, although they were considerably superior to those resulting from the first two systems. It is considered that with slight modifications this system could be developed to give satisfactory operation.

Both of the arrangements indicated in Figs. 23(c) and 23(d) have been employed in the tests on the 8-in. diameter bed.

With the proposed arrangement, the fluidizing water will be contaminated with oil and must therefore be contained in the settling chamber of the separator unit. Consequently the practicability of this unit will depend largely on the total quantity of water required to complete the cleaning operation, as this will determine the major dimensions of the separator. It was proposed to employ steam, air and water to provide heat, agitation, and fluidization in the process. The effects of each of these media on the 1/16-in.—1/8-in. pebble bed were investigated separately.

It was not possible to fluidize the bed using air or steam alone, and in each case the water was blown out of the bed.

With water alone, various conditions of fluidization were noted. With a flow rate of 52lb./hr./sq. in. of bed, areas of local fluidization were promoted at the top and bottom of the bed and, as the water supply was increased to 80lb./hr./sq. in. the areas of fluidization extended until the top and part of the lower sections of the bed became fluid and the bed expanded from 13in. to 13½in. Complete fluidization was achieved with a flow rate of 120lb./hr./sq. in., when the depth of the bed expanded to 16in.

These conditions were modified slightly when the effects of combinations of water and air were examined. The results from these examinations are given in Table VI.

TABLE VI.—FLUIDIZING CONDITIONS WITH WATER AND AIR COMBINED

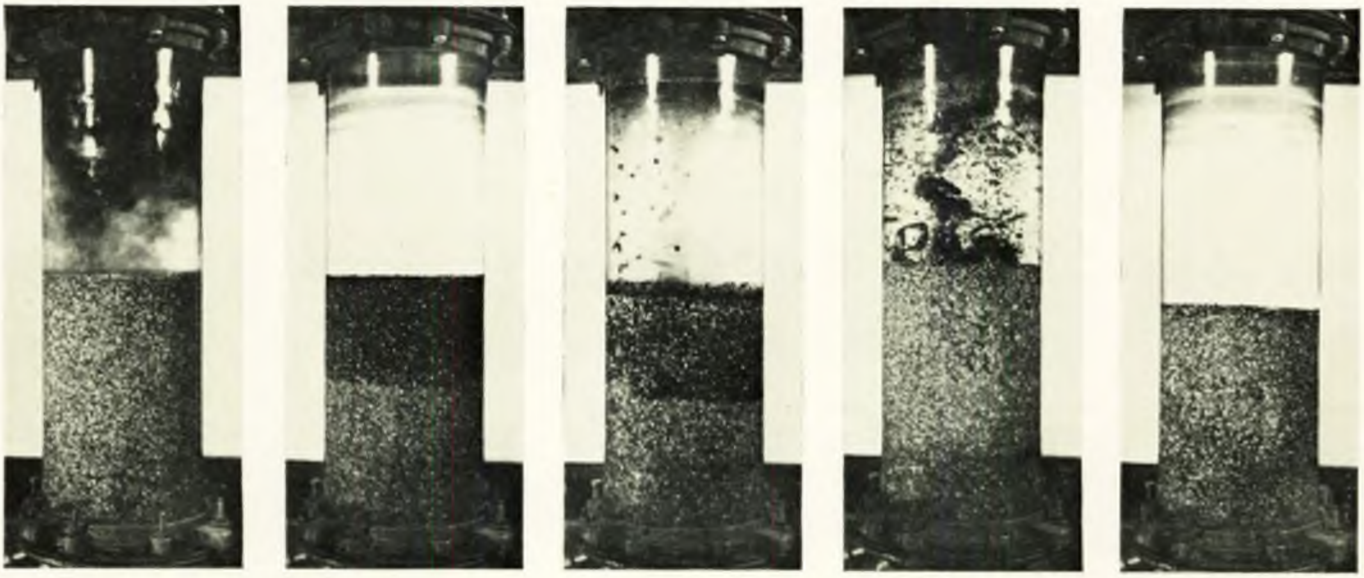
Rate of supply of fluidizing water, lb./hr./sq. in. of bed	Rate of supply of air, cu.ft./hr./sq. in. of bed	Condition of bed
0·0	0·0	Depth of bed 12½ in.
29·6	0·95	No fluidization—air bubbles formed channels through bed
29·6	2·7	Bed almost floating—expanding and retracting
29·6	5·7	Bed floating—but not expanding
53·5	3·4	Bed floating—but not expanding
67·2	0·95	Bed almost floating
67·2	1·9	Bed floating—slight recirculation
67·2	3·8	Bed floating—comparatively violent agitation with recirculation and no expansion

Complete fluidization was achieved with water rates of 120lb./hr./sq. in. although subsequent cleaning tests confirmed that this was not essential to facilitate the complete removal of oil from the bed, and conditions which produced a hot floating bed with air agitation proved to be satisfactory. Such conditions were attained with approximately 67lb. of water/hr./sq. in. and 1·9 cu. ft. of air/hr./sq. in. Fig. 24 illustrates the action resulting from these conditions.

The speed with which the bed could be cleaned was directly related to the temperature of operation and at a temperature of about 60 deg. C. the final stage could be carried out in 1 to 2 minutes.

In many cases it may be inconvenient to supply com-

FIG. 24—*Conditions in the filter bed during the cleaning phase*



a b c d e

FIG. 25—*Conditions in the filter bed during the main stages of its cycle of operations*

pressed air on board ship, and so further tests were undertaken to investigate a cleaning procedure using water and steam alone. Under these conditions steam must be added to the fluidizing water to raise its temperature to boiling point, so that "live" steam is available to replace the air as the agitating medium. This method was at least as efficient as the former, although slight difficulties were encountered in maintaining control of the agitation, which became excessive when too much steam was supplied.

Both these systems of cleaning was extremely effective, and it is considered that either could be developed for application on board ship.

The photographs shown in Figs. 25(a)—(e) indicate the main stages and conditions in the filtering and cleaning procedures described. Dense clouds of extremely fine globules of oil can be seen approaching the clean filter in Fig. 25(a), whilst the condition of the pebbles and the concentration of the extracted oil, at the end of the filtering operation, is clearly illustrated in Fig. 25(b). In the next operation the bed is heated by the introduction of steam, and on attaining a temperature of about 70 deg. C. large globules of oil float off from the pebbles. Fig. 25(c) shows the commencement of this phase. Subsequently, the bed is fluidized and agitated to remove quantities of trapped oil. This condition can be seen in Fig. 25(d), where the bed is being agitated by steam and quantities of oil can be seen leaving the surface. The final condition is shown in Fig. 25(e), where the bed is perfectly clean.

The life of the pebbles is of importance to the trouble-free operation of such a filter. It may be curtailed either by disintegration, in which case the bed would be floated off gradually with the oil, or by "oiling up", when considerable difficulty would be experienced in cleaning the oil-wetted pebbles.

The extent to which these factors influenced the filter over a period representing 12 months' normal service was investigated by completing 25 consecutive cycles of filtering and cleaning. After each cycle the cleaned bed was entirely free from oil and showed no signs of deterioration at the end of this investigation.

DESIGN OF A 10 TONS/HR. OILY WATER SEPARATOR

The work on the laboratory scale filter unit indicates that the principle of the proposed system can be suitably employed in the design and operation of a practical oil/water separator unit.

The dimensions of such a unit will depend on the quantity of fluidizing water required, this being related to the size of filter, which in turn will be governed by the specific rate of deballasting and the estimated quantity of oil presented to the filter.

The amount of oil passing to the filter cannot be assessed exactly, as it will vary according to the type of oil, the temperature of operation, the type of deballasting pump employed and the design features of the individual deballasting installations. Consequently an approximate assessment must be made as a basis from which a suitable size of filter may be designed.

The results obtained from oil/water separator tests on board ship have been examined, and these, in conjunction with those from the laboratory filter tests, have been used to determine the dimensions of a 10 tons/hr. oil/water separator.

Estimation of the Total Amount of Oil Arising in the Effluents from Separator Installations on Board Ship

Throughout a number of deballasting tests carried out by the Fuel Research Station, the total quantities of oil in the mixtures leaving different designs of separators ranged from 2·4lb. up to 20·7lb.—the average being about 13lb. when operating at equivalent rates of 10 tons/hr. With a settling chamber, having a similar efficiency to the separator employed in the worse case, a similar quantity of oil would be expected as pollution in the discharge. Such a chamber, designed to accommodate a flow of 10 tons/hr., would be about 2¼-ft. diameter, and, under the most unfavourable conditions, a total of about 20lb. of oil would be contained in its effluent.

Estimation of the Total Weight of Oil Fed in to Oil/Water Mixtures Entering Separators

Much of the oil fed into a separator enters as dry oil and presents no problems with regard to extraction; it usually flows through the settled-oil space directly into the oil reception tank. The greatest pollution occurs just before the interface between the dry oil and the relatively clean ballast water, when slugs of oil are extracted and dispersed to varying extents in the water. An attempt to assess the quantity of oil involved at this stage of the proceedings has been made by considering a typical 10 tons/hr. deballasting operation, which was carried out on H.M.S. *Bern* in December 1956.

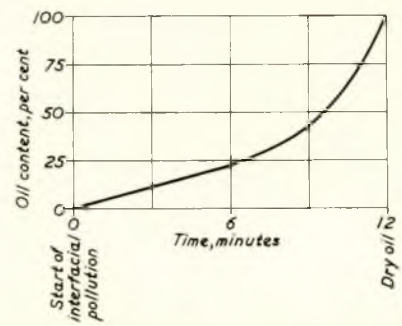


FIG. 26—*Percentage of oil in the ballast water throughout the interface*

The curve plotted in Fig. 29 indicates the oil content of the ballast water over the 12-min. period before the dry oil entered the separator. From this graph the total weight of oil encountered in the oil/water phase was calculated to be approximately 1,500lb., and, depending on the degree to which this oil is disintegrated prior to its entry into the separator, a certain proportion will remain with the effluent.

For design purposes it is assumed that particles smaller than 0·015-in. diameter will not be extracted in the separating chamber.

Investigations into the disintegrating effects of pumps (see Part II of this paper) have shown that, when dealing with dilute mixtures of oil in water, 3 per cent of the oil might be reduced to globules smaller than 0·015-in. diameter when passing through a selected type of pump. However, as the oil/water ratio increases, especially when ratios greater than 1 : 1 are encountered, it is considered that this figure of 3 per cent will fall progressively to zero when dry oil is pumped.

Assuming that the percentage by weight of the oil, in the form of globules smaller than 0·015-in. diameter, varies according to a straight line law (3 per cent—0 per cent) over the range of oil pollution indicated in Fig. 26, it is estimated that approximately 19lb. of oil would be present in the effluent and would pass to the filter.

It appears therefore, that the filter may have to deal with oil in varying quantities up to about 20lb. and a figure of 25lb. will be considered in the following design:

Diameter of Filter

From the laboratory scale tests using 1/16-in.—1/8-in. pebbles, a bed polluted to a visible depth of 5in. contains 0·032lb. of oil/sq. in. of surface area.

Therefore the area of a bed to accommodate 25lb. of oil

$$= \frac{25}{0{\cdot}032} = 780 \text{ sq. in.}$$

The approximate diameter of the bed =30in.

The depth of the bed allowing for an ample safety factor = 9in.

