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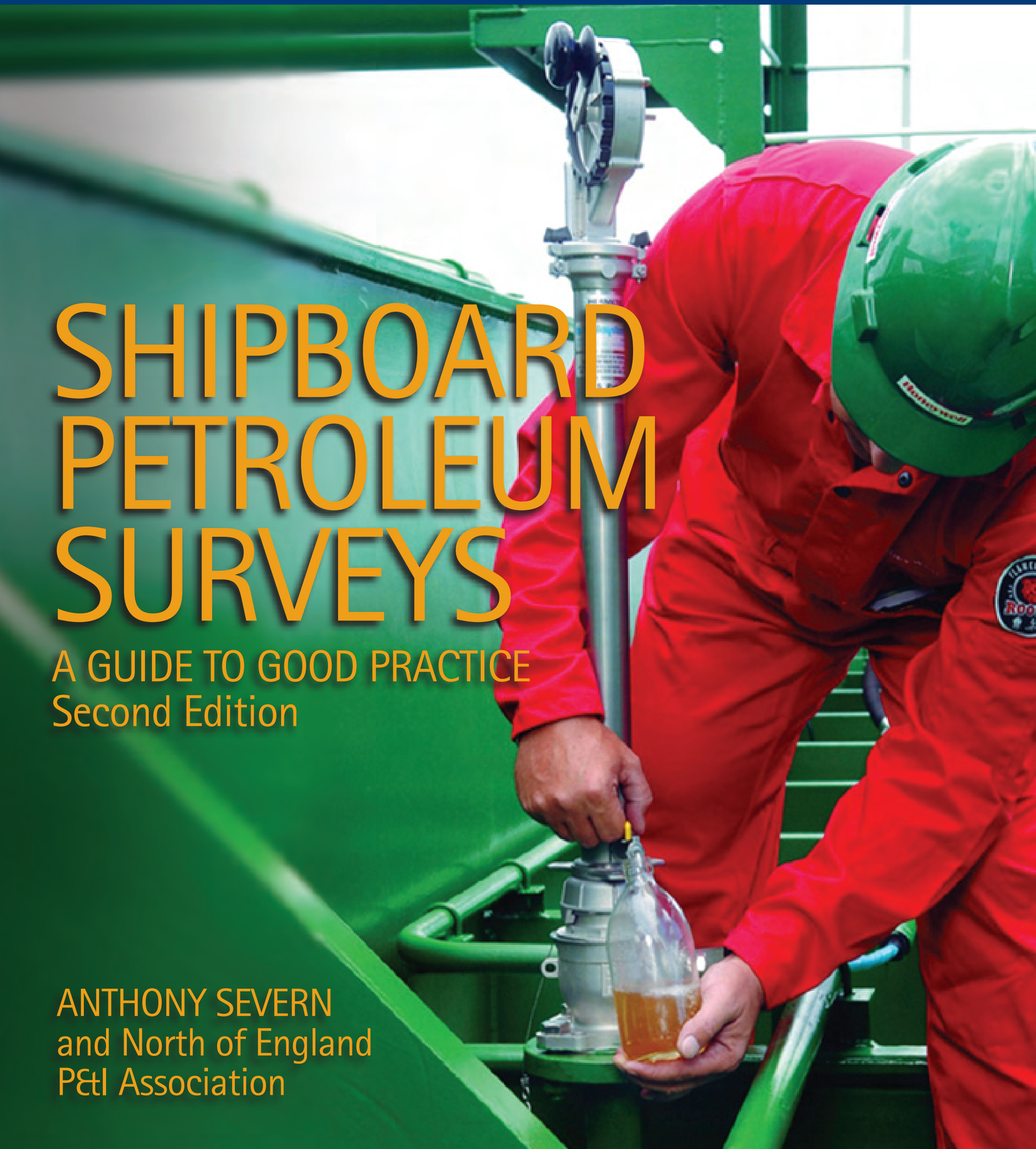

SHIPBOARD PETROLEUM SURVEYS

A GUIDE TO GOOD PRACTICE

Second Edition

ANTHONY SEVERN
and North of England
P&I Association

NORTH OF ENGLAND P&I ASSOCIATION

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Chapter 1

INTRODUCTION

PURPOSE

This guide explains how good shipboard survey practice can significantly reduce the risk of shortage or contamination claims arising from loading or discharging crude oil and petroleum products. The large volumes involved and the many potential errors which can arise during custody transfer mean that close supervision is vital to avoid costly and time-consuming disputes. The guide is intended primarily for ship's officers but will also be of value to cargo surveyors and others involved in monitoring oil cargo operations. A range of quantitative and qualitative monitoring and recording techniques is recommended which should ensure that potential loss or contamination problems become apparent at an early stage and can be remedied cost-effectively. Should problems remain undetected and claims subsequently arise, the monitoring will at least ensure that relevant shipboard factors can be identified, assessed and – when unfounded – used to exonerate the ship. The guide is intended to complement standard industry guidelines and procedures, not replace them.

Recommended references are provided in Appendix I and a glossary of the industry terms used in the publication is provided in Appendix V.

MASTER'S OBLIGATIONS

Tanker owners, like all ocean carriers, are bound by certain legal obligations with regard to the cargoes they carry. These are usually in line with the terms of the Hague or Hague Visby Rules as enacted in the relevant jurisdiction. In the context of this guide, two very important aspects are set out in article III, rules 3 and 4, parts of which are reproduced below.

Hague / Hague Visby Rules, article 3, rule 3

After receiving the goods into his charge, the carrier or the master or agent of the carrier shall, on demand of the shipper, issue to the shipper a bill of lading showing among other things:

(a) The leading marks necessary for identification of the goods as the same are furnished in writing by the shipper before the loading of such goods starts, provided such marks are stamped or otherwise shown clearly upon the goods if uncovered, or on the cases or coverings in which such goods are contained, in such a manner as should ordinarily remain legible until the end of the voyage.

(b) Either the number of packages or pieces, or the quantity, or weight, as the case may be, as furnished in writing by the shipper.

(c) The apparent order and condition of the goods.

Provided that no carrier, master or agent of the carrier shall be bound to state or show in the bill of lading any marks, number, quantity, or weight which he has reasonable ground for suspecting not accurately to represent the goods actually received, or which he has no reasonable means of checking.

Hague / Hague Visby Rules, article 3, rule 4

Such a bill of lading shall be prima facie evidence of the receipt by the carrier of the goods as therein described in accordance with paragraph 3 (a), (b) and (c).

It is thus of vital importance that the tanker master establishes the quantity of cargo – and its apparent order and condition – as accurately as possible in order that the bill of lading can be properly completed.

THE NEED FOR AWARENESS

Bulk liquid cargoes account for 42% of seaborne trade and are typically carried in tankers and oil/bulk/ore (OBO) ships which, in combination, account numerically for some 25% of the world's ocean fleet (some 11,500 tankers in total). The annual trade in bulk liquids is worth many millions of dollars and so it is important that the cargoes carried by this fleet are carefully monitored and accurately accounted.

