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**INTERNATIONAL CONFERENCE ON  
MARINE POLLUTION, 1973**

**REPORTS ON NINE STUDIES**

Attached hereto is a copy of the final report of Study No. III - Retention of Oil on Board - submitted by the Government of the United Kingdom.

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## IMCO

SUB-COMMITTEE ON MARINE POLLUTION -  
13th session  
Agenda item 2(a)

### PREPARATION FOR AN INTERNATIONAL CONFERENCE ON MARINE POLLUTION IN 1973

Continuing reports on studies initiated at  
the tenth session

#### Final Report on Study III (Retention of oil on board)

Submitted by the United Kingdom

1. ANALYSIS OF THE LIMITATIONS OF THE PRESENT PROCEDURES
- 1.1 OUTLINE OF PRESENT LOAD ON TOP PROCEDURES, CAPABILITIES AND DEFICIENCIES
- 1.1.1 GENERAL PROCEDURE

The load on top procedure may be considered to consist of six principal stages:

- (1) Before departure from a discharge port, or en route, water ballast is loaded into dirty cargo tanks. The minimum number of tanks are ballasted consistent with good operating practice and weather conditions. The amount of ballast required might typically be some 40% of the ship's cargo carrying capacity but this might need to be increased substantially in severe weather. Cargo pumps and lines are washed as far as possible at this stage.

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- (ii) During the voyage selected cargo tanks are washed, primarily to provide clean ballast capacity, but additional tanks may be washed to control the accumulation of residues or for tank inspection and minor repair. Contaminated water from tank washing is transferred to a slop tank where the oil is allowed to settle out from the water. On older ships the slop tank may be a cargo tank but more modern ships are likely to have specially constructed slop tanks. The washed tanks are subsequently filled with water ballast to replace that contained in the dirty cargo tanks.
- (iii) The bulk of the ballast water in the dirty cargo tanks, from which most of the oil will have settled out by gravity, is discharged to the sea. This process is stopped as the oil/water interface is approached and the remaining mixture of oil and water is transferred to the slop tanks, which will now contain oil and residues from the tank washing process, from the last few feet of emptying the dirty ballast tanks and from line washings.
- (iv) After a further period of settling the bulk of the separated water in the slop tank is discharged to the sea.
- (v) The relatively small amount of free water remaining in the slop tank is discharged to the sea at a slow and decreasing pumping rate until serious entrainment of the oil/water interface is detected when the operation is stopped. The mixture of oil and water remaining in the slop tanks will be mixed with the next cargo by loading that cargo "on top".

- (vi) Finally the clean ballast loaded into the cargo tanks washed on the voyage can be discharged into harbour waters at the loading port.

The review which follows examines the procedures under each of the above heads (except for (i) which calls for no further comment) and gives figures for the amount of oil discharged at sea which may be expected in conscientious and competent operations.

(11) Washing of Cargo Tanks

The following procedures are typical for in-service operation, where perhaps one-third to one-half of the tank capacity is washed on any voyage (in certain cases, such as before proceeding to dry dock, all tanks will be cleaned):

- (a) On older ships washings are stripped to a normal cargo tank. Separated water may be run down to the sea continuously or the washings may be allowed to settle. In the latter case, if the quantity of washings exceeds the capacity of the tank, the washing process is interrupted until further capacity can be made available by discharging settled water. Settled water is pumped to the sea or run down by gravity. Typical effluent characteristics are:

	<u>With settling</u>	<u>With continuous run-down during washing</u>
Total Quantity	6,000 cubic metres	6,000 cubic metres
Rate	1,000 cubic metres/hour	140 cubic metres/hour
Oil Content	150 ppm	250 ppm
Oil Rate	10.5 litres/mile	2.5 litres/mile
Total Oil	0.9 cubic metres	1.5 cubic metres

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- (b) On newer ships of moderate deadweight equipped with re-circulating systems, water is loaded into slop tank(s) and washing water and eductor stripping drive water is re-circulated on closed cycles. No effluent during washing.
- (c) On VLCCs equipped with re-circulating systems but currently unable to use them because of possible explosion hazards the system is at present operated on open cycle as for (a). Because of the high capacity cleaning guns fitted on some of these ships and the eductor drive water requirements the open cycle effluent rate is high. Typical effluent characteristics are:

Total Quantity - 80,000 cubic metres

Rate - 2,000 cubic metres/hour

Oil Content - 200 ppm

Oil Rate - 25 litres/mile

Total Oil - 16 cubic metres.

Effluent characteristics in category (a) above are inherent to the ship and perhaps somewhat dependent upon the previous cargo(es) but little subject to maloperation. Category (c) with its high total oil can be abandoned when it is possible to revert to the use of re-circulatory washings on VLCCs.

(iii) Discharge to sea of the bulk of the settled "dirty" ballast water

Lines and pumps washed during the initial ballasting are used or if necessary additional lines and pumps are washed into the slop tank(s). In calm to moderate weather typical effluent characteristics are:

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Total quantity - 25% of Dwt (cubic metres)

Rate - 2.5% of Dwt/hr. (Cubic metres/hour)

Oil Content - 30 ppm

Oil rate -  $\frac{2.5}{100} \times \frac{30}{10^6} \times \frac{\text{Dwt}}{\text{Speed}} \times 1,000$  litres/mile

Total Oil -  $\frac{25}{100} \times \frac{30}{10^6} \times \text{Dwt}$  cubic metres

Characteristics for a 70,000 Dwt ship therefore might be:

Oil rate - 3.5 litres/mile

Total oil - 0.5 cubic metres

For a 200,000 Dwt ship:

Oil Rate - 10 litres/mile

Total Oil - 1.5 cubic metres.

Correct operation of this part of the procedure is at present a matter of experience and good judgment. On a normal voyage, by the time discharge of dirty ballast starts the bulk of the ballast will have "cleaned" itself to 15-30 ppm. to within inches of the floating layer of oil and can safely be discharged to sea. However, when the floating oil layer begins to be drawn down to the pump suction the oil content in the discharge starts to rise dramatically; at this point the effluent must be quickly diverted to the slop tank. The tank sounding when this occurs will depend on the rate of pumping, the sea state and consequent ship motion, and upon the characteristics of the pump suction and tank bottom. A competent operator will know from experience at what sounding to divert to be certain of non-entrainment of the floating oil but if the required judgment and experience are lacking, over-late diversion to the slop tank may result. Fitting of a reliable oil content monitor to indicate the rise of oil content as entrainment begins can overcome this problem and avoid the risk of excessive discharge of oil.

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Experimental work undertaken in the USSR suggests that the risk of pollution during the discharge of dirty ballast can be minimized if the ballast is discharged through a vacuum tank (one or more cargo tanks kept under a vacuum as a result of hermetic sealing or the use of a special vacuum pump or ejector pump). It is claimed that in this way the oil/water mixture is not agitated in the pumps and the danger of discharging oil overboard through entrainment of the oil layer when the level of ballast in the tanks is lowered is avoided. It is stated that the oil content of the ballast water can be kept down to an average of 50 ppm and always below 100 ppm by the use of this method.

(iv) Discharge to the sea of the bulk of the separated water in the slop tank(s)

To a large extent the oil contained in the slop tank(s) will be in the form of a water in oil emulsion generated by the washing process and possibly also by the pumps when passing oil and water mixtures containing a large proportion of oil. Experimental work in Japan suggests that this effect is greater when the cargo pumps are used to transfer mixtures to the slop tanks than when stripping pumps are used. The water content of this emulsion can vary widely depending probably on the asphaltene and wax content of the recovered oil and will in any case vary through the depth of the oily layer in the slop tank, with the dryer oil at the top and the wettest emulsion (with up to 70% water content) near the interface of the oil and the water. The emulsion is extremely stable but can be broken to release virtually all its entrapped water by heating to above 60°C or by the addition of a chemical emulsion breaker together with a lesser degree of heating. Many ships are equipped with heating coils arranged at oil layer height in the slop tank to dehydrate the recovered residues.

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The interface between the floating oil or emulsion layer and the water is always sharp though its profile is jagged. The depth of the profile (as judged from shore simulation in translucent model tanks) is probably no more than 1 or 2 inches, although the layer immediately above the water is likely to be an emulsion with a high water content.

The water below the oily layer is an oil in water dispersion. Any major oil contamination of this water settles very rapidly as is shown by the low contamination (around 200 ppm) of re-circulated wash water. Below this level the free water clears somewhat slowly and in this respect is quite different from oily ballast water. This difference is most probably due to the finer dispersion of oil generated in the washing or pumping (or educting) processes and to the presence in the washing water of fine particulate matter coated with oil and having a near neutral buoyancy. The Japanese work referred to above suggests that settling is slower when slops are transferred by cargo pumps than when stripping pumps are used. After several hours settling the free water in the slop tank in calm to moderate weather may generally have an oil content of between 100 and 300 ppm, though higher values have been reported.

The amount of free water to be discharged and the rates employed vary with size and design of ship. Typical characteristics are:

For a 30,000 TDW crude carrier

Total quantity - 1,000 cubic metres (aft centre tank used  
as slop tank)

Rate - 1,000 cubic metres/hour

Oil Content - 150 ppm

Oil Rate - 10.5 litres/mile

Total Oil - 0.15 cubic metres



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For a 200,000 TDW crude carrier

Total Quantity - 3,500 cubic metres (from special slop tank(s))

Rate - 3,000 cubic metres/hour

Oil Content - 150 ppm

Oil Rate - 30 litres/mile

Total Oil - 0.53 cubic metres

The effluent characteristics of this phase of the procedure are intrinsic and not subject to maloperation but performance in heavy weather with much ship movement will result in higher oil content. Oil content could be reduced by passing the whole of the slop tank water via a separator, but the discharge rate would have to be considerably reduced since existing separators have a maximum throughput of 300 cubic metres/hour and the improvement in oil content would be only marginal.

Because the approach to the oil/water interface is a critical phase in terms of pollution it is dealt with separately in the next section.

(v) Final discharge of slop tank water

Any water left in the slop tank must ultimately be delivered to the refinery receiving the next cargo. Since the refiner must remove any salt water before the crude enters the distillation stream there is pressure for tankers to minimize the salt water associated with load on top cargoes. In the USSR the amount of contaminated oil which may be mixed with a subsequent cargo is limited according to its water and salt content. Quantities of residues above the limit are pumped ashore at the loading terminal and further processed before being mixed into cargoes taken by other tankers.

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Under full rate pumping by a main cargo pump the oil/water interface may well start to be entrained when the water innage is 6 to 10 feet. The conscientious operator will therefore reduce his pumping rate as these levels are approached and change over from a main cargo pump to a stripping pump so that ever decreasing rates may be employed. Serious entrainment of the interface may then be postponed until only a few inches of water innage remains. This decanting of the last few feet of slop water has two distinct phases - the slow pumping period (2-3 hours) during which the oil content is gradually increasing and the short period required to stop the pump once serious entrainment of the interface has been detected.