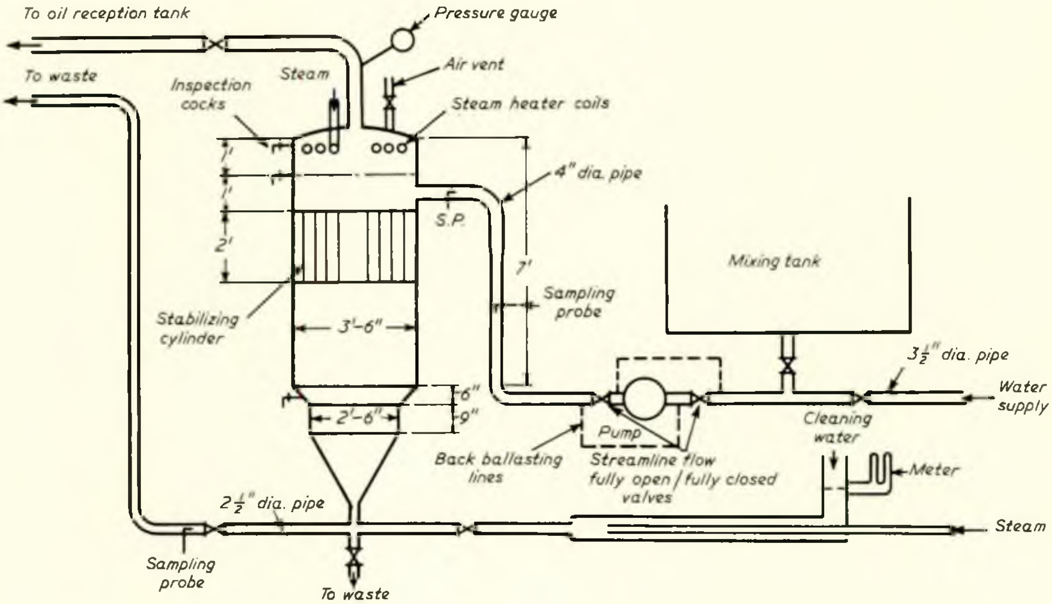


FIG. 27—*Design and layout of separator test plant*

Diameter of Settling Chamber

The settling velocity of a globule of oil, 0·015-in. diameter, in sea water at 15 deg. C. (S.G. of oil = 0·97) is approximately 0·011ft./sec., and a tank having a diameter of 3·4ft. (3·5ft. design) would accommodate such a velocity at a flow rate of 10 tons of water/hr.

Height of Settling Chamber

The volume of the settling chamber must be large enough to accommodate the fluidizing water. Assuming that the flow rate of the fluidizing water through the filter is 1 cu. ft./hr./sq. in. and that the cleaning operation will not take longer than 4 minutes, the volume of water passing through a 30-in. diameter bed during the cleaning operation will be 47 cu. ft. A cylindrical tank 3·5ft. in diameter, containing this volume, will be about 5-ft. high.

A number of assumptions have been made to determine the size of the filter by estimating the maximum quantity of oil which may be expected to collect in it. Therefore, it is considered essential that reasonably large-scale tests be carried out, under practical conditions, to obtain a more realistic value for this quantity and to indicate the factor of safety under which the filter would normally operate.

The layout of a separator/filter unit for test purposes is shown in Fig. 27.

The dimensions of the separator are considered to be more than adequate to accommodate the rating of 10 tons/hr. and it is suggested that preliminary land-based trials should be carried out to investigate its approximate rating prior to shipboard proving tests.

CONCLUSIONS

Laboratory tests have shown that the installation of a pebble bed filter provides a simple and extremely efficient method of removing oil from the effluents pumped out of ships. Further, the adoption of such a system for deballasting operations would be entirely practical in view of the long filter life and the simple fluidized, agitated bed techniques which have been developed for cleaning.

The dimensions and physical conditions required to operate this system are within the limits employed in modern separating installations, and the proposed schedule of operations for filtering and cleaning have proved effective.

It is considered that, with further tests on the proposed unit, a separator could be developed having a much higher efficiency of operation than existing types and still be comparable in size.

ACKNOWLEDGEMENTS

The work described in the paper formed part of the programme of the Fuel Research Board of the Department of Scientific and Industrial Research, and is published by permission of the Director of the Warren Spring Laboratory.

The illustrations in Section I are Crown copyright, and are published by permission of the Controller, H.M.S.O.

As regards the work described in Section II, the authors with to acknowledge the co-operation of the pump manufacturers in loaning their equipments for testing, and also the valuable work carried out on the programme by J. C. Wilson. Figs. 8, 9, 10, 12(a)—(d), 13, 14, 15 and 16, are Crown copyright and are published by permission of the Controller, H.M. Stationery Office. Figs. 11(a)-(j), are reproduced by kind permission of the manufacturers.

Figs. 17 to 27, in Section III, are Crown copyright and are published by permission of the Controller, H.M. Stationery Office.

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Discussion

MR. F. J. COLVILL, C.B.E. (Member) said that, as the authors pointed out, this timely paper was the result of some research work carried out by the Department of Scientific and Industrial Research for the Ministry of Transport. The Ministry had had to take the responsibility of endeavouring to bring about improvement with regard to the pollution of beaches and the cruel slaughter of sea birds by oil which everyone knew came from ships.

Might the title of the paper not be more appropriate if the words "Prevention of" were added before the word "Pollution"?

Part I of the paper contained a theoretical assessment of the minimum size of free oil globule which available separators might be expected to deal with successfully when worked at the makers throughput. This assessment was a very useful one since it showed the futility of expecting success when the oil in the mixture had been broken down into the fine particles described, by an unsuitable pump or other cause.

The advantages as regards separation to be gained by increasing the temperature of the oily water mixture were clearly indicated, but that the increased temperature might assist disintegration by the pump or other component was also pointed out in the paper.

As the authors stated, the investigations, including the tests on board ship, were carried out in 1955 and 1956.

Part I also contained the results of investigations into the effect of several types of baffles, orifices, etc., as fitted in some separators. The results of this investigation were disappointing and in spite of the clearly negative conclusions there could be little doubt that internal details such as baffles, cones, and other such devices could affect performance by persuading the little globules to join forces to make bigger ones. He suggested that if more time and study could have been devoted to this aspect, some very useful facts might have been brought to light, but he understood that time and money were the preventing factors. He suggested that there was yet plenty of scope to find out what internal arrangements of baffles, guides, cones, etc., would, for a particular shape and size of separator shell, give the best separating performance.

Some useful suggestions from design aspects were made at the end of Part I. Suggestions (a) and (b) could, and should, be readily adopted. Suggestions (c) and (d) were more difficult, but should be given the consideration they deserved.

Part II of the paper was an investigation into the disintegrating effect of various designs of pumps on the oil in an oily water mixture, and the pumps were placed in order of merit, the least disintegrating being placed first. This was, as far as he knew, the first research that had been carried out with the object indicated, and the authors were to be congratulated on the ingenious methods adopted for the investigation. There were, of course, many variables in practice; he had carried out some successful performance tests on shore using reciprocating pumps. The pumps were in each case run at well below the maximum capacity. At one shore test where a centrifugal pump was used, all went well, and the early specimens of effluent were quite good until it became necessary to speed up the pump slightly; the immediate result was a very serious disintegration and excessive oil in the form of very small particles in the effluent.

With reference to the practical standard performance shore test for separators which was now prescribed by the Ministry of Transport, he said that, with the coming into force of the Oil in Navigable Waters Act which was imminent in 1956, it became necessary to lay down a standard of performance for oily water separators and to prescribe a test to satisfy the Ministry that separators on the market could reasonably be expected to do what was required of them. A lead on what would be required when the separator was doing its job after installation in the ship was given in the International Convention of 1954, as mentioned in Part I of the paper, and the O.I.N.W. Act, 1955, consequently adopted the same figure of 100 p.p.m.

It had been recognized that, between performance in a standard test rig ashore and the limit figure of 100 p.p.m. referred to in the Act, there must be a good margin, and so a purity of 50 p.p.m. was decided as the maximum to be permitted under shore test conditions.

The test itself was made as simple as possible, since the test rig would be a costly item which would have to be paid for by the separator makers, but it was designed to provide a somewhat more severe condition of mixing of the oil and water than could be expected to obtain in a straightforward ballast/deballast operation in a ship. The oil having been run into a mixing tank, the water had to be sprayed on to the surface and consequently make its way down through the oil. Immediately the required quantity of water had been delivered, which must not take more than a prescribed time, the pump must be started, drawing from the bottom of the tank and delivering to the separator at the makers' rated throughput.

The tests consisted of two runs, one with 5 per cent oil and 95 per cent water, and one with 25 per cent oil and 75 per cent water, and a limiting temperature for the mixture was laid down. Specimens of the effluent from the separator were taken throughout the run and on analysis were required to contain not more than the 50 p.p.m. of oil. Since the method of mixing, quantities, times, etc., were similar for all tests, only occasional specimens of the inlet to separator were taken, these having satisfied the Ministry that from 100 to over 500 p.p.m. could be expected at the inlet during the test run.

With regard to the pumps used on the shore test rig, at that time no tests had been made on the relative disintegrating effects of the various types, and some differences of opinion were apparent as to relative merits, so the only stipulation therefore was that the pump should be capable of pumping at the rate corresponding to the rated throughput of the separator. Later, the results of the D.S.I.R.'s investigations had become available to the separator makers having separators to test.

No regulations had been made yet concerning the pump to be provided on shipboard for an oily water separator, but the authors' recommendations at the end of Part II should, in the meantime, be heeded and the advice of the separator maker should be taken with regard to the installing and running of the separator.

In his opinion, Part III of the report was an interesting and valuable contribution. To be of real assistance in an oil separating plant, a filter must be easily cleaned without withdrawal or renewal of the filtering medium, which should be of long lasting quality. Otherwise, cleaning of an oily filter could be a dirty and unpleasant job. The filter described had a non-destructible filtering medium and a method of cleaning easy to apply and apparently fully effective; moreover the choking medium, i.e. oil, was chased back to where it was required to be, in the top of the filter separator body where it could be run off.

There was no doubt that an apparatus of this type in series with the discharge side of an oily water separator could, if properly worked, enable a high degree of purity in the discharge to be obtained.

LIEUTENANT COMMANDER E. D. HOBSON, M.B.E., R.N. (Member) congratulated the authors upon their presentation of a paper which could not fail, in his opinion, to be of value to those shipowners and shipbuilders who were inevitably involved in implementing the requirements of the Oil in Navigable Waters Act in ships which required to ballast fuel oil tanks with sea water and particularly those whose ships required provision for the utmost rapidity of refuelling at intermediate ports, concurrently with oil-free deballasting of a high proportion of the fuel stowage.

The necessity to replace consumed fuel by sea water in surface warships arose during World War II, and such provision as could be made within the framework of existing fuel systems and space limitations was far from satisfactory. In subsequent new construction, the demand for increased endurance had called for more fuel stowage, which, in combination with increased armament top weight and refuelling rates had, in turn, increased the necessity for compensation for consumed fuel and the maximum rapidity of deballasting during the refuelling operation when the vessel was at sea.

It was on this account that the Yarrow-Admiralty Research Department was entrusted with an investigation of the specific fuel tank ballasting problems arising in surface warships, wherein it was axiomatic that no item of equipment which was not indispensable to the fighting efficiency of the vessel in wartime could be contemplated, consistent with fulfilment of the stringent requirements of the Act in peace time. During this investigation, the authors had participated in several of the full-scale shipboard tests carried out in naval vessels, often under conditions of extreme discomfort, and he wished to pay tribute to their wholehearted co-operation and their highly developed techniques for the collection and evaluation of the large number of liquid samples involved, and which were subsequently adopted in the laboratory installed in H.M.S. *Cumberland* during the extensive operational trials of the naval ballasting systems which had been evolved.

It had been necessary to approach the warship problems on the understanding that oil/water separators commensurate with the requisite deballasting rates could not be accommodated and that, in consequence, the majority of the ballast must be discharged directly overboard. Accordingly, all but the minimum of oil residue must be transferred from the fuel tanks to the settling and service tanks, before deballasting, by means of a separate sullage stripping system. By so doing, not only was the eventual build-up of sludge in the former reduced to a minimum, with consequent extension of the intervals between tank cleaning, but a significant increase in the availability of fuel for endurance purposes had been achieved. Normally it was habitual to make an allowance of 5 per cent for unusable fuel. Now an allowance was made for no more than 1 per cent, in calculating the endurance of the vessel. Similarly, the ability to remove all but the merest traces of emulsified oil and water before refuelling had eliminated contamination of the fuel by residual ballast water.

