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CRUDE OIL WASHING:
Implementation and Operating Procedures

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Crude Oil Washing

Implementation and Operating Procedures

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SYNOPSIS

The authors describe the circumstances leading to the use of crude oil washing as standard procedure on VLCCs as a means of reducing the time spent water washing tanks for clean ballast. This led to greatly reduced quantities of retained oil on board as part of the load-on-top operation and eliminated the problems of sludge build up in tanks. Crude oil washing was adopted in 1978 by the Tanker Safety and Pollution Prevention Conference as an alternative to segregated ballast tanks in existing tankers. This preserved deadweight capacity and although the back-fitting of complete crude oil washing and inert gas systems will cost at least £1M per ship, it is still an attractive alternative. The authors discuss generation of electrostatic charges and tank atmosphere control, the impact of the TSPP crude oil washing specifications and operational procedures. They conclude that even these regulations will be of no avail unless staff are trained and dedicated to safe tanker practice.

1. THE EARLY YEARS

Virtually all crude oils contain relatively heavy components of waxy and asphaltic substances. During a tanker's loaded passage, these components settle out and horizontal members of tank structures acquire substantial coatings of sludge deposits. After the oil is discharged from tanks, the majority of this sludge will remain. Unless it is removed, it will build up over several voyages and eventually impede the efficient drainage of the tanks. This will effectively reduce the cargo carrying capacity of the ship.

In the past, sludge was removed from tanks by using water jets from hand-held hoses, which led to the development of portable tank washing machines (Fig. 1). With the introduction of the VLCC, machine manufacturers, in conjunction with tanker operators, developed fixed-in-place tank washing machines such as shown in Fig. 2.

Preparing tanks to acceptable clean ballast standards by water washing has always been intensive in time and labour and, when using hot water, costly in terms of bunkers consumed. In steam turbine ships there was inevitably some loss of engine revolutions and the whole operation could take a week. Translated into financial terms the loss was significant.

Water is not the best medium for tank cleaning because:

i) It contributes to corrosion of the tank structure;
ii) sludge remains on board after washing when operating load on top;
iii) it introduces unwanted salt-water into refineries;
iv) it leads to large quantities of oily-water slops which require decanting with consequent operationally allowed, or accidental, pollution;
v) it increases deadfreight; and
vi) it is incompatible with oil.

In some tank areas sludge deposits were difficult to remove, even when washing with hot water and chemicals. This led to expensive hand digging when preparing for repair periods and it was not unusual for VLCCs (without fixed tank washing machines) to take between two and three weeks for cleaning tanks to hot work standard.

On occasions heavy wax deposits had been removed by using other oils (such as heated gas oil) which were pumped round tanks and were found particularly effective in cleaning and removing heavy sludge from tank sides and horizontal surfaces. This became standard operational procedure at some oil terminals 30 years ago. Cleaning with crude oil could not be considered (although its solvent properties had been known from biblical times) as it could only be carried out during cargo discharge and the recirculation of crude oil

Fig 1 Portable tankwashing machine

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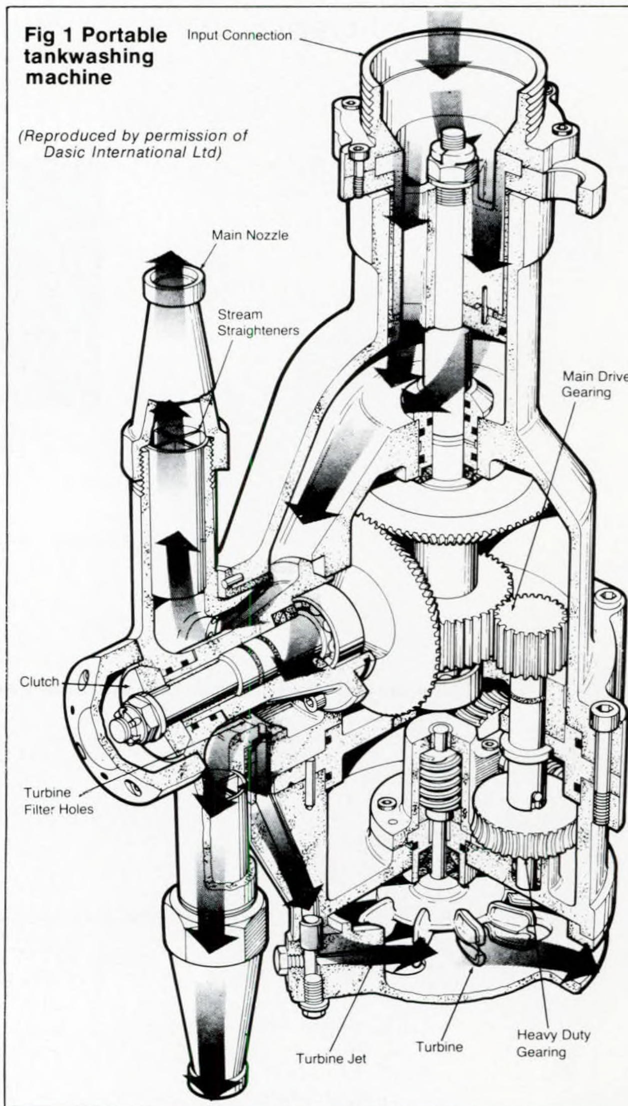

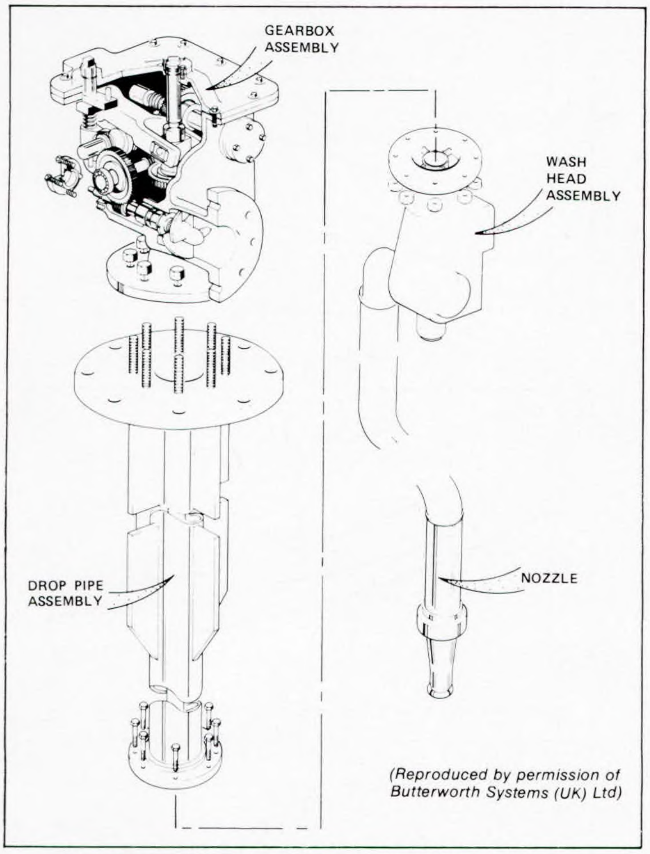

Fig 2 Typical fixed-in-place tankwashing machine

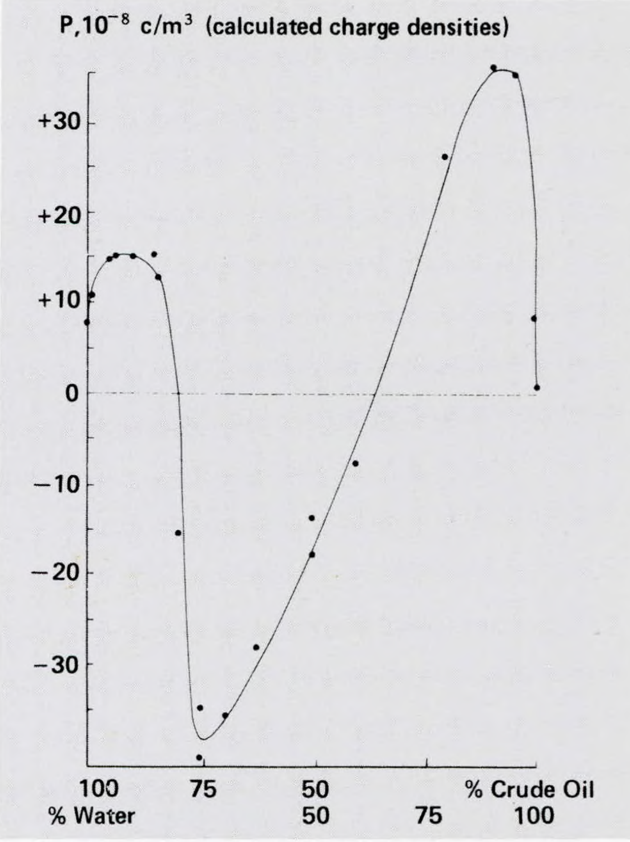

Fig 3 Charge densities created by oil/seawater mixtures

through portable tank washing machines would have presented a considerable pollution danger on the decks of ships.

The introduction of the fixed-in-place tank washing machines, operated by cargo pumps via permanent piping, solved the pollution problem. However, in December 1969 three VLCCs exploded off the African coast whilst water washing of tanks was in progress. One ship sank and the other two suffered severe structural damage. Development of crude oil washing in non-inerted tankers was held in abeyance while the causes were established.

2. STATIC GENERATION AND TANK ATMOSPHERE CONTROL

The three VLCC explosions had several common features. These were:

2.1 All ships had the same type of fixed tank washing machine.
2.2 All ships were water washing their centre tanks at the time of the explosions.
2.3 Two of the ships were using bottom blowing systems to ventilate tanks before and during tank washing (the third ship was washing a tank that had previously contained departure ballast).
2.4 All ships were in the tropics.

In view of 2.1, the tank washing machine manufacturer recommended that the machines should not be used until the cause of the explosions had been established. This meant that many ship owners were unable to wash their tanks to provide clean ballast for discharge at loading ports.

Investigations covered four basic possibilities which were: auto-ignition of cargo residues by over-hot steam coils; compression-ignition of flammable gas by the washing jet; spark from impact of fallen metallic objects; electrostatic charge generation by the washing process.

A number of experiments were undertaken which eliminated the first three possibilities as being improbable and it was concluded that static generation was responsible for the explosions. In fact, laboratory work indicated that water mists produced in cargo tanks during washing would have high levels of static electricity. It was decided to check this under operational conditions and, in view of the risk of explosion, this was carried out on *British Surveyor* which was fitted with an inert gas system and could thereby practice tank atmosphere control. The objectives were to take electrostatic measurements in cargo tanks during:

i) cold washing with oil/water mixtures containing from 90 per cent to 5 per cent of oil;
ii) normal cold washing for clean ballast;
iii) hot washing at two temperatures with 95 per cent water/5 per cent oil mixture; and
iv) hot washing with tank cleaning chemicals.

Captain W. D. J. Barker joined BP Tankers in 1950, after pre-sea training at Sir John Cass College. He served in all ranks and in 1967 was seconded to North Sea Operation on the drilling rig Sea Quest. He came ashore in 1970 and was appointed Fleet Marine Superintendent in 1974, working in the crude oil fleet. He became Chief Marine Superintendent in 1976. Captain Barker serves on the BP Group's Marine Technology Board, is a Member of the Honourable Company of Master Mariners, and a Council Member of the Society of Underwater Technology.

T. W. Allsop attended a pre-sea training course at the School of Navigation, University of Southampton, during 1960. He served his cadetship with P & O-Orient and, after obtaining a Second Mate's Certificate of Competency, joined the China Navigation Co in 1963. He obtained a Master's Certificate of Competency in May 1968 and joined BP Tanker Co in 1970. He came ashore in 1973 as Technical Assistant working in the crude oil fleet.

Promoted to Assistant Marine Superintendent in January 1975, he had been involved in COW since its inception in 1972. Currently in charge of the crude oil washing modification programme, he is a Marine Superintendent in the BPTC Marine Division. He is also a member of the Nautical Institute.

The measurements were carried out in centre tanks and included cold recirculatory washing with various oil/water mixtures and hot washing at temperatures of 110°F and 150°F, with a minimum of oil in the mixture. It was found that, for the purpose of electrostatic measurements, it was not necessary to carry out full washing cycles. Therefore, at each stage of the programme the liquid was sprayed through the tank washing machines until equilibrium had been reached.

Results of the tests are shown graphically in Fig. 3. The least amount of static was generated when 100 per cent crude oil or 100 per cent water was used as the washing medium. The highest readings were obtained with mixtures of 95 per cent oil (positive) and 25 per cent crude (negative). Zero readings apparently occurred at mixtures containing 60 per cent crude and 20 per cent crude.

In parallel with the static trials, hydrocarbon vapour generation in cargo tanks during crude oil washing was measured. One of the findings was that, despite the rapid mixing and high gas evolution rates during crude oil washing, it was impossible to maintain the vapour concentration above the flammability limit in air throughout the tank at all times. That is, large flammable regions could exist in tanks before and between crude oil washing periods and even during the actual washing, unless they are protected with inert gas.