Effluent characteristics typical of these two phases are:

For a 30,000 Dwt crude carrier

Interface approaching suction

Quantity - 300 cubic metres  
Rate - 100 cubic metres/hour  
Oil Content - 500 ppm (average)  
Oil Rate - 3.5 litres/mile (average)  
Oil quantity - 0.15 cubic metres

During cut off

Quantity - 2 cubic metres  
Rate - 50 cubic metres/hour  
Oil Content - 4,000 ppm (max)  
Oil Rate - 14 litres/mile (max)  
Total Oil - 0.008 cubic metres (max)

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For a 200,000 Dwt crude carrier

Interface approaching suction

Quantity - 500 cubic metres  
Rate - 200 cubic metres/hour  
Oil Content - 500 ppm (average)  
Oil Rate - 6 litres/mile (average)  
Total Oil - 0.25 cubic metres

At cut off

Quantity - 15 cubic metres  
Rate - 100 cubic metres/hour  
Oil Content - >10,000 ppm  
Oil Rate - >67 litres/mile  
Total Oil - >0.15 cubic metres

At the moment the only method generally available of detecting the cut off point is to sight visually the overboard discharge or, if this is under water, to survey the wake for the first appearance of oil. The above figures relate to this method. It has been found reliable on ships up to 70,000 Dwt if conscientiously practised but is less satisfactory on the new VLCCs with underwater discharges. It seems likely that on these ships the dilution of the effluent stream as it passes round the large hull and through the powerful propellor race is such that substantially more oil can pass undetected into the wake than on smaller, less powerful ships.

This problem could, however, be solved by processing oil drawn from the interface in an efficient gravity separator of adequate capacity (>200 cubic metres/hour). This has the added advantage of obviating the continuous attention required in the present visual procedure. The separator can accept neat oil whilst automatically preventing any significant oil passing to the sea.

Thus it would be possible without constant attention to pump right down through the interface and rid the slop tank of all its free water with consequent improvement in dead freight and reduction in salt water passed with the next cargo to the refinery.

An alternative to the use of a separator as a means of improving cut off technique would, of course, be the provision of a reliable rapid response oil in water monitor.

(vi) Discharge of clean ballast

Clean sea water loaded into cargo tanks cleaned by the standard washing techniques may contain up to about 5 ppm of oil, which will not cause a sheen when discharged into harbour water. Discharge is, however, via main cargo lines and pumps which are full of oil on the loaded voyage and may have passed oily water during the tank washing and deballasting procedures. These lines and pumps are cleaned as far as possible when ballast is being taken into dirty tanks and by flushing into the slop tanks but the thorough washing of lines is a tedious, and on many existing ships a difficult process. The most competent operator can rarely be absolutely sure that his ballast discharge lines are completely clear of oil, and that oil will not be emitted at the start of deballasting. It has consequently become standard practice briefly to operate the ballast discharge route whilst still at sea. Any entrapped oil discharged cannot be measured since it passes out in seconds. Observation suggests that if lines have been conscientiously washed the amount may be no more than a bucketful, but if care has been lacking with a difficult pipeline layout the amount can be very much more. There is a need to design future pipeline configurations with a view to ease of washing and study is being given to providing means of drainage or flushing of deadends in pipework on existing ships.

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1.1.2 SUMMARY OF TOTAL OIL TO SEA (ASSUMING AVERAGE BALLAST VOYAGE)

For a 30,000 TDW crude carrier typically:

- (a) During washing of tanks - 1.5 cubic metres
- (b) During discharge of dirty ballast - 0.225 cubic metres
- (c) During bulk discharge of slop water - 0.15 cubic metres
- (d) During final decanting of slop water - 0.16 cubic metres
- (e) During flush of deballasting line - negligible with good operation.

Total oil - 2.04 cubic metres plus oil during deballasting flush.

1969 Amendment limitation =  $1/15,000 \times \frac{30,000}{.85} = 2.35 \text{ cu.m.}$

For a 200,000 TDW crude carrier using re-circulation as designed:

- (a) During washing - 0
- (b) During discharge of dirty ballast - 1.5 cubic metres
- (c) During bulk discharge of slop water - 0.53 cubic metres
- (d) During final decanting of slop water - 0.4 cubic metres
- (e) During flush of deballasting line - negligible with good operation.

Total oil - 2.43 cubic metres plus oil during deballasting flush.

1969 Amendment limitation =  $1/15,000 \times \frac{200,000}{.85} = 15.7 \text{ cu.m.}$

For a 200,000 TDW crude carrier designed for re-circulation but operating temporarily open cycle:

- (a) During washing - 16 cubic metres
- (b) During discharge of dirty ballast - 1.5 cubic metres
- (c) During bulk discharge of slop water - 0.53 cubic metres

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(d) During final decanting of slop water - 0.4 cubic metres

(e) During flush of deballasting line - negligible with good operation.

Total oil - 18.43 cubic metres plus oil during deballasting flush.

$$1969 \text{ Amendment limitation} = 1/15,000 \times \frac{200,000}{.85} = 15.7 \text{ cu.m.}$$

Comparison of Quantities discharged for one complete washing cycle (for an assumed ship speed of 16 knots) and all cargo tanks washed.

TONNAGE DWT TONS	WASH WATER QUANTITY M <sup>3</sup>	OIL CONTENT PPM	PUMPING RATE OVERBOARD DISCHARGE M <sup>3</sup> /HR	OIL DISCHARGED LITRE/MILE	TOTAL OIL DISCHARGED M <sup>3</sup>
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(a) Open cycle washing with continuous discharge during washing

30,000	12,000	250	140	2.20	3.0
70,000	28,000	250	200	3.10	7.0
200,000	80,000	250	400	6.30	20.0

(b) Washing with settling of mixture before discharge

30,000	12,000	150	1,000	9.50	1.8
70,000	28,000	150	1,500	14.10	4.2
200,000	80,000	150	4,000	37.50	12.0

(c) Recirculation of wash water with settling before discharge

30,000	1,200	150	1,000	9.50	0.2
70,000	2,800	150	1,500	14.10	0.4
200,000	8,000	150	4,000	37.50	1.2

(d) Recirculation of wash water with final discharge through separator

30,000	1,200	100	140	0.90	0.1
70,000	2,800	100	200	1.25	0.3
200,000	8,000	100	400	2.50	0.8

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## 1.2 PROBLEMS OF OPERATING SHIPBOARD SEPARATION SYSTEMS WITH SHORT HAUL CARRIERS

Experience with short haul carriers of 65,000 to 90,000 DWT indicates that a minimum of 50 hours is needed to carry out an effective load on top operation in good weather but much more time may be required if conditions are adverse. This assumes that there are no ballast receiving facilities at the loading terminal and vessels are required to tank clean for clean ballast en route, and the decanting process is assisted by heating in the slop tank and the addition of a chemical demulsifier to expedite the separation process. Ballast carried approximates to 30% of the deadweight.

Ships on short haul runs have therefore been advised where there is insufficient time to carry out an effective load on top operation at full speed, to slow down and take more time to complete the operation or, in certain circumstances, to proceed at speed and deadfreight the entire contents of the slop tank which may amount to 3,500 cubic metres of oil and water mixed.

As a means of improving the load on top operation on short haul runs one owner is evaluating the performance of separators on short haul carriers since there is more incentive to install separators on vessels in this trade.

## 1.3 TANK CLEANING PROBLEMS OF LARGE OBO VESSELS

There are two basic approaches to operating OBO vessels:

- (a) to employ them in either the oil or dry bulk trade in isolation for a long period;

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- (b) to employ them in a trade which may regularly require them to carry oil and dry bulk cargoes on consecutive legs of the voyage thus necessitating frequent alterations to adapt a vessel for the next cargo.

When used as at (a) above for the carriage of oil the vessel can be regarded as to all intents and purposes a tanker operating on the "load on top" principle. The tank cleaning problems are basically similar to those of crude carrying tankers of corresponding size but will often be less severe due to the considerable reduction of structural members in the holds. Furthermore, less oil residue is left after discharge than in the case of the normal tanker. Unlike the VLCC the OBO vessel may have some 28% to 36% clean ballast capacity though it would still, dependent on weather conditions, probably ballast one or two holds to achieve a satisfactory sea-going condition after discharging an oil cargo.

Generally speaking the "load on top" method employed on OBO vessels is no different from that used on tankers, but in fully inerted ships it is usual to carry out oil/water separation in two stages. Initially all tank washings are collected in an after cargo compartment and the clean water bottom run off. Because of the large surface area of liquid in relation to the depth of the compartment this is a somewhat slow operation even if heating is applied but because of the large quantities of water/oil involved (up to 10,600 cubic metres for a 75,000 tonner and about 16,500 cubic metres for a 150,000 tonner, or double these quantities if stripping eductors are used) it is necessary to reduce the bulk of the tank washings before the slop tanks proper are used. Following this initial separation the remaining oily water mixture is pumped into the primary slop tank and allowed to separate, after which the water bottom is run off into the secondary tank (as in the dual slop tank system used in many tankers). In the case of non inerted vessels tank washings must be stripped direct



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to the primary slop tank and because of the time required for the natural separation of oil and water the process is generally longer.

Having cleaned holds and tanks the OBO vessel, will, like a tanker, have in her slop tanks a quantity of cargo oil residue and contaminated water. If the next cargo to be loaded is oil, the problem of dealing with these slops is no different from that with a conventional tanker and provided the cargo can be loaded on top of the slops or the slops can be received ashore no great difficulty arises.

Where, however, the next cargo to be loaded is a dry bulk cargo, either because of a change of use under (a) above or because the vessel is being operated as at (b), difficulties do arise because the time required to clean tanks and gas free (from 3 to 5 days for a 75,000 tonner or from 8-10 days for a 150,000 tonner) may exceed the normal steaming time between the oil discharging port and the loading port for the dry cargo. Even when there is sufficient time to clean and gas free, vessels will still arrive at the loading port with slops on board and, in the absence of slop reception facilities at that port will have to leave with correspondingly less dry cargo.

To cater for the carriage of oil residue on dry cargo operations the arrangement of slop tanks on recently built OBO vessels is as follows:

- (i) The tanks are completely segregated from other cargo compartments by means of cofferdams and are normally located in the vicinity of the pump room (on some vessels saddle tanks are used for cargo oil residues).
- (ii) They have independent gas venting systems.

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- (iii) The pumping and pipeline system connecting the slop tanks to the main oil cargo pumping system is designed so that it can be completely blanked off when residual cargo oil is carried on dry cargo operations.

Lloyds Register do not in fact permit vessels to their classification to load a dry bulk cargo whilst retaining slops on board unless these conditions are substantially complied with.

There are indications that some port authorities may in the future insist that OBO vessels are completely gas free before permitting loading or discharge of dry bulk cargo.

There is no scope for dealing with these problems by the fitting of additional equipment aboard the ships concerned. Possible solutions are:

- (i) Port authorities to accept a vessel for loading with the slop tanks made safe by means of inert gas, high expansion foam or by ballasting so as virtually to eliminate the air space above the liquid cargo. At best this only postpones the problem of disposing of the slops and could not be used by some vessels, e.g. those which use their saddle tanks as slop tanks.
- (ii) Clean and gas free cargo oil spaces at the discharging port, disposing of oil residues ashore. This would require slop reception facilities at all oil discharge ports and involve additional cost and delays for shipowners.
- (iii) Clean and gas free vessels at sea but discharge slops ashore or into a barge prior to loading. This is the ideal solution for the shipowner but it is doubtful whether these facilities could be provided at all bulk loading ports.