The authors had shown that the majority of the ballast water below the oil/water interface was suitable for direct overboard discharge through uncontaminated pipes, more particularly when it was heavily diluted by the adoption of fireman-operated eductors for its delivery, provided that it was not subject to "weiring" and vortex formation within the tanks. The former was obviated by ensuring that under no circumstances was the velocity of approach of the ballast to the suction entry in excess of 1ft./sec. through limber holes; the vortex formation was eliminated by the use of the very effective cylindrical anti-vortex baffles around flexible bellmouth suction entries, on the lines of those devised by Professor Markland and Professor Pope, and described in their paper*, which was read before the Institution of Mechanical Engineers in November 1955.

Entirely separate systems were provided in surface warships for fuel filling and transfer, and the ballast duties, thus eliminating the seriously adverse effects of pipe line contamination, and overboard deballasting was stopped at the minimum prescribed and clearly indicated tank water levels. Thereafter, the relatively small volume of contaminated sullage, certainly not more than 5 per cent of the appropriate fuel stowage, was removed through the separate stripping system which he had mentioned before, taking suction from the lowest portion of each tank and discharging to an oil recovery tank. It was heated and received additive treatment in the tank as opportunity arose, in order to render the water suitable for discharge overboard and the oil for normal use, after passing through the service tanks.

This procedure had proved entirely successful under operational conditions in a destroyer in which ballasting had been applied to wing tanks, and in connexion with heavily subdivided double-bottom tanks in H.M.S. *Cumberland*, wherein a low level suction duct, extending the whole length of the double bottom, had been substituted for the ballast bellmouth suction entries, in order to provide a sensibly uniform rate of entry and discharge of ballast from each subdivision of the tank.

His remarks were not intended to suggest the omission of oil/water separators in merchant ships, but to corroborate the views of the authors regarding the necessity to afford them every assistance in the performance of the very arduous duty imposed upon them, by meticulous attention to every aspect of their associated pipe systems, if such limitations as were revealed by Figs. 6 and 7 of the paper were to be overcome.

It had been shown that, by completely divorcing the fuel and ballast systems and the provision of an effective stripping system, the type of pump utilized to discharge large quantities of uncontaminated ballast through the separator would be immaterial and that an adequate standard of effluent purity could be assured when the separator was subsequently called upon to deal with relatively small amounts of contaminated sullage, at the low rate appropriate to a stripping pump of suitable type and size, discharging directly to the separator, on completion of the main operation. An alternative to passing the contaminated sullage through the separator would be to subject it to additive treatment in an oil renovating tank. In that case, the prime function of the separator would be to provide a safeguard against mal-operation of the system throughout the main operation, since oily bilge water could also be treated in the oil recovery tank.

It was very interesting to note that with this procedure, the amount of oil generally remaining on the surface of the water in a ballasted tank was generally no more than odd patches of oil. It was not a complete covering, and under those conditions it could be seen that it was a relatively simple operation to deballast directly overboard.

MR. M. P. HOLDSWORTH (Member) said that most of those present would know of the close concern which the shipping industry had for matters relating to oil pollution of the sea, and for this reason Mr. Logan* wished him to say how sorry he was that he could not personally be present. He was, in fact, presenting a paper himself to a sister institution, but had asked Mr. Holdsworth to pass the following brief comment, having in mind the views Mr. Logan had expressed

* Markland, E., and Pope, J. A. 1956. "Experiments on a Small Pump Suction Well, with Particular Reference to Vortex Formations". Proc.I.Mech.E., Vol. 170, p. 95.

* A. Logan, O.B.E. (Vice-President).

at the Copenhagen Conference on Oil Pollution in July of last year.

Within its particular terms of reference the paper was a truly remarkable one in its comprehensive nature and outstanding clarity of detail. The only word of criticism concerned the title, which, by its general nature, would lead one to believe that the subject matter covered the whole field of present day pollution. However, the large and unfortunately important problem of the crude oil tanker remained unmentioned except for a dismissive sentence on page 410.

The problem of tanker washing disposal was somewhat different from the problem so ably described, and one of the main differences lay in the very stable emulsions which were usually formed in tank cleaning, due to the nature of crude oil and to the high pressure water jets necessary in the cleaning operation. In a well designed, fuel oil tank deballasting installation, only oil disintegration and dispersion were involved, and emulsification should not enter into it.

The present approach to emulsion breaking lay, of course, with surface active chemicals and it was well known that Dr. Shackleton had been closely concerned in some of this work. He thought Dr. Shackleton would agree that crude oil emulsions were a very much tougher nut to crack than most fuel oil emulsions. In view of Dr. Shackleton's interest in these matters, could he, in his reply, express an opinion on the crude oil tanker problem?

COMMANDER C. M. HALL, R.N. (Member) said first of all he would like to congratulate the authors on the scope of their most interesting paper. Normally, rather specialized papers were given, but here a very wide survey had been carried out.

Among the pumps discussed, the double-screw pump had not been listed; could the authors give their views on that

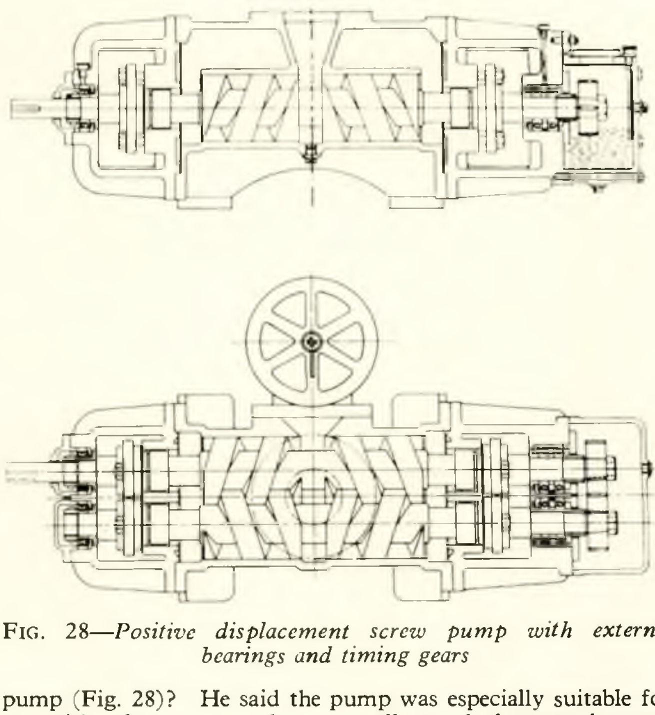

FIG. 28—*Positive displacement screw pump with external bearings and timing gears*

pump (Fig. 28)? He said the pump was especially suitable for use with salt water, as there was all-round clearance between the screws with no sliding or rolling contact and the bearings and timing gears were isolated from the fluid being pumped. He would suggest that it had advantages for prolonged use at sea because there would be little wear as might be expected with some of the other pumps. With reference to derating of the pump, this had been done by speed reduction in the experiments. With this particular type of pump, there was the option of a finer pitch, which would enable the pump speed to be maintained but would reduce the rate of flow. This would have the advantage of enabling a faster running motor to be used, thereby saving cost.

He agreed with all the remarks about avoiding high pressures and cavitation.

He trusted that the authors' work would have a most beneficial effect on pollution of the sea, bearing in mind that even when on holiday oil on the beaches and fatality among sea birds were matters of importance.

MR. J. PARK (Associate Member) added his congratulations to those of previous speakers for a most informative paper.

Upon reading the conclusions to Part I of the paper, and upon studying Table III on page 421, it would appear that, with a combination of the best pump at a reduced throughput and the most efficient separator (neglecting the effect of valves, line velocity, etc.) the oil content at the inlet to the separator should not exceed 1 per cent or 10,000 p.p.m. of the mixture, or the maximum allowable oil content, 100 p.p.m. at discharge, would be exceeded. As it was most likely that the percentage of oil in water supplied to the separator would exceed 1 per cent in practice, it would appear that the shipowners, while complying with all the requirements regarding apparatus to be fitted, could still be in trouble for discharging oil contaminated water overboard.

From the operator's point of view, he was rather disappointed that the authors did not comment upon the method of control for the separators, as from the information in his possession, supplied by a leading separator manufacturer, it would appear that, with the electronic probe method in common use, the most accurate probe at present on the market would not indicate an oil content in the mixture of less than 2 per cent, or 20,000 p.p.m. Thus, the operator of a separator might discharge overboard, quite unknowingly, badly contaminated water. Would the authors give their views on the amount of oil contamination which might be visually detected on the surface of the sea, and also what might be visually detected when samples from the effluent were collected in glass jars? Could they also state whether they, as a result of tests which they had carried out, had any preference for fully automatic or manually operated separators?

It would appear that, with the existing apparatus available on the market, the oil contamination level of effluent allowed by the Act of Parliament, i.e. 100 p.p.m., was rather stringent. Would the authors care to comment on this?

With regard to the oily water separator filter units described in Part III of the paper, what were the authors' views on the use of a fibreglass filtering medium in place of the pebble bed described?

MR. P. E. PEARCE said that Mr. Holdsworth had mentioned a matter which concerned the prevention of pollution in dealing with intractable emulsions. It was well known that Dr. Shackleton had done work with his (Mr. Pearce's) company in breaking these emulsions to give readily treatable oil and water layers. Dr. Shackleton was better versed than himself in the work he had carried out on these emulsions, and it would be interesting to hear of his results, in answer to Mr. Holdsworth. The products on the market were not yet very widely used, but they were gradually getting known as the question of pollution became more important. There was a material which his company had developed in conjunction with Dr. Shackleton, called "Fomescol". He felt that the important apparatus mentioned in the talk and discussion, together with this product, would contribute to the prevention of pollution of the sea by oil.

MR. W. E. L. TAYLOR said that he had worked alongside Dr. Shackleton on this work—and had confirmed, in other trials, the shape of his curves, which showed that the oil content of the effluent ballast water was high at the beginning and at the end of a deballasting cycle. It was agreed that the quantity of oil entering the separator could be kept to a minimum, if the deballasting lines and pump were washed before beginning the deballasting operation; if a common ballasting and deballasting line *via* the pump were fitted, this object could be achieved.

The authors had done a service by producing a mechanical means for controlling oil pollution of the sea instead of relying on operators' visual observations. He thought that the paper had left two questions unanswered; had the authors had any information on the effect of surface active agents on the ballast water before passing to the separator, and had they considered a shipboard test which would give an instantaneous reading of the quantity of oil being discharged overboard. The method described on page 410 and used by the authors would be difficult to carry out on board ship and the time required to carry it out would, of course, be unacceptable.

MR. E. ALCOCK said that his interest was in the hypocycloidal pump. On page 421 it was mentioned that acceptable results might be achieved if the hypocycloidal pump flow paths were streamlined and larger pockets provided between rotor and stator and reduced rotor speeds were employed. A remark had been made just before the meeting that it was not legitimate to derate a pump to improve its performance. He thought it was worth keeping in mind that pump manufacturers were in open competition with one another in connexion with any business that was going, and if a pump manufacturer could derate his pump and at the same time retain its competitiveness, he was entitled to derate it. They were satisfied that the hypocycloidal pump could gain entrance to the satisfactory classification. They were satisfied because of the testing they had carried out subsequent to the work of the Fuel Research Station. Their testing had covered the pattern of the flow in the path of approach to the hypocycloidal mechanism. They had also studied the effect on performance of varying the relative values of the three dimensional components: the eccentricity, the pitch and the diameter, which controlled the shape of the co-operating surface of the rotor and also the co-operating surface of the stator. They had also gained valuable information on the pattern of flow from the usage of the hypocycloidal pump as the arterial return unit in heart/lung surgery.

He concluded by asking if the authors could give information on the dimensions of the suction branches and the discharge branches of the pumps which were tested at the Fuel Research Station.

Correspondence

MR. E. J. COLE, A.R.T.C. (Associate Member) writing as a member of a company actively engaged in the manufacture of oily water separators, particularly welcomed Part II of the paper and its comprehensive treatment of different types of pumps.

In the past their technical data sheets covering separators had never yet mentioned the type of pump to be used, but they intended to rectify this in the future and to make recommendations along the lines proposed by the authors.

He found Part III of the paper most interesting, in that the design of the separator arrived at was, to a certain extent, very closely allied with his own company's patent separators, which roughly followed the patent taken out by their founder dated 16th November 1934 (Patent Number 419,712).