3. RESEARCH AND DEVELOPMENT

In September 1972 two tanks were crude oil washed on *British Scientist* during the discharge of Iranian light crude oil at Angle Bay. The ship is fitted with VP-matic single-nozzle programmable COW machines with 32 mm nozzles. (See Fig. 4 for performance details). During the washing, oil supply pressure was 150 lbf/in^2 and the inert gas supply contained 2.8 per cent of O_2. Each tank was washed in three stages, 120° to 30°, 40° to 10° and 10° to 0° of nozzle angle from 0° being vertically downwards.

Two cycles were given at each stage, a cycle being two passes of the nozzle (eg, 120° to 30° to 120°). After washing, hydrocarbon gas and oxygen readings were taken in both tanks and also in one that had not been washed. Measurements were 26 and 2.1 per cent and 22 and 1.9 per cent, respectively in the washed tanks; and 7 and 2.1 per cent in the unwashed tank. Subsequent tank inspections showed excellent results with considerable reduction of sediment in the tanks.

A full crude oil washing programme took place on *British Prospector* during November 1972. During washing, oil supply pressure was varied between 90 and 150 lbf/in^2 to assess performance and variations of cleanliness. Wash patterns were also varied (ie, single-stage to multi-stage, and half cycles to two full cycles). Inert gas supply quality was 3 to 4 per cent O_2 throughout. No hydrocarbon gas readings were recorded. Inspections showed tanks to be virtually sediment free and No. 1 centre tank was actually ballasted satisfactorily with arrival ballast without any further oil or water washing.

The exercise showed that ballast water could be put into a tank that had been crude oil washed only, without water washing, causing only a minor discolouration of the ballast water; but this would not meet the criteria of "no visible sheen" on the sea surface.

From this work a number of conclusions were immediately apparent:

3.1 when using crude oil at the design pressure of the machines and draining with eductors, the results obtained are of a higher standard than can be obtained by water washing alone;

3.2 crude oil washing can largely be carried out while the ship is discharging its cargo without any undue loss of time but this depends on such factors as the ship's pumping system and the shore discharge facilities;

3.3 although tanks can be cleaned sufficiently for the shipping of arrival ballast directly (without water washing), some residual oil does remain in the strum area which will need to be removed before ballasting;

3.4 water washing of tanks is not necessary for sediment control;

3.5 hydrocarbon gas is generated during crude washing;

3.6 the supply of good quality inert gas during discharge is essential; and

3.7 subsequent tank cleaning at sea is reduced by 9 or 10 days and this saves both man-hours and fuel.

Following the initial R & D, further crude oil washings were undertaken during which the findings were substantiated and exact operating criteria determined. This included three ships that drydocked in Japan; these were given full crude oil washes, followed by full hot water and chemical washes, gas-freeing, slops discharge and the issue of "hot work" certificates. On each ship there was a substantial reduction in slops (see Table 1) and a time saving of 2.5 days, valued at £50,000 per ship. When compared with the conventional method of preparing for drydock, the time saving was 10 days or, in monetary terms, £200,000 per ship.

Crude oil washing continued to be developed by major oil companies as a normal operational procedure. Some resistance to the operation is still found at some installations where throughput is small and where there is doubt on the ability of the refinery to handle wax. However, it has become a procedure which, though originally commercial in intent, can also clearly be shown to benefit environmental control.

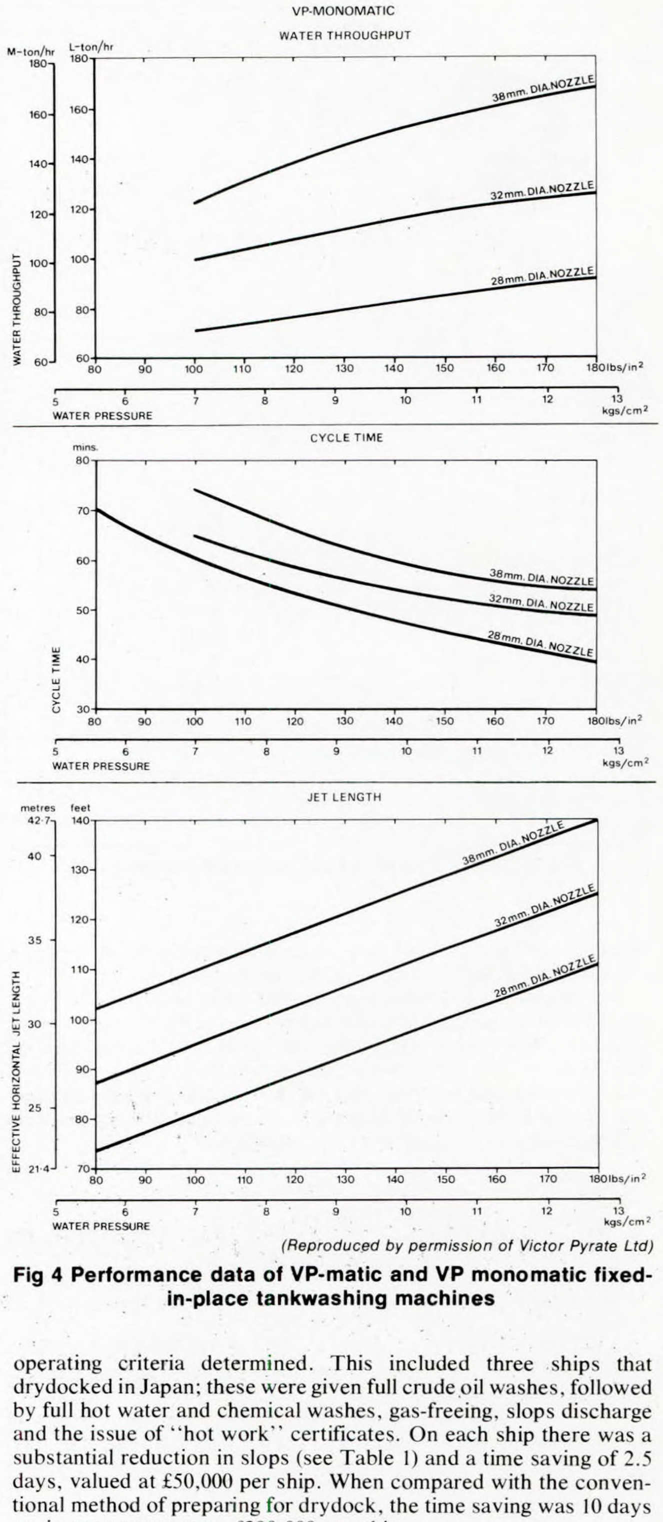

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Fig 4 Performance data of VP-matic and VP monomatic fixed-in-place tankwashing machines

4. INTERNATIONAL TSPP CONFERENCE, 1978

By 1977 crude oil washing had been widely adopted by a large number of major oil companies and independent tanker owners as a means of sediment control. It was offered as an alternative to the fitting of segregated ballast tanks, SBT.

The International Conference on Tanker Safety and Pollution Prevention, convened in London during February 1978, resulted in Protocols amending those of the International Convention for the Safety of Life at Sea, 1974 (SOLAS) and the International Convention for the Prevention of Pollution from Ships, 1973 (MARPOL). The main changes are summarised in Fig. 5.

Briefly, existing crude oil carriers must be fitted with SBT systems if they are 40,000 dwt or above but, as an alternative, crude oil washing or a clean ballast tank system (CBT) may be allowed. In the case of CBT, the shipowner declares certain cargo tanks as "dedicated ballast tanks" and these are not allowed to carry cargo. A CBT system is similar to an SBT system except that pumps and lines serving the CBT tanks may also be used for cargo operations.

New crude oil ships over 20,000 dwt must be fitted with SBT/PL and COW: they are not allowed to operate CBT. Lastly, any ship must have an inert gas system (IGS) before it may operate COW.

In adopting the Protocols, the TSPP conference recognised crude oil washing as an important anti-pollution measure.

5. DEVELOPMENT AND IMPLEMENTATION OF THE TSPP REQUIREMENTS

Resolution 15 of the Protocols comprised the "Specifications for the Design, Operation and Control of Crude Oil Washing Systems" which laid down specific criteria for COW. These were based on work carried out by the OCIMF (Oil Companies International Marine Forum) Crude Oil Washing Committee. At the time of the Conference, some national maritime administrations had little knowledge or practical experience of crude oil washing and the "Specifications" provided an invaluable basis on which to gain the necessary experience. Practical experience depended on the oil companies who had been operating COW for some time.

The target date for entry into force of the Protocol relating to MARPOL was set for June 1981, then three and a half years away. However, the magnitude of such changes affecting the whole of the tanker industry would inevitably take time to implement and this made the period seem all too short. BP drydocked its VLCCs every five years and it was planned to drydock eight ships during 1978, with the next scheduled drydocks in 1983.

The necessary modification and conversion work was therefore carried out and, in the case of the first ship, was ahead of the IMCO meetings at which interpretations and amendments were made to Resolution 15. Many other shipowners have adopted a "wait and see" policy and will not be taking action until a very late date. This may concentrate the work load on administration surveyors since owners will probably require a large number of ships to be inspected at the same time.

BP's policy on crude oil washing required all ballast tanks to be washed to a high standard. Therefore, these tanks tended to have better washing machine coverage than other tanks which were washed for sediment control only. Resolution 15 required the higher standard of cleanliness for all tanks, regardless of type. Thus additional tank washing machines had to be fitted to meet the more stringent requirements. The other major modification required was the fitting of a special small diameter stripping line to ensure proper draining of the main cargo lines and pumps to shore.

The first administration inspection was carried out on *British Norness* at the Isle of Grain terminal in June 1978. It consisted of an examination of the COW installation, inspections of requisite centre and wing tanks and the sampling of the oil on top of the departure ballast. The tanks were entered by the Department of Trade's surveyors who were able to assess the cleanliness of a crude-oil-washed tank. This was followed by inspections of other BPTC ships, and ships belonging to other tanker companies.

As a result the Department's surveyors now have a very wide experience of cleanliness of tanks of differing configurations, washed with different crudes. These inspections confirmed guidelines for tank entry devised with the agreement of the Department and OCIMF; guidelines for the production of shadow area diagrams (see Table II) and the Operations and Equipment Manual.

The TSPP Conference required crude ships to be fitted with SBT, CBT or COW (see Fig. 5). A shipowner who wishes to follow either the SBT or CBT option must face certain cost penalties. As the ballast tanks were originally used for cargo, the ship must lose deadweight capacity, estimated at 30 per cent. That is, a VLCC of 270,000 dwt will be effectively reduced to 190,000 dwt with an equivalent reduction in freight earnings. For example, the VLCC of 270,000 dwt, fixed at a rate of $3 per month per deadweight ton in 1972, will lose earnings of $2.9M per year; which is near enough the cost of retro-fitting COW and IG systems (estimated at £1M).

These are 1972 rates, a time when freight rates were high. But even in 1980, with rates of $1/dwt the economics favour retrofitting COW in VLCCs, as opposed to losing cargo carrying capacity.

6. POLLUTION PREVENTION CERTIFICATE

Implementation of the MARPOL and the TSSP protocol will require all ships that carry oil to be issued with an International Oil Pollution Prevention Certificate (IOPP). Trading patterns require

Table I Cargo and slop quantities non crude oil washed ships and (below) time saved with COW

British Inventor		*British Explorer*		*British Pioneer*		*British Navigator*	
Cargo	Slops	Cargo	Slops	Cargo	Slops	Cargo	Slops
207,031	1,571	207,446	1,528	214,503	3,245	207,396	3,186
209,879	1,793	210,376	997	212,724	2,417	207,328	3,148
210,211	900	210,762	1,906	213,614	1,587	206,927	1,241
207,303	2,519	206,577	2,046	216,338	1,550	208,477	2,460
209,049	1,387	206,966	1,647	214,825	1,578	208,018	2,463
206,521	2,040	209,778	1,276	205,464	2,503	207,128	2,411
206,369	5,039	207,943	1,540	213,900	1,079	207,670	1,862
1,456,363	15,249	1,459,848	10,940	1,491,368	13,959	1,452,944	16,771

i.e. 56,919 tons in 28 voyages say, 2,000 tons of slops representing 1.0 per cent of vessels cargo carrying capacity.

Ship	Cargo quantity	Slops quantity	Actual time (days)	Stemmed time (days)
Scientist	210,234	360	2¼	5
Prospector	210,924	236	2½	5
Explorer	210,817	282	2¾	5
TOTAL	631,975	878	7½	15

i.e. 878 tons total of slops representing 0.14 per cent of vessels cargo carrying capacity. Drydock preparation time reduced by 50 per cent.