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- (iv) A partial solution in the long term may lie in the development of techniques to enable cargo oil residues to be used as a main propulsion fuel. (Experiments have been carried out in the USSR, using a tanker, and preliminary results show that the addition to boiler fuel of not more than 10% of residual cargo oil, suitably treated to lower the flashpoint and reduce the salt content, does not cause any material changes in the physical characteristics of the boiler fuel).

#### 1.4 SUMMARY OF SECTION 1

As stated, the figures given above are capable of achievement by conscientious, careful and competent exercise of the load on top system. It is recognized, however, that wide variations must be expected in the degree of care with which the system is operated and that taken over the "load on top" fleet as a whole (some 80% of the world's tankers) the amount of oil reaching the sea is likely to be greater than the above figures would imply. The greatest weakness of the system as currently practised is that it relies to an undesirable degree upon human observation and judgment so that, lack of care apart, any deficiency in the exercise of those two faculties carries with it the risk of avoidable discharges of oil. As the foregoing makes clear, particularly vulnerable points are:

- (a) the approach to the oil/water interface during the discharge of dirty ballast, when inexperience or faulty judgment may lead to delay in diverting the effluent to the slop tank as the interface is approached;
- (b) the approach to the oil/water interface during the discharge of settled water from the slop tank;

- (c) the final discharge of slop tank water. In this phase excessive discharge of oil is possible both as a result of failure to pump sufficiently slowly or delay in stopping the pump when serious entrainment of the interface is detected and as a result of the configuration of modern VLCC's with underwater discharges, when difficulties may arise in detecting oil in the ship's wake until substantial quantities have been discharged.

Section 2 of this paper describes the equipment currently available and in prospect, which will help to eliminate reliance upon the human element and ensure that the low figures for total oil discharge achieved by the most efficient operators are obtainable in all "load on top" operations.

## 2. EQUIPMENT AVAILABLE

### 2.1 SEPARATORS

#### 2.1.1 USES OF SEPARATORS

The use of separators on board ships can be considered in three main areas:

- (i) to clean up engine room and other bilges on tankers and on other ships and to remove the oil content from ballast water in dry cargo ships which use their bunker fuel tanks for water ballast;
- (ii) to ensure that the dirty ballast water pumped overboard from a tanker contains the minimum amount of oil;
- (iii) to reduce the oil content of slops water in tankers and allow the oil/water interface to be reached without a marked increase in the amount of oil entering the sea.

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### 2.1.2 SEPARATORS FOR TANKER MACHINERY SPACE BILGES AND FOR NON-TANKERS

In machinery spaces there are two aspects of daily operation which are possible sources of ocean pollution:

- (a) In motor vessels there is the problem of fuel oil purification. A 15,000 bhp continuously rated installation will consume 58 tonnes/day and this will produce, depending upon fuel quality, between  $\frac{1}{2}$  and  $1\frac{1}{2}$  tonnes of sludge over a voyage length of 10 days. In a large installation of 28,000 bhp between 3 and 6 tonnes of sludge will be accumulated on voyage from Europe to Persian Gulf. There is also the possibility of bunkering inferior quality blended fuel in which case sludge could amount to 1 tonne per day, but such instances are rare.

The majority of vessels are provided with sludge tanks where the residue is collected for eventual disposal ashore.

- (b) Some existing vessels which do not utilize fuel tanks for ballast purposes are not provided with oily water separators, thus oily bilge water collected in machinery spaces is assumed to have settled allowing "water" to be discharged overboard leaving the oil residue to be dealt with by manual means. Even the settled water will have some oil content but in practice it is highly probable that the whole of the bilge contents is pumped directly overboard.

The cost of a separator for dealing with oily bilge water in a dry cargo vessel varies according to capacity and type. For a medium-sized ocean-going vessel, a separator with a capacity of 50 tons per hour should be adequate. Typical separators of this

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capacity cost in the region of £1,000. A 20 ton per hour model can be obtained for around £850. Pumps for these models are priced at around £500.

Installation costs for this equipment vary from ship to ship, dependent upon (i) the shipyard chosen, (ii) the availability of space to site the separator and pump, and (iii) the design of the ship, taking into account the necessary pipe-work, provision of an in-port holding tank and saveall and drainage arrangements in way of service tanks. Accordingly, estimates for the provision and installation of a separator and ancillary equipment in a new ship range from £1,850 to £4,800, and in an existing ship from £3,500 to £8,000.

It is normal in modern installations to have an oily bilge and a so-called "clean bilge" system. In the first case small tanks and units which may produce oil leaks are provided with savealls and drainage which is led to the oily bilge(s). The remaining areas are dealt with as a clean bilge. However, it is probable that this bilge water will be contaminated with oil due to main engine leaks, etc. Further effort is required in the design of machinery to minimize the possibility of oil leaks. Present practice is to pump the oily bilge through the separator, the recovered oil being returned to an oil storage tank whilst the separated water is discharged overboard.

The "clean" bilge can be pumped directly overboard via the bilge pump. Alternatively it is possible to utilize the oily bilge pump and separator in a similar manner to the treatment of the oily bilge.

It is the practice on many vessels not to pump the whole of the bilge water but to maintain a level in the bilges such that the tank top is reasonably dry. Tunnel wells are seldom pumped dry due to the possibility of blocking the suction with waste, etc.

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This arrangement does allow a natural settlement to occur, but as bilges are sometimes pumped each watch, the time allowed could be insufficient.

It must be admitted that with the pipe line arrangement aboard many vessels it is all too easy to discharge bilges overboard without settlement. A further problem arises whilst vessels are in port - a special tank will therefore be necessary for retention of oily bilge water unless facilities are available for shore discharge.

The majority of separators fitted to UK vessels are of the static type, which the manufacturers claim can produce a result of 35 ppm in purified water. However, such results demand strict adherence to operating instructions, regular maintenance (the cost of which is negligible, and is usually carried out by ships' staff) and cleaning generally - the comments in paragraph 2.1.3 also apply.

### 2.1.3 USE OF SEPARATORS IN TANKERS

Experience has shown that an effluent quality better than 100 ppm cannot be assured under all conditions which may be experienced in service. In general, the greater the contamination in the inlet to the separator, the higher the oil concentration in the effluent. Conversely, if the throughput is reduced below the rated capacity of the separator, the unit can successfully treat quite heavily contaminated water. However, the maximum instantaneous rate of 60 litres a mile for oil discharge laid down in the 1969 amendments can be reliably met under normal operating conditions for slop separation purposes.

Certain precautions need to be observed in operating separators to obtain the best results. These include washing out the separator before use to avoid the possibility of a slug of oil going overboard; limiting throughput to 80% of theoretical

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capacity; and cleaning out the separator during the discharge operation if the slop contains excess sediment.

During normal operation the separator will ensure that no undiluted oil goes overboard should there be entrainment at the pump suction, thus relieving the crew of the need to observe the discharge continually and reducing the net amount of work to be done.

To handle the bulk discharge of dirty ballast a separator would need to deal with flow rates up to 6,000 tons/hour. Since the bulk of the dirty ballast already has an oil content much below 100 ppm, a separator would need to reduce such levels substantially to be of value. If free oil enters the system, when the oil/water interface is reached, the separator should not allow it to be discharged overboard. Most separators designed for tankers have relied on gravity separation and have been designed for flow rates up to about 350 tons/hour. These have in some cases operated reasonably well when the oil droplets are fairly large and uniformly dispersed. They cease to operate efficiently as the droplet size decreases, unless the throughput is substantially decreased. They do, however, have the advantage that they will stop free oil from being discharged overboard.

Other types of separator are now being considered. One is based on the principle of filter coalescence of the oil droplets. Many of them would need a pre-separator of the gravity type to ensure that free oil did not enter the main separator. Such separating systems would also need efficient oil content meters and monitors as discussed below.

It is also theoretically possible to pass the water being discharged overboard through a filter after passing through a separator. By this means, the oil content in the discharge could be reduced to less than 20 ppm. However, taking account



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of the large volumes of water encountered in cargo tank cleaning, it is unlikely that a discharge filter would be economically feasible at present. Such a device could be viable for machinery space discharges.

Consequently at present it is not considered that separators will give a significant decrease in the oil content of dirty ballast water or for the bulk of slops water discharge. They may, however, have an increasing use to allow the oil/water interface to be approached closely without excessive discharge of oil.

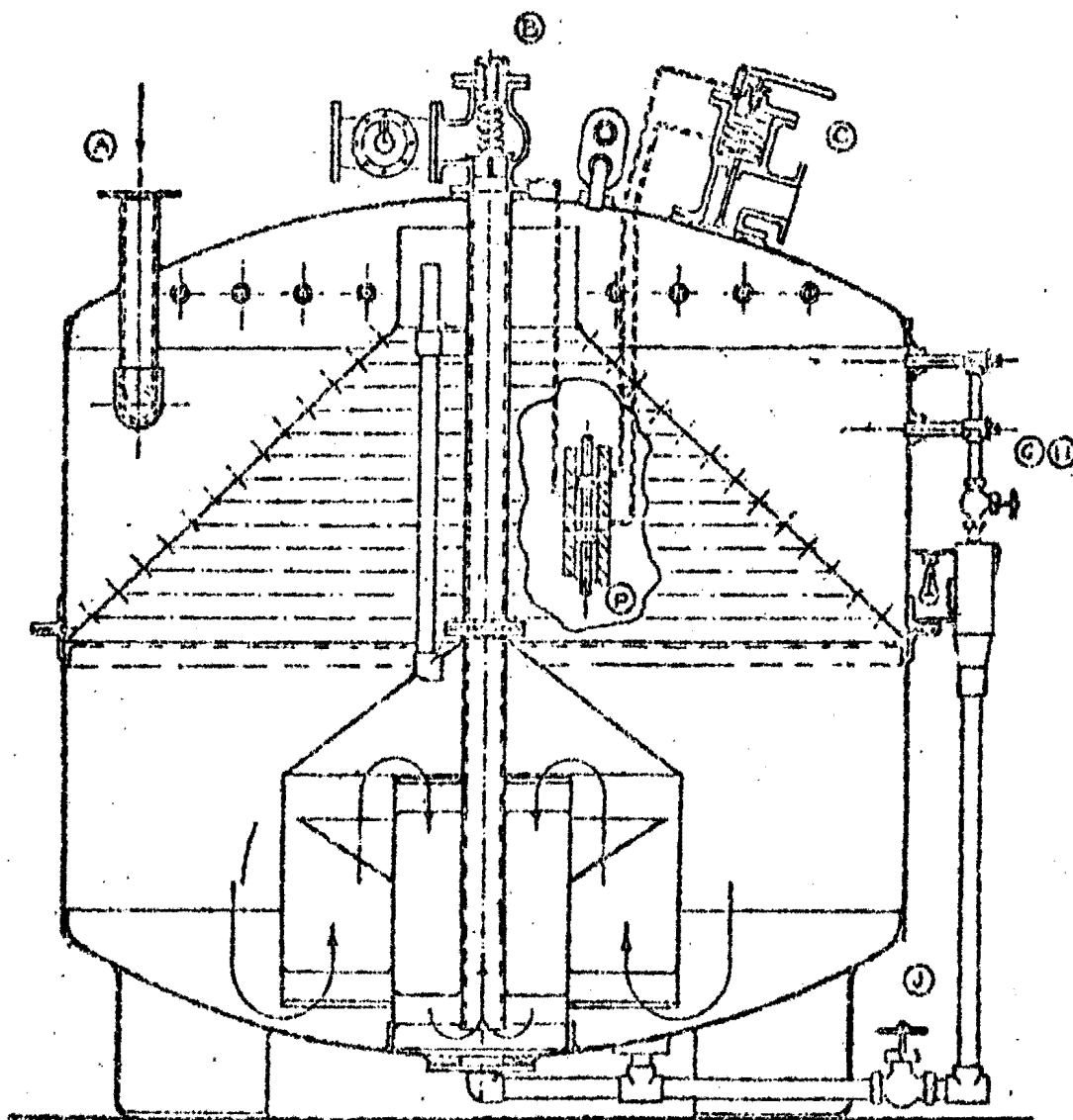
The cost of fitting a suitable separator of 250 tons per hour capacity to an existing tanker is estimated at £15,000 to £20,000.