This patent had led to their final design, which was shown in Fig. 29; the principle of separation was as follows:

The separator was first completely filled with clean water

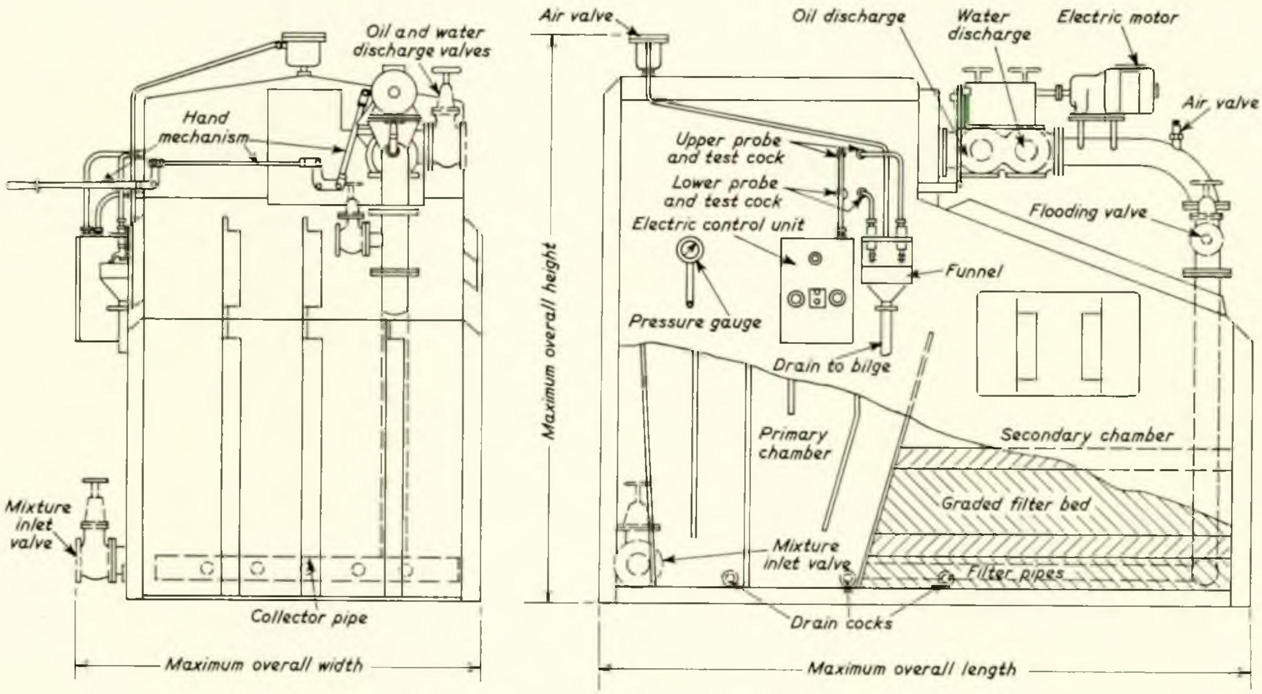

FIG. 29—*Details of patented separator*

in all compartments. The oil and water mixture to be separated was then pumped through the mixture inlet valve and entered the bottom of the first sections of the primary chamber through slots in the internal pipe. By means of the near vertical internal baffles the flow changed its direction through 180 degrees a number of times before passing into the secondary, or filtering, chamber. The oil in the mixture was separated from the water in each of the passes of the primary chamber and rose to the top of the collector, where it remained until discharged. The greater part of the oil was separated in this way but the filter bed, composed of specially graded materials, removed the very small proportion of oil which might still be in fine suspension, and any pieces of grit coated with oil which might be in the mixture. At the bottom of the filter bed were a number of horizontal collecting pipes with slots in the bottom, which collected the purified water and led it to a common vertical discharge pipe and water discharge valve, whence it was led overboard in the usual way. From time to time the oil which had accumulated in the collecting chamber was discharged through the internal pipe in this chamber which led to the oil discharge valve, directing the oil back to the storage tanks or dirty oil tank, as might be required. To wash back the filter bed the inlet and discharge valves were closed and the drains in the primary chamber were opened. Clean water was then slowly passed through the filter bed in the reverse direction by opening the flooding valve, and the liberated oil rose to the collecting chamber and discharged with the separated oil when the separator was next in normal operation.

The graded filter bed consisted of ⅛-in. Winston coarse sand and ⅛-in. pebbles, and the mass velocity of the mixture through this bed varied from 21 to 62lb./hr./sq. in. of bed, which he noticed was roughly in agreement with Table VI.

The cleaning recommended by his company as outlined, was carried out by himself under laboratory conditions. The apparatus consisted of a large perspex tube filled with the appropriate grades of filter material and an oil/water mixture passed through the filter at roughly the same mass rate of flow as in the full scale separators, until the filter bed was thoroughly contaminated.

During the wash-back period one could quite clearly see the particles of sand scrubbing each other clean and the same occurred with the small pebbles. On completion of the wash-back the filter bed appeared to be completely clean.

It was interesting to note that the pressure drop through the filter bed was approximately the same as the pressure drop at the beginning of the tests; that was, when the filter bed was initially used and was completely uncontaminated.

The separators had been tested on site from time to time and during one test—of which he had no first hand knowledge —the purity of discharge contained, when separating out a mixture of 25 per cent oil, 1·7 oil p.p.m. This figure of 1·7 p.p.m. was measured by a public analyst in Newcastle on Tyne

The observations made by the authors on the heating of the mixture were, in fact, incorporated within his company's separators. This heating was done at the inlet of the separator, and usually consisted of a number of steam coils. This was a standard that they normally recommended where extremely heavy oils were being separated and high contamination could be expected.

It might be of interest that his company supplied these separators either manually operated or fully automatic; the automation relied on the difference in permativity obtained when using oil or water as an electrostatic medium.

Mr. G. S. Jackson (Member of Council) considered that the authors had presented a paper that basically emphasized the colossal problem that still awaited practical resolution at sea of the increasing menace of oil pollution, as menace it was, primarily in attempting to cope with an ever-increasing traffic in and use of oil, where ballasting and deballasting of tanks at sea was affected by the limitations of the design of the separator used, and secondly in the attempt to comply honestly with the Oil in Navigable Waters Bill introduced in 1958.

In congratulating the authors on the clear outline of the results of the long and laborious investigations of the last few years, it was possibly not realized by the general public that in importance it ranked with the development of nuclear energy, without the advertisement that the latter had had. The investigations had been exhaustive and thorough and the results described in the paper provided a firm basis upon which one could develop some solution in the future. The paucity of reliable information, the inherent reluctance of operators and manufacturers alike, together with the urgency required in arriving at a workable solution had all contributed to magnify the problem.

The standard of separation, as laid down by the Convention, of 100 p.p.m. of oil in any effluent, was proving consistently difficult to abide by and as regards the discharge of persistent oil or oily residue in forbidden sea areas or harbours, either by accident or design, world wide experience of the sizable penalties imposed by local authorities had focused the necessity for more rapid advancement in this field.

It occurred to him that since the Bill had come into operation, dry cargo and passenger vessels had endeavoured to comply with the conditions as far as a literal interpretation of the statute was concerned, and despite the odds against, owing to badly designed separators which required the maximum of attention during the course of operation to achieve a modicum of result, it was still a far cry indeed before one could conscientiously feel free from guilt when deballasting through separators, however much attention was given to the operation. Whilst endeavouring to comply with the Act there still remained a feeling of frustration when one saw vessels flying the flags of nations who were not signatories to the agreement gaily pumping oily residues over the side, and the authorities powerless to act. The Ministry of Transport appeared to have been satisfied that suitable measures were available for oil tankers; he wondered if the authors could confirm that such was the case?

A further point which had been enlarged upon was the size of the globules and speed or velocity of separation. With specific gravity of 0·95 to 0·99, the difficulties of coalescing appeared to be the chief obstacle to surmount. Whilst the authors had confined all investigation on the subject to the normal type of gravitational differential separator, would it be fair to ask if any improvement of the situation had been found by the use of centrifugal separation? Manifestly the speed of separation was linked with the proved average working capacity on any gravity separator, the throughput velocity of the mixture, and the size of the separator, together with overall efficiency of the plant, pumps, pipe lines, etc. Where the time factor of the operation of bunkering simultaneously with the deballasting of, say, 3,000 or 4,000 tons was so very important, it would be clearly seen that the increased size of the ordinary separator, together with the multiplicity of valves, pipe lines, etc., became a major problem in the design and operation of such a vessel—not forgetting the capital cost involved, which showed little or no economic return. One would have thought that the employment of some type of centrifugal separation would overcome some of the disadvantages experienced.

Could the authors establish in the light of their investigations that the use of additives in the fuel tanks in any way improved the coalescing factor during the deballasting operation through the separators?

Whilst agreeing wholeheartedly with all the recommendations in the preamble and having carried these through, one was still in some doubt that the efficiency of separation in the final stages of deballasting depended so largely upon the non-disintegration of the mixture during its transit from the tank to the separator, that it would appear some kind of induced flow, say, on the ejector principle without the continued use of pumps, would be of some assistance in obtaining an increased efficiency. During the course of their numerous investigations had the authors ever encountered such a layout?

The final section of the paper was in his opinion by far the most interesting and emphasized the ultimate necessity of the incorporation of a filter unit where and when finer or higher standards were envisaged. Judging from the amount of washed up residues found around the pebbles of British beaches he would say that the principle of pebble filtration was undoubtedly correct, but it must be apparent that the size of such an addition, together with the fitments necessary for steam and air to give complete fluidization, say, to cope with the case previously quoted, i.e. 3,000—4,000 tons of mixture to deballast, would in turn increase the difficulties of this already major operation in relation to the time factor. Could it be, therefore, that some chemical re-agent, similar to some extent to additives, could be employed?

In conclusion, he was confident in saying that he was voicing the opinion of all marine engineers in expressing thanks to the authors for providing so lucid a paper, the subject matter of which had been the cause of so much contention during recent years, and supplying a fund of information which was fundamentally of vital importance in the pursuit of further investigations. The paucity of any previous literature on the subject magnified its importance.

MR. H. D. MAKINSON (Associate Member) had been surprised to read that "The Ministry was satisfied that suitable preventive measures were available for oil tankers". Lamb* had written in 1958 that "none will deny that most of the oil emanates from oil tankers between discharging one cargo and loading the next". If a remedy had been found for tankers, could it not be applied to other vessels?

With regard to the remark, "where possible tanks should be pressed up in order to reduce free space", the writer would advocate that the tanks be kept "just full", but thought considerable caution ought to be exercised before sailing the ocean with double-bottom tank tops "pressed up". It should not be forgotten that if damage to cargo occurred through leakage somewhere in the hold, it was all too easy to lay the blame on the fact that the tanks had been "pressed up".

The view that tanks should be kept as full as possible in order to reduce agitation and break-up of the oil confirmed the views expressed by Gray and Killner† who had described an interesting experiment in ballasting and emptying a fuel tank. They had pointed out that there was often motion of the vessel during ballasting which was very conducive to the formation of an emulsion. Also, the very irregular interface of some oil and water emulsions was mentioned and the suggestion was made that the early appearance of oil might be partly due to the low buoyancy of some sections of the emulsion which broke off and were easily drawn down to the pump suction. Perhaps the authors would comment on that?

The paper should prove very useful in leading the way to the manufacture of more efficient oily water separators. It had shown that the operational staff had difficulties to contend with that had not always been fully realized. Efficient separators however were only one aspect of the struggle against pollution of the sea by oil.

Oil and emulsion separated from oily water were usually discharged to a "sludge tank" and stored until the vessel was outside the prohibited limits, when it might be pumped overboard. To help relieve vessels in port of the need to store sludge more facilities ashore could probably be provided. Some years ago the Dock and Harbour Authorities Association were opposed to the suggestion of increasing the shore facilities at ports for the disposal of oily water, claiming that existing arrangements were not used nearly enough. This was in reply to a suggestion by the Chamber of Shipping that facilities were either inadequate or non-existent. There was probably still room for much improvement in that field.