The measurement of bulk liquid is prone to uncertain error and it is fair to say that a conscious effort has been made by the oil industry generally to improve the reliability of cargo surveys. The introduction of industry-approved guidelines has set standards by which, ideally, all cargo surveyors should operate. These standards enable the parties which trade in crude oil and its various derivatives to make commercial and operational decisions on the basis of consistent and reliable information.

In the first instance, it is normally the case that the custody transfer survey is the responsibility of an independent inspection company contracted by the cargo owner (possibly also the charterer and receiver) to certify the quality and the quantity of the cargo delivered and/or received. In this regard, the inspector should normally have reasonable access to both ship and shore facilities and may also be closely involved with the cargo shippers to ensure final quality control in the case of blended cargoes.

It should be noted, however, that the inspection company is often a local office which depends on the local refinery or terminal for the bulk of its work. Notwithstanding the professionalism of the surveyors involved, there is inevitably the potential for an undeclared conflict of interest which may become apparent if something goes wrong. This in turn could give rise to an unfair criticism of a ship's performance or even a misdirected claim against it.

It is therefore essential that a ship's officers maintain a vigilant awareness of the inspector's quantity determination and quality control procedures, including monitoring operations on the shore side of the manifold.

INADEQUACY OF THE KEY MEETING

Obviously one of the difficulties confronting a ship in monitoring shore-side operations is the lack of access normally afforded to its crew. Information is usually only obtainable from the independent inspector, the loading master and even the jetty watchman.

In all cases, however, the loading/discharging plan should be discussed between all parties at the so-called 'key meeting', which is designed to reduce the risk of handling losses and product contamination and which ensures that delays are kept to a minimum.

Unfortunately the key meeting is often reduced to filling out a checklist, signed by both ship and shore representatives, addressing aspects relating to both cargo and general safety.

If checklists are completed uncritically and without regard to the specific circumstances, the crucial safeguards afforded by the key meeting are compromised and, in the worst case, rendered useless.

WHAT CAN GO WRONG

The terms of reference of the cargo survey will necessarily vary depending on whose behalf the survey is being conducted. For independent inspectors, the main purpose of a cargo survey is to provide a certified statement of the quantity and quality of oil loaded or discharged. In conducting such a survey, it may be necessary to advise on procedural aspects which may have a bearing on the quality of the loaded cargo.

Notwithstanding the closer scrutiny being applied by the independent inspectors, problems can and do occur and there remains a prevalent risk of serious claims arising against tankers for contamination and shortage of all petroleum cargoes.

Shortage claims

Not surprisingly, an oil shortage is a perceived loss by the purchaser/receiver of a consignment of oil. The benchmark against which the receiver assesses the amount of 'missing' oil is the bill of lading as issued at the port of loading. Depending on the contracts prevailing at the time of this perceived loss, the cargo receiver (or more probably its insurer) will claim damages. It is a feature of the trade that the central recipient of loss claims is normally the carrier of the cargo, namely the shipowner – supported in most instances by a P&I club.

In addition to the normal shore/shore loss (bill of lading less the outturn), a claim for short delivery might arise if a large amount of pumpable cargo is left remaining on board (ROB) after completion of discharge. Such claims are normally governed by the wording of specific cargo retention clauses in the voyage charterparty and do not take into account the magnitude of any shore/shore loss. In other words, it is possible to have a gain on outturn and a claim for retained cargo (uncommon but not unheard of).

Early identification of potential losses arising on board a ship is important in order that remedial action may be taken. Shipboard losses are limited to evaporation via the installed venting system, leakage to non-cargo spaces (or, less frequently, to sea), and excessive ROB (high pour-point cargoes, pumping deficiencies, ineffective crude oil washing). Unfortunately shipboard losses also include the deliberate retention of cargo for illicit purposes (see Figs 1 & 2).

It is important that a ship is able to defend itself against potential (unwarranted) allegations of cargo diversion. Adequate records should be maintained covering all aspects of shipboard operation, in particular loading and handling of bunker fuel.

Historically, it was considered acceptable if a receiver's shore tanks contained 99·5% of the bill of lading quantity. To a large extent, this trigger still applies and a claim for short delivery may not be successful for an outturn difference of less than 0·5%.

The Energy Institute has published outturn statistics which indicate the mean losses experienced by oil traders for various grades of crude oil. These statistics represent the only published data from which it is possible to assess an individual shipment. In global terms (covering in excess of 3000 voyages) the mean gross loss (that is gross standard volume

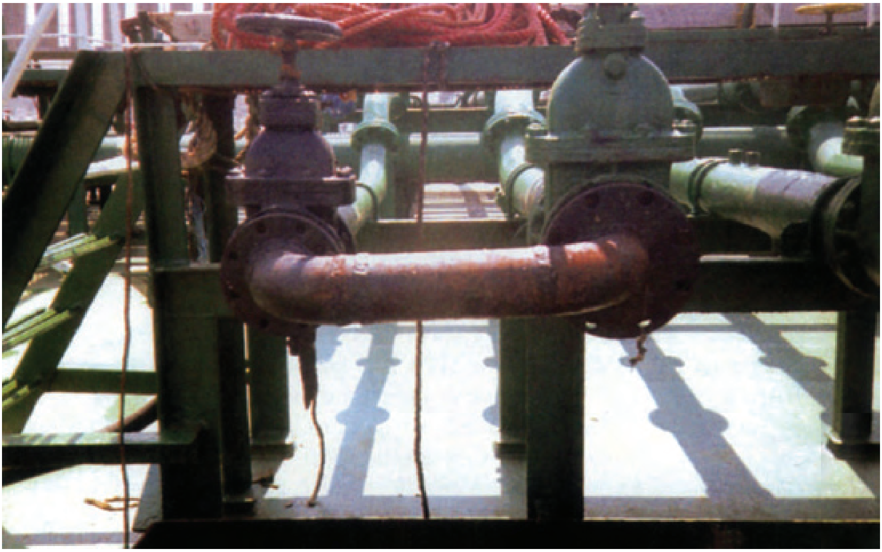


Fig. 1. Connection between cargo and bunker lines at the ship's manifold such as this will inevitably raise the suspicions of an attending surveyor, leading to further investigation and possible delay