## 2.1.4 TYPICAL GRAVITY SEPARATORS

### 2.1.4.1 PRESSURIZED

#### (a) Gravity Type (VICTOR)

This consists of a vertical cylindrical pressure vessel, fitted as shown in the cross sectional elevation below.



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The separator is first filled with clean water.

Oily mixture enters at connection A, giving an internal pressure of  $103\text{KN/M}^2$  ( $15\text{ lb f/in}^2$ ). At this pressure, valve B opens and flow through the separator commences. The mixture is given a circumferential flow on entry, the oil separating and flowing upwards and the separated water downwards through the perforated conical plate. Passage through the cone has a coalescing effect. Separated water is then discharged through the weir system and the discharge valve B.

Oil is discharged through the spring loaded hydraulically operated valve C, which can be manually or automatically controlled. As the oil content in the upper part of the separator increases, the oil/water interface level drops. This level is detected by test cocks, or by electrical means, and the hydraulic control for valve can be operated at a pre-determined low interface level. On opening valve C, the internal pressure in the separator drops to about  $69\text{KN/M}^2$  ( $10\text{ lb f/in}^2$ ) and water discharge valve B closes. Oil is then discharged until the interface level rises to the required level, when valve C closes, and the pressure rises to  $103\text{KN/M}^2$  and valve B is automatically opened.

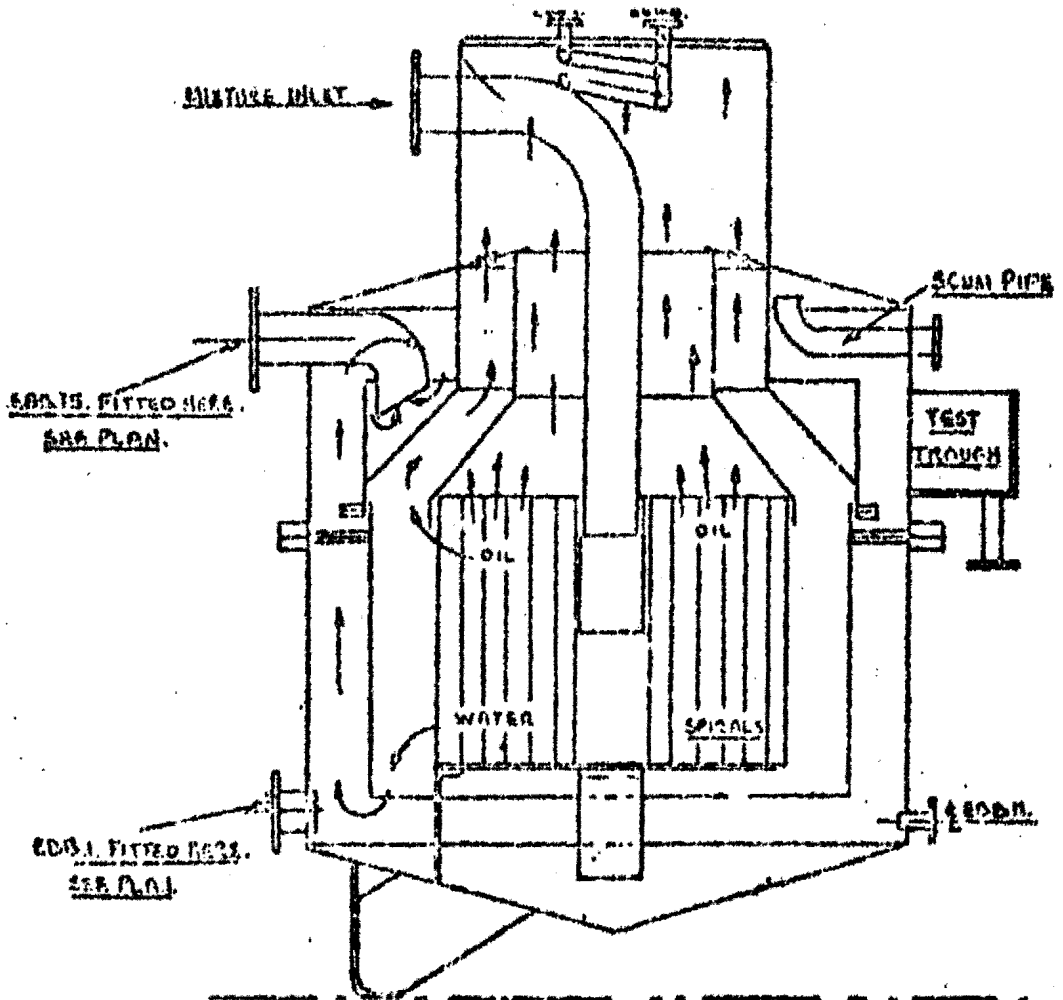
Sludge can be drained from the bottom of the separator body. Heating coils are fitted in the oil space.

Separators operating on these lines are made in the range of  $\frac{1}{4}$  ton/hr to 250 ton/hr for general duties. For oil tank de-ballasting, the 80, 100, 150, 200 and 250 ton/hr capacity ratings are reduced to 70, 75, 80, 90 and 110 ton/hr respectively.

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(b) Spiral Plate Gravity/Coalescer Type (COMYM).

This consists of a vertical cylindrical pressure vessel, fitted, as shown in the cross sectional elevation, with a bank of spiral plates.



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The separator is first filled with clean water.

Oily mixture enters, as shown, and is directed downwards to the centre of the spiral plate bank. A pressure of about  $103\text{KN/M}^2$  is generated within the separator. The mixture passes between the spiral plates in a generally radial direction, and during its passage, oil and water are separated both by gravity and by coalescence on the plates. The oil flows upwards into the dome and the water downwards to the discharge valve.

Sensing of the oil/water interface and discharge of oil is similar to that for gravity type described at (a). Heating coils are fitted in the oil dome, and sludge drains in the bottom of the separator.

This type of separator is made in the range of 2 tons/hr to 200 tons/hr for general duties.

Both of the above types of separators have been tested in the United Kingdom, using tests simulating pumping an oily bilge. A blended residual oil of specific gravity about 0.95 was used. The tests were run at two temperature levels,  $10^{\circ}\text{C}$  ( $50^{\circ}\text{F}$ ) and  $21^{\circ}\text{C}$  ( $70^{\circ}\text{F}$ ), and the oil content of the water discharge was found to be below the 100 ppm limit specified in the Convention.

#### 2.1.4.2 UNPRESSURIZED GRAVITY/COALESCER TYPE (SEREP)

This consists of a vertical cylindrical body fitted as shown in the sketch.

Oily mixture enters at the inlet connection 1, and passes down the outer annulus to the bottom of the separator, where the sludge is separated, at 3. The mixture then enters

the first gravity/coalescer section, at 5, and then passes through the connection 7 to the second separator section. Oil from the separation processes is channelled to oil discharge, and the separated water flows over the weir, 13, to the water outlet.

Provided that the capacity of the separator is not exceeded, and the setting of the weir is correct, no further regulation of this type of separator is necessary. As the discharges are at atmospheric pressure, the separator must be positioned above the liquid levels to which it must discharge.

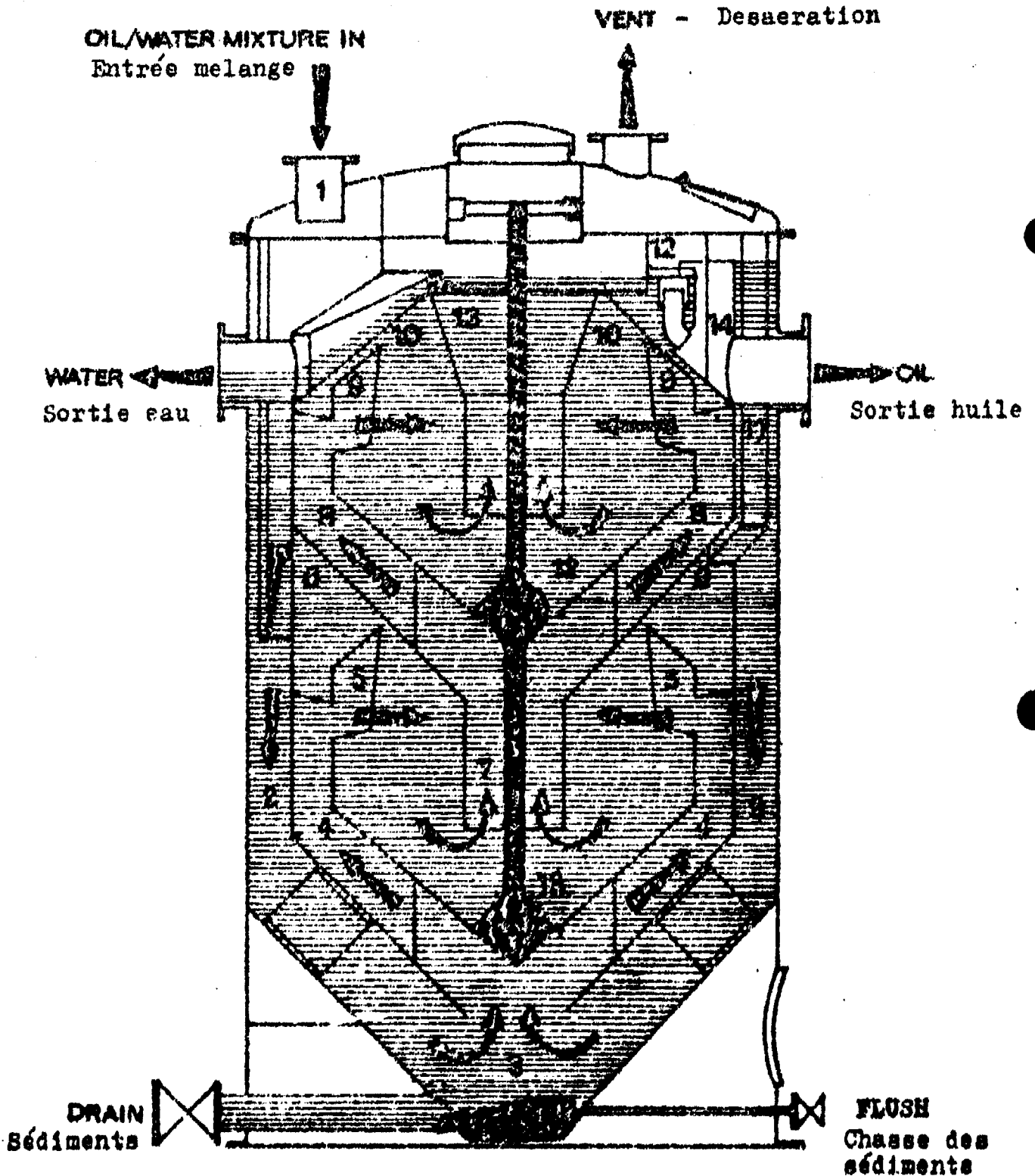
A range of separators of this type from 1.5 ton/hr to 300 tons/hr is available. Separators of this type are currently being fitted on VLCCs (two units could be used in parallel to give increased capacity to deal, specifically, with cargo tank oily water discharges.