* LAMB, J. 1957/58. "The Recovery of Oil from Sludge in Oil Tankers". Trans.N.E.C.Inst., Vol. 74, p. 369.

† GRAY, C. J., and KILLNER, W. 1948. "Sea Water Contamination of Boiler Fuel Oil and Its Effects". Trans.I.Mar.E., Vol. 60, No. 2, p. 47.

MR. F. POLLAK, M.B.E. (Member), referring to Part II of the paper, dealing with the effects of pumping a mixture of oil and water, believed that it would be of great interest and advantage if the concluding statement could include some absolute figures or parameters which would give an indication of the suitability of a pump type, instead of a statement referring to the derating of pumps, etc.

It was perhaps reasonable to assume that the distribution and creation of oil globules occurred as a result of various factors, as follows:

a) A shock loss at the entry to the rotors, valves, etc., depending upon the type of pump varying with the square of speed.
b) Speed changes varying with the square of the speed.
c) The effect of rotating surfaces in contact with the liquid, varying possibly with the cube of the speed.
d) Multiple deflexion of liquid varying directly with the speed.
e) Leakage through clearances varying directly with pressure.
f) The squeezing action of the liquid varying with the square of the speed.

The relative influence of the above factors probably varied with the type of pumps, and an attempt had been made to interpret the results relating to the various pump types and factors which contributed to oil globule distribution at percentage influence (Table VII, columns 10—15).

It would also have been of interest to see the effect of viscosity and to know the viscosity of the oil used during the test. In the paper there were some figures that could not be directly interpreted and therefore the following assumptions had been made:

1) It was assumed that in the case of the double vane pump, the figures published in Fig. 14 referring to 315 r.p.m. and in Fig. 15 referring to 200 r.p.m. were based on the pump running with the rotor at its maximum eccentricity and with the globule percentage as shown in Table III referring to 315 r.p.m. output 10 tons/hr.
2) It was assumed that the values for globule percentage (Table III) referred to the actual quantity pumped, i.e. as in Figs. 14 and 15, which were bound to vary from the rounded-off figures of 10 and 6 tons.
3) In the region of the acceptable globule distribution, i.e. say between 0·01in. and 0·02in., the curves as in Fig. 14 were so steep that some of the results recorded in Table III might be doubtful. This became apparent when studying the figures for the double vane pump, where the percentage of 0·010in. globules dropped from 21 to 1 per cent. Assuming that the 21 per cent was based on a speed of 315 r.p.m., i.e. maximum eccentricity, it would appear that a correction to, say, 16 per cent was permissible. Indeed the improvement shown in Fig. 15 might be due partly to a lower speed than 200, as an output of 5·1 tons/hr. calculated directly from Fig. 14 seemed to be low.

It was assumed that the test region that was of interest extended up to a globule size of 0·02in., and that the remaining part of the curve was of less direct interest but served as an indication of the shape of the curve of globule distribution.

Considering the results, it must be borne in mind that the types of pump shown were apparently standard units incorporating features, which, from the point of view of this investigation, contributed to an unsatisfactory performance. Furthermore, some of the results, like those shown in Fig. 16, were a little misleading, as the characteristic of the centrifugal pump was fundamentally different from the characteristic of the remaining pumps. For a constant pressure and varying quantity—depending on its characteristics—there could only be a very small speed reduction in the case of centrifugal pumps.

The general shape of curves showing the globule percentage (of a certain size, within certain limits) against flow would

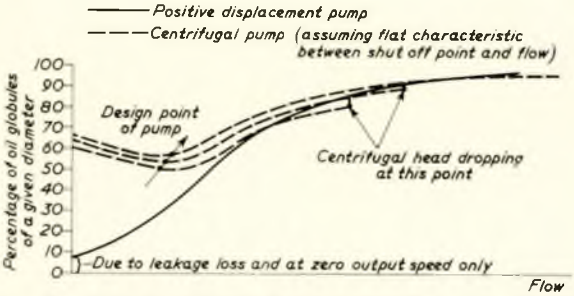

FIG. 30—*Theoretical globule percentage as a function of flow for centrifugal and positive displacement pumps*

presumably be as in Fig. 1, assuming a constant pressure. Thus, it would be apparent that the only pump that could not be treated satisfactorily on this basis was the centrifugal pump, as, depending on its characteristics, the flow quantity would not be a direct or suitable indication of its speed. In any case, the centrifugal pump shown did not appear to be the most suitable selection to achieve the aim of the user, namely a coarse oil globule distribution; preferably a special impeller, say for instance one with a very small number of special vanes or possibly without vanes, i.e. a channel impeller, would have been a more suitable choice.

From Fig. 30 it would appear that with increasing flow quantity the centrifugal pump performance would approach the positive pump, mainly due to the fact that the centrifugal pump of suitable characteristic could produce at the same speed a larger flow. This approach of performance would however occur in a region where the oil globule distribution was unsatisfactory. From the figures published in the paper it would appear that the centrifugal pump performance at 10 tons was nearer to the design point than the performance at 6·2 tons, i.e. the globule distribution remaining practically constant although the speed and flow dropped. From this it became apparent that entry conditions in the centrifugal pump for such duties was of paramount importance.

Judging from the results, it appeared that in order to achieve less than 3 per cent of the total quantity to be pumped to be in the form of oil globules smaller than 0·010in., an absolute velocity of 3ft./sec. within the pump should not be exceeded, and that tentatively the distribution in this range for higher speeds could be calculated very roughly, taking into account factors as stated in Table VII (these factors being of course only applicable to pumps as shown). Reductions in the percentage of oil globules could be achieved for instance by attacking the influence contributing most to the formation of oil globules; thus, for instance, in the case of the centrifugal pump, a reduction of entry shock losses; in the case of the vane pump, speed only; whilst in the case of triple screw pumps entry and passage formation would form areas of improvement, etc. It would be noted that a tentative distribution of influences showed reasonably correct results in column 16 of Table VII as compared with column 9, except in the cases of items 8, 9 and 10, namely single vane, double vane and rotary gear pumps, where the actual improvement at the lower speed was greater than calculated. This might be explained by the relatively greater effect of the rotating surfaces in breaking up oil globules, but that in these cases, a higher power than the cube law was valid.

It was to be hoped that this important subject would be further investigated by the various pump manufacturers.

TABLE VII.

Item	Pump type	Based on Fig. 14		Based on Fig. 15		Output calculated direct with speed	Globule percentage <0·01,ø as in Table III*		Influence of factors leading to break up and variation factor with speed						Calculated globule distribution for speed as in col. 5 from cols. 4 and 8 (see appendix) to be compared with figures in col. 9
		Speed	Output	Speed	Output				Shock loss	Speed change	Rotating surface	Deflexion	Leakage	Squeeze	
									Variation with speed						
									Square	Square	Cube	Direct	Nil	Square	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	Hypocycloidal	1,000	9·7	600	6·0	5·8	40	11	5	50	33	2	6	4	14·22
2	Centrifugal	1,050	10·3	995	6·2	—	56	56	71	10	2	5	12	—	50·70
3	Flexible vane	—	—	1,180	4·5	—	—	98	5	8	7	2	8	70	
4	Disc and shoe	550	10·6	350	6·2	6·75	56	36	25	20	5	27	15	8	30·96
5	Diaphragm	—	—	65	6·4	—	—	12							
6	Reciprocating	44	10	29	6·0	6·60	24	9	20	40	—	—	—	40	10·45
7	Triple screw	970	10	500	5·6	5·20	12	3	20	27	30	10	8	5	3·73
8	Single vane	108	8·5	67	5·2	5·30	20	4	5	15	53	5	10	12	7·59
9	Double vane	315	10	200	5·1	6·35	16	1	3	10	60	5	10	12	6·15
10	Rotary gear	500	10	335	6·0	6·70	22	5	20	8	52	2	10	8	9·46

*Assumed to refer to speeds and outputs as in Figs. 14 and 15.

(Percentage item 9, col. 8 corrected.)

APPENDIX

Showing Calculation of Result in Column 16 for Item 7, Triple Screw Pump (Table VII).

$$\text{Speed ratio } R = \frac{500}{970} = 0{\cdot}515$$

Percentage of oil globules at 970 r.p.m. = 12 per cent.

TABLE VIII.

Influence Type	Per- centage	Globule content at 970 r.p.m.	Corrected to 500 r.p.m. at relevant speed ratio
Shock loss	20	$0{\cdot}20 \times 12 = 2{\cdot}40$	$2{\cdot}40 \times R^2 = 0{\cdot}64$
Speed change	27	$0{\cdot}27 \times 12 = 3{\cdot}24$	$3{\cdot}24 \times R^2 = 0{\cdot}86$
Rotating impeller	30	$0{\cdot}30 \times 12 = 3{\cdot}60$	$3{\cdot}60 \times R^3 = 0{\cdot}49$
Deflexion	10	$0{\cdot}1 \times 12 = 1{\cdot}20$	$1{\cdot}20 \times R = 0{\cdot}62$
Leakage	8	$0{\cdot}68 \times 12 = 0{\cdot}96$	$0{\cdot}96 \times 1{\cdot}0 = 0{\cdot}96$
Squeeze	5	$0{\cdot}05 \times 12 = 0{\cdot}60$	$0{\cdot}60 \times R^2 = 0{\cdot}16$
Total	100	12·0	3·73

MR. D. ROYLE, B.Sc.(Eng.) (Associate Member) remarked that Dr. Shackleton and his co-authors, in their paper on the subject of the pollution of the sea by oil, only briefly mentioned in the introduction the kinds of oil that tankers and dry cargo vessels were forbidden to discharge within certain sea areas, by quoting the same phrase, namely, "persistent oil or oily residue", as used in the "Manual on the Avoidance of Pollution of the Sea by Oil", reference 10, in the paper. The Manual, in paragraph 54, included fuel oil and heavy Diesel oil in the category of persistent oils, and defined heavy Diesel oil as marine Diesel oils other than those distillates of which more than half the volume distilled at a temperature not exceeding 340 deg. C. when tested by the ASTM Standard Method D 158/54.

Many products sold as marine Diesel fuel at bunkering ports throughout the world had 50 per cent distillation points below 340 deg. C., and this was the case in the United Kingdom, where, due to Customs Regulations for revenue purposes, this requirement was mandatory. It was presumed that the use of the same distillation limit by the Oil in Navigable Waters Act, 1955, and the U.K. Customs was coincidental.

Could the authors give any reasons or literature reference which gave technical support to the theory that marine Diesel fuels with 50 per cent distillation points above 340 deg. C. should be classified as persistent oils, whereas those which were more volatile could outside territorial waters be discharged overboard from a ship without creating an offence?

It was fairly common for the bunker fuels at U.S.A. West Coast ports to have a specific gravity at 60 deg. F. of 1·016, and therefore it would be interesting to know if the oily water separator/filter unit described in Part III of the paper would be suitable for use with such fuels.

Authors' Replies

Dr. Shackleton, in replying to the remarks of Mr. Colvill concerning the heating of ballast water, stated that in the paper it was clearly indicated that the heating should be carried out down stream of the pump, so that increased disintegration of the oil, by reason of reduced viscosity as a result of the heating, could be avoided. Heating of the ballast water, however, was not considered to be an essential requirement of a properly designed deballasting system. If inefficient separation occurred, it was not simply a question of blaming the oily water separator, for pipe lines and valves might be causing disintegration by being incorrectly installed, or else the wrong type of pump being used. He was still of the opinion that the introduction of baffles, with the object of causing coalescence, was not only useless but dangerous, in that additional surfaces were then introduced on which oil build-up could take place.

Dr. Shackleton was of the opinion that future work should be directed towards preventing the formation of very small droplets of oil rather than simply allowing them to form and then seeking a means of coalescing them.

With regard to Ministry of Transport test procedure, the rate of separation of oil from water by gravity differential was not just a question of the oil-water ratio used in the test mixture, but was determined by oil droplet size, temperature, and gravity differential.