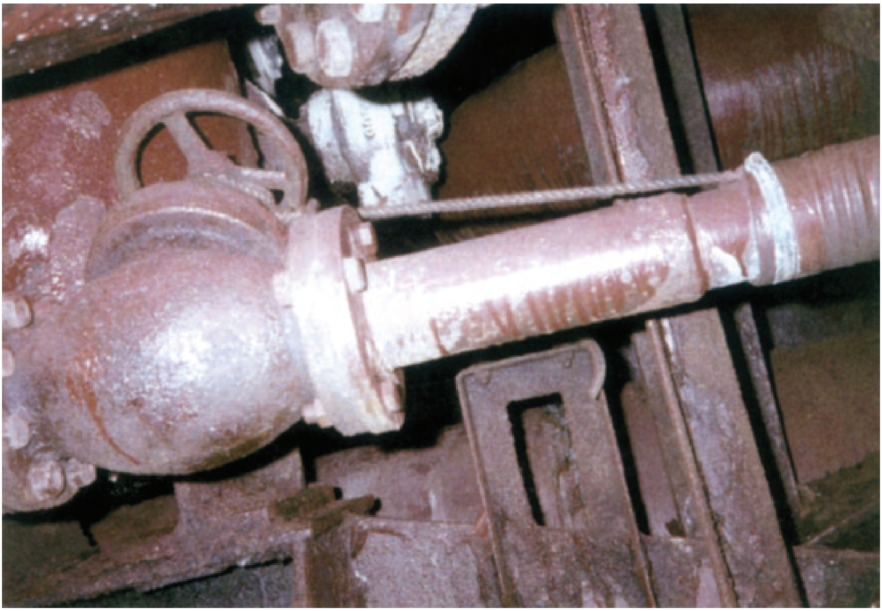


Fig. 2. A semi-permanent line observed beneath the bilge plates of a ship's pump room. This valve/hose arrangement was not shown on the official piping plan and was investigated as a cause of excessive losses arising during discharge

loss) is calculated as 0·14% (2006 figures – latest data). This means that, on average, the receivers' tanks contained 99·86% of the bill of lading quantity.

In practical terms, this means that the inevitable losses arising on tankers carrying crude oil – including evaporation and ROB – account for something in the region of 0·1%.

Unfortunately, similar statistics do not exist for petroleum products though, over the range from condensate (potential evaporation) to waxy fuel oil (potential ROB), there is no reason to consider that shipboard losses should be significantly different if carriage and discharge instructions are complied with.

Contamination claims

A contamination may be defined as the observed alteration of the quality of a particular product due to the ingress (and subsequent detection) of an alien substance. Contamination claims, however, may be the result of an observed alteration (depreciation) in quality arising from poor sampling and/or analysis at loading or at discharge. Such 'apparent' claims may also result from an inherent instability of the product being shipped due to poor processing or other deficiencies in product blending/preparation by the supply terminal.

It is the normal experience that contamination incidents occur on board tankers due to co-mingling with previous cargo residues, ballast or other grades stowed on board. Contaminations can also arise due to inadequate segregation of incompatible grades within shore facilities. If a breach in segregation exists between a ship's manifold and the shore reception tanks at the discharge port, then no amount of control procedures on board will detect such contamination at the time of the incident.

Defending claims arising from shore-side errors thus requires a methodical monitoring procedure to provide contemporaneous evidence showing that the problem was not due to shipboard factors.

Similarly, if shore-side co-mingling problems arise at the load port, then it is possible to monitor loading in such a way as to rebut potential claims for shipboard contamination. The same monitoring process will also assist in identifying 'apparent' contaminations, where the observed quality of the cargo has changed without any external influence or ingress (poor quality determination in the shore tank and/or inherent instability of the cargo).

Many cargoes are shipped at a quality which may only just comply with the purchaser's specification in which case the scope for error or misjudgement on tank cleanliness is negligible. Other cargoes, which are shipped well within the purchaser's specification, may accommodate a minor contamination without problem. As in all things, it is a question of degree. From the cargo seller's perspective, the comfort of a margin of safety has to be weighed against the commercial disincentive of 'quality giveaway'.

Chapter 2

MEASUREMENT CONTROL

TERMINOLOGY

There is still confusion in the tanker trade with regard to the terminology adopted in the measurement and calculation of bulk oil. The historical definitions of 'gross quantity' being quantity at observed temperature and 'net quantity' being standardised quantity at 15°C or 60°F are erroneous.

For the purposes of loss control, the preferred approach is to deal in units of volume: m^3 @ 15°C or US barrels @ 60°F. This approach reduces the scope for calculation errors caused by uncertainty in establishing true density. It is difficult to obtain an accurate density on board, particularly if stratification has formed in the bulk volume. Normal practice is to obtain an official density of the supplied product from the terminal, which will have sampled and analysed the designated cargo within the shore storage tanks or from an installed in-line sampler, and to use this figure for all subsequent shipboard measurements. The density obtained by the shipper of a cargo and by the eventual receiver will vary to some extent, normally showing higher at outturn due to some loss of light fractions during the loading, voyage and discharge. Such variation in density will have a direct effect on the measured weight but normally will have very little effect on the measured volume.

The principal terms used in the measurement of oil are as follows (Fig. 3).

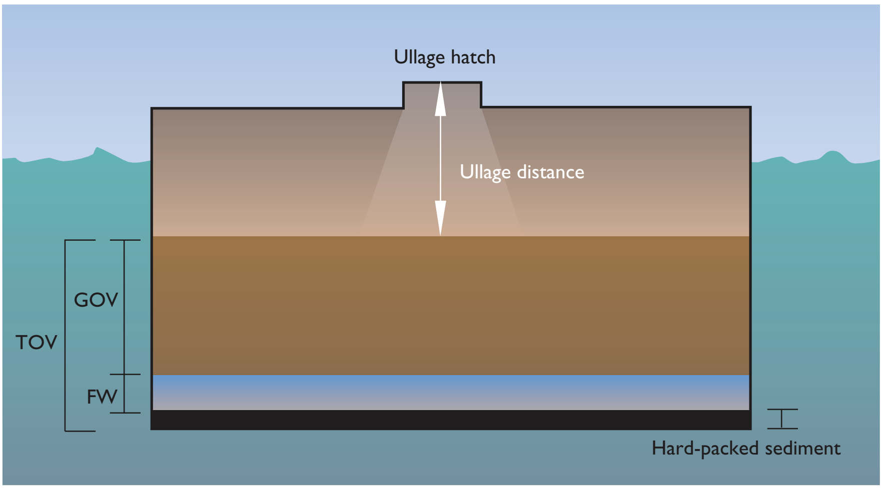


Fig. 3. Terminology for oil quantities

Principal terms used
Total observed volume (TOV) – total volume of material measured in the tank including cargo (oil), free water (FW), entrained sediment and water (S&W), sediment and scale as measured at ambient (observed) temperature and pressure.
Free water (FW) – water layer existing as a separate phase, normally detected by water paste or interface detector and usually settled at the bottom of the tank (depending on relative density of cargo).
Gross observed volume (GOV) – TOV less FW and bottom sediment, being the measured volume of oil and S&W at observed temperature and pressure. In practice, GOV is usually calculated with no deduction for bottom sediment, which is very difficult to quantify.
Gross standard volume (GSV) – measured volume of oil and S&W at standard conditions of 15°C and atmospheric pressure. In practice, the GSV is the GOV multiplied by the volume correction factor (VCF) obtained from the appropriate ASTM/IP *Petroleum Measurement Tables* (see next section). The GSV is the primary quantity measured and reported on tankers.
Sediment & water (S&W) – entrained material within the oil bulk, including solid particles and dispersed water. Sometimes known as base sediment and water (BS&W).
Net standard volume (NSV) – normally applicable to crude oil, NSV is the GSV minus S&W, being a measurement of the 'dry' oil quantity at standard conditions. For products, S&W is not normally deducted and is included (where appropriate) within the receiver's quality specifications. Whereas samples of crude and product are commonly drawn from ship's tanks after loading (and before discharge), the measured S&W is not advised in time for ship's officers to calculate the NSV on board.
Total calculated volume (TCV) – total amount of oil, FW and S&W reported at standard temperature. In practice, TCV is the GSV plus the measured FW.