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MARINE TYPE OIL SEPARATOR  
SEPARATEUR D'HYDROCARBURES TYPE MARINE

OPERATING PRINCIPLE  
PRINCIPE DE FONCTIONNEMENT

Modeles T24-C15-C14-T27



## 2.2 SLOP TANKS

### 2.2.1 FACTORS AFFECTING SEPARATION IN SLOP TANKS

As originally conceived the slop tank consisted of one of the main cargo tanks with the normal cargo pumps and pipe work. In recent years, however, more thought has been given to the use of a special tank, or system of tanks, to improve the settling process, possibly with the incorporation of additional features.

Basically the slop tank is a settling tank which allows the oil to flow to the surface of the oil/water mixture and the water to drop to the bottom, where it may be drained away to sea. The amount of oil discharged in this process is governed by the oil content of the water and the amount of water used in the washing procedure.

As discussed above, the amount of wash water can be reduced by the use of re-circulatory washing in place of the once through process. With re-circulatory washing, the amount of water can be reduced to a minimum of about 4,700-7,000 cubic metres compared with up to 10 times that amount for once through washing. Although settling can be more difficult with re-circulatory washing the total amount of oil reaching the sea should be less than with once through washing even though the oil content of the water may be higher.

The following methods can be used to improve the separation:

- (i) The settling time can be made as long as possible by speeding up tank washing and washing the minimum number of tanks.
- (ii) Rapid mixing in the water layer can be avoided to allow as much settling as possible while tank washing.
- (iii) The viscosity of the oil can be decreased by heating the contents. This can also help to break down any emulsion. Experiments on heating, however, indicated that the length of time the mixture was heated was more important than the final temperature. This may be because the convection currents set in motion during



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heating help the droplets to coalesce and hence increase the rate of separation. Where a quantity of emulsion has accumulated proper separation of oil and water can only be effected with heating coils within the layer of emulsion raising the temperature of the mixture to higher than 60°C.

### 2.2.2 SHAPE AND ARRANGEMENT OF SLOP TANKS

The factors affecting the rate of separation can obviously be greatly affected by the design and number of slop tanks in use. Some work has been done to determine the optimum arrangement, but no clear cut solution has been obtained. It is likely that the optimum arrangement will differ depending upon the main type of operation.

Even the best shape of slop tank has not been verified. On land the preferred arrangement is a shallow depth and a large surface area, allowing the minimum settling distance before the interface is reached. At sea, however, wave action probably creates sufficient turbulence to outweigh the advantages of a small settling distance. A tall narrow tank avoids wave action, gives very clear water at the bottom of the tank, where draining takes place and allows a sharp cut off at the interface with the minimum of contamination. This is confirmed by limited experimental work carried out in Japan, which tends to show that deep tanks promote efficient separation. A compromise often used is to have long, but narrow tanks, giving a large surface area immune to wave action with a sloping base to allow clean separation.

If the voyage is long enough to allow a considerable settling time after tank washing, then the design of the re-circulating system is not of primary importance. On short voyages, however, much of the separation has to take place while washing is in progress. This requires the minimum amount of movement in the slop tank and this may be achieved by suitable design of the wash water inlet. Another way of reducing movement in the water layer would be to make the turnover time as large as possible by limiting the circulation rate or increasing the total volume of water. The

circulation rate is, however, usually fixed by the needs of the washing machines and eductors, while increasing the circulating volume means a larger volume of water to be discharged to the sea. This increased discharge could give a higher total volume of oil discharge even though the oil content of the water were reduced. There is similarly a large volume of water to be discharged in an open cycle system. Thus in practice the optimum solution will be a compromise between these conflicting factors.

### 2.2.3 DOUBLE SLOP TANK SYSTEM

This system has been developed primarily to separate oil from water during tank cleaning and is especially suited for use with a re-circulatory washing system. It may also be used to treat the oil and contaminated upper layer of water from dirty ballast tanks and from pump and line washings.

As shown in the sketch at Appendix, the system consists of two separate tanks each of between 1% and 2% of the deadweight capacity of the vessel. The tanks are used as primary and secondary separators. During the washing procedures slops are stripped into the primary separator. After initial separation the treated water passes, via the cross connection, to the secondary separator. The water is then returned to the washing machines by the pumping system.

During tank washing the treated water can have an oil concentration of up to 200 ppm. On completion of tank washing, and after settling for at least 30 hours and heating, 95% of the depth of the secondary tank contains water with an oil concentration of about 40 ppm, with slightly higher concentrations immediately under the oil/water interface and above any sludge at the bottom of the tank. The main body of this water may be discharged, the heavily contaminated portion being transferred to the primary separator, allowing the secondary separator to be cleaned.

The double slop tank system is not effective in dealing with the large quantities of wash water and slops which results from open cycle washing. Due to the amounts involved (80,000 cubic metres

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in some cases) it is necessary to use a cargo tank for settling out water.

In addition to the double slop tanks, an oily water separator may be used (see sketch) and an oil content meter may also be fitted. As a further stage an oil filter (e.g. activated carbon filter) may be connected into the overboard discharge line, giving an oil concentration of less than 10 ppm in the discharged water. This final treatment is costly in comparison with the amount of oil removed from the effluent.

An additional advantage of the double slop tank system noted in experimental work carried out in Japan is a tendency for the connecting pipe to act to some extent as a coalescer when oily water is passed through it. This may be an area in which further study would be useful.

#### 2.2.4 THE CASCADE TANK

Some advantages have been claimed for a system in which free water from the slop tank is discharged overboard by way of a "cascade" tank constructed immediately under the tanker's main deck. An oil content meter operating from three widely spaced sampling points in the cascade tank operates a triple alarm system as water with an excessive oil content passes each sampling point, allowing a maximum of 8 to 10 minutes in which action can be taken to stop the flow of water. The system is said to be capable of fully automatic operation by arranging for valve closure to be actuated when a high oil content is detected at the second sampling point. Whilst this system may have a certain value as an observation tank it seems doubtful whether in terms of the reduction of the amount of oil reaching the sea its use has any significant advantage over direct discharge to the sea, monitored by a reliable oil content meter.

### 2.3 USE OF CHEMICAL DEMULSIFIERS

When there is a tendency for the oil residues to form a water in oil emulsion, which may take a long time to separate, some increase in the settling rate may be obtained by the use of chemical demulsifiers. This can be especially useful on short haul voyages.

In 1966/67 a study was made on four ships, over a total of 43 voyages, to study the effect of heating and the addition of a demulsifier on the settling time and compare the results with simple settling (BSRA Report MS 620). From the data a regression equation was derived which gave the reduction of water content in the emulsion layer as a function of settling time, time of heating, and the addition of a demulsifier. The results showed that with an available settling time of 12 days there was little point in using a demulsifier, whatever the initial water content of the oil. An initial water content of 30% could be reduced to 4% with a demulsifier in 3 days rather than in 12 days by settling alone. With an initial 10% water the times to the 4% level were 1½ days compared with 6 days.

In none of these ships were fixed washing machines used or re-circulatory washing carried out, but with the new washing techniques and the smaller quantities of water in circulation the use of demulsifying chemicals may be more effective and more economically viable.

Care needs to be taken, however, to ensure that such emulsifying chemicals have no effect on refining operations and that their toxicity is such that at the concentration used they will have no effect on marine life.

So far no major problems have occurred in refineries through the use of demulsifiers or tank-cleaning chemicals; indeed in one respect the use of demulsifiers may be helpful. One of the problems caused for refineries by the load on top system is the salt content

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of the crude oil from the slops. To deal with this many refineries have installed desalter units where the crude is mixed with water to dilute the suspended salt solution and take any dissolved salt into solution. The mixture is then separated by settling and normally about 95% of the salt is removed with the water. If demulsifiers reduce the water content of the slops in the load on top operation this will remove much of the salt before discharge and hence decrease the load on the desalters.

Care is needed, however, to ensure that new products do not introduce problems. If, for instance, any of the formulations contained organic halides these could go forward with the crude oil and cause complications in catalytic reformers or hydro-treaters. Difficulties could also arise if new products proved incompatible with additives used to ensure good heat transfer characteristics in heat exchanger units. There should therefore be close co-operation between tanker and refining companies to ensure that any new treatment chemical has no disadvantages which may outweigh its usefulness in tank cleaning or in load on top operations.

The principal value of demulsifiers in the load on top operation lies not in reducing the amount of oil entering the sea but in removing excess water from emulsified slops more efficiently and more rapidly than by normal settling. This can be of economic benefit to shipowners in that it helps to avoid the carriage of deadfreight on the loaded voyage and may remove some salt from the cargo. There is also a practical benefit, however, in that demulsifiers are capable of removing a large amount of water that would not be removed by normal settling. Their use could thus assist in making it practicable to use load on top on short-haul voyages or on longer voyages where the conventional load on top system gives an emulsion with a low settling rate.

## 2.4 OIL CONTENT METERS AND RECORDS

### 2.4.1 CRYSTAL MICROBALANCE

This is a laboratory type instrument designed and manufactured by Esso Research. It operates by extracting oil from sea water along with a solvent and placing it on the electrode of one of two vibrating quartz crystals. The solvent evaporates leaving the oil only thus reducing the vibration frequency in direct proportion to the oil mass. It is very accurate and is valuable for research and development work but cannot be recommended for normal operation.

### 2.4.2 THE SOLVENT EXTRACTION/COLORIMETER BATCH MONITOR

The method and simple equipment of this monitor has been developed by an oil industry laboratory based upon recommendations by the Warren Spring Laboratory. Oil is extracted from the sample by chloroform, the chloroform extract is drawn off and filtered to remove particulate matter and is then placed in a colorimeter and a reading is displayed on a photocell output meter. The colorimeter is first calibrated by known oil in water dispersions made up from clean sea water and oil taken from the tank to be washed or from the surface of a dirty ballast tank as appropriate. The necessary glass ware, filter material, chloroform and colorimeter are packed in a hand carried case which opens up in the form of a convenient work unit; the price, including carrying case, is about £140. Once set up and calibrated the kit enables samples to be monitored on board within 3 to 4 minutes of being taken. Apart from its advantages of portability and speed of analysis the method is as accurate as its calibration and has been found to have excellent repeatability independent of the operator.