He was in agreement with the remarks of Lieutenant Commander Hobson and mentioned that the rubber bellmouths were suggested by him. It had been found that if a tank were properly emptied, oil would, of course, be left adhering to the walls and floor, but if the tank was then water ballasted, sampling after 12 hr. had revealed that less than 8 p.p.m. oil were present at various depths from the bottom of the tank up to about 2in. from the top. The layer of oil on the top was about $\frac{1}{16}$in. thick. This proved that if tanks were properly emptied, then refractory oil-water mixtures could be avoided.

In reply to Mr. Holdsworth, Dr. Shackleton said that his terms of reference were clearly outlined in the paper, and that tankers had been excluded. He had been informed by the Ministry that adequate provision for tankers was available in the way of shore reception tanks.

Emulsions of crude oil had not been particularly studied; almost all work had been carried out on furnace fuel oil to Admiralty specification, and also Bunker C oil. One difficulty that could be encountered when cleaning tanks which had contained crude oil was that the hot cleaning jet would cause lower boiling hydrocarbons to be released, with the possible establishment of explosive conditions. If a tank were gas free, then there was no reason why Fomescol should not be used and satisfactory cleaning and subsequent good separation of oil and wash water obtained*. The rate at which water-in-oil emulsions could be broken depended on the particle size of oil globules and the temperature—the smaller the particles then the slower the breaking, and the higher the temperature the more rapid the breaking would be.

Water-in-furnace fuel oil emulsions were stabilized by reason of the polar group(s) of the asphaltenes present in the oil becoming preferentially wetted by water at the oil-water interface and, in effect, forming a skin around the water globules. If such emulsions were heated, the water particles would fall to the bottom and usually remain there as a black sludge. If an agent like Fomescol were present, then these water wetted polar heads would, so to speak, be wetted back into the oil, and the particles of water would join up to form a clear layer.

Here Dr. Shackleton coupled a reply to Mr. Taylor—two systems could be formed from the two phases, oil and water, i.e. oil-in-water and water-in-oil, and these were quite different in their properties and method of stabilization. With an oil-in-water system, free oil globules were floating in water, but with water-in-oil, the formation of wetted polar heads, the influence of electrolytes and the presence of electric charges were involved.

While an agent like Fomescol would break water-oil emulsions, they had never obtained any evidence that a surface active agent influenced the rate of separation of oil from a mixture of oil in water. If Fomescol was used during deballasting operations, then it could not be claimed that more rapid separation of oil from water would occur, but certainly a dryer oil should be obtained at the top of the oily water separator and there would be some chance that any emulsion present would be broken, although when normally breaking emulsions heating should always be resorted to. The use of surface active agents not specifically designed for this type of work should be avoided, for their use could easily lead to very severe troubles being encountered.

In reply to Mr. Park, who enquired about an apparatus for indicating the amount of oil present in the water throughout a deballasting operation, Dr. Shackleton said that he knew of no apparatus which would do this. When the team on this work was taking samples of oily water, guesses were sometimes made before the actual laboratory analyses were carried out as to the amount of oil present. In their experience it proved to be extremely difficult to give a rough assessment—for example, with two samples of oily water containing identical amounts of oil, in one the oil could be present as a few large globules, and in the other, as a very large number of very fine globules. With regard to water-in-oil, however, an apparatus for determining continuously the amount of water present in the oil was available; it was suggested that Mr. W. E. L. Taylor of the Admiralty Oil Laboratory should be consulted. The electronic probes and controls generally advertised were level indicators and controllers, installed to prevent gross pollution occurring through the separator becoming full of oil. They did not control the oil content of the outlet from the separator in any other way.

On the subject of pollution, Dr. Shackleton mentioned that apart from very evident oil "slicks" it could occur in another manner. If oil was in a very finely divided state in waves beating on a stony beach, the oil would not be visible to the eye but the stones could be preferentially wetted by the oil, and in consequence the oil would be removed from the water and so left deposited on the stones. Subsequent wave action would not remove the oil. The stones would appear to be mottled and at a casual glance one would not think oil was present. On handling the stones, oil would of course, then be observed to be present. Pollution of this kind had

* Shackleton, L. R. B., Taylor, W. E. L., and Moore, C. D. March 1959. "A Dual-purpose Agent for Tank Cleaning and Breaking Emulsions." *The Motor Ship,* Vol. 39, p. 580.

been observed at several seaside resorts. Oil could be removed from oil contaminated stones by spraying them with a solution of a spontaneous emulsifying agent in a petroleum fraction, when subsequent wave action would then dislodge the oil from the stones. The method was costly to apply and, of course, was only a temporary solution, for after the agent had been expended, contamination of the stones could occur again. Also, it was not known how long it would be before the oil-water emulsions produced by such a mechanism would break down, so enabling globules of oil to coalesce and be brought inshore again to cause contamination on the same beach or else on another by movement in currents.

This preferential wetting of silica by oil was one of the mechanisms involved in the separator designed by Mr. Douglas. At a later stage, when conditions were changed, oil was removed from the silica, which later became preferentially wetted with water and ready again for oil removal. When oil removal from the silica occurred simply by continuing the passage of oily water, the mechanism was that the oil built up on the already oil wetted silica, and then portions broke away as large globules. Dr. Shackleton said he had had no experience with normal filters as applied to the treatment of large volumes of oily ballast water, but it had been reported that a fibre glass filter had been used and recleaned successfully at Portsmouth Harbour over a period of 15 years. He said that he was surprised that trouble had not been experienced through channelling of the bed during back steaming.

In reply to comments by Mr. Jackson, Dr. Shackleton was of the opinion that the standard of 100 p.p.m. of oil in discharged ballast water required by the Act could only be achieved if attention were paid to the various factors outlined in the paper, and, bearing in mind the many ships' installations examined and tested during the course of the work, he thought that very few ships at present would be able to comply strictly with this requirement. He regarded 100 p.p.m. as a target to be aimed at rather than a practical figure which could be achieved under present conditions. Unless a team used to this type of work were taking samples throughout the deballasting period, it would be difficult to prove that this figure was being exceeded, unless of course, the pollution was obviously very gross. A query regarding the use of surface active agents had been dealt with earlier.

Placing the pump on the discharge side of the separator would certainly greatly decrease any tendency for oil to be disintegrated. The authors had already suggested such a system as this, but ships' architects had said that great difficulties would be encountered in ship design by such a scheme.

Oil could, of course, be separated from oily ballast water by centrifugal means, but when ships had 4,000 tons or more of ballast to deal with in a very short time, the amount of equipment and power requirements made the use of centrifuges for this purpose quite uneconomical. With a properly designed ballasting/deballasting installation it might be possible to discharge the bulk of the ballast directly overboard and then only employ a centrifuge as the oil-water interface was being approached. Centrifuging of all the ballast water could thus be avoided. Some ships had been examined where such a procedure could be adopted, but it would be most unwise to adopt such a scheme for general application at the present time.

In reply to Mr. Royle, Dr. Shackleton said that he had not been associated with any work relating to the persistence of petroleum fractions. The high boiling point constituents of furnace fuel oils were obviously going to be persistent. The higher hydrocarbons of the paraffinic type would remain unchanged on exposure, but certain other types containing double bonds would polymerize or oxidize on exposure with every possibility of the formation of sludges. Heavy oils contained small amounts of reactive compounds other than hydrocarbons. Dr. Shackleton did not know where the boiling range determining the persistence and non-persistence should be placed, and could only assume that the regulations were framed in an attempt to grapple with a very difficult situation.

The usual oily water separators functioned by reason of the gravity differential between oil and water, and as this decreased the rate of separation must decrease also. With oil of the same density as water at normal temperature, separation under gravity would not take place—in such a circumstance it would be worth heating the mixture in the hope of gaining some gravity differential so that separation could occur. However, Mr. Douglas's separator, which relied in some measure on the preferential wetting of silica by oil, might well be an answer to the problem.

Mr. Douglas, in replying to Mr. Colvill, said that the use of baffles could be divided into two categories. The introduction of baffles to promote streamline flows would produce conditions favourable to separation and should be encouraged. For example, other conditions being equal, the Reynolds number of flow was directly proportional to the equivalent diameter of the cross sectional area of the flow path and consequently turbulent conditions would attain with the larger diameter equipments. In order to take full advantage of the extra capacity afforded by the installation of large separating tanks, a carefully designed system of baffles should be recommended to induce the stream line conditions which are essential to efficient separations.

The use of baffles to promote the coalescence of small oil globules appeared to be ineffective. The globules to be coalesced were extremely small and their specific gravity was similar to that of the fluid in which they are contained, consequently extremely large forces must be brought into play if these globules are to be effectively displaced and agglomerated. With most designs of separators such forces were not available and in some instances the devices employed for coalescence provide surfaces on which oil collects, thereby interfering with the operation of the separator.

He agreed with all but one of Commander Hobson's points and where he disagreed, the disagreement was only slight. He thought it unfair to dilute the water going overboard to reduce the effluent to 100 p.p.m.

With regard to Commander Hall's remarks concerning the double screw pump, he had no reason to believe that these pumps would be any worse in their operation compared with the triple screw type which was tested. It had not been possible to compare the different designs of each type of pump which had been tested, although it is probable that a screw type, whether a double, triple, or single screw, operating under similar conditions, would produce similar results to those obtained from the screw pump tests reported. However, it is possible that, for this particular role, a uni-directional flow would be preferred to the double inlet and central outlet type which Commander Hall had shown on the slide.

In spite of the reduced costs of the driving motor employed with high speed low pitched screw pumps, such a design could not be recommended for installation in a separator system. The trends indicated by the results obtained show clearly that increasing disintegration was associated with high speeds of operation and a low speed pump should therefore be preferred.

Mr. Park mentioned at the beginning of his remarks that the oil contained at the inlet to the separator should not exceed 1 per cent. This was difficult to understand as the percentage of oil in the mixture fed to a separator could vary from practically nothing to 100 per cent throughout a deballasting cycle.

Regarding the use of electronic probes, these were not used to determine the pollution in the effluent but only to indicate the position of the oil/water interface in the separator, and to operate the regulating valves as required by this variable.

Fibre glass was an excellent filtering medium but, if it was employed in a fixed form with the thick types of oil encountered in these tests, then difficulties in cleaning could arise. Experience with similar systems had proved "blowing or steaming back" to be relatively ineffective and only a small proportion of filter surface could be cleaned by such measures. In operation, after a certain area was cleaned, all the cleaning fluid passes through it taking the path of least resistance and leaving considerable pollution still in the filter. Consequently, during the next filtering operation, the small area which had been cleaned previously was quickly fouled up and further cleaning was required.

If Mr. Park intended that the fibre glass should be in granular form then, assuming the surface conditions were suitable for retention of the oil, such a filter should work similarly to the pebble bed. An account would have to be taken of the specific gravity of the material to determine the amount of fluidizing water required and this would govern, to a large extent, the size of the separator produced.

It was reassuring to know that Mr. Taylor had confirmed some of the results in tests he has carried out. With regard to ballasting through the pump and deballasting lines, this has been suggested in the paper and allowances for this are shown in Fig. 27.

He congratulated Mr. Alcock on the work he had done with the hypocycloidal pump and was pleased to learn that the design had been considerably improved for this specific work.

In supplying information regarding the sizes of the suctions and discharges on the pumps tested, it was stated that these varied according to the individual pumps. In every case, the manufacturers had inspected the plant to ensure that their pump was fitted to their satisfaction and in particular that the suction and discharge lines were according to their requirements.

In reply to Mr. Pollak's interesting and helpful written contribution it should be noted that this investigation was carried out to survey the operations and equipments involved in the oily water separator systems installed in cargo vessels. It was agreed that this was an extremely wide field and, in spite of the efforts directed to this subject and reported here, many additional and more fundamental investigation could be undertaken to elucidate the various mechanisms involved. However, in order to provide data of immediate practical value to ship builders and personnel concerned with separator operations, recommendations have been made in respect of equipment already available. For example a number of different designs of readily available pumps have been tested and the most suitable types, together with the recommended conditions of operation, have been listed.