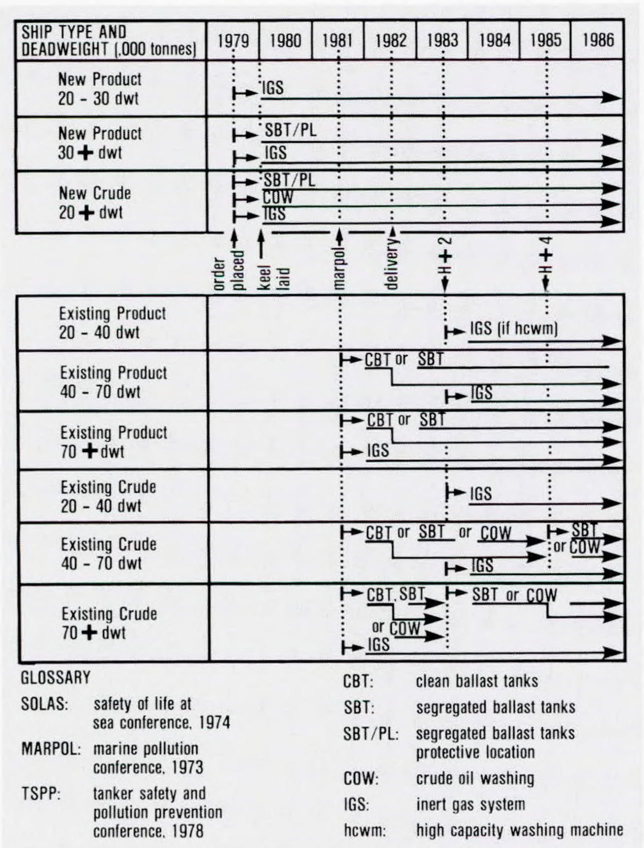


Fig 5 SOLAS, MARPOL and TSPP: SBT, CBT, IGS and COW requirements

ships to carry crude or product, or both simultaneously, and under the new regulations ships in each category must fulfil certain requirements, which are shown in Fig. 5. As some of these are the same for both product ships and crude oil ships, IMCO have agreed to three categories (Fig. 6) for the IOPP which are:

6.1 *Crude oil and products carrier*

(Allowed to carry either crude oil or product oil or both simultaneously)

6.2 *Product carrier*

(Allowed to carry product oil but not crude oil)

6.3 *Crude oil carrier*

(Allowed to carry crude oil but not product oil).

One anomaly among new ships are those larger than 70,000 dwt, fitted with SBT but without PL or COW, that are built between the differing "new ship" dates laid down by MARPOL and TSPP.

The IOPP certificate is issued for a period of five years, during which there will be at least one intermediate survey to ensure that ships' equipment does not materially differ from that shown on the certificate. In addition the inspections will check that ships are being operated in a correct and approved manner.

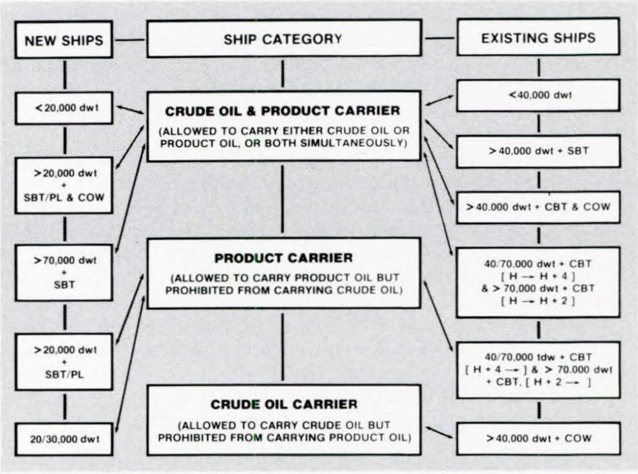


Fig 6 International oil pollution prevention certificate: IMCO agreed interpretation of ship categories

7. CONTROL OF CRUDE OIL WASHING

To obtain COW notation on its IOPP certificate, a ship will need to go through a stringent inspection and survey by its national administration officials or their duly authorised deputy. This process covers three areas which are:

7.1 an inspection of tanks after they have been washed with crude oil;

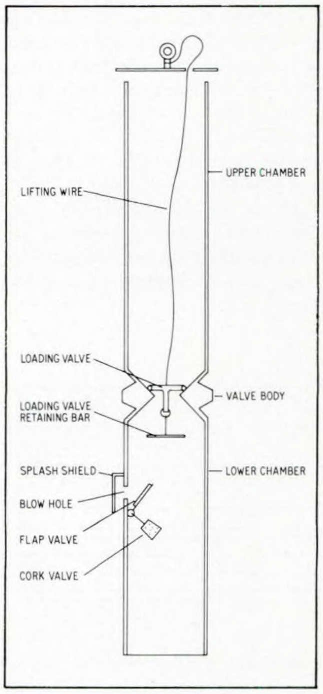
7.2 an inspection of the crude oil washing installation;

7.3 the measurement/testing of ballast samples.

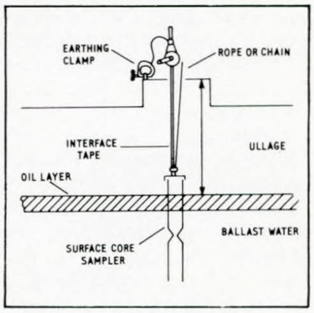
The in-tank inspections are to verify the cleanliness of the tank after it has been crude-oil washed. Normally, all tanks on the ship are to be inspected but, where several tanks are similar in all respects, only one of that group will need to be inspected. Before a tank is entered, the bottom may be flushed with water to remove any heel of oil remaining; but, if this is done, then a similar tank must be ballasted and surface samples taken to prove that the stripping of the tank is effective.

The installation inspection serves to check that it complies with the requirements of the IMCO Specifications. That is:

- pipework and valves are permanently installed and made from steel or equivalent (spheroidal graphite cast iron to BS 2789 SNG 27/12 is an equivalent);
- a pressure release device (or equivalent) is fitted to prevent overpressure of the tank-washing pipeline;
- any hydrant valves on the system are correctly blanked;
- all gauges and other instrumentation connections are fitted with proper isolating valves;
- no part of the COW system enters machinery spaces and the steam heater is fitted with double shut-off valves or blanks;
- the piping system for crude oil washing is sufficiently large to operate the number of machines required to be operated simultaneously;
- the piping is properly anchored to the ship's structure and the system has been tested to one and half times the normal working pressure;
- the tank washing machines are of an approved type and, if they are operated by portable control units, there are sufficient drive units on board so that they are not moved more than twice during the COW operation;
- there are sufficient tank washing machines fitted to ensure that tanks are properly washed and their correct operation can be monitored externally to the tank;
- there is sufficient pumping capacity to supply the necessary amount of crude oil to the COW system and this capacity can be maintained by more than one pump (in the case of pump failure);
- there is a facility for increasing the pressure in the tank washing line, should the back pressure of the cargo discharge fall below the minimum pressure required (ie, about 8 Kg/cm^2);
- there is sufficient stripping capacity to remove the oil whilst tank washing machines are in operation (ie, stripping capacity is 1.25 times the maximum oil throughput when the machines are in operation);
- the stripping of tanks is effectively monitored by means of level gauges, hand-dipping and stripping system performance gauges;
- there are at least four hand-dipping positions on each tank;
- means are provided for draining tanks, pipelines and pumps that are used during the cargo discharge and crude oil washing;
- stripping pumps are fitted with proper instrumentation to check that they are being run efficiently;
- all ballast lines and pumps can be effectively drained of oil before ballasting commences;
- a special small diameter stripping line is fitted for the stripping of tanks, cargo pumps and lines to the outboard side of the manifold valves, port and starboard, on completion of discharge;
- an approved inert gas system is fitted to the ship so that COW can be safely carried out; and
- the ship can simultaneously discharge and ballast so as to avoid vapour emission to the atmosphere (this applies to ships where it is necessary to take ballast into cargo tanks for departure ballast purposes).



◀ **Fig 7 (a) Ballast surface core sampler**



▲ **Fig 7 (b) Ballast core sampler in use**

Surface samples of departure ballast are required to determine the amount of free oil floating on top of it, which must not exceed 0.00085 of the ballast tanks' volume.

Measurements with an accuracy of better than 1 mm can be taken with the types of surface sampler illustrated in Fig 7a and 7b. These tests are required to prove the effectiveness of the stripping and drainage arrangements on board the ship and Table III illustrates typical sets of readings taken on board ships during national administration inspections.

The IMCO Specifications require that the arrival ballast is monitored by an oil/water monitor when it is discharged at an arrival port. However, within the oil industry the testing and development of monitors has yet to be completed. Thus large numbers of ships cannot be fitted with monitors.

As an alternative, IMCO have approved the taking of samples during the discharge of ballast so that these can be later analysed under laboratory conditions. Whatever method is used, the oil in the water must not exceed 15ppm. In any event, ships must also comply with the "visible sheen" criteria during the discharge of their ballast.

In addition to the on-board inspections, administrations are also required to approve shadow-area calculations for cargo tanks. These are, diagrams drawn to indicate the areas within a tank that are shielded from direct impingement of the crude oil washing jets. The IMCO Specifications require that all surfaces (both vertical and horizontal) must be covered by direct impingement or by the splash-back from tank washing machine jets; but reliance on splash-back only must not exceed 15 per cent of vertical areas and 10 per cent of horizontal areas.

Guidelines for the preparation of shadow-diagrams are shown in Table II, and an example of such a diagram in Fig. 8. Alternatively, if a tank structure is particularly complicated, the effectiveness of the tank washing machine coverage is to be established by building a model of the tank and then shining pinpoint lights from the positions where tank washing machines are sited.

All ships must be provided with an "Operations and Equipment Manual" which contains the complete text of the IMCO Specifications and all operational data relating to a particular ship. The IMCO agreed format for this Manual divides it into 17 sections, which are:

Table II Guidelines for the assessment of shadow diagrams

1. The shadow diagrams must be on drawings the scale of which must be at least:
   i) for tankers less than 100,000 dwt 1:100
   ii) for tankers of 100,000 dwt and above 1:200
2. The drawings must provide at least a plan view, a profile view and an end elevation for each tank or tanks considered to be similar.
3. Sufficient detailed drawings of the vessel must be provided to check that all large primary structural members have been included.
4. The term "large primary structural members" is to be construed as those components of a tank structure which contribute significant strength to the ship such as web frames and girders. It is intended that smaller components such as those that contribute to the plate stiffening be excluded. In general the following list in conjunction with the diagram may be used to amplify this construction.

Include	*Disregard*
1. web frames	1. longitudinals
2. girders	2. brackets
3. stringers	3. stiffeners
4. webs	4. ladders
5. main bracket	5. pipe work
6. transverses	
7. crossties in transverse web frames unless it can be verified by tank inspection that their presence does not affect the cleanliness of the tank. However, for the purpose of making an initial assessment where there are no more than two crossties and each is less than 1/15 of the total depth of the tank they may be ignored.	

5. Shadows cast upon the underside of decks, web frames, centre and side girders can be ignored.
6. Calculations must be provided either on the drawing or separately to show how the percentages required by section 4.2.8 have been arrived at. The calculations should be itemised so that it is possible to relate each item with a particular shadow area.
7. Where a curved surface is presented to jets it is not necessary to provide exact geometric projections to determine the resultant shadow. A reasonable estimate is acceptable.
8. For the purpose of determining the bottom area of wing tanks the breadth of the tank is to be taken as the horizontal distance measured across the top of the bottom longitudinal frames to the inside of the shell plating, midway between the tank bulkheads.
9. A swash bulkhead may be taken as a tank boundary. However, in this event the bulkhead must be assumed to have no openings in it.

1. Text of the Specifications.
2. Drawings of the crude oil washing system.
3. Description of the crude oil washing system and operational and equipment parameters.
4. The dangers and precautions against oil leakage.
5. The use and control of inert gas.
6. Precautions against electrostatic hazards.
7. Personnel requirements.
8. Methods of communication.
9. List of crude oils not suitable for crude oil washing.
10. Crude oil washing check lists.
11. Approved methods and programmes for crude oil washing.
12. Typical crude oil washing programmes.
13. The method of draining cargo tanks.
14. The method and procedures of draining cargo pumps and lines.
15. Typical procedures for ballasting and the method of preventing hydrocarbon emission.
16. Compliance procedures for Regulation 9 of Annex 1 to MARPOL 1973.
17. Inspection and maintenance of equipment.

The Operations and Equipment Manual is a comprehensive document which will cost over £25,000 to produce. When it has been approved by their national administration, ships must operate within the parameters laid down within it.

From time to time administrations will make spot checks on ships to ensure that the COW installation still complies with the data given on the IOPP certificate, and in the Operations and Equipment Manual. These may take place at any port. Where a surveyor finds that the equipment differs to a great extent from what it should be, he may require the ship to effect necessary repairs/modifications and, if necessary, to sail from the discharge port to a repair port.

Section 9 of the Manual should list crude oils that are not suitable for crude oil washing. To date, no crude oils have proved unsuitable for this purpose.