### 2.4.3 SHIP'S EXPRESS LABORATORY (USSR)

A portable rapid analysis laboratory known as "SEL-1" has been developed in the USSR and found by laboratory investigations

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to give sufficiently accurate measurements for practical application. It operates on the principle of visual comparison of the intensity of coloration of samples, prepared by dissolving the oil to be tested in aviation gasoline, with a scale of standard solutions. It is proposed during 1972/73 to equip cargo vessels of the USSR's seagoing fleet with these instruments.

#### 2.4.4 BAILEY TANKER DEBALLASTING OIL CONTENT MONITOR

(Fluorescence of aromatic hydrocarbons to ultra-violet light).

This equipment operates on a continuous sample drawn from the pump discharge line. The sample is pumped to a sample conditioning pump which homogenises the oily water mixture. The mixture is fed through a jet cell, to avoid fouling of the cell windows, which is irradiated with ultra-violet light. A sensitive photo-detector measures the amount of fluorescence due to the oil content in the mixture, and amplified signals are fed to a milliammeter fitted with a suitable scale to read in ppm of oil in the mixture. The electrical output from the sensing system can be used to feed a continuous recorder. An audible alarm indicating excessive oil concentration is fitted. During tests in the United Kingdom various crude oils were used as contaminants, ranging in viscosity from 35 secs. to 95 secs. Redwood No. 1 at 100<sup>o</sup>F. It was found that an alarm setting of 80 ppm would ensure that warning would be given as the oil concentration reached 100 ppm, this allowance being sufficient to cover variations in the system. Further development and evaluation work is proceeding.

This is a robust piece of equipment which has been developed over a number of years for use aboard ships. Research and development has proceeded continuously, and evaluation trials have been carried out by at least one tanker company. The monitor is designed to detect concentrations of crude oil in water over the range of 0-1,000 ppm. It is automatic in operation and has a short time lag between sampling time and indication of the oil

concentration in the mixture, and is capable of continuous operation. Each instrument may have a number of sampling points, any one of which can be monitored, and can be fitted with a continuous recorder. The monitor is designed so that all electrical connections can be accessible from safe areas.

Equipment and installation costs total about £6,000 for an existing ship.

#### 2.4.5 RUR SERES. OLEOMETERS AND PRE-DETECTOR

The Oleometer is an optical device, operating on the amount of obscuration of light between a transmitting head and a receiving head placed in the oily water stream. Light is transmitted along optical fibres from the control panel, 13, as shown in the diagram, to the transmitting head, 2. The beam passes along the sample in the pipe, 1, and is detected in the receiving head, 3, the light signal being returned to the control panel by another line of optical fibres. A comparison of the light transmitted with the light received enables the proportion of oil in the water stream to be measured.

The Pre-detector is fitted to avoid the fouling of the pipe loop, 1, containing the Oleometer. It was found that, where the concentration of oil in the mixture exceeded 20,000 ppm, oil tended to cling to the pipe, and this adversely affected the response and accuracy of the Oleometer when subsequent lower concentrations of oily mixture were monitored. The Pre-detector is a photo-electric device, placed upstream from the Oleometer in the main discharge pipe. It is set to shut off the mixture flow to the Oleometer when the oil concentration exceeds 1000 ppm, and thus



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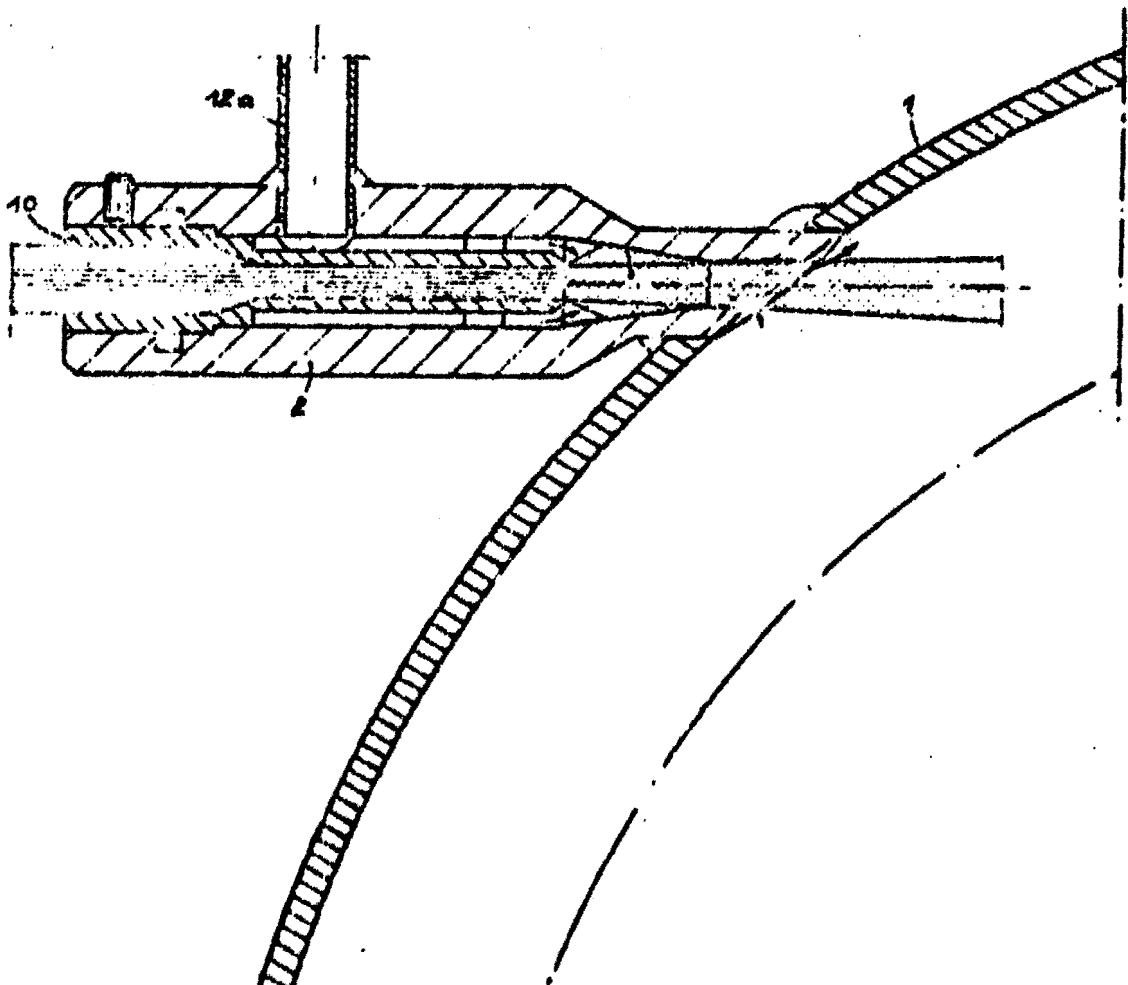
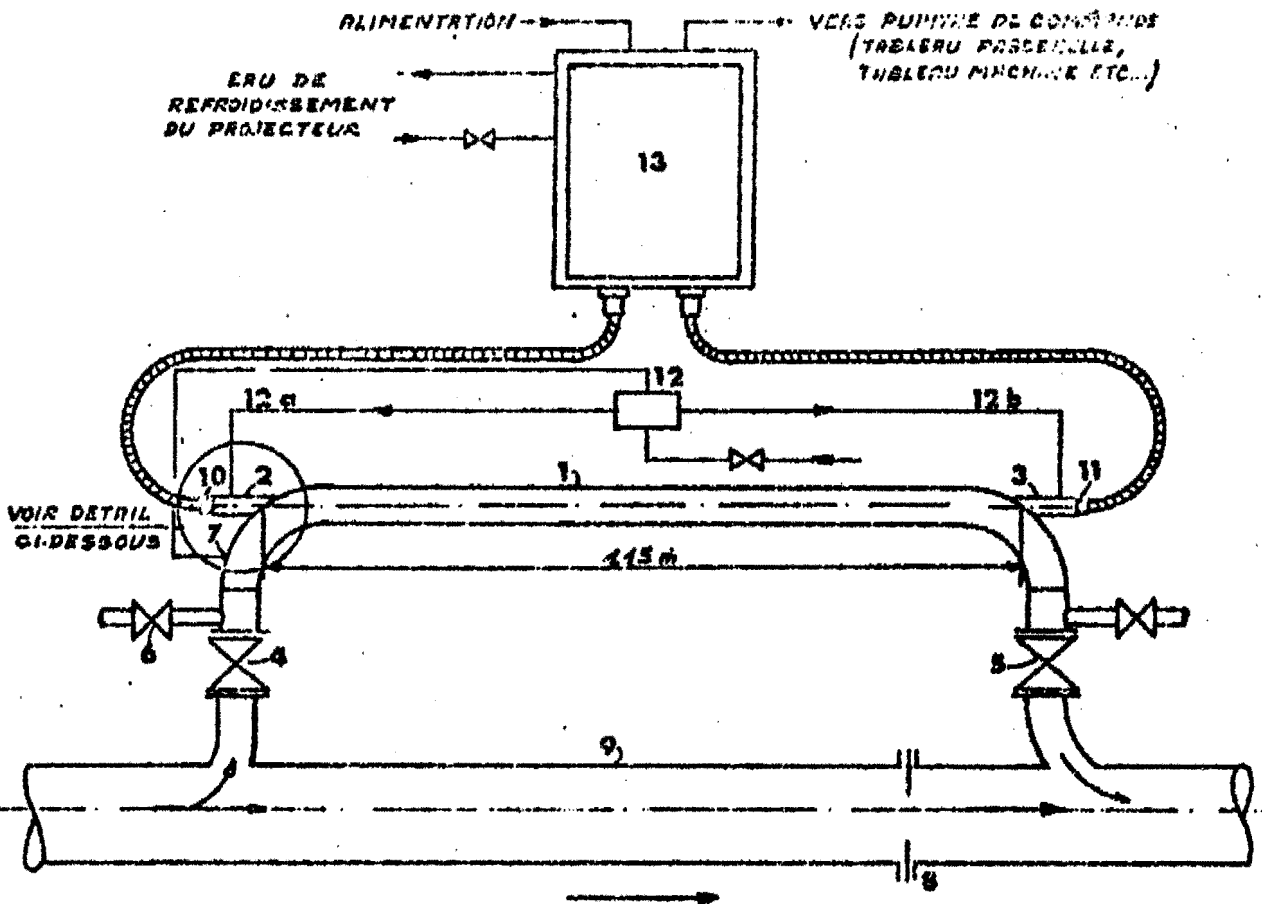
prevents oiling of the loop, and to restart mixture flow to the Oleometer when the oil content drops below 1000 ppm.

The Pre-detector has a transmitting head with a light source and a receiving head with a photo electric detector, and these are placed diametrically opposite each other in the discharge pipe. The heads are contained in heavy pyrex glass envelopes which project slightly into the mixture stream. The glasses are self cleaning, provided that the mixture speed exceeds 0.6 m/s. This speed is below that normally found in de-ballasting operations.

Control of these units is simple, and the oil concentration is continuously recorded on a strip chart.