Each type of pump has its own characteristics and an investigation into the fundamental mechanisms involved in each of the separate stages, i.e. inlet shocks, rotor shearing and turbulence effects, disintegration in valves, etc., would be an interesting but extremely lengthy task. The agreement between Mr. Pollak's calculated globular size distribution and those achieved in practice was remarkable, and indicated considerable accuracy in assessing the "influence fractions" (Cols. 10-15, table VII) for each particular equipment.

Again an investigation into the effects of viscosity would be of considerable interest although a number of test difficulties are envisaged. For example, an adequate procedure for assessing the relative effects when non-Newtonian oils are encountered was difficult to visualize. The heavy fuel oil used throughout the test reported in this paper had a constant viscosity at all rates of shear and this was measured at 3,000 secs. (Redwood) at 100 deg. F.

Mr. Pollak's assumptions (1 and 2) in relation to the results from the double vane pump were correct. However, his remarks associating the inaccuracies of the results with the steepness of the curves in Fig. 14 (assumption 3) were misleading. The accuracy of the results for globular sizes 0·01in. and 0·02in. were related to conditions in the flotation tube and the actual time laps between taking the respective samples. In fact, a settling time of approximately 7 mins. was allowed for the larger globule and this should be compared with the 20 mins. allowed before taking the final "0·01in." diameter sample.

Close scrutiny of the original results confirms that the 21 per cent reported here was slightly high and should read 20 per cent but certainly not 16 per cent.

It was basically incorrect to calculate the throughput of this pump on the assumption that speed = constant × throughput. In fact, the characteristic over the range investigated was of the form speed = C × throughput + K and this accounts for the lack of correlation between the reported figures and those calculated by Mr. Pollak.

He failed to see how the curves shown in Fig. 1 of the paper bore any relationship to the characteristics of the centrifugal pump, however, having tested this equipment and having examined the results, he agreed that this design was wholly unsuitable for deballasting purposes. He pointed out however that the nature and objects of these tests were fully explained to the pump manufacturers concerned and they supplied the equipments considered and recommended by them to be most suitable.

He agreed wholeheartedly with the final paragraph of Mr. Pollak's contribution which expresses the hope that the manufacturer's concerned would tailor a pump for installation in oily water separator systems.

Mr. Walsh was unable to agree with Mr. J. Park's suggestion that if the oil content in the mixture at the inlet of a separator exceeds 1 per cent then contamination exceeding 100 p.p.m. will result in the effluent.

In one phase of these investigations it was noted that changes in the oil content of mixtures fed to a pump affected the resulting disintegration.

Higher percentages of oil were associated with coarser size distributions in the effluent, obviously, in the limit, if the feed "mixture" contains 100 per cent oil then no disintegration will occur and no particles smaller than ·010in. diameter will form. Consequently Mr. Walsh considered Mr. Park was not correct in assuming that pump feeds containing more than 1 per cent oil will necessarily produce discharges exceeding 100 p.p.m. $<$ ·010in. diameter.

INSTITUTE ACTIVITIES

Minutes of Proceedings of the Ordinary Meeting Held at The Memorial Building on Tuesday, 12th April 1960.

An Ordinary Meeting was held by the Institute on Tuesday, 12th April 1960 at 5.30 p.m., when a paper entitled "Pollution of the Sea by Oil" was presented by two of the authors, L. R. B. Shackleton, B.Sc., Ph.D., and E. Douglas, B.Sc., and discussed. The third author, T. Walsh, was unable to be present.

Mr. Robert Cook, M.Sc. (Chairman of Council) was in the Chair and eighty members and visitors were present. Eight speakers took part in the discussion that followed.

A vote of thanks to the authors, proposed by the Chairman, was accorded by acclamation. The meeting ended at 7.35 p.m.

Section Meetings

West Midlands Section

A meeting of the West Midlands Section was held at the Engineering Centre, Birmingham, on Thursday, 27th October 1960 at 7.0 p.m. at which an illustrated lecture entitled "Recent Developments in Pump Auxiliaries for Ships" was presented by Messrs. T. McAlpine and I. S. Paterson.

Mr. Cotterill presided over the meeting which was attended by thirty members and guests.

Mr. McAlpine, who presented the first part of the paper, showed numerous slides illustrating the latest designs in centrifugal boiler feed water pumps and feed water systems. Attention was drawn to the saving in space which can be achieved by utilizing water cooled bearings.

During the second part of the paper Mr. Paterson discussed the characteristics which have to be taken into account when designing centrifugal pumps for specific or general purposes. Slides were shown illustrating some of the latest types of pumps for dealing with bilge water, liquid cargo and fuel oil.

In the ensuing discussion all questions put by members were fully answered by the lecturers.

Mr. Cotterill called upon Mr. Gilbertson to propose a vote of thanks for a most interesting paper.

The meeting closed at 9 p.m.

Dinner Party for Mr. Pemberton in New York

(Left to right) standing: Captain W. N. Landers, U.S.N., (Secretary of Naval Architects and Marine Engineers), J. H. Thomas (Chairman of the Eastern U.S.A. Section) and Sir W. Guy Ropner. Seated: Dr. A. W. Davis (Member), A. R. Gatewood (Vice-President I.Mar.E., U.S.A.), H. N. Pemberton (Member of Council), Charles Macpherson and W. J. Roberts

Eastern U.S.A. Section

The first lecture meeting of the Eastern U.S.A. Section, was held in New York on Monday, 17th October, and was attended by more than 130 members and guests. Mr. H. N. Pemberton, (Member of Council) Chief Engineer Surveyor to Lloyd's Register of Shipping, delivered his paper entitled "Marine Machinery Failures". Contributors to the discussion on the paper were Mr. John W. Heck, Chief Surveyor-Machinery, American Bureau of Shipping, and Capt. L. S. McCready, Head of the Department of Engineering, U.S. Merchant Marine Academy, Kings Point.

At the lecture

(Left to right) A. R. Gatewood (Vice-President I.Mar.E., U.S.A.) H.N. Pemberton (Member of Council) and J. H. Thomas (Chairman of the Eastern U.S.A. Section)

Mr. John H. Thomas, Section Chairman and President, John H. Thomas Inc., Marine Consultants, New York, was in the Chair. The meeting was followed by a reception and dinner.

Minutes of the Proceedings of the Student Meeting held at the Institute on Monday, 7th November 1960.

A meeting of the Student Section was held at The Memorial Building, 76 Mark Lane, London, E.C.3, on Monday, 7th November 1960 at 6.30 p.m.

A short film preceded the lecture on the "Construction and Layout of Modern Ships" which was given by Mr. R. S. Hogg (Member).

91 members and visitors were present and the lecture was followed by a short question period.

Mr. F. A. Everard (Member) was in the Chair and a vote of thanks to the lecturer by the Chairman was carried by acclamation.

Election of Members

Elected 14th November 1960

MEMBERS

Alfred Maurice Clift, Captain, R.A.N.
James Arthur Conn
Alexander Cathcart Coward, M.B.E.
Alan Cumyn
Kenneth Farnell, B.S.c.(Eng.), London
Harold Musgrave Finlinson
John Seymour Harper, Lieut., R.C.N.
James Allen Hide
Thomas Howard Rogers
Bernard Joseph Jennings, Lieut.(E), R.C.N.
Herbert V. Jones
Francis Edwin Kilvert
Norman Frederick Lee, Lieut. Cdr.(E), R.C.N.
John Louden McCann, Eng. Lieut., R.N.
Alexander McGarva
Arthur Frederick James Morgan
Edgar Camillus Victor John Morton
Melvin Samuel Moulton, Lieut. Cdr.(E), R.C.N.
Vivian Flanders Phillips
Charles Kenneth John Price
Carel Schavemaker
Robert Dickie Sinclair
Thomas George Threkeld, Lieut. Cdr.(E), R.C.N.
Harold Wagner
Edward George White
Leslie Williams
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Bruce Anthony Bolland
Kenneth Bradshaw
George Branton
Leslie Gordon Broad
Peter George Coldrick
Jack Anthony Pennington Collings
James Husband Donaldson
Kaye Alan Francis
Christian Anderson Connon Groundwater
Donald David Jones
James Kelly
Rudolph Johannes Kuhn
John Cecil Douglas Lock
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Paul Robert Marshall, Lieut., R.N.
Alan Mather
Robert Millar
Jonathan Alfred Lawrence Moody
William Norman Ower, Lieut.(E), R.C.N.
Herbert William Antony Oram
Keshaw Narayan Patwardhan, Sen. Cdr. Eng., I.N.
Shashikumar Damodar Pradhan
John Anthony Puckett
Douglas Russell Riley
Ashim Kumar Roy
Emanuel Peter Sanders
Norman Skene
Peter Smith
John Derrick Stephenson
David Arthur Timperley
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Albert Harold Wagner, Lieut.(E), R.C.N.
William Colin Weeks
John Weston
Alan Wood
Reginald Brook Wrenn, Lieut., R.N.

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Andrew James Lockhart McNab
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Peter Edward Calder
Barry Owen Field
Robert Campbell Houston
William Charles Mackay
William Dugald McLellan

John Albert Mathews
Robert William Miller
Desmond Leonard Morgan
John G. Vlavianos
Gerald Peter Ward

STUDENTS

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Richard Dudley Ault
Michael Roger Balsdon
Jeffrey Bates
Christopher James Belton
David John Blackwell
Cyril Edgar Brown
Peter Brown
Roy Frank Cheers
Richard James Duncan
David Ferry
Malcolm Guy Fletcher
Jeffery Ewart Harding
Alan Edgar Higgs
Peter Wayne Hopper
Richard Rae Howitt
Gordon Nicholas Hukins
Nigel Baines Hulley
Derek Edward Jennings
Patrick John Kennedy
Rodney Victor Kennedy
Alan David Lipscomb
Anthony Meese
Richard Samuel Newey
Richard Bernard Pykett
Rodney James Roberts
John Brian Smith
Robert Raymond Love Tilley
David John Webster

PROBATIONER STUDENTS

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Colin Michael Attwood
Peter Chalker
Kenneth Dale
Geoffrey Daniels
Paul Ebsworth
Clifford Everett
William Paton Forster
Timothy David Gibbs
Roger Edward Gillett
Robert Hancock
Peter Howard Nielsen Harrap
S. S. Hasson
R. A. Hepworth
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Timothy Francis Hudson
George William Leaver
Siu Siu Ng
Godfrey Laurence Nunn
Malcolm John Patman
David Alan Pink
Edmund John Saunders
David John Seear
Christopher Charles Thomas
Peter Guy Walton Vickers
Donald Ian Wallace
Christopher Wells
Douglas Stanley White
Christopher George Young

TRANSFER FROM ASSOCIATE MEMBER TO MEMBER

Vincent Whayman Bugg
Ronald Henry Paddon Row

TRANSFER FROM ASSOCIATE TO ASSOCIATE MEMBER

Ahmed Nawaz, Lieut., P.N.
Thomas James Gorham Wright

TRANSFER FROM GRADUATE TO ASSOCIATE MEMBER

William Christian Birkett
Alister Donald Bisset
Kyi Khin
Eric McLanders
Peter James Morgan
Colin Alexander Osborne
Gordon Trevor Stickland, B.Sc.
Paul Victor Turner
Terence John Wild

TRANSFER FROM STUDENT TO GRADUATE

Andrew Charles Wilkins

TRANSFER FROM PROBATIONER STUDENT TO GRADUATE

Peter John Bray

TRANSFER FROM PROBATIONER STUDENT TO STUDENT

Erik John Bannister
David Samuel Bloomer
Graham John Fennell
George Islay Gardner
David George Hosgood
David Vivian Jones

OBITUARY

CYRIL BERNARD IVES (Member 13723) died on 30th August 1960 aged 57 years. Born in London, he spent most of his early youth in Trieste where his father was a principal surveyor for Lloyds. He was educated at the Austrian State School, Trieste; Highgate School; and St. Andrew's College, Dublin. His apprenticeship was served with Fallons of Great Yarmouth and Denny Brothers Limited, Dumbarton. In 1924 Mr. Ives was appointed manager of the Yare Dry Dock Co. Ltd., Yarmouth, in 1929 assistant manager of White's Southampton Yacht Building and Engineering Co. Ltd. and a year later general manager of this company. He left this company in 1934 to become a partner in the firm of Bradford and Ives, marine surveyors and engineering agents, at Marseilles, where he remained until forced to leave because of the German occupation of France. From 1940 to 1943 Mr. Ives was temporarily with Grayson, Rollo and Clover Docks Ltd., Liverpool as ship repair and engineer manager but in 1943 volunteered for service with the Royal Engineers and was granted the rank of captain with responsibilities for marine craft repairs. After serving in the Normandy landings, he was first at Antwerp and then, at the cessation of hostilities, his company was transferred to Duisburg, Germany, where Captain Ives was required to assist in getting the inland shipyards and the local shipbuilding industry into operation once more. After release from the Army, Mr. Ives continued working for the Shipbuilding Branch, Control Commission for Germany, for as long as his services were required. In 1952 he was appointed manager of a subsidiary of the Beldam Packing and Rubber Co. Ltd. at Antwerp and remained in this capacity up to his death.