For crude cargoes, claims for shortage are invariably presented in terms of net standard volume (NSV). Therefore, if the free and entrained water content is understated at load port, the receivers will apparently receive more water than was loaded and this may give rise to a corresponding 'apparent' shortage. It should be noted that the loss statistics published by the Energy Institute demonstrate that the difference between the mean GSV and NSV is globally of the order 0.04 %. This provides an indication of the apparent losses arising due to understatement of water at the point of loading. Some of this increase in water is due to the inevitable retention of tank wash water and/or heavy weather ballast in the cargo system prior to loading, though this is only considered to be a relatively minor factor.

For products, especially the lighter distillates, claims for short delivery are typically presented in terms of GSV.

CALCULATION OF CARGO QUANTITIES

Calculation of the amount of oil within a ship's cargo tanks is a straightforward procedure. Using a pre-determined temperature and the advised density, the volume correction factor (VCF) is readily determined from the American Society for Testing Materials (ASTM) and Institute of Petroleum (IP) *Petroleum Measurement Tables*. The GOV is multiplied by the VCF to obtain the required GSV. Depending on the units in use, the VCF will standardise the oil volume to 15°C (m^3) or 60°F (US barrels). For most applications, ASTM/IP tables 6, 24 and 54 are utilised to establish the VCF for a given density and temperature. Each of the tables is produced in three versions.

- **A version** – for generalised crude oils.
- **B version** – for generalised (petroleum) products.
- **C version** – for individual and special applications.

Depending on the reported volumetric units (m^3 or US barrels), the density units (American Petroleum Institute (API), specific gravity or density in kg/l at 15°C) and the standard temperature required (60°F or 15°C), the relevant ASTM/IP tables are summarised below.

- **Table 6 (A, B, C)** – used to standardise US barrels (or gallons) to 60°F when density is reported as an API gravity at 60°F and the temperature is in °F.
- **Table 24 (A, B, C)** – used to standardise US barrels (or gallons) to 60°F when density is reported as a relative density or specific gravity at 60/60°F and the temperature is in °F.
- **Table 54 (A, B, C)** – used to standardise m^3 (or litres) to 15°C when density is reported at 15°C and the temperature is in °C.

The current *Petroleum Measurement Tables* were revised and published in 1980, superseding the old tables which were originally developed in the 1940s. In practical terms, the main difference between the 'old' and 'new' tables is that the old tables will overstate the amount of oil being measured when the observed temperature is higher than the reference temperature – that is in most cases at crude export terminals in the Middle East and Asia regions. Typical overstatement for Middle Eastern crude oil is of the order 0·1 %. For heated cargoes such as fuel oil, however, the overstatement can be very significant (in excess of 0·2%). The effect of using the old tables is illustrated in Table 1.

Table 1. Effect of new versus old ASTM/IP Petroleum Measurement Tables on calculated crude oil quantities (API = 33·0)

Temperature: °F	Old table VCF	New table VCF	Difference: %
50	1·0044	1·0046	+0·02
60	1·0000	1·0000	0·00
70	0·9956	0·9954	-0·02
80	0·9913	0·9907	-0·06
90	0·9869	0·9861	-0·08
100	0·9826	0·9814	-0·12
110	0·9782	0·9768	-0·14
120	0·9739	0·9721	-0·18
130	0·9695	0·9674	-0·21

Notwithstanding the fact that the revised tables have been in existence since 1980, a large number of oil export terminals around the world are still using superseded tables in the calculation of bill of lading quantities (see Table 2). This gives rise to a systematic overstatement of the supply quantity and hence a potential loss against the outturn.

Once the ship's loaded quantity has been determined, comparison should be made with the shore figure to assess the existence of any discrepancy. This comparison is known as the vessel load ratio (VLR). The vessel discharge ratio (VDR) should also be determined at the discharge port if the ship is advised of the provisional outturn figure. Clearly it is necessary for the ship's officers to be aware of the ASTM/IP measurement tables used by the shore facility in order that the comparison between ship and shore figures is made on a consistent basis. As well as calculating GSV on board/ loaded/discharged, the ship should also compare ship and shore quantities using the TCV (GSV plus FW), often a more meaningful cross-check. In some instances, highly waxy crudes such as Libyan Bu-Attifel crude, are not deemed suitable for calculation utilising the normal *Petroleum Measurement Tables.* In such cases, there may be a significant difference between ship and shore figures if disparate calculation methods are adopted.

Table 2. Crude loading terminals still using old ASTM/IP Petroleum Measurement Tables (as at 2005)
Note: This list is only for guidance.

Table 6	
Country	**Port**
UAE	Fateh
	Jebel Dhanna
	Zirku Island
Indonesia	Ardjuna
	Blang Lancang
	Bunyu, Dumai
	Cinta (Java Sea)
	Kuala Beukah
	Kasim, Lalang
	Balongan
	Kakap, Senipah
	Udang
	Tanjung Santan
Kuwait	Mina Saud
Qatar	Umm Said
Saudi Arabia	Ras Al Khafji
	Juaymah
	Ras Tanura
	Yanbu

Table 24	
Country	**Port**
Oman	Mina Al Fahal
Qatar	Halul Island
Syria	Banias

Table 54	
Country	**Port**
Argentina	Caleta Olivia
	Comodoro Rivadavia
	Tierra del Fuego
Algeria	Arzew
	Bejaia
India	Cochin, Vizag
	Haldia
	Bombay
	Sikka, Madras
	Vadinar
Poland	Gdansk
Syria	Tartous
Tunisia	Ashtart
	La Skhirra

VESSEL EXPERIENCE FACTOR

The vessel experience factor (VEF) is basically the historical difference in ship and shore figures for a given ship over a given period, typically based on the previous 10 loadings. It is a factor which indicates the ship's calibration error. The VEF may vary over the life of a ship for a number of reasons.

The VEF is the principal method by which the chief officer is able to assess if the bill of lading quantity is reliable. It may also provide an indication of potential shortages on outturn. It is essential that the ship's loaded quantity is correctly determined from measurements made prior to and on completion of loading. It is also essential that the ship's figure and the bill of lading quantity are determined by consistent calculation procedures, with particular reference to the applied VCF.

In general terms, VEF is only applicable to a fully laden ship and cannot normally be applied to part loadings or to individual tanks (though some ships engaged in the parcel trade will maintain a tank-by-tank experience factor if one tank represents one certified consignment). The VEF thus normally applies to ships loading all tanks at one port. If more than one grade is loaded, then it is possible to assess only the reliability of the total bill of lading quantity against the total loaded without assessing the reliability of individual bills of lading.