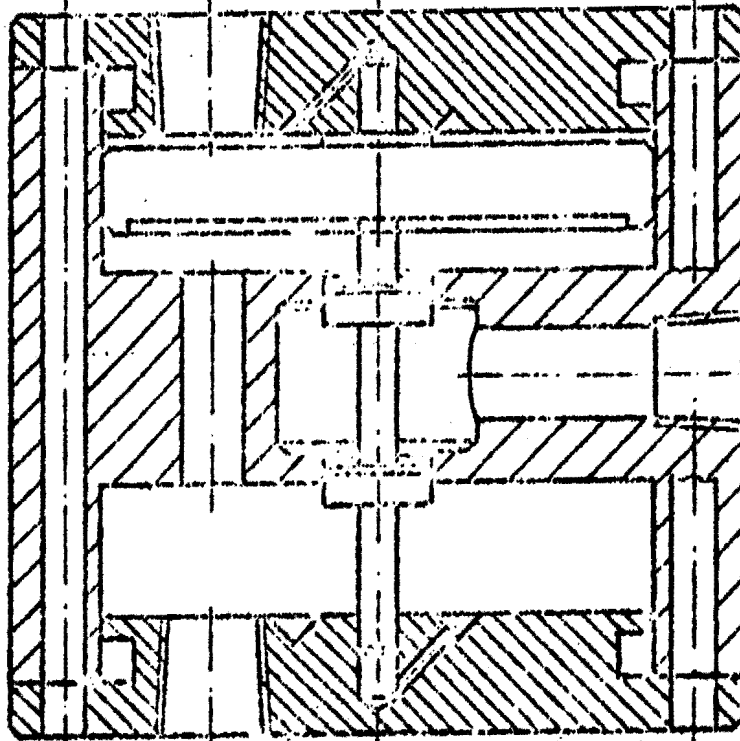
Work is proceeding on a method of calibration, and a test facility is being designed.

The combined Oleometer and Pre-detector unit has been tested during de-ballasting and tank washing operations at the Tanker Service Station, Marseilles. Satisfactory results were obtained, and further trials and evaluation tests are being performed.



PRESSION DANS  
LA CONDUITE

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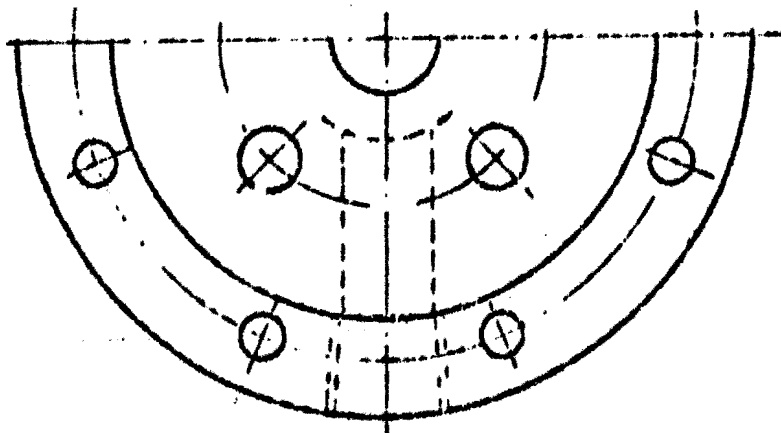


ARRIVEE EAU

$\phi 1/8''G$

$\phi 2/8''G$

SORTIE EAU



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## 2.5 AUTOMATIC CONTROL BY METERS AND RECORDERS

In the initial Bailey detector experimental installation diverter valves, actuated by the oil and water detector, were installed. These valves were intended to return the overboard discharge to the slop tank if the oil content exceeded 100 ppm. To date, however, a number of engineering problems have arisen which have not yet been resolved. The continued development of automatic diversion must, however, be pursued.

## 2.6 OIL/WATER INTERFACE DETECTORS

Two types of detectors are used:

- (a) Water Ribbon type. This depends on sighting the discolouration on a sensitized strip and suffers a serious disadvantage in that the markings can be obliterated while the strip is being withdrawn through the slop oil. Under ideal conditions some useful results can be obtained, but the system is not now in widespread use.
- (b) Electrolytic type. This type depends on setting up an electric cell, using the water as an electrolyte, and its successful use depends on the end of the zinc-tipped weight used to generate the electrolytic current being clean and a proper earth connection being made. When the weight passes through the oil into salt water a small current flows from the zinc tip to the steel structure and finally to a milliammeter via a bonding wire which connects the steel structure to the meter. Except when dealing with very viscous oils on water satisfactory results are generally obtained, the interface being located to within  $\pm 5$  cms under normal working conditions. When very heavy slop oil is encountered some difficulty is experienced in lowering the weight through the oil layer and in cleaning the weight in the water underneath to enable the current to flow. This type is in widespread use; it costs about £30.

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(c) Another type of instrument is available in which the current is provided by a set of batteries instead of being induced by electrolysis. This has not yet been tested in the UK.

### 3. POSSIBLE METHODS FOR THE CONTROL AND ENFORCEMENT OF SHIPBOARD SEPARATION PROCEDURES

#### 3.1 TANKERS

##### 3.1.1 CONTROL OF SHIPBOARD PROCEDURES

As has been shown the load on top system as currently practised suffers from a number of disadvantages:

- (i) It involves the discharge to the sea of water containing some oil at all its major stages, namely tank washing (except where re-circulation is practised), discharge of ballast from unwashed tanks and discharge of settled water from the slop tank. Each of these discharges involves the possibility of pollution;
- (ii) it relies heavily upon human observation and judgment for critical decisions as to the points at which overboard discharges must be stopped if pollution is to be avoided;
- (iii) inefficient operation or deliberate failure to apply the correct procedures are not readily detectable;
- (iv) even when operated at maximum efficiency some oil is inevitably contained in overboard discharges.

It follows that the prospects for major improvement in the system lie in the elimination of avoidable discharges and the provision of automatic equipment to control and reduce the oil content of discharges which cannot be avoided and in the development of a system of enforcement which will ensure that incorrect operation and deliberate evasion cannot go undetected.

The further development of re-circulatory systems of tank washing appears to be the only practicable way of eliminating avoidable discharges of oily water in sight at present and this is something plainly to be encouraged. Useful progress is being made in the development of automatic devices both to indicate when overboard discharge should be stopped and to control the oil content of the effluent. An oil content meter already exists which will give a sufficiently rapid indication of a significant rise in the oil content of the discharge from ballast tanks or slop tanks to enable the overboard discharge to be stopped or diverted before pollution can result. This device can be combined with an alarm system or with a system for automatic diversion of discharges to the slop tank. It is not yet, however, capable of giving an absolutely precise indication of the actual content of the mixture.

Further development of and practical experience with high capacity oily water separators is required before they can be regarded as of significant value for direct control of the oil content of overboard discharges from ballast tanks and slop tanks. They may, however, prove to be increasingly useful in allowing the oil/water interface to be closely approached without excessive discharge of oil. Further development work on this aspect of their application would be valuable.

### 3.1.2.1 POSSIBLE IMPROVEMENTS IN SHIPBOARD EQUIPMENT AND PROCEDURES FOR TANKERS

So far as shipboard procedures are concerned, significant improvements in control could be achieved by:

- (a) universal adoption of the re-circulatory system of tank washing provided that tanks were inerted or otherwise rendered safe;
- (b) installation of oil content meters or similar devices to warn of increases in the oil content of overboard discharges and/or divert them to the slop tanks;

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- (c) installation of a suitable oily water separator to enable the oil/water interface in ballast and slop tanks to be approached without excessive discharge of oil.

The time scale involved in these measures is governed only by the time needed to make the necessary structural alterations to ships and install the necessary equipment. A possible standard layout for operation with equipment currently available is as follows:

#### Slop Tanks

An arrangement consisting of two slop tanks each of about 2% of the ship's deadweight capacity will provide a good degree of oil/water separation and at the same time enough flexibility for processing the last few feet of dirty ballast water from the unwashed, ballasted cargo tanks. The re-circulated washing water will have an oil content generally below 300 ppm which is perfectly acceptable for tank washing purposes.

It is generally found convenient to use as slop tanks the aft sections of the aftermost wing tanks, but any arrangement of two or even three slop tanks, either in wing tanks or in a centre tank will give similar results. The size indicated is sufficient to provide a long enough residence time and good separation but if for structural or other reasons the size of the slop tanks had to be increased this would only be beneficial.

The two slop tanks are linked by a large diameter cross-over pipe open in the vicinity of the tank bottom (about 1 metre) in the primary slop tank and terminating some 30% of the height of the tank in the secondary slop tank. (See diagram at Appendix Primary slop tank on starboard side).

### Re-circulation

The most commonly adopted re-circulation system utilizes a main cargo pump to provide the motive power. This cargo pump takes suction from the secondary slop tank via the cargo bottom line system. At the discharge side of the pump, the flow is split in two directions:

- (a) Washing water is supplied to the deck tank cleaning line end to the tank cleaning machines.
- (b) Driving water is supplied to a set of two eductors, the suction side of which is linked to the two stripping lines.

The water issuing with great force from the tank cleaning machines in the tank being washed, dislodges and entrains the residues which pass through the stripping suction and, via the stripping lines, to the two eductors where they mix with the driving water and are discharged into the primary slop tank. The eductor discharge pipes are separate and terminate some 20% of the height above the bottom of the tank. The eductor outlets discharge upwards to prevent establishing a circulation pattern inside the tank.

In the primary slop tank the separation of oil and water occurs and an emulsion layer of increasing thickness accumulates at the surface. From the water layer underneath, the water flows, via the balance line, to the secondary slop tank where a further separation takes place and finally the loop is closed when the water is drawn, via the main suction, to the cargo pump, for re-use in tank washing.

### Ancillary fittings

As discussed in paragraph 2.2.1 above, the residues which accumulate in the slop tank are not pure oil but a mixture of



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sludge and water forming a stable water in oil emulsion with a water content varying over a wide range (10-70%) according to the nature of the residues. Heating coils need to be fitted and they are most effective when they are totally immersed in the oil layer. Therefore they should be fitted where the emulsion accumulates in the first place, i.e. at about  $\frac{3}{4}$  or  $\frac{2}{3}$  of the height of the primary slop tank. An additional grid of coils located at the bottom is useful to keep the residues fluid after the water has been removed and until the next cargo is loaded.

#### Oil/Water Separator

A gravity type separator fitted either on deck, or in the upper part of the pumproom, will substantially improve the results to be expected from the system although the maximum capacity of a single unit is limited to about 250 tons/hr. The effluent inlet should be connected to the stripping pump discharge. The water outlet can be led directly to the sea, or be linked with the overboard discharge, and the oil outlet should lead to the primary slop tank. In order to avoid blocking the separator outlet with waxy sludge, it is useful to equip the separator with a set of heating coils which is generally an optional fitting.

#### Oil Content Meter

An oil content meter fitted with a high level alarm will ensure a good control of the operation. It should offer the possibility to monitor and eventually record the oil content of the water passing through:

- (a) The overboard discharge line.
- (b) The water outlet of the separator.
- (c) The tank cleaning line (although the sampling point is not related to a sea discharge, it would give a continuous indication of the efficiency of the re-circulation system).