8. TRAINING OF PERSONNEL

The Specifications require that only properly qualified personnel carry out crude oil washing. The person taking overall charge must have:

8.1 at least one year's experience on oil tankers where his duties have included the discharge of cargo and associated crude oil washing. Where his duties have not included COW, he shall have completed a training programme in it;

8.2 he must have participated at least twice in COW programmes, one of which shall be in the particular ship for which he is required to undertake the responsibility of cargo discharge; or alternatively, a ship similar in all relevant respects;

8.3 be fully knowledgeable of the contents of the Operations and Equipment Manual.

Other persons concerned must have at least six months' experience on oil tankers where they should have been involved in the cargo discharge operation. In addition, they must be instructed in COW on the particular ship and be fully knowledgeable of contents of the Operation and Equipments Manual.

These requirements mean that ships' personnel will need certificates proving their involvement in crude oil washing operations and, if necessary, participation in an authorised COW course. Typical certificates are shown in Figures 9 and 10.

Table III Typical ballast surface samples (using surface sampler)

British Reliance

Total Oil 13.10 m^3 Total Tank 207,031 m^3 Oil: Tank .00006329

	PORT			STARBOARD		
TANK	Oil Depth	Oil Volume	Tank Volume	Oil Depth	Oil Volume	Tank Volume
1A	0	0	10,314.0	0	0	10,314.0
1B	0	0	13,952.3	0	0	13,952.3
2A	5mm	2.62	13,960.1	10mm	5.24	13,960.1
2B	2mm	1.05	13,960.1	0	0	13,960.1
3A	0	0	13,960.1	3mm	1.57	13,960.1
3B	0	0	13,959.9	0	0	13,959.9
4A	0	0	13,700.7	0	0	13,700.7
4B	5mm	2.62	9,708.3	0	0	9,708.3
TOTALS		6.29	103,515.5		6.81	103,515.5

British Pride

Total Oil Volume 42.89 m^3 Total Tank Volume 156,837 Ratio Oil: Tank Volume 0.00027

	PORT			CENTRE			STARBOARD		
TANK	Oil Depth	Oil Volume	Tank Volume	Oil Depth	Oil Volume	Tank Volume	Oil Depth	Oil Volume	Tank Volume
1				3mm	3.09	26,818			
2	2mm	1.37	17,235				2mm	1.37	17,235
3	21mm	14.35	17,237				2mm	1.37	17,237
4	13mm	8.88	17,234				11mm	7.51	17,234
5				6mm	4.95	26,607			
TOTALS		24.60	51,706		8.04	53,425		10.25	51,706

BP TANKER COMPANY LIMITED

QUALIFICATION FOR CRUDE OIL WASHING

Under the requirements as specified in the annex to the Marpol Protocol of 1978 covering the specification for the design, operation and control of Crude Oil Washing Systems.

THIS IS TO CERTIFY THAT:

Discharge Book Number:

is qualified to take charge of Crude Oil Washing Operations on the ships or classes of ships listed overleaf.

GUIDANCE NOTES FOR MASTERS

In order to qualify as competent to take charge of a Crude Oil Washing Operation, an Officer must have:

1. Served for at least one year in tankers
2. Must have participated in at least two previous joint Discharge and Crude Oil Washing Operations. One of these two joint operations must be on the ship, or another ship of the same class, for which this certificate is to be endorsed.

Having satisfied these two requirements, the ship's stamp together with the Master's signature should be annotated on this certificate. When an officer is certified competent against a ship, no further stamp is necessary for any other ship of the same class.

This certificate should be kept in the Officer's discharged book as it may have to be produced to a Government Surveyor.

Ship Class	Deadweight (Tonnes)	Other Ships in Class	Signed — Master Ship Stamp
RESPECT	277,000		
RELIANCE	270,000	RANGER; RESOURCE	
NORNESS	270,000	RENOWN; RESOLUTION; TRIDENT	
PATIENCE	253,000	PROMISE	
PROGRESS	228,000	PURPOSE	
PIONEER	226,000	SHOUSH	
PRIDE	222,000		
EXPLORER	219,000	INVENTOR; SCIENTIST; SIVAND	

Fig 9 Typical certificate of participation in COW operations onboard ship

CERTIFICATE NUMBER BP 0251

BP TANKER COMPANY LIMITED

CRUDE OIL WASHING TRAINING CERTIFICATION

This is to certify that:

NAME

RANK DISCHARGE BOOK NO.

CERTIFICATE OF COMPETENCY/

GRADE (IF APPLICABLE)

DATE AND PLACE OF BIRTH

has satisfactorily completed a course of training, approved by the DEPARTMENT OF TRADE, detailing the procedures for the washing of cargo spaces of oil tankers with crude oil as laid down in the "Specification for the Design, Operation and Control of Crude Oil Washing" published by IMCO.

Held at From To

Authorising Signature Course Lecturer

Date of Issue Signature of Holder

Fig 10 Typical COW course certificate

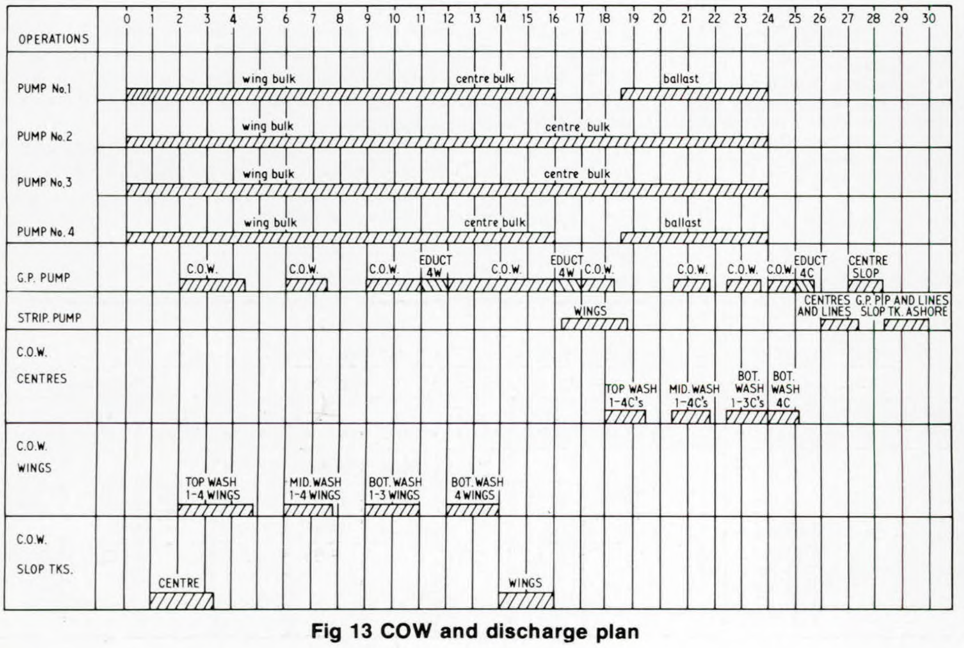


Fig 13 COW and discharge plan

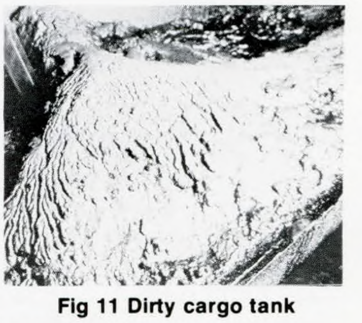


Fig 11 Dirty cargo tank

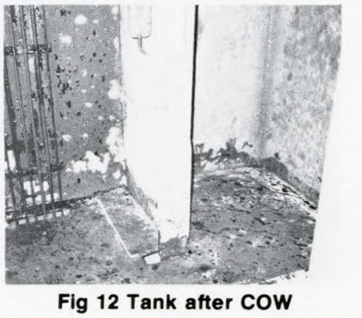


Fig 12 Tank after COW

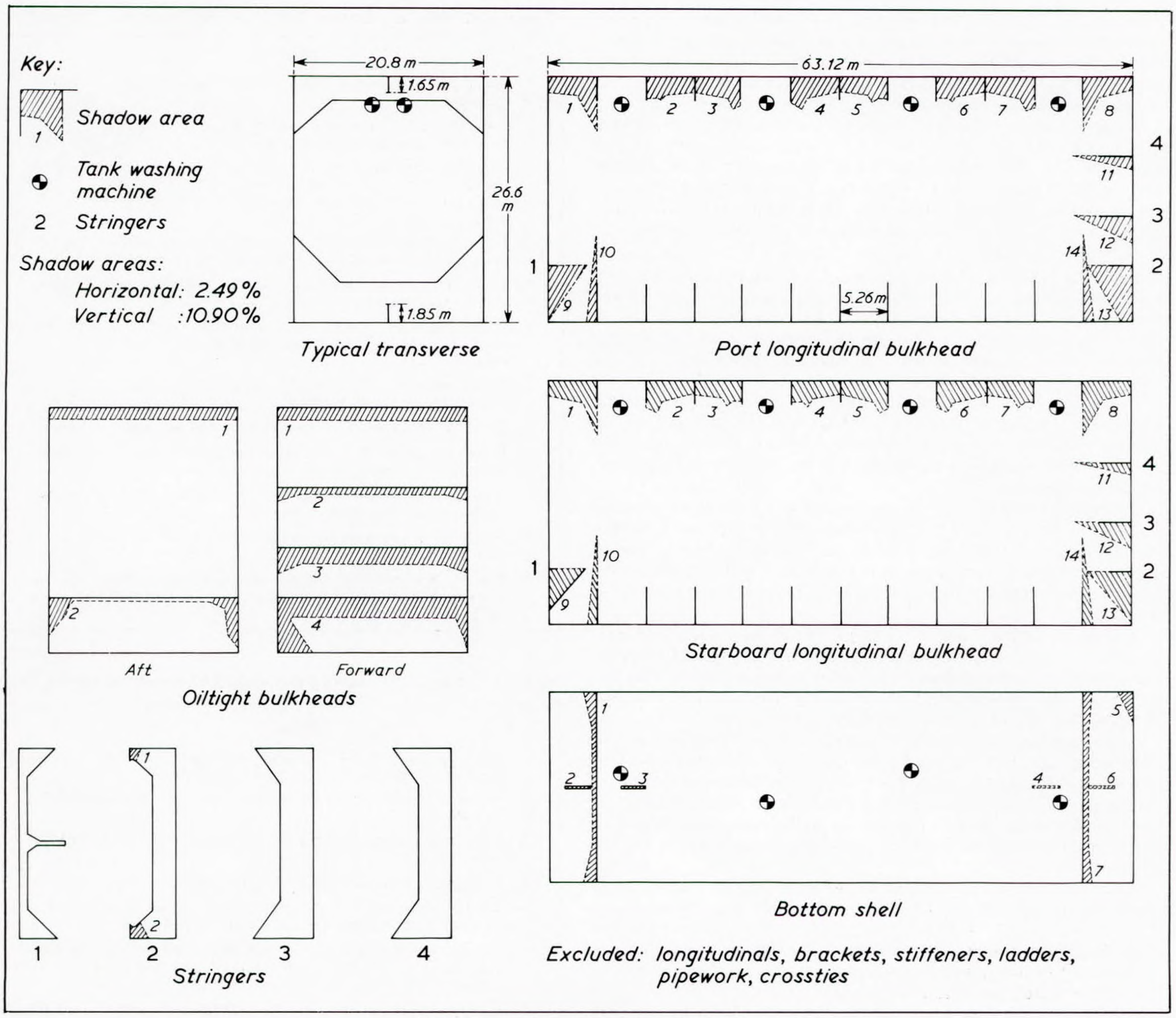


Fig 8 Typical shadow area diagram

Table IV Check List: pre arrival at discharge port

NO.	ITEM	
1.	Has the terminal been notified that the vessel wishes to crude oil wash tanks during discharge?	Yes/No
2.	Is the oxygen analysing equipment (portable and permanent) tested and working satisfactorily?	Yes/No
3.	Is the tank washing pipeline system isolated from the water heater and engine room?	Yes/No
4.	Are all the hydrant valve connections on the tank washing line blanked?	Yes/No
5.	Are all the valves to the fixed tank washing machines shut?	Yes/No
6.	Have the tank cleaning lines been pressurised and leakages made good?	Yes/No
7.	Have the portable drive units for fixed tank washing machines been tested and fitted?	Yes/No
8.	Have the pressure gauges on the top discharge line, the manifold and the tank cleaning main been checked?	Yes/No
9.	Has the stripping system monitoring equipment been checked?	Yes/No
10.	Has the communications system been checked and tested?	Yes/No
11.	Has the organisation plan been drawn up and posted with duties and responsibilities defined?	Yes/No
12.	Have the discharge/crude wash operation plans been drawn up and posted?	Yes/No
13.	In cases where the terminal has a standard radio check list, has this been completed and transmitted?	Yes/No

9. OPERATION OF CRUDE OIL WASHING

The advantages of crude oil washing are summarised as follows:

9.1 Less sea pollution due to reduced water washing;
9.2 Reductions in time and cost of tank cleaning;
9.3 De-sludging by hand obviated (see Fig. 11);
9.4 Reduced tank cleaning time at sea;
9.5 Increased outturn of cargo;
9.6 Reduced deadfreight as less oil-water slops are retained on board (see Fig. 12);
9.7 Less salt water discharged to refineries;
9.8 Tank corrosion due to water washing is reduced.