Accurate determination of VEF is important. It is not acceptable to say, for example, that the ship's figures are normally higher by 'about 200 tonnes'. There are at least three approved methods for determining a VEF, as published by both API and IP. The most reliable results are obtained by using the statistically rigorous IP method 2. There is no reason why this approach cannot be adopted by ship's officers instead of the simpler 'field' method (IP method 1 or API method). Examples of both IP methods are shown in Appendix II as is the API VEF form as an example of a blank, inspector's document.

Whereas application of VEF provides an early indication of measurement discrepancies (either on ship or ashore) it is important to recognise that its value is fully dependant upon the validity of the base calculation data. It is possible continually to update the list of loadings, ensuring that the recorded ship (and, if possible, shore) figures are correctly calculated in the first instance and then accurately transcribed onto the VEF calculation sheet. All ships are fitted with personal computers which can be readily programmed to perform the updated calculation. Whilst all ships tend to keep a record of the load-port VEF (VEFL), it is necessarily more difficult to maintain a discharge-port VEF (VEFD) as the shore outturn is rarely advised to the ship before sailing.

The VEF can change over time due to a number of factors such as

- change of trade (different cargoes and load ports)
- accumulation of sediment and scale
- dry-docking preparation (de-scaling)
- structural alteration in the cargo spaces.

Clearly a calculated VEF prior to structural modification is no longer relevant and all voyages prior to modification must be disregarded.

By definition, each ship has a different VEF. In practice VEF varies from –1% to +1%, though the global average for tankers is reported to be in the region of –0·2% to +0·2% ship over shore.

The relevance of being aware of the VEF is illustrated in Table 3 which calculates the difference in ship and shore figures for a ship which is well calibrated, and for ships under calibrated and over calibrated by 1% respectively. In the example, the bill of lading quantity overstates the true quantity by 0·8%. In the case where the ship is well calibrated and under calibrated, this overstatement would be readily obvious and a protest may be considered appropriate (once the ship's figures were rechecked). In an over-calibrated ship, however, the ship/shore difference is calculated as 0·19% ship over shore, in line with the global 'norm' and not indicative of any potential short loading. If the officers are unaware of the VEF of the ship, such a short loading might well go undetected and un-protested. Thus a positive ship/shore difference is not necessarily an indication that the bill of lading figure is acceptable.

Table 3. Effect of VEF at load port

	Ship over-calibrated by 1%	Ship well calibrated	Ship under-calibrated by 1%
1. Bill of lading	100,000	100,000	100,000
2. Actual supply quantity: m^3	99,200	99,200	99,200
3. Bill of lading overstatement (potential apparent short delivery) (1-2): m^3	800 (0.08%)	800 (0·08%)	800(0·08%)
4. Vessel loaded figure: m^3	100,192	99,200	98,208
5. Ship/shore difference (4-1): m^3	+192 (+0·19%)	-800 (-0·80%)	-1,792 (-1·79%)
6. Anticipated response of master	NO PROTEST	PROTEST	PROTEST

Industry guidelines stipulate that an individual loading or discharge operation should result in the VLR and VDR being within 0·3% or two standard deviations of the calculated VEFL and VEFD respectively. A ship/shore difference which falls outside these criteria should act as a trigger to the independent inspector to recheck all measurements. Depending on the consistency of a particular ship's load ratios, however, there may be grounds to protest even if the VEF adjusted ship/shore difference is less than the stipulated 0·3%.

Ship to ship transfer

In cases where a ship is loading from another (mother) tanker, the resultant difference in the two sets of figures will incorporate the experience factors of both ships. In such cases, the VEF of the other ship should be obtained in order to allow a coarse comparison of transferred quantities. Such comparisons are fraught with difficulty and will be affected by various operational aspects including

- the number of tanks discharged by the mother tanker
- whether or not the mother tanker carried out any crude oil washing (COW)
- the nature of the cargo.

It is important that as much information as possible is obtained from the mother ship as this will have a bearing on both the quantity and quality of the loaded cargo.

The above considerations apply equally to discharge operations.

Calibration tables

The VEF essentially is a measure of calibration error within the ship's cargo tanks. Such error can be attributable, among other things, to poor calibration of the bottom-most part of the tank due to hull curvature and the presence of tank structural members and cargo lines. These factors can give rise to inaccurate determination of the on-board quantity (OBQ) and ROB which, in turn, will result in an inaccurate determination of the quantities nominally loaded and discharged. In order to minimise the scope for error, a clear understanding of the ship's calibration tables is required. Some ships require an adjustment to the obtained volume to compensate for the bottom cargo lines. The tables should be clearly marked accordingly, and the independent inspector so advised.

In particular, the advent of electronic gauging systems via installed vapour lock valves has resulted in adjustments being made to the reference height of each tank where such

Fig. 4. The reference height of the tank has been clearly marked on this hatch coaming to assist the surveyor during cargo gauging. However, the retro-fitted vapour control valve (centre) is higher than the ullage port (right) to which the tank reference height relates. Ullage readings taken via the valve must thus be corrected before being entered in the calibration tables

systems have been installed retrospectively (see Fig. 4). An adjustment must be made to the observed ullage to allow for this new reference point.

Calibration tables should again be clearly marked and, if possible, endorsed by the appropriate authority. Any change of ullage position will not only affect the reference height. The corrections applied for changes in trim and list will also be directly affected by any horizontal or axial movement of the ullage position and due account must be taken.

In order to facilitate a consistently obtained ship's volume, therefore, the calibration tables should clearly indicate from which point the ullage should be taken, specifying any adjustment for electronic or auto gauging in terms of reference height and trim/list correction.

CARGO MEASUREMENT

Static measurements

Static measurements are carried out either as a means of calculating a loaded or discharged quantity, or to assess any depletion or ingress of material from a particular tank either after transfer from adjacent tanks (intermediate measurement), or after a loaded voyage.

It is generally accepted that ship's measurements may vary by up to 0·2% at different gauging operations. After a lengthy sea passage, and depending on the volatility of the cargo, there will inevitably be some loss arising due to the evaporation of light ends. In order to minimise such losses, it is important that the pressure/vacuum valves are correctly set and that the hatch seals are tight (particularly on OBO and oil/ore (O/O) ships). If under inert gas, a suitable balance should be achieved to minimise the need for venting via the mast-riser as diurnal temperature effects take hold.

If consecutive sets of ship's figures differ by more than 0·2% between measurements, it is recommended that the tanks be re-gauged. All measurements must be recorded onto clearly designed ullage reports and filed for future reference.

In cases where loss of containment has occurred, and cargo is detected in non-cargo spaces, this should be brought to the attention of the attending inspector and measured in the normal manner using the relevant calibration tables. A decision to discharge such cargo or transfer it back into the cargo tanks will depend on the prevailing circumstances including

- safety (inerting the space to terminal requirements)
- pollution
- availability of pumps
- risk of contamination.

OBQ and ROB determination

Determination of OBQ and ROB quantities is arguably the most difficult of all shipboard measurements. This is mainly due to

- the uncertain nature and formation of bottom residues
- uncertainties relating to calibration of cargo tanks at bottom-most levels
- blocked drainage or lightening holes
- undetected (unmeasurable) residues remaining on the tank sides and internal framework, known as 'clingage' (Fig. 5).