Mr. Ives's Membership of the Institute dated from 1952.

THOMAS JOSEPH LEIGHTON (Member 12464) was born on 5th April 1907. He was apprenticed to John Lynn and Co. Ltd of Sunderland between 1924 and 1929 when he joined the British India Steam Navigation Co. Ltd. as junior and fourth engineer. In 1934 he went to the Blue Star Line serving as junior engineer and as third and fourth refrigerating engineer; he was aboard the *Doric Star* when she was sunk, and consequently spent 3 months on the German prison ship *Altmark*. In 1940 he took up employment with the B.P. Tanker Co. Ltd and spent some time in the Persian Gulf. It was during his homecoming trip for leave from Abadan in 1943, that he was aboard the *Empress of Canada* when she in turn was sunk. From 1948 Mr. Leighton sailed as chief engineer with the B.P. Tanker Co. Ltd. until 1958 when he collapsed while at sea with coronary thrombosis and was taken to a nursing home in Colombo. It was ten months before he could return to work and then it was as engineer in charge of care and maintenance of ships laid up at Falmouth. After a short period there, Mr. Leighton was transferred to the head office of his company in London but was forced to retire through ill health in March of this year.

He held his First Class Board of Trade Steam Certificate with Motor Endorsement and had been elected a Member in 1949.

AENEAS MACNEILL (Associate Member 7450) was born on 22nd September 1908, and was apprenticed to the Australasian United Steam Navigation Co. Ltd. from 1925 to 1930, at the same time attending Sydney Technical College. He obtained an Australian Second Class Certificate and went to sea in 1930 serving progressively in the positions of seventh to fourth engineer, and in 1933 served in the last category on the s.s. *Nellore*. During this period he obtained his Australian First Class Certificate. Throughout the war he served with the Royal Australian Naval Reserve (S) and was promoted engineer lieutenant in 1943. Demobilized in 1949, Mr. MacNeill was appointed assistant superintendent engineer with Howard Smith-Australian Steamship (Proprietary) Ltd. He was a Member of the Australian Institute of Marine and Power Engineers and joined the Institute as an Associate Member in 1933.

Mr. MacNeill died in Australia on 13th September 1959.

HUGH MACNIVEN, M.B.E. (Member 6268) died suddenly of coronary thrombosis on 30th August 1960. Mr. Macniven served his apprenticeship from 1917 to 1922 with David Rowan and Co. Ltd. of Glasgow. He went to sea in 1922 and obtained his First Class Board of Trade Certificate. In 1929 he was a second engineer with the Bombay and Persia Steam Navigation Company and in the same year was elected a Member of the Institute. In 1942 he was commissioned captain in the Royal Army Ordnance Corps and served for two years in the United Kingdom, later with the Royal Electrical and Mechanical Engineers, with whom he went to North Africa and Italy, being awarded the Africa Star and M.B.E. (Military Division). In 1944 he was demobilized with the rank of major and returned to his former employment as superintendent engineer with the Anglo-Iranian Oil Co. Ltd., later rising to deputy chief engineer and finally, chief engineer (fields and pipelines). After the evacuation of Persia by the British, Mr. Macniven was appointed by British Petroleum as fields manager of Khanaquin Oil Co. Ltd. from 1951-54. He was transferred to Britannic House, London, where he spent two years on research in underwater drilling in South America and the Gulf of Mexico. It was Mr. Macniven who prepared the arrangements for British Petroleum's offshore drilling platform and base on Das Island in the Persian Gulf. In March 1956 he retired to Glasgow and with Weir and Cawder of Bishopbriggs, formed The Keir and Cawder Arrow Drilling Co. Ltd., the first Scottish company to drill under contract for oil abroad. As managing director, he started this company and secured contracts with Shell Oil Co. Ltd. in Turkey and with the Iraq Petroleum Co. Ltd. in Basra; he retained this position until his sudden death.

Besides his early Membership of the Institute, Mr. Macniven was a Member of the Institute of Petroleum and an Associate Member of the Institution of Mechanical Engineers.

WINDSOR COLIN MCKENZIE (Member 6576) died on 22nd July 1960, aged 75 years. Educated at Wiamatuku Public School and Invercargill Grammar School, New Zealand, he served his apprenticeship with the New Zealand Government Railways, and for a year also attended Dunedin Technical School. He first went to sea in 1911, for the New Zealand Shipping Co. Ltd. and, after obtaining his First Class Board of Trade Certificate, joined the Blue Star Line, serving as chief engineer on the *Gothic Star, Trojan Star* and *Arandora Star*. He received an Admiralty Commendation and Admiralty award during the First World War for bringing into port a ship which had been torpedoed. From 1918 to 1920 he was supervising repairs to torpedoed vessels in Italy, returning to sea until 1926 when he was for a year the Blue Star Line's resident engineer at the shipyards of Cammell Laird and Co. Ltd. In 1928 he finally left the sea to take up the appointment of assistant superintendent engineer of the Blue Star Line in London, later becoming chief superintendent of the line until his retirement in 1953 after 40 years' service with the company. Mr. McKenzie was a member of the Refrigerated Cargo Research Council, of which he was chairman of the technical committee in 1949, a Fellow of the Society of Consulting Marine Engineers and Ship Surveyors, a Member of the Institution of Mechanical Engineers and of the Royal Institution of Naval Architects and was elected to Membership of this Institute in 1930.

Francis Joseph Meredith (Student 14409) was born on 16th May 1928 at Victoria, British Columbia. He was apprenticed at the age of sixteen years at H.M. Canadian Dockyard, Esquimalt, B.C. until 1948 and then served in seagoing appointments almost continuously until 1950 when he was appointed stationary engineer to the British Columbia Power Commission at the John Hart power station, Campbell River. In 1951 as petty officer, first class, Royal Canadian Navy (Reserve), Mr. Meredith served on board H.M.C.S. *Athabaskan* while the ship was on a continuous tour of duty in the Korean war until July of the following year. Transferred from the Reserve to the Royal Canadian Navy in November 1952, he retained his rank and remained in the Korean Theatre, serving there on H.M.C.S. *Canyuga* till November 1954. Other appointments followed in Royal Canadian Navy ships and Royal Navy submarines including H.M. submarines *Tiptoe, Alliance* and *Amphion* for two years and in 1959 H.M.C.S. *Jonquière* and *Cape Breton.* Other periods in his naval career were spent in the shore bases H.M.C.S. *Cornwallis,* Annapolis County, Nova Scotia; H.M.C.S. *Stadacona,* Halifax, N.S.; and H.M.C.S. *Naden,* Esquimalt, B.C.

Mr. Meredith was elected a Student of the Institute in 1953. He died at a Royal Canadian Navy hospital on 11th July 1960.

Albert Ostens (Member 9412) died in London on 30th October 1959, aged seventy-four. He had been a consulting engineer, naval architect and marine surveyor in Middlesbrough for thirty-eight years.

He was apprenticed for six years to the North Eastern Marine Engineering Co. Ltd., Wallsend on Tyne, and then served the same company as senior draughtsman for a further two years before going to sea. He was in merchant ships for two years and then Engineer Lieutenant Commander in the Royal Navy for four. This experience was followed by employment with Smith's Dock Co. Ltd., successively as chief draughtsman, engine works manager and manager on ship repairs.

In 1919 Mr. Ostens set up in private practice as the principal of Albert Ostens Ltd.; he was hull and machinery surveyor to Germanischer Lloyd, the British Corporation and Bureau Veritas; he was superintendent for two shipping companies, surveyor for underwriters and war risks insurance associations, surveyor in the Tees district for Treasury solicitors, and consultant to the Ministry of Labour as senior technical officer. He retired from business in 1957.

Mr. Ostens was elected to Membership of the Institute of Marine Engineers in 1942. He was a Member of the Royal Institution of Naval Architects and a Fellow of the Society of Consulting Marine Engineers and Ship Surveyors.

Robert Cecil Rhodes (Member 14003) died aged 61 years on 5th September 1960 at Edinburgh. He started his career as a mine engineering apprentice with Vickers-Armstrongs (Shipbuilders and Engineers) Ltd. at Barrow-in-Furness. From 1922 to 1936 he served at sea in the motor tankers of the Anglo-American Oil Company and at the age of 29 he was chief engineer of m.v. *Narraganset,* the largest motor tanker afloat at that time (1927). He returned to Vickers-Armstrongs in 1936 first as a draughtsman and was later appointed marine engine manager. During the war Mr. Rhodes specialized in naval work and submarine construction at the famous High Walker Naval Yard in Newcastle. In 1945 he returned to the Barrow works and was associated with such ships as the *Orcades, Oronsay, Himalaya* and the large Niarchos tankers. After a period of four years with William Doxford and Sons Ltd. from 1952, he joined the board of Andersons Insulation Co. Ltd. of Liverpool with the appointment of general manager.

Mr. Rhodes was elected a Member of the Institute in 1952.

William Frederick Springgay (Associate 10829) was born on 23rd August 1901. Mr. Springgay served a six and half-year apprenticeship in shipbuilding and marine engineering. He attended evening classes in the Church Square Schools, West Hartlepool. From 1924 he began his seagoing career and served in many capacities in the oil tankers of the Venezuelan Gulf Oil Co. During the Second World War he was engineer in charge of a minesweeper and in June 1945 became engineer officer in charge of the Nore Special Pool, East India Import Dock. Mr. Springgay joined the United Glass Bottle Manufacturers Ltd. in 1948. He underwent four major abdominal operations in the last two and a quarter years, the fourth being in December 1959. This seemed to overcome the cause of his illness and he finally obtained his surgeon's permission to return to work. He reported for duty on Monday, 25th April 1960, and after saying two sentences to his colleagues, collapsed and died immediately.

Mr. Springgay was an engineer lieutenant in the Royal Naval Volunteer Reserve and became an Associate of the Institute in 1946.

Thomas Ken-Yan Tam (Associate 11765), who was born on 28th February 1916, died recently. He served his apprenticeship with the Hongkong and Whampoa Dock Co. Ltd. from 1936 to 1939, having graduated in 1935 from the Government Naval College, Kwangtung, South China, where he had taken an engineering course. In 1939 he began studies at the University of South China, Kwangtung, and three years later obtained a Bachelor of Science degree in Mechanical Engineering. Between 1943 and 1944, Mr. Tam came to England and took up employment as a post graduate student first with Swan Hunter and Wigham Richardson Ltd., Newcastle upon Tyne and then with the Associated Equipment Company, Southall, Middlesex. Returning to China in 1948, he was appointed Lecturer in Marine Engineering at the Central Navigation College, Canton. After three years Mr. Tam set up privately in the export/import business, making good use of his marine engineering knowledge. In 1955 he decided to establish himself in Zurich and later opened the first Chinese restaurant in the city, called the Restaurant Hong Kong, which has become well known for its cuisine and is very popular with the citizens of Zurich. He worked very hard to achieve this result and it is thought that these exertions brought on the sudden heart trouble which afflicted him.

Mr. Tam was a Graduate of the North East Coast Institution of Engineers and Shipbuilders, a Member of the Anglo-Chinese Chamber of Commerce, London, and of the Chinese Engineering Society in Great Britain, and was made an Associate of this Institute in 1948.