Disadvantages are possible increases of discharge times and an increased workload on ships' staff. Therefore it is important to plan the discharge operation properly so that COW is not interfered with in any way. Increase of discharge time will be least when cargo discharge is restricted by shore limitations.

The Specifications require crude oil washing during each discharge of all tanks that are likely to carry ballast. This includes arrival, departure and heavy weather ballast tanks. In addition one quarter of the remaining tanks are to be washed for sludge control purposes (these tanks may include those required for heavy weather ballast) but they need not be washed more than once in every four months. The requirements allow ships' staff to prepare a plan for the full discharge operation; a typical one is shown in Fig 13.

At various stages before, during and after a COW programme, safety and operational checks are made. A full set of check lists is illustrated in Tables IV to VII.

Experience indicates that one and a half full machine cycles are necessary to clean a compartment and any further washing is superfluous. The programme will depend on the type of tank washing machine fitted. If it is the single-nozzle, programmable type, the multi-stage system minimises the time loss during cargo discharge. The upper limits of the first stage will be about 90° from vertical downwards, in centre tanks and 120° in wing tanks; and the lower limit about 70°. The second stage will be between 70° and 40° and the bottom (final) stage between 40° and 0°. On ships fitted with non-programmable machines, multi-stage oil washing is not feasible and a cargo tank is washed starting when there is 1 m of oil remaining in it.

The optimum pressure for oil washing is 8.5 to 10.5 bar. This is obtained by bleeding off from a main cargo pump discharge line into the crude oil washing line or by using special pumps that are fitted for COW and stripping duties only. If a low shore back pressure, or the loss of the hydrostatic head during discharge, results in the line pressure being too low, it must be increased by closing down an isolator valve on the discharge line.

During crude oil washing the quality of the inert gas must be frequently checked by portable analyser and the pressure and 0_2 content must be continuously recorded. The tank washing line pressure should be frequently monitored and the cycles of the machines carefully watched.

Towards the end of discharge the line pressure will be too low and washing is carried out by recirculation. The pump takes suction directly from the slop tank, delivers into the tank cleaning line to supply the machines and powers the eductors. These drain the tanks being washed, into the slop tank. This will maintain the oil level in the slop tank.

The Specifications require all cargo pumps and associated lines and the COW lines to be stripped ashore, using a special stripping line connected to the outboard side of the manifold valves. This can be done either by stripping them all to the slop tank and then discharging this ashore; or stripping them directly ashore.

A port authority can prohibit discharge of hydrocarbon gases to the atmosphere. When a ship loads ballast into tanks that have previously contained cargo, this must be done concurrently with cargo discharge from other tanks. During this time the atmospheric pressure in the cargo tanks must be carefully monitored and, if it becomes excessive, the inert gas allowed to recirculate, or the fan stopped.

After oil washing all surfaces within tanks will be clear of sediments but a small quantity of free oil will remain in the strum areas. This will need to be washed out before arrival ballast is shipped and a single water-washing cycle will be sufficient. Washing water is recirculated from the slop tank system because tanks must not be washed by water taken from the sea and returned to it.

Ballast lines will also require cleaning and this is done by pumping through during the shipping of departure ballast. During line washing the slop tanks are filled with water to the levels required for recirculation of tank washing water.

After water washing the tanks are repurged as necessary. Pumps and lines required for working ballast are flushed through. Arrival ballast is shipped by taking suction direct from sea and discharging to tanks via direct drop lines from deck or via drop lines into the tank ring main. Departure ballast is initially discharged directly overboard and the discharge must be closely monitored. When the first discolouration is observed or if the instantaneous rate of discharge of oil content exceeds 60 litres per nautical mile, the discharge overboard must be stopped. The remaining departure ballast is transferred to the slop tank system and decanted after a settling out period of several days.

On some ships the ballasting and deballasting operations are carried out simultaneously to limit the stresses in the hull, whereas on others ballasting precedes deballasting. Whichever method is used, the overboard discharge during deballasting must be above the waterline so that the discharge can be monitored at all times.

Table V Check list: before the crude oil washing operation

NO.	ITEM	
1.	Are all the pre-arrival checks and conditions in order?	Yes/No
2.	Has the discharge/crude oil wash operation been discussed with both ship and shore staff and is the agreed plan readily available for easy reference?	Yes/No
3.	Have the communication links between the deck/cargo control room, cargo control room/engine room and cargo control room/shore been set up and are they working properly?	Yes/No
4.	Have the crude oil wash abort condition and procedures been discussed and agreed by both ship and shore staff?	Yes/No
5.	Have fixed and portable oxygen analysers been checked and are they working properly?	Yes/No
6.	Is the inert gas system working properly and is the oxygen content of the delivered inert gas below 8% by volume?	Yes/No
7.	Is the oxygen content of the tank(s) to be crude oil washed below 8% by volume?	Yes/No
8.	Have all the cargo tanks positive inert gas pressure?	Yes/No
9.	Have responsible personnel been assigned to check all deck lines for leaks as soon as washing starts?	Yes/No
10.	Are the fixed machines set for the required washing method and are portable drive units mounted and set?	Yes/No
11.	Have valves and lines both in pumproom and on deck been checked?	Yes/No
12.	Has the slop tank been emptied and recharged with dry crude and the water bottom of cargo tanks been discharged?	Yes/No

Table VI Check list: during the crude oil washing operation

NO.	ITEM	
1.	Is the quality of the delivered inert gas frequently checked by portable instrument and recorded?	Yes/No
2.	Are all the deck lines and machines frequently checked for leaks?	Yes/No
3.	Is the crude oil washing in progress in designated cargo tanks only?	Yes/No
4.	Is the pressure in the tank washing line 10 bar or above?	Yes/No
5.	Are the cycle times of the tank washing machines as specified in the Operations and Equipment Manual?	Yes/No
6.	Are the washing machines in operation (together with their drive units) frequently checked and are they working properly?	Yes/No
7.	Is a responsible person stationed continuously on deck?	Yes/No
8.	Will the trim be satisfactory when bottom washing is in progress as specified in the Operations and Equipment Manual?	Yes/No
9.	Will the recommended tank draining method be followed?	Yes/No
10.	Have the ullage gauge floats been raised and housed in the tanks being crude oil washed?	Yes/No
11.	Is the level in the holding (slop) tank for tank washings frequently checked to prevent any possibility of an overflow?	Yes/No

Table VII Check list: after the crude oil washing operation

NO.	ITEM	
1.	Are all the valves between the discharge line and the tank washing line closed?	Yes/No
2.	Has the tank washing line been drained of crude oil?	Yes/No
3.	Are all valves to the washing machines closed?	Yes/No
4.	Are cargo pumps, tanks and pipelines properly drained?	Yes/No

10. ATMOSPHERE CONTROL AND TANK ENTRY

Hydrocarbon gas burns in air when its concentration is within the flammable range. At concentrations above or below the flammable limits it will not burn because it is either over-rich or too lean. An over-rich mixture will become flammable when diluted sufficiently with air. The flammable limits of crude are generally taken as 10 per cent and 2 per cent in atmospheres containing 21 per cent oxygen. If the oxygen is reduced, the range of flammability narrows until the mixture becomes non-flammable because there is insufficient oxygen present to support combustion. This occurs at 11 per cent oxygen (see Fig. 14).

The main constituent of air is nitrogen which is an inert gas and does not support combustion. Boiler flue gas also consists mainly of nitrogen and, with good combustion conditions in the boiler, the oxygen content of the flue gas can be maintained below five per cent. It can therefore be used to make tank atmospheres safe. For an explosion to occur an ignition source is required.

Normal safe tanker practice will prohibit ignition sources on the cargo deck but a potential source within cargo tanks is electrostatic generation during washing. Therefore, tanks must be inerted with good quality gas as they are emptied of cargo and kept under a positive pressure to prevent ingress of air. Before crude oil washing of a tank commences, the oxygen content of the atmosphere must be checked at a distance 1 m below the deck level and at the mid level of the ullage space. If the oxygen reading is greater than eight per cent, crude oil washing must not take place.

After sailing from a discharge port, all empty cargo tanks should be purged with inert gas to reduce hydrocarbon gas concentrations to below the lower flammable limit. Tanks that are water-washed for arrival ballast or tank entry should be re-purged as necessary. Tanks containing departure ballast should be purged once they have been discharged.

When it is necessary to enter tanks for inspections or repairs, they should be purged to below the lower flammable limit and water-washed, followed by re-purging and ventilation to 21 per cent oxygen.

Under exceptional circumstances, brief entry into oil-washed tanks may be permitted for cursory inspection only, without prior water-washing of the tank. However, such entry must be subject to stringent safety precautions.

Statutory inspections by administration surveyors are required after tanks have been crude washed. It is normal for the surveyor to be accompanied by a shipowner's representative when he enters a tank and experience has shown that it is easier for the deck party to keep sight of those who enter the tank if reflective tape is attached to the tops of safety helmets and CABA cylinders. When carrying out inspections at the bottom of the tanks, the inspecting team should keep to centre-line walkways on tank bottoms where they are fitted. This does not prevent the surveyor leaving the walkway to inspect particular areas of the tank bottom if he so requires. Formalised procedures for the entry into tanks by administration surveyors have been published by IMCO.

11. CONCLUSIONS

The spate of regulations brought about by the TSPP conference has caused mixed reactions. Inevitably there will be the body of opinion intending to do nothing until forced to do so. Others remain convinced that SBT and not COW is the only method by which pollution of the seas will be avoided.

It has indeed been argued that crude oil washing is too demanding on crew time and too difficult to monitor. In our company we argue that good tanker practice, no matter what the task, requires effort and dedication by well trained crews. These regulations (no matter how well they are implemented or policed) will be to no avail unless the crews are well trained. The shipowner's contribution must be to ensure the highest standard of dedication, effort and training on board all his ships.

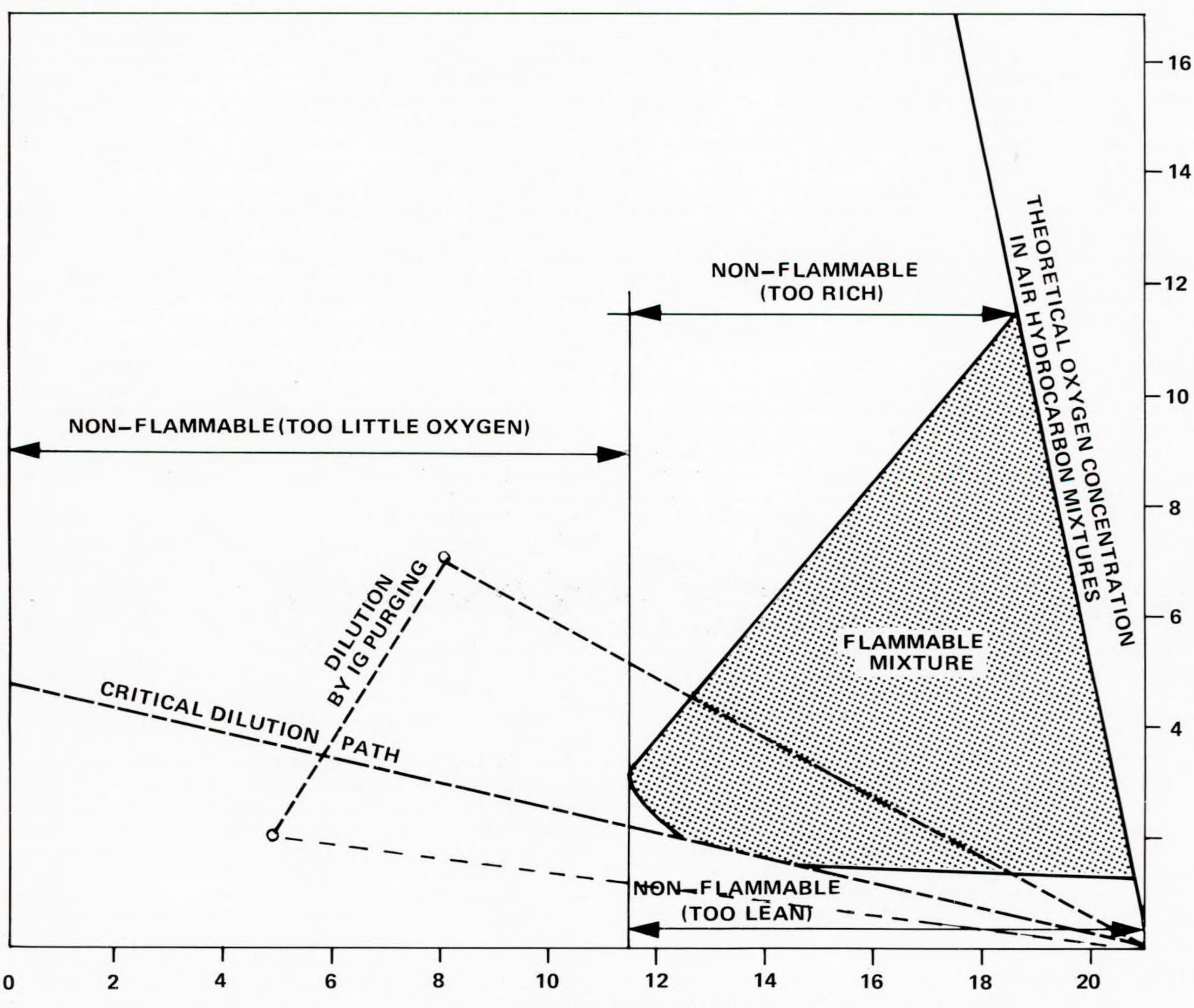


Fig 14. Limits of flammability of hypothetical hydrocarbon nitrogen/oxygen mixtures

Discussion

MR J. S. C. BLOOMFIELD CEng, MIMarE (Lloyd's Register of Shipping):
Being involved in the approval of Crude Oil Washing (COW) systems, I feel that anyone having to interpret the IMCO regulations before designing a system for their tanker would do well to read this paper first. I should like to make the following comments:

The Administration requires the vibration characteristics of each type of tank-cleaning machine to be investigated and approved. Having made such an investigation, have the authors ever had to move the gun positions on deck or alter the deck stiffness by doublers or brackets? Over the years, have any guns fallen down into the cargo tanks or failed from fatigue damage due to vibrations?