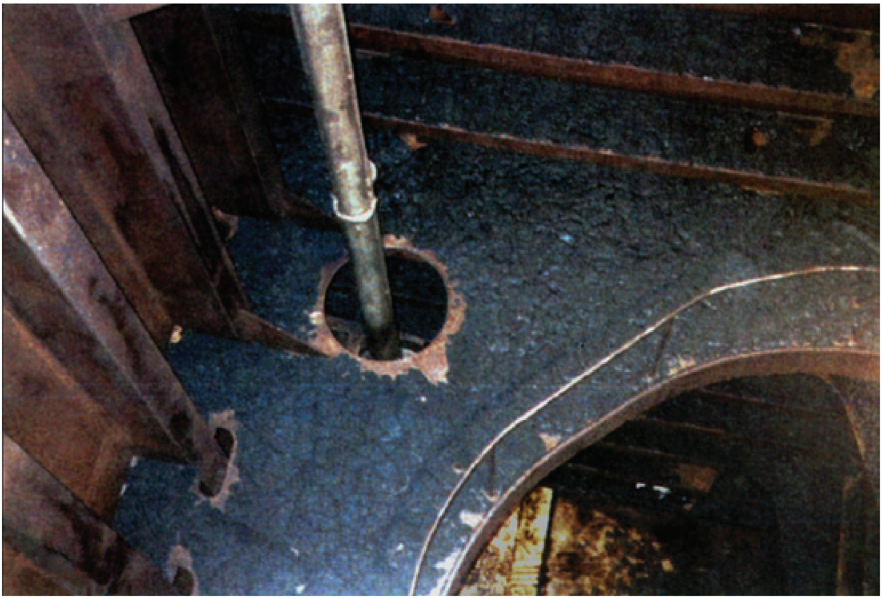


Fig. 5. Serious ROB problems caused by on-board blending of incompatible fuel oils. The remaining residue comprises precipitated asphaltenes which could not be removed by conventional water washing

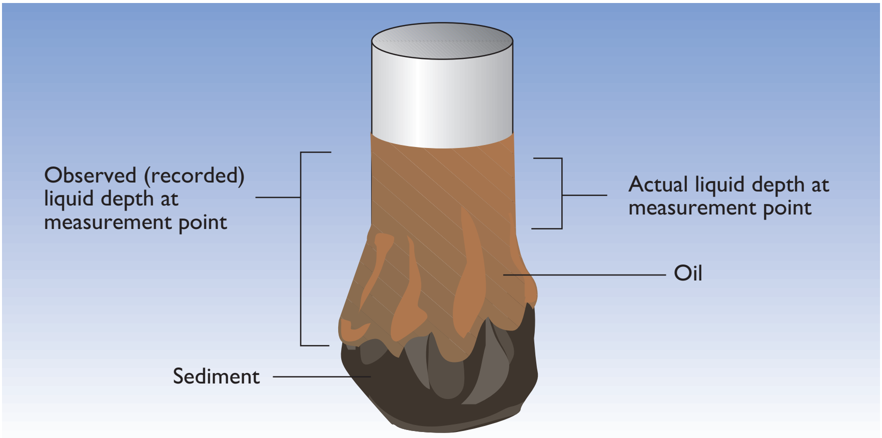


Fig. 6. Typical composition of ROB on a sounding rod

OBQ and ROB measurement problems are essentially limited to ships engaged in the carriage of crude oil and/or heavy products such as fuel oil and waxy gas oils. Apart from the potential for pumping problems (such as cavitation) with highly volatile cargoes, it is normally the case that ships carrying clean products will have virtually nil OBQ and, similarly, nil ROB. In cases where residues do exist, it is important to assess whether such residues are compatible with the next cargo to be loaded into the relevant tank (see section on quality control).

From the ship's point of view, it is undesirable for the OBQ to be understated as this will give rise to a corresponding overstatement of the ship's loaded figure. Similarly, it is undesirable for the ROB to be overstated as this clearly represents a shipboard loss for which a claim may ultimately be forthcoming.

One of the biggest problems in quantifying the amount of residue remaining in the bottom of the cargo tank is the partitioning of this residue into liquid and non-liquid components, the former influenced by changes in trim and list. A typical composition on a sounding rod or bob comprises a mixture of liquid and sediment. It is often the case that the liquid component is overstated due to the fact that the liquid has run down over the sediment (see Fig. 6).

This is not the only problem. In cases where inert gas pressure is still positive, the liquid can be forced upwards along the sounding probe/gauging bob also giving rise to an overstatement of the liquid component.

Crude shipments are frequently governed by cargo retention clauses in the voyage charterparties which can allow the deduction, from freight, of the value of the liquid cargo remaining on board. It is thus essential that this component is not needlessly overstated.

If the attending inspector has deemed that the residue is wholly or partially liquid, this must be quantified using the appropriate approved method. Chapter 17.4 of the API *Manual of Petroleum Measurement Standards* (MPMS) sets out the various methods adopted by the industry.

In practical terms, once the existence of a liquid residue in the cargo tanks has been determined, allowance must be made for trim and list. Depending on the amount of residue remaining, it may be appropriate to utilise either the established wedge formula or the ship's trim-corrected calibration tables. An example of a wedge formula calculation is given in Appendix III. If the liquid residue reaches the forward bulkhead of a cargo tank, then the wedge formula cannot be utilised and a trim correction must be applied. As necessary, large amounts of liquid residue should be subjected to temperature correction.

Whenever possible, dips should be taken at more than one point in each tank in order to establish the nature and formation of the bottom residue. Non liquid material may still form a wedge shape and, accordingly, be subject to correction. Whenever possible, and particularly in the event of disagreement, samples of the ROB should be taken from the cargo tanks, the pump suction (mud box) and also from the manifold if waxy residues are found. These samples may assist in evaluating the nature of the cargo actually reaching the pumps at the completion of discharge. Any samples taken should be acknowledged and/or annotated by a shore representative wherever possible, and a list of samples drawn handed to the inspector. The samples should be retained on board the ship or handed to a representative of the P&I club.

A full OBQ and ROB survey should include all void spaces and ballast spaces. The inspector should be invited to survey the ballast tanks, cofferdams, double bottoms, fore and aft peak, and so on. It is of considerable value to demonstrate that a full survey of the ship was carried out, particularly on completion of discharge, and that no inadvertent leakage or misrouting occurred. Where possible, the inspector should be able to determine that the ship's lines are empty and stripped of cargo, including the duct keels on OBO and O/O ships. As necessary, the line content should be drained into a suitable tank and quantified.

The survey may also include the bunker spaces (depending on the cargo involved) and, if possible, the sea valves will normally be sealed or the seals checked at discharge port.

An accurate record should be kept of the amount of slops on board and the associated tank washing and recovery procedures. Once any decanting has been carried out, and prior to any slop disposal or load-on-top (LOT) procedure, a sample should be drawn from the oil layer for retention purposes. It is important that the quantity of recovered oil being sampled is also recorded. Whereas this ideally should be done on every occasion, it is recognised that this might not be practical and instead such sampling should only be carried out if the previous ROB was excessive and/or the amount of recovered oil greatly exceeds the previous ROB. Any samples drawn should be acknowledged or verified by an independent inspector if possible.

It is normally possible to place an upper limit on the ship's liability towards a claimed shortage if the above procedures are observed.

Determination of post-loading, pre-discharge and intermediate measurements

It is very common for basic errors to be made in the gauging of cargo tanks. Such errors, while not normally having a direct effect on the outturn difference as based on shore figures, do give rise to complications in the subsequent reconciliation of cargo quantities whereby the source of any loss can be identified. In certain instances, the bill of lading quantity might be based directly on the ship's nominal loaded figure in which case any errors in shipboard measurement will have a direct effect on the outturn difference. In such cases, a coarse adjustment can be made by applying the VEF although a prerequisite is an accurate set of ullages and product temperatures.

The presence of a number of surveyors does not minimise the risk of errors occurring as it is quite likely that one surveyor will read the tape while the remainder will nod their heads as he or she reads out the figures. The ship's officers should ensure that the figure recorded by the independent inspector is accurate and should not depend on the inspector's own reading. The ship's representatives should have a reasonable idea of what the ullage in any tank is prior to leaving the control room and any significant discrepancy should become readily apparent. Ullaging should only be carried out once cargo transfer is complete. Internal transfer of cargo should not be undertaken until all tanks are ullaged.

Due allowance must be made for trim and list, with observed draft readings taken whenever possible.

If FW is detected at the bottom of the cargo tanks, this must also be corrected for the effects of trim and list. If significant quantities of water are detected, samples should be drawn and retained for future analysis.

The temperature of the cargo should be obtained: normally the average of three readings per tank – top, middle and bottom. The temperature in each tank should be recorded as an average temperature across the ship is insufficient and may give rise to inaccurate calculation. The quantity being measured will be understated when adopting a temperature that is too high (for example, taken in the region of a heating coil). Similarly, the quantity will be overstated if the adopted temperature is too low. See Table 4.

Table 4. Impact of temperature errors

	Adopted	Typical lower limit	Typical upper limit
Average bulk temperature: °F	82	80	84
VCF (TCA) (API 41·9)	0.9887	0·9897	0·9876
GSV: bbls @ 60°F)	609,973	610,590	609,294
Difference: bbls @ 60°F	n.a.	+617	-679
% bill of lading	n.a.	+0·10%	-0·11%

When the ship is rolling or pitching during measurement, it is important that repeated measurements are taken to confirm the reliability of the reported ullage (see Fig. 7).

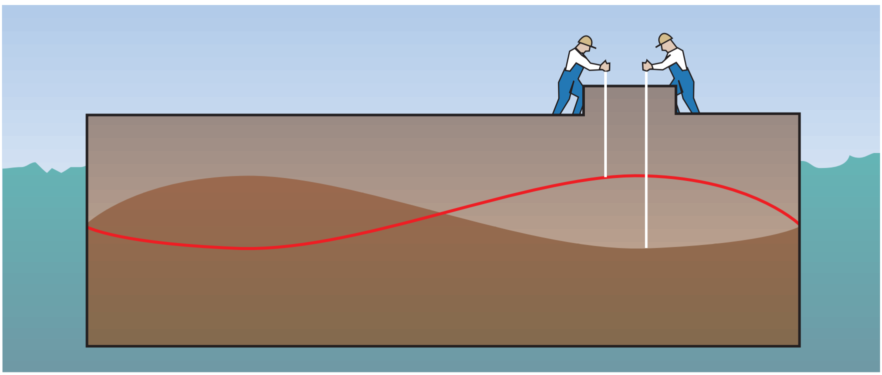


Fig. 7. Ullage variation due to oil moving in tank

As many as five measurements may be required, with the middle three readings being averaged for the official ullage.

Cargo rate book

Shipboard measurements are normally undertaken on a routine basis at load port and at discharge port. The normal measurements are

- before loading (OBQ)
- after loading
- before discharge
- after discharge (ROB).

Additional shipboard measurements should be carried out at intermediate load and discharge ports and also during simultaneous ballast and cargo transfer. Accurate measurements are necessarily carried out during static periods when the tanks are shut and no transfer is taking place.

However, from a loss investigation stance, the most important measurements are those taken during the loading, discharging and ballasting operations. These measurements should be taken hourly and recorded in the ship's rate book as well as on a blackboard in the cargo control room to give an instant summary of the ship's operational status to all personnel engaged in the oil transfer operation (Fig. 8).

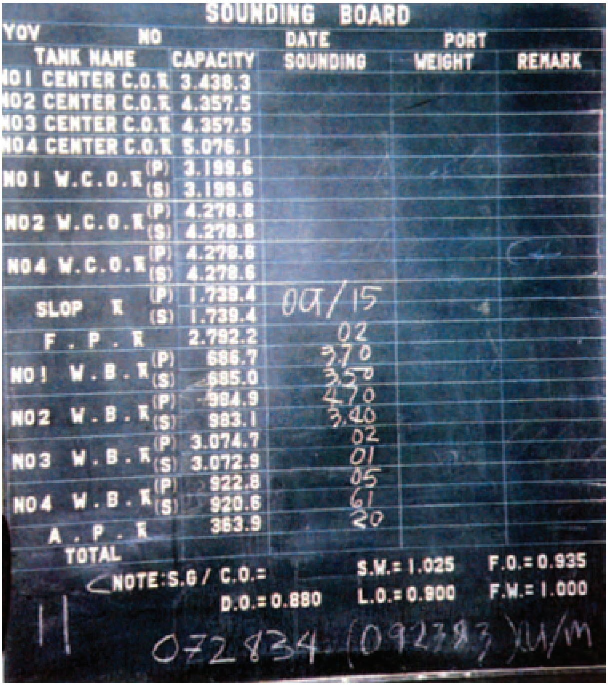


Fig. 8. Hourly ullage measurements should be shown on a blackboard in the ship's cargo control room during loading, discharging and ballasting

Whereas manual ullaging is generally more accurate than auto gauging with remote readouts (or even real-time data on the ship's computer), the latter enables tanks to be measured very quickly – a big advantage if the loading or discharging rate is high. Whichever approach is adopted, the same method should be kept throughout the whole of the transfer operation, with due allowance for any significant change in trim. It is reiterated that the information should be transferred from the automatic readout (or computer) to a manual record/board to allow a 'hands on' feel to be maintained in an age when technology and automation tend to keep the crew away from where the action is taking place.

The purpose of the hourly rate calculation is twofold. In the first instance, it provides an indication of when a particular tank will be at topping off or stripping levels and/or when cargo operations will be complete. Also, however, it provides an immediate indication of any possible cargo misrouting, either ashore or on board. This indication is only apparent when the shore figure is compared with the ship figure and the shore representative should be asked to provide the necessary corresponding information whenever possible.

Statement of facts

The hourly rate book is a particularly useful document when completed in conjunction with a detailed cargo log or statement of facts. This does not refer to the official statement of facts which sets out mooring details, pilot on board and so on, but instead is a detailed record of cargo handling operations. It should include the following.