Operational Procedure

(a) Tank cleaning

The two slop tanks are filled with clean sea-water up to about  $\frac{2}{3}$  of their capacity and the washing operation proceeds in closed cycle with no discharge of oil to the sea. The oil content meter, drawing samples from the tank cleaning line gives a continuous indication of the degree of oil/water separation achieved in the system. As soon as a definite oil layer has accumulated in the primary slop tank, steam is applied to the heating coils and eventually an emulsion breaker is added.

When a sufficient number of tanks have been washed, those intended for clean ballast can now be loaded with clean sea-water.

(b) Deballasting of the settled "dirty" ballast water

During this phase of the operation the oil content of the effluent, which as mentioned in paragraph 1.1.1 (III) is of the order of 30 ppm, is continuously monitored. The pumping rate is reduced at the first sign of increase in oil concentration and the effluent is ultimately diverted to the slop tank as soon as the floating oil begins to be entrained by vortexing.

According to the size of the slop tank this transfer of dirty ballast water can either take place without preparation, or if additional capacity is needed in the slop tanks, by pumping out some water from these beforehand.

(c) Deballasting of slop tanks

This is done in three steps:

- (1) Settled water is removed from both slop tanks using a main cargo pump. The discharge from the primary slop tanks is stopped when the oil/water interface is still some 2-3 metres above the bottom. The discharge from

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the secondary slop tank can go on until the oil monitor indicates an increase in oil concentration or when the interface is some 2-3 metres above the bottom.

- (ii) The secondary slop tank is emptied using a stripping pump via the separator which discharges the clean effluent to the sea and the oil to the primary slop tank. When all the water has been removed any oil left can be transferred directly to the primary slop tank.
- (iii) After a further settling period, the water from the primary slop tank is pumped through the separator in the same way.

Throughout the discharge, the quality of the effluent is monitored. Experience in the UK indicates that under the above conditions the oil content should not exceed 300 ppm but because of the slow pumping rate the instantaneous rate of discharge will be well below the maximum of 60 litres per mile permitted by the 1969 amendments.

Depending upon the development of suitable equipment, this layout might be further refined by (i) completely automatic control of discharges via the oil content meter, with continuous recording of the oil content of overboard discharges, (ii) provision of oily water separators capable of dealing with all contaminated water from ballast tanks and slop tanks and (iii) provision of a filtering device between the oily water separator and the overboard discharge to reduce still further the oil content of the discharge. No time scale can at present be forecast for these developments.

### 3.1.2.2 POSSIBLE IMPROVEMENTS IN SHIPBOARD EQUIPMENT AND PROCEDURES FOR NON-TANKERS

The following measures could be adopted to effect an improvement in the discharge effluent:

- (i) Design pipe arrangement so that all bilge contents must pass through the separator.
- (ii) Provide holding tank for use whilst vessel is in port.
- (iii) Develop reliable oil content meter for fitting in separator outlet.
- (iv) Automate equipment so that content meter switches off pump if effluent exceeds a specified limit.

### 3.1.3 ENFORCEMENT

Enforcement in respect of tankers will also be assisted by the further application of automation to the system as suggested above. The development of a reliable continuous reading oil content meter constructed in such a way that it was incapable of being bypassed would be a further major step forward. In the meantime IMCO is exploring the possibility of co-operation by the administrations of oil producing countries and the oil companies in examining tankers presenting themselves for loading to ensure that they have on board a quantity of slops commensurate with the nature of their last voyage and the type of oil carried. The work of this Inspectorate will be facilitated if proposals by the USSR, adopted by the eleventh session of the Marine Pollution Sub-Committee, for the carriage by all tankers of ullage tables and for the development of reference tables indicating how much oil ought to be on board and of reliable oil/water interface detectors, bear fruit. Inspection of vessels in this way is unlikely to show up minor irregularities in the operation of the load on top procedures; control by the maximum practical amount

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of automation must be relied upon for this. But it should be capable of detecting flagrant and deliberate breaches of the rules.

So far as non-tankers are concerned the best prospects for improved enforcement lie in minimizing the opportunities for the direct discharge overboard of water contaminated by oil. This could be achieved by requiring:

- (a) All non-tankers to be equipped with an oily water separator whether or not they customarily use their bunker fuel tanks for water ballast;
- (b) pipework to be so arranged that no bilge water, whether from an oily bilge or one which is nominally clean, can be discharged overboard, except in emergency, without first passing through the oily water separator; and
- (c) provision of a reliable oil content meter to monitor the oil content of the effluent from the separator and ultimately, when suitable instruments have been developed, to stop the overboard discharge when the oil content exceeds a specified level.

It is recognized that provision must be made for bilges to be discharged directly overboard in an emergency. Such emergency discharges should be permitted only in the circumstances envisaged in Article IV(a) of the 1964 Convention.

#### 3.1.4 ASSESSMENT OF POSSIBLE REDUCTIONS IN OIL TO SEA

Based on an estimate of 1,500,000,000 tons of crude oil currently moving by sea the theoretical maximum total discharge permitted by the 1969 amendments is 100,000 tons. Assuming no increase in the present figure of 80% of the world's tankers using the load on top system the maximum permitted total figure

for load on top operators is 80,000 tons. As shown above, a 200,000 ton crude carrier using re-circulation as designed is capable, in optimum conditions, of operating in a way which results in its discharging only some 15% of the maximum permitted by the 1969 amendments. A 30,000 ton crude carrier, on the other hand, comes very close to the maximum. Dramatic reductions in the amount of oil reaching the sea from load on top operations are unlikely, but given universal adoption of the 1969 amendments and the application of the improvements proposed above there appears to be good reason to assume a progressive reduction towards the theoretical minimum of 12,000 tons based on present movements of crude oil by sea. This figure will of course increase proportionately with the increase in amounts of crude oil moving by sea.

#### 4. AN ANALYSIS OF THE COST OF THE VARIOUS CONTROL SYSTEMS

##### 4.1 OIL CARRIERS

Equipment required to achieve a significant improvement in control of operational discharges of oil as outlined in section 3.1.2.1 is, in the case of tankers

- (i) an adequate oily water separator
- (ii) an efficient oil content meter.

It is estimated that to install a suitable separator in all vessels of the world merchant fleet normally capable of carrying oil in bulk as a cargo would cost £m 130.

The fitting of a Bailey Meter to such vessels is estimated to cost £m 40. This figure could be halved if the SERES apparatus (outlined in Section 2.4.5) was to be used instead. However it should be remembered that the SERES equipment has not so far been evaluated under sea-going conditions.

The maximum cost for the fitting of this equipment would therefore be £m 155. Using the principles set out in

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paragraph 22 of MP XI/2/3, this is equivalent to an annual cost of £m 18.6. Also it should be appreciated that many vessels are already equipped with oily water separators.

It is unfortunate that no figures can yet be produced for the fitting of automatic shut off equipment as this is still very much in the experimental stage and no costs are available.

#### 4.1.1 SHIPS OTHER THAN OIL CARRIERS

The fitment of a suitable separator and ancillary equipment (as outlined in section 2.1.2 (b)) to all vessels other than oil carriers throughout the world merchant fleet would cost around £m 160. (Annual equivalent £m 19.2). However that section introduces many variables into the costs of such fitments and this figure can only be taken as a rough guide. Further, it should be noted that oily bilge separators are already fitted in most ships, although many are of insufficient capacity.

#### 4.1.2

The calculations upon which this section is based are made on the figures for the world merchant fleet as at 1 July 1971 and on the figures for capital and installation costs for the various items of equipment given in the earlier sections of this paper. Only capital costs (including installation costs) have been considered because the best evidence available suggests that such factors as operating and maintenance costs and possible reductions in carrying capacity e.g. as a result of fitting separators, are so small that they can safely be ignored for the purpose of this exercise.

### 5. CONCLUSIONS AND POSSIBLE COURSES OF ACTION

#### 5.1 CONCLUSIONS

The following principal conclusions emerge from the material in the earlier sections of this paper:

- (a) Operating procedures and equipment are currently available to enable the discharge of oil from both tankers and non-tankers to be kept well within the limits set by the 1969 amendments to the 1954 Convention, which are themselves recognized as a major step forward towards the complete elimination of the discharge of persistent oils into the sea.
- (b) Present procedures depend to an undesirable degree upon the efficiency and conscientiousness of those charged with carrying them out and upon human observation and judgment. For this reason the results achieved world-wide in minimizing pollution probably fall short of those obtainable if the best practices were universally adopted and practised with maximum efficiency.
- (c) The best prospects of further reductions in the amount of oil getting into the sea in the normal operation of ships therefore lies in eliminating as far as possible this reliance on the human element; there are reasonable prospects of procedures and equipment becoming available which will enable this to be done.
- (d) It is not possible to make firm estimates of the time-scale within which particular levels of reduction can be achieved since the whole process of improving equipment and procedures is a continuing one. Significant reductions could be achieved however, within the time-scale needed to fit the equipment and make the structural alterations recommended in Section 3.
- (e) The maximum cost of equipping the world fleet in the ways outlined in Section 3.1.2.1 of this Report is estimated at £ 155 million (annual equivalent £ 18.6 million) for oil carriers and at £ 160 million (annual equivalent £ 19.2 million) for other ships...



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- (f) Some types of vessels, e.g. tankers on short hauls and OBO carriers in mixed oil/dry bulk cargo trades, will continue to present special problems to which further study should be given.
- (g) Further development work on instruments and equipment is needed, particularly as regards large oily water separators to deal with tanker ballast; the accuracy of oil content meters and their application as part of automated control systems for overboard discharges; and interface detectors.

## 5.2 POSSIBLE COURSES OF ACTION

Amendment of the Oil Pollution Convention to make use of a system of the kind proposed in section 3.1.2.1 mandatory is not practicable in the present stage of development but it is a possibility which might be kept in mind as a long term aim.

In the meantime, if IMCO decides that improvement in the methods and procedures for the retention of oil on board ship is the path, or one of the paths, by which the goal of the complete elimination of wilful and intentional pollution of the sea by oil should be approached, the following steps would be practicable:

- (a) The method of operation of the "load on top" system proposed and procedure outlined in section 3.1.2.1 could be acknowledged by IMCO as typical of presently available improved methods of operation of the "load on top" concept which could be recommended to governments for adoption to the maximum extent practicable.
- (b) Pending full adoption of the system referred to at (a) governments could be urged by IMCO to encourage the adoption to the maximum extent practicable and

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consistent with current safety requirements on tankers registered under their flags of the recirculatory system of tank washing, as a means of eliminating one substantial source of oil pollution during the normal operation of tankers.

- (c) Governments could be recommended to give first priority to the development of oil content meters to a sufficient degree of accuracy to enable them to be used to stop overboard discharges automatically when the oil content exceeds an acceptable level.
- (d) High priority could also be recommended for the development of high capacity oily water separators capable of dealing with the discharge of contaminated ballast water and the free water from slop tanks.
- (e) Further study could be encouraged of the specific problems of operating the "load on top" system on tankers on short sea voyages and OBO vessels.
- (f) Governments could be recommended to investigate the practicability of devising a method of processing crude oil residues so that the recovered oil may be safely consumed in the ships' boilers or alternatively modifying the design of fuel supply to the boilers so that unprocessed residues may be safely consumed. An ability to consume crude oil residues might be particularly useful for OBO carriers.
- (g) Investigations into the practicability of consuming within the ship the residues from separation or filtering of heavy diesel oil could be similarly recommended.