Static generation of electricity due to the tank atmosphere has been well investigated and the information is concise. Have the authors ever attempted to take readings on board their vessels using COW since the original trials and, if so, how was the investigation carried out?

The cost of £1M for retrofitting COW is illuminating. I imagine this cost is for large tankers with many deck and submerged machines. Could the authors give a simple breakdown of how these costs are made up?

The table of ballast surface samples shows that tank washing and stripping in those particular vessels was very good. Have these values been maintained in other vessels and with different types of crude oil? When discharging ballast water from washed tanks at night, is the crew able to detect the sheen on the water surface or from the discharge overboard?

Concerning stripping of the cargo tanks, have the authors found the shipyard design and positioning of the suctions satisfactory or have they had to improve the system by either redesigning or positioning the suctions?

Which design of stripping head has proved the best and has the steel plating under these suctions been affected by erosion? It is common practice to increase the thickness of steel plate under the main cargo suctions: should this be extended to the strip suctions?

When operating the inert gas system during discharge and crude oil washing, what pressure fluctuations take place? I have heard of cases where the tank hatch joints have blown when the guns have been started up. Has this happened to any of the authors' vessels and, if so, what alterations were made to their washing programme to avert this?

In general, has the control valve in the inert gas system operated smoothly to control the pressure when electrically-driven, constant-speed fans are fitted?

The discharge plan makes the discharging and ballasting seem straightforward. A number of operation manuals now being prepared have increased the amount of information recorded on this plan, e.g., the bending moment and shear force values at various stages, the quantities of crude oil remaining in the tanks, etc. Have the authors found that the ships' staff use these charts; do they add their own remarks and, if so, what is the extra information they record?

The fitting of purge pipes is not mandatory at present, but a number of owners are specifying them when retrofitting, anticipating the Revised Regulation 62 which should come into force in June 1981 for large vessels. Have the authors experienced any difficulties containing vapour emissions when simultaneously discharging and ballasting? Can they describe their control methods or any experiences encountered with vapour control?

The IMCO Regulations require four hand-sounding positions in each tank, so the crew must be very busy on deck during the stripping operation. Is this number really necessary and what methods of sounding are envisaged for the future?

Records of the inert gas pressure and oxygen level in the cargo tanks have to be kept for three years. Have they proved useful to indicate any abnormalities and have any national authorities demanded to see them?

More regulations mean more work for someone. What changes in the IMCO Regulations would the authors like to see to make COW simpler and safer?

MR G. VICTORY CEng, FIMarE:
The author's very interesting paper is the latest idea in that long-running serial — "How do we get tankers which will operate more safely and release less oil into the sea?" Such problems have bedevilled administrations and the tanker industry since the introduction of the VLCC and ULCC with their higher disaster capability and greater environmental impact and news-worthiness.

A table in "Lloyd's List" of 1 April 1980 shows the desirability of increased operational safety: 14 large tankers from 100,000 to 320,000 dwt are given as lost from 1 January 1979 to 1 April 1980. Not shown are the ten tankers of 20,000 to 100,000 dwt lost in the same period.

The need for a reduction in the quantity of operational and accidental oil released into the sea is demonstrated by a number of large releases like those of *Amoco Cadiz* and *Christos Bitas*, but perhaps more so by the many small to medium operational releases which inconvenience many people, destroy sea birds and give the environmentalists the ammunition they need.

In looking to see whether COW will solve those problems we should ask, "Why was it necessary to go to COW?" and "Do the proposals for operating COW give a better level of intrinsic safety and added assurance than the previous operational practices which it replaces?"

COW has some advantages in principal, but it has to be admitted that it has found more ready adoption because it is the last resource for those who find the protected segregated ballast requirements anathema!

It has come to this because too many tanker owners and operators have made little or no effort to operate the Load on Top method effectively. It is no use some responsible operators washing their hands of the "cowboys", for they are part of the same overall picture — "tarred with the same oil residues" — since many of the "cowboys" are on charter to the major companies. Had Load on Top been assiduously practiced by all tankers on long haul trades, such as the Middle East to Europe, and had the Industry been more willing to accept that segregated ballast, or the discharge of all washings and residues ashore were the only acceptable operational practices in short-haul trades and areas of special weather problems, those who preferred the more flexible arrangements would not have been forced into an untenable position.

I look now at the proposed COW arrangements to see whether they are intrinsically safer than those presently applicable which, judging by results, leave something to be desired. The authors say that it is impossible to maintain the vapour concentration throughout the loads at all times above the flammable limit, and that large flammable regions could exist in the tanks, unless they are protected with inert gas. In this respect I think that the ICS/OCIMF Tanker Safety Guide is too permissive. I hope it will be amended so that at least two, preferably three, of the four alternatives permitted for Tank Working Atmospheres in Section 8.21 will be deleted and more emphasis will be placed on the need to maintain a properly-inerted atmosphere in the tanks; not only during washing but during periods when tanks might be empty but "crude oil" residues remain — certainly as far as crude oil carriers are concerned.

I am pleased the authors agree that a supply of good quality inert gas during discharge is essential and the 0_2 content should be continuously recorded. But it is at variance with the requirement (Table VI) that the quality of inert gas delivered should be frequently checked and recorded by portable instruments: surely, in such a vital area it should be additional to continuous recordings. The authors say that the 0_2 content must be checked one metre below deck level and at mid level in the ullage space; if greater than eight per cent, COW must not take place. If a realistic safety margin is to be allowed for, an alarm should be given when the level exceeds five per cent.

It is also surprising that "hand dipping" of tanks as well as surface and atmosphere sampling, is envisaged: are deck openings into tanks to be permitted? The statement that "normal tanker practice prohibits ignition sources on the cargo deck" is a dangerous generalisation. It is just not true: even the level of static generated by nylon undergarments can produce an incendive spark, so when will the tanker industry accept that a positive pressure of inert gas cannot be guaranteed if tank openings have to be used. It should be possible to carry out all operations without recourse to opening any part of the tank at, or near, deck level.

The authors suggest BP would be carrying out their retrofits in dry-dock. Nevertheless, it seems likely that many companies will be carrying out a major part of the conversions during ballast or on voyages, by using shore labour additional to ship's staff. This could well require welding and burning metal on deck and in the pump room (or double bottom in the case of an oil/bulk carrier), which introduces hazards as long as crude oil residues remain aboard. This could well result in ships being lost. Too often spaces can be considered as gas-free by persons not fully qualified to issue official gas-free certificates, with tragic results.

Entry into oil-washed tanks for brief inspections in exceptional circumstances seems to be considered acceptable. This may be taken as a general statement by personnel. That such entry must be subject to stringent safety precautions, which incidentally are unspecified, is not appropriate. One such precaution for all ship personnel must be the proper gas-freeing and ventilation of the tank to remove the unsafe aspect of tank entry.

Whilst applauding the intent of the paper to inform and educate those who are to implement the IMCO Regulations and Guidelines for Crude Oil Washing, and accepting that the authors' company will be most conscientious in applying them, I must agree that "there will be a body of opinion intending to do nothing until forced to do so". Casualties and pollution will recur unless greater supervision and enforcement (maybe with some system of "black marks" for wrongdoers) are efficiently implemented by both operators and administrations, in contrast with the Load on Top situation. *Laisser faire* will only allow those convinced that SBT is preferable, to have their way. So the Industry is saddled with Load on Top, Crude Oil Washing and Protected Segregated Ballast for new ships and it might even be said they have only themselves to blame.

It is up to all concerned to see that COW can be, and is, made to operate safely and effectively. This will require a more positive acknowledgement of the need for the greatest margins of intrinsic safety in tanker operations, for we are still far from that desirable objective.

DR J. COWLEY BSc, CEng, MIMarE, (Department of Trade): Referring to Captain Barker's remarks about the "1978 Protocol" conference battlelines being drawn between the advocates of segregated ballast (SBT) and crude oil washing (COW) respectively, I agree that SBT was not the panacea that some people assumed, as cargo tank bulkheads do develop leaks in service, resulting in contamination. However, there were other factors in the Tanker Safety and Pollution Prevention Conference held in February 1978. Some of the advocates of SBT were concerned about the surplus tanker capacity and saw SBT as a means to reduce carrying capacity and avoid laying up tankers. Other countries were concerned about the cost of retrofitting SBT to existing tankers and the higher transportation costs of oil using SBT tankers, and so supported the COW alternative.

These factors influenced the COW specifications as the opponents of COW, claiming (rightly) that it is an operational procedure, endeavoured to make the specifications as rigorous as possible. The result was the very tight regulations and initial test procedures, that have been commented upon.

With respect to the safety aspects of COW operations, Fig 3 of the paper shows the change in static charge generation as the oil/water proportions in the washing medium were varied. The Specifications took this factor into account by requiring that, before COW commenced, the slop tank was discharged ashore and the initial one metre of any tank used for COW was also discharged, to remove the water and avoid the high static levels. I agree that an over-rich atmosphere could not be guaranteed throughout the tank-washing process, although such an atmosphere would be an explosion-inhibiting factor for a large proportion of the time. Nevertheless, an inert gas system maintaining a maximum eight per cent oxygen in the tanks throughout the operation would be mandatory.

The approval tests listed in the Specifications were intended to be relevant to the design of the installation and the operating procedures in practice. For this reason the tank inspections to determine the cleanliness of tanks had to be conducted after the COW operation without a water wash. Such inspections could only be undertaken when the surveyor was satisfied that the tank was gas free and then by taking special precautions. It was for these reasons that the Department of Trade had formulated Guidance Notes for its surveyors and these had been published by IMCO as Information Paper Number MEPC XII/INF 6.

The approval test for oil on the surface of departure ballast was intended to represent conditions in practice. It was reassuring to hear that Captain Barker felt that the limit of free oil floating on the surface of 0.00085 of the departure ballast tanks' volume was reasonably achievable, as several tankers have failed this test.

Captain Barker was not, however, so content with the requirements of the clean (arrival) ballast test and had queried the specified figure of 15 ppm and its origin. The Convention specified "clean ballast" as effluent which 'if it were discharged from a ship which is stationary into clear calm water on a clear day would not produce visible traces of oil on the surface of the water or on adjoining shorelines or cause a sludge or emulsion to be deposited beneath the surface of the water or upon adjoining shorelines'. However, if there were visible traces of oil and it could be shown that the effluent did not contain more than 15 ppm of oil then the ballast could be considered as "clean". Therefore, the Specifications included the figure of 15 ppm. I share the authors' reservations about the value and practicability of this test but, unfortunately, it could not be dispensed with. However, the Department is submitting a paper to IMCO making proposals for conducting the test, which will remove the need to have a surveyor on board the tanker from discharge to loading port, as well as make the test more appropriate to actual tanker operating conditions.

Mr Allsop had commented on the importance of crew training and BP's establishment of a DOT-approved course was in line with the Company's policies of soundly training its personnel. The certificates to be issued to the officers shown in Section 8 of the paper were intended to satisfy Port Authorities that the ships' staff had appropriate training. The DOT had no immediate intention of issuing certificates covering COW training to ships' officers. However, one major company had asked the DOT to endorse their certificate to confirm that the officer concerned had performed service on particular tankers using COW procedures. This endorsement was by no means an assurance of competence, merely confirmation of the officer's presence on board when COW was being carried out.

The importance of the Operations and Equipment Manual could not be over-estimated. This expensive document for UK-registered tankers was compiled in co-operation with the DOT, which was required to approve it as meeting the IMCO requirements. To date, the DOT has completed 25 ships for COW but only one manual (for a BP tanker) has been approved. Other Administrations and Port Authorities would be entitled to demand the manual to confirm that the ship's equipment and operations complied with the data given in the manual. Because of the Department's need to be associated with the document, it was not approved until all other procedures had been completed.