Hourly rate book checklist
Stop and start times for pumps.
Change of tank (identifying the line systems used).
Change of line system.
Ballast details (clean, dirty and permanent).
Unusual events, ship or shore.
Reason for stoppages (particularly if shore-requested).

MEASURING EQUIPMENT

For the purpose of custody transfer, it is possible that shore measurements may be determined by automatic (permanently installed) gauging devices subject to approval being given by the supplier and purchaser of the cargo. On tankers, however, it remains normal for manual measurements to be taken, especially for OBQ/ROB and water dips, though progressively new tankers are being equipped with fully-automated closed-system measurement devices (radar systems).

The means of ullaging varies considerably depending on the port and cargo involved. For crude oils, it is the norm for electronic ullage equipment to be used (see Figs 9 & 10).

Whatever system is in force, ullages should be reported to at least the nearest 5 mm. In this regard, it is worth noting that the accuracy claimed by the manufacturers of electronic devices is typically of the order ±3 mm. Temperatures should be accurate to within 0·2°C or 0·5°F.

Whereas it is often stipulated that independent inspectors should carry their own equipment, it is the case that independent inspectors will frequently depend on the ship's own measuring equipment. This results from the incompatibility of the vapour lock valves associated with the different systems and it is therefore essential that the ship's equipment is well maintained and in good working order.

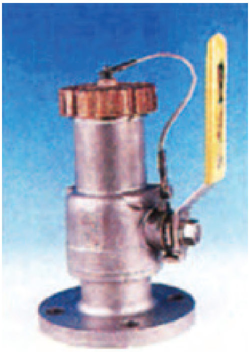
Ideally, electronic gauging equipment should be calibrated and certified on an annual basis at an approved agency of the manufacturer. Such calibration will be over the entire range of the working temperature as opposed to the normal, isolated check against a calibrated mercury and glass thermometer. Diligent maintenance and upkeep of the supplied measuring equipment should allow the carrier to demonstrate that proper care was exercised in the event of any claim.

DOCUMENTATION

Independent inspectors will normally provide full documentation relating to the shipboard inspections performed before and after cargo transfer operations. It is very important that all parties are agreed on all aspects of the transfer operation, including the timing of different operations and the quantities reported on the ullage forms. The ship should be aware of all samples drawn by the independent inspector and these should be listed accordingly.

Fig. 9. Typical portable gauging device for closed-loading systems. This device measures the ullage. temperature and oil/water interface

Fig. 10. (below). Typical vapour control valve for closed-loading measurement systems



Ullage reports should be prepared by the ship and signed by the inspector, as should a detailed statement of facts. All documentation must be filed for future reference and the load port data incorporated in to the VEF determination.

If any aspect of the transfer operation or the paperwork provided by the shore representatives (including independent inspectors) is not agreed by the ship, then a written statement should be made and acknowledged accordingly. Such protests may include the following.

Protest checklist
Quantity of cargo loaded or discharged.
Quality of cargo loaded or discharged (including the presence of water).
Delay due to shore reasons • stoppage • high back pressure • insufficient hoses.
Nature of OBQ and ROB • liquid • sediment • pumpable / un-pumpable • water.
Nature and quantity of slops.
Observed loss of containment ashore.

For discharge operations, it is essential that a comprehensive pumping and pressure log is maintained, as follows.

Discharge log checklist
Pumps in use.
Operational status.
Suction and discharge pressures.
Pressure at the manifold.
Whether or not used for COW or internal stripping.

Equally important is the COW log (where appropriate). The only means by which a ship can demonstrate that COW was performed in a reasonable manner is the completion of a detailed log. The effects of COW in terms of sludge removal are largely undetectable and the COW log remains the only evidence of good operation. The log should include the following.

Crude oil washing log checklist
Start and stop times for each tank.
Number of cycles.
Status of each tank (top wash, bottom wash and so on).
The type of machine and the pressure within the wash line (at pump, aft end of line and at a forward point).

All shipboard records should be acknowledged and signed by the attending inspector (or shore representative) whenever possible.

Tank cleaning records should be kept for all washing (COW and water washes). Such records should not necessarily be limited to the mandatory oil record book.

Early departure procedure

In some terminals, considerable pressure is placed on the ship, and on the attending independent inspector, to leave the berth quickly. In such cases, tank gauging and corresponding generation of documentation is performed in a hurried fashion and the onus is on the ship's officers to ensure that careless errors are not made.

By definition, the early departure procedure (EDP) normally requires that the ship departs prior to a bill of lading quantity being officially determined. For this reason, there is no benchmark against which the ship can check the loaded quantity and thus no immediate notification of any discrepancy is apparent. As soon as the bill of lading figure is received (normally by email or similar), the usual ship/shore comparison should be made with the ship's figures and the charterer advised of any significant difference – once ship's figures have been rechecked as necessary.

In some instances, it may be the case that the ship is asked to return to the load port for a re-check of the figures. Alternatively, independent surveyors may be placed on board at a suitable intermediate port. It is important that the implementation of EDP does not expose the ship to any unwarranted liability caused by an unexpected passage loss, in turn attributed to unreliable gauging at the load port.

HEATED CARGOES

An entire range of cargoes may need to be heated in accordance with the terms of a specific voyage charterparty. These may vary from waxy crude oils to fuel oils and encompass some refined products such as vacuum gas oil and lubricating oil. The amount of heat required will depend on the nature of the cargo.

An important consideration for the master of a ship is whether or not the ship is capable of maintaining the specified carriage and discharge temperature. If doubts exist, then these must be quickly relayed to the owner or operator in order to protect them from breach of charterparty and any subsequent liability towards damages for delayed delivery and shortage.

Most charterparties stipulate a maximum carriage temperature of 135°F (57ºC) although the ship should obtain confirmation from the charterer if any doubts exist. If the voyage instructions require the cargo to be heated to a higher temperature than that of the loaded cargo, sufficient ullage should be left to preclude the possibility of overflow.

Prior to carriage of heated cargoes, the heating system should be checked for any signs of leakage. This provides a double check. In the first instance, leaking coils will be inefficient and will have a detrimental effect on the ability to heat the cargo. Secondly, a leaking coil may result in an excess of FW within the cargo on arrival at the discharge port giving rise to a contamination claim.

A heating log should be maintained on a daily and tank-by-tank basis to demonstrate compliance with the heating instructions during the loaded voyage.

For detecting FW, particularly at load port, it is important that the water-indicating paste should be able to withstand the elevated temperatures and that all water present in the tanks is properly accounted for. Suitability for use will be stipulated by the manufacturer.

Another potential problem is the inherent difficulty in obtaining a valid water cut in the case of high viscosity and cargoes with a high pour point. In such cases, the bob should remain at the tank bottom for at least one minute.

Chapter 3

QUALITY CONTROL

GENERAL

Quality control measures serve two main purposes.

- Vigilant monitoring of the cargo quality should enable any problems to be detected at an early stage allowing the most cost-effective remedial