MR D. J. GIBBONS CEng, FIMarE (BP Tanker Co. Ltd.): I refer to the advantages of COW listed in Section 9, and particularly item 9.8. Whilst the corrosion reduction may arise because of reduced water washing, there must be a likelihood of increased corrosion in tanks subsequently water washed, or where water is otherwise introduced, unless appropriate corrosion control measures are installed. Would the authors care to comment?

Authors' Replies

To Mr Bloomfield:

During the development of the single-nozzle, fixed, tank washing machine, vibration characteristics were identified as a problem. If the natural vibration frequency of the machine standpipes were the same (or near to) the natural and/or induced vibration frequencies of the ship's hull, then the standpipes could fracture (due to metal fatigue) and allow the machine to fall into the tank. It has been argued that if manufacturers design their machines such that the standpipes, nozzle and driving mechanism remain suspended in the event of vibration-induced fracturing, then the vibrations need not be considered. However, in our opinion the effects of vibration on the deck plating must be considered; it can be stiffened, but it is bad practice to install machines that will subject it to almost constant vibration stresses when steaming.

Taking this into account, BP decided that all fixed tank washing machines on their ships must have natural vibration frequencies in excess of the maximum propeller-induced hull vibration. On a VLCC developing a maximum of 90 rev/min with a six-bladed propeller, the frequency must exceed 540 cycles per minute (9 hertz). A suitable safety margin of ten per cent was added to the figure giving a minimum natural frequency of approximately 600 cycles/min (10 hertz).

Consequently, on the authors' ships, no machine positions on deck have had to be moved, or the deck stiffness altered, to counteract vibration problems. Similarly, no machines have fallen into cargo tanks or failed due to fatigue damage caused by vibration. However, machine vibration could pose serious problems on a ship if not properly investigated before the COW system is installed. This is why Administrations require the vibration characteristics of the machines to be investigated before they are approved.

Measurements of static generation of electricity using crude oil have not been taken since the experiments carried out on *British Surveyor* in 1972. However, two detailed investigations using water were undertaken in 1975 (on a 68,000 tdw crude oil ship) and in 1977 (on a 225,000 tdw VLCC). An assessment was made of the electrostatic ignition hazards during tank washing using sea water as the washing medium through portable and fixed tank washing machines. The results can be summarised as follows:

(1) when using portable tank washing machines moderate space potentials of less than 4 kV were generated;
(2) a small number of sparks were observed when starting and stopping the water-flow through the portable machines, but none whilst they were in operation;
(3) when using fixed tank washing machines comparatively high space potentials of up to and about 30 kV were generated;
(4) sparks occurred when the fixed machines were started and stopped and occasionally during the washing programme, particularly when washing the top part of the tank (i.e., machines' arc 100° to 140°);
(5) in wing tanks, sparks occurred during the bottom washing (0° to 40°), coinciding with the times that the machine jets were able to reach the tank bottom unobstructed.

In addition to the measurement of space potentials, microphones were located in the tanks so that sound recordings could be made. These were connected to an automatic camera and flash system so that, whenever the static-generated sound reached a certain level, photographs were automatically taken. The static noise recorded during washing was similar to that heard on radios during electric storms. A large number of flash photographs were taken after being triggered automatically.

The two investigations concluded that, when tank washing with portable machines, electrostatic ignition hazards are unlikely, but precautions should, nevertheless, be taken. When using fixed machines, proper control of the atmosphere is absolutely essential as electrostatic ignition hazards do exist and occur quite frequently during the washing programme. Using dry crude oil will, of course, reduce the risk but it will not remove it completely.

The sum of £1M refers to the backfitting of COW and IG systems. In 1978, BP carried out an examination of ten VLCCs of differing tank construction, to determine their probable COW and IG requirements. It was estimated that these ships would require between 72 and 103 fixed tank washing machines (dependent on construction), the cost of purchasing and fitting these would average £376,000/ship (price ranging from £316,000 to £436,000), including fitting of the special stripping line, hand-dipping positions and other COW ancillary equipments.

At the same time, the cost of retrofitting an IG system was estimated as:

Equipment and machinery	£85,000 to £90,000
Electrical equipment	£13,000 to £17,500
Pipework, etc.	£150,000 to £175,000
Deck house	£40,000 to £80,000
Purge pipes	£22,000 to £30,000
Installation costs	£80,000 to £95,000
Total cost:	£390,000 to £487,500

ie, an average of £488,750

Therefore, in 1979, the costs of retrofitting COW and IG on a VLCC were:

	Minimum cost	Maximum cost	Average cost
COW	£316,000	£436,000	£376,000
IG	£390,000	£487,000	£438,000
Totals	£706,000	£923,000	£814,000

After allowing for inflation, the sum of £1M is soon reached.

It is agreed that the stripping in *British Reliance* was very good, if not exceptional. The ship had carried Kuwait and Iranian heavy crudes in the tanks prior to the ballasting operation. The stripping on *British Pride* was average; it had carried Forties crude prior to ballasting. On other ships, the surface samples have been as follows:

SHIP	VOLUME	TANK VOLUME	OIL/TANK RATIO	CRUDE TYPE
British Patience	45.7	196,112.0	.00023	Forcades
British Pioneer	61.4	89,595.8	.00069	Forties
British Norness	71.8	194,054.0	.00037	Forcades & Bonny
British Respect	298.1	183,118.3	.00130	Forcades
British Reliance	13.1	207,031.0	.00006	Kuwait & Iranian
British Pride	42.9	156,837.0	.00027	Forties
Total	533.0	1,026,748.1		
Average	88.8	171,124.7	.00052	

This shows that, with the exception of *British Respect*, other BP ships have been able to meet the requirements of the Revised Specifications.

It is not normal for the crew to be able to detect sheen on the water surface at night. For this reason, BP has instructed its ships to discharge ballast during daylight hours only, whenever operationally practicable. A further requirement is that all ballast discharges (i.e., departure and arrival ballasts plus slop tank decantings) are to be monitored by the oil/water monitor when this is fitted.

The shipyard design and positioning of the suctions in tanks have always been subject to scrutiny by the Company Naval Architects Division. This means that any known problem areas are allowed for during the design stage and BP has not found it necessary to modify the in-tank stripping systems in any ships.

Regarding the stripping head, there is no evidence to suggest that one type is better than another but this does depend on the "pass area" ratio i.e., the ratio of the area calculated by multiplying the length of the periphery of the suction head by its height above the tank bottom to the cross-sectional area of the stripping line. Or, by the formula:

$$\frac{a}{b} = \frac{4Dh}{d^2}$$

where $\frac{a}{b}$ = ratio
D = diameter of the suction head
d = diameter of the stripping line
h = height of suction head above the tank bottom

The policy in BP is to favour a ratio of 2:1 in preference to the ratio of 1.5:1 that is often used.

Experience has shown that there is very little erosion of the steel plating under stripping suctions. However, bottom pitting and corrosion can, and does, occur under the suctions which are located at the lowest point in the tank and, cannot be stripped completely dry. As an alternative to increasing the thickness of the steel plating, it can be coated locally with paint beneath the suction heads.

Pressure increases will occur within a tank space during COW due to gas evolution. The actual amount will depend on the type of crude involved. Gassy crudes, such as Qatar, will evolve approximately 50 per cent more than other crudes, such as Basra, Kuwait and Iranian. Experiments indicate that the gas evolution rate at a given background vapour concentration can be calculated from the formula:

$$2^{R/K} = \frac{10\times TVP}{C}$$

where:
R = gas evolution rate in $m^3\ min^{-1}\ machine^{-1}$
K = a constant and equals 5 for Kuwait (or similar) and 12.5 for Qatar,
TVP = the true vapour pressure of the crude oil expressed in bars at the temperature of the cargo,
C = the background hydrocarbon vapour concentration as percentage by volume.

This formula enables a predicted gas evolution rate to be calculated and from this an estimate of the pressure variation in a tank during COW.

A typical graph of predicted and actual readings is shown in Fig D1. These observations were taken on *British Scientist* during the crude oil washing of a starboard wing tank using Kuwait crude through four VP-matic machines with 32mm nozzles. The actual and calculated quantities differed, due to additional hydrocarbons being drawn into the tank from another tank during simultaneous ballast and cargo discharge operations.

There have been no cases in BP where tank hatch joints have blown when the machines have been started up. Tanks are initially protected from pressure increases by simple deadweight gas relief valves fitted on each tank (these operate at 2.5 lbf/in^2) and by the inert gas deck oil-seal. The inert gas main is common to all tanks and there are no individual tank isolating valves fitted.

During normal cargo operations, the initial pressure increase is catered for by the discharge of crude: the gas evolved displaces the space that the cargo has vacated. Therefore, the tank space pressure can be controlled by carefully regulating the supply of the inert gas. Instances have occurred where the deck seal has been blown when crude oil washing at sea between multiple discharge ports. During these operations an extra careful watch must be kept on the tank pressure, particularly when machines are first started.

Generally speaking, the control valve in the inert gas system operates smoothly in BP ships. Alternatively, the pressure can be regulated by starting and stopping the fans as required but this practice would generally be during slow cargo discharges only.

The "COW and Discharge" plan illustrated is a basic bar chart type. This can be easily added to and the actual amount of information that it contains will depend on the tanker owners/operators requirements. The recent incident where a ship broke in half during discharge indicates that in some cases it is very necessary to record stress information on the chart at periodic intervals. However, it must be realised that if too much information is included on the chart, then ships' staff will tend not to fill it in nor use it correctly.

The complexities of cargo operations require that ships' staff properly pre-plan each event and experience has shown that the bar chart is the best method as it presents a complete picture of all the different operations involved. Within BP, ships' staff record other information such as: oil remaining/discharged; discharge rate; pump speeds and pressures; times of starting and stopping tank washing machine cycles; personnel on duty; bunkering operations; storing etc. Some of these are recorded in the cargo log book and some on blackboards in the Cargo Control Room.

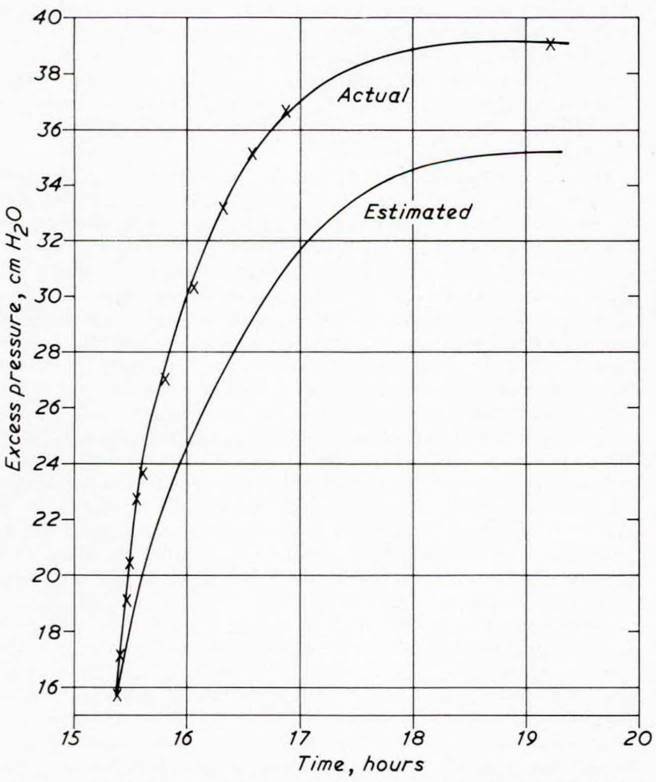


FIG D1 Variation of pressure in 2 starboard tank during COW.

Although purge pipes are not yet mandatorily required it has always been BP policy to fit them. It is felt that a tank cannot be properly and efficiently purged unless they are used. An oil tank is most at risk when the cargo has been discharged and the atmosphere contains a relatively heavy concentration of hydrocarbons. It is therefore necessary to purge the tank with inert gas so that the hydrocarbon level is below that which can support combustion (see Fig 14). If purge pipes are not used, then "layering" will probably occur, (see Fig D2 a and b).

A VLCC recently discharging a cargo was requested not to use the inert gas during discharge so that "the bottom of the tanks can be seen after discharge to check that they are dry". After sailing, an attempt was made to purge tanks using inert gas inlet pipes in after hatches of the tanks with high velocity vents at the fore end. The IG was supplied at six per cent 0_2 and after purging for 12 h the 0_2 readings in the first tank were six per cent down to 14 m ullage and 18.5 per cent at 14.2 m ullage: well within the flammable range. At this stage, an attempt was made to purge by introducing the inert gas in one tank and exiting through another via the tank cargo suction lines. This proved impossible due to the sludge build-up on the tank bottom.

It can be argued that the inert gas supply velocity of some systems is sufficient to penetrate to the bottom of the tank and that venting through a high velocity vent will be sufficient properly to inert the tank. This may be true but, in BP, the policy of using purge pipes remains.

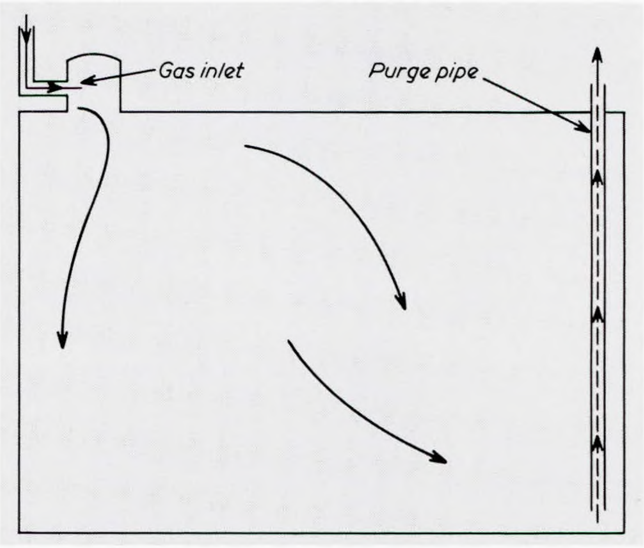


FIG D2a Tank with purge pipe.

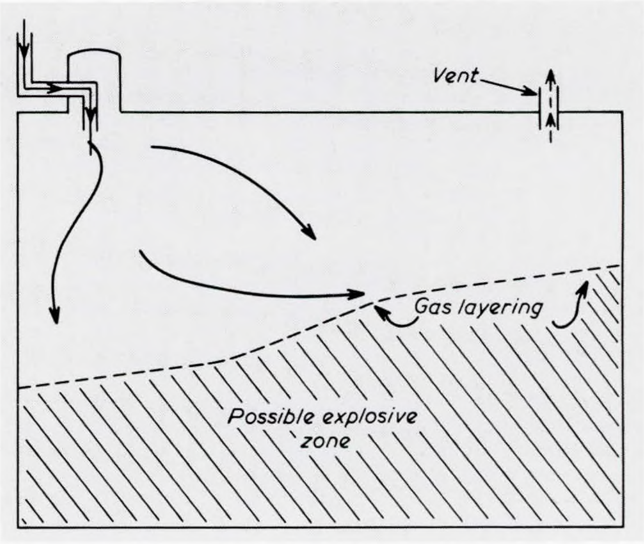


FIG D2b Tank without purge pipe.

The cargo systems of the BP VLCCs were designed so that approximately half the ballast loaded into empty cargo tanks would be during the last stages of the cargo discharge programme. In order to comply with the "no hydrocarbon emissions" requirement, it has only been necessary to adjust the discharge programme so that all ballast into cargo tanks is shipped before the cargo discharge is completed. In this way, the vapours displaced by the ballast are transferred via the inert gas pipeline system (which is common to all tanks) to the spaces vacated by the cargo being discharged. Careful monitoring and manual (or automatic) adjustment of the IG supply will ensure that an over or under pressure will not occur in the tank space.

Successful experiments have taken place where all the cargo has first been discharged and then the minimum quantity of ballast required for sailing loaded and the cargo tank space allowed to pressurise, ie, the vapours have been retained on board without venting to atmosphere. This system may be necessary on ships where it is not possible to discharge cargo and load ballast simultaneously, but it ought to be avoided.

The hand-dipping points are required firstly to check that COW has effectively removed the sludge deposits from the tank bottom and, secondly, to ensure that the tank has been properly drained. The minimum requirement for four hand-dipping positions on each tank will give an indication of the state of the tank bottom but, if a complete picture is to be formed, more are required. In BP, the simplest solution has been found to have each deck aperture plate drilled, threaded and fitted with a 25mm stainless steel stud. Even when the inert gas pressure is at its highest, it is still possible to take dips using a conventional dip rod.

Regarding personnel, one of the requirements of the IMCO Specifications is that there must be at least one person on deck at all times during washing to:

(1) keep a watch for leaks and malfunctioning equipment;
(2) to test the oxygen content of tank atmosphere before washing;
(3) to check the tank atmosphere pressure;
(4) to sound tank bottoms;
(5) to lift ullage floats;
(6) to set washing limits and change drive units.

This means that this person, who will be statutorily required on deck, will be available to take dips as and when required.

It is known that a number of firms are developing equipments to facilitate the sounding of tanks but so far these have tended to concentrate on the deck area. Several patented devices are available, for obtaining cargo samples, temperatures and soundings using portable "gas-tight" units that fit onto valve-controlled deck mountings. These are not strictly necessary. The problem of measuring dips at the tank bottom other than using a hand dip rod and line has yet to be solved.

The draining/stripping of oil from a tank can be monitored by keeping a careful watch on the ullage of the tank into which the drainings are being transferred. When the oil level stops moving, then the tank may be adjudged dry. However, this will not obviate the requirement to dip tanks to check sludge levels or, finally, to dip the after end of the tank to ensure it is properly drained.

Records of the inert gas pressure and oxygen levels have been kept since the systems were first fitted in BP in the late 1950s. Analysis of these have helped to identify problem areas and they have been well documented in other publications. Occasionally, particularly in the UK and near Continent, records have been examined by Administration Surveyors to ensure that the systems are being, and have been, operated correctly.

The COW Regulations do impose more work on National Administrations (or their duly authorised deputies), ships' staff and ship owners but this must be an acceptable fact of reducing sea pollution. It is doubtful if any changes can be made to make COW simpler. The safety of the operation is dependent on the person in charge and those carrying it out, who must be properly trained.

Reply to Mr Victory:

Although COW will reduce the amount of oil released to the sea, it does not necessarily mean that tankers will be operated more safely. However, as a ship carrying out COW must be fitted with an inert gas system it must, by inference, operate more safely. But as previously stated, the safe running of the ship will ultimately depend on the operating staff.

COW does not in itself replace any of the previous operational practices. It was offered as an alternative to segregated ballast requirements on existing tonnage. On new tonnage, it will be a statutory requirement together with the provision of protected segregated ballast. Experience has shown that when a proper COW operation has been carried out coupled with the efficient draining of pumps, associated lines and cargo tanks, the resultant slops after operating load on top will be between 200 and 300 tonnes. This reflects a substantial reduction in the amount that would normally be accumulated during a load on top exercise where COW had not been previously carried out.

The majority of oil companies have a policy of inspecting all ships prior to their being taken on either time or voyage charter. This has sometimes led to ships being refused a prospective charter or to owners carrying out necessary repairs to bring the ships up to an acceptable standard. Sometimes, it can be very difficult to persuade an owner that his ship does not meet the charterer's standard when it does meet the statutory requirements. A certain amount of control can be, and has been, exercised over charter ships by the industry keeping a check on the quantity of slops on the ships at the loading ports. Where the slop quantity is abnormally low the ship owner is asked to explain.

The proposed statutory requirement to fit segregated ballast tanks with protective location on new tonnage is to be applauded. However, it should not be considered that the fitting of segregated ballast tanks alone will stop all the pollution problems. The ships will still need to wash cargo tanks for the purposes of sediment control. If the ships is not capable of COW, it must be done by using water as washing medium, which in turn increases the pollution danger. Hence, the requirement on new tonnage to have COW as well as segregated ballast. The same arguments could also apply to existing tonnage.

The requirements for inert gas systems have been considerably tightened up by the revised Chapter 62 of SOLAS 1974. Also, COW Specifications set minimum requirements for the operation of inert gas system during washing. However, it is agreed that the ICS/OCIMF Tanker Safety Guide requires updating.

One of the requirements of the revised Chapter 62 is that the oxygen content and pressure of the inert gas supply must be continuously monitored and recorded. A further requirement is that periodical samples should also be taken using a portable monitor, as a double check on the inert gas supply. Sometimes sample lines from the inert gas supply to the fixed monitoring equipment have become blocked with carbon particles and, although the monitor indicated an oxygen content of below five per cent, a higher content was actually being supplied. Therefore, this double check is necessary. The requirement to check tanks one metre below deck level and at middle level of the ullage space is contained in Section 6.6 of the COW Specifications. This also contains the eight per cent maximum oxygen level requirement. It is not considered that eight per cent is a particularly high point as it allows a three per cent safety margin, ie, the minimum oxygen level to support combustion is approximately eleven per cent.

Hand dipping of tanks is required by Section 4.4.4. of the COW Specifications. These are required so that it can be definitely established that a tank has been completely stripped after the discharge of cargo. It is agreed that the statement "normal tanker practice prohibits ignition sources on the cargo deck" could be a dangerous generalisation. However, it is not a case of the tanker industry accepting that a positive pressure IG cannot be guaranteed if tank openings have to be used. These are statutory requirements contained within proposed IMCO legislation and, therefore, it will not be possible to carry out all operations without opening part of the tank at deck level some time during the cargo operation.

It is agreed that many owners will carry out COW retrofits whilst the ships are on ballast passages. Several such operations have already been carried out successfully and, as a precaution during such operations, the atmospheres of tanks in the vicinity must be carefully checked to ensure that no hazardous atmospheres exist. In some cases, shipowners have required a qualified chemist to sail with the ship to carry out the necessary tests before any burning or welding work has been carried out.

Entry into oil wash tanks must be strictly controlled. It has been a Company policy that, whenever Administration inspections are carried out by the DOT (in compliance with the COW Specifications), the inspection team is accompanied by one of the Fleet Safety Officers. As a result, it was possible to lay down the minimum requirements for entry into a tank. At a later date, the DOT published, through IMCO, guidance notes for Surveyors for entry into tanks. Basically, before a tank is entered after COW, but before water washing, the tank must be purged with inert gas to remove all hydrocarbon particles, vented with fresh air and hydrocarbon, and oxygen readings taken throughout the tank at all levels.

Efforts are being made by Industry to persuade shipowners to fit COW and IG systems on ships. With time charter ships, this takes the form of financial incentives and, in the case of voyage charter ships, refusing to take them on time charter if they are not so fitted. An international system of "black marks" might be necessary at some stage. It is not agreed that Industry has been "saddled" with load on top, crude oil washing and protected segregated ballast for new ships. With the exception, perhaps, of segregated ballast, load on top and crude oil washing are a benefit to Industry as well as to the marine environment.

In BP efforts are being made to ensure that COW operates safely and effectively. Since the inception of the Specifications in 1978, COW courses have been held and, to date, some 500 persons have been through the course, a large proportion of which were non-BP personnel.

Reply to Dr Cowley:

There cannot be too great an emphasis placed on the cost of retrofitting SBT to existing tankers. Fitting of SBT may have brought a lot of ships out of lay-up, but the total cost of several thousand million pounds would only have been permissible by passing the cost onto the consumer. It is felt that this cost, coupled with the suspicion that SBT was not the complete answer, is not really justifiable.

It should be noted that the IMCO maximum of eight per cent oxygen in the inert gas supply should be improved upon wherever possible. Experience indicates that on a VLCC, the oxygen level would be as little as 1.5 to 2 per cent during cargo discharge. Therefore, it is important for the Operations and Equipment Manual to stress that eight per cent is the maximum, not the normal, working oxygen content.

In addition to the purging, venting and testing of tanks mentioned previously, personnel who enter a tank that has been crude oil washed, but not water washed, should also carry with them breathing apparatus, torches and walkie-talkie radio sets. As an additional precaution they should also wear safety harnesses so that if they do get into trouble they can be easily connected to rescue lines.

It is interesting to note that several tankers have failed the surface departure ballast test. There is no doubt in the authors' minds that, wherever COW is carried out properly coupled with an efficient stripping, there is no reason why the 0.00085 requirement contained in Regulation 4.2.10 (ii) cannot be met.

The problem of monitoring the discharge of arrival ballast has yet to be resolved and is still under discussion with IMCO.

With regard to the certification of persons authorised to carry out COW on board a ship, it is not thought necessary for administrations to endorse the certificates. If a person has attended a recognised Administration COW course then the Administration must ensure that the course organisers issue a certificate of participation. The second certificate, is purely a record of personnel service on board a ship where COW has been carried out: it only confirms the officer's presence and does not reflect his competence.

The manual referred to by Dr Cowley, authorised by the DOT, is for a class of four ships of 270,000 dwt. These manuals have already been forwarded to the four ships involved, which have been instructed to operate accordingly. Although the SBT, COW and CBT requirements will not now enter into force until at least mid-1982, the COW regulations are being voluntarily implemented ahead of time.

Reply to Mr Gibbons:

There is a growing concensus of opinion that COW tends to remove the oil film that used to be left on tank surfaces after a cargo of oil had been carried. Therefore, when subsequent water washing takes place, the oil film coating is not there to protect the tank surfaces from water-induced corrosion. The advantage of reduced water washing may be counteracted to some extent by the increased corrosion possibility in tanks that are water washed.

In view of this, appropriate corrosion control measurements are necessary in tanks that require water washing regularly and/or carry ballast. Ballast tanks should be fitted with sacrificial anodes and the tank atmosphere oxygen level should be kept to the absolute minimum by proper use of the inert gas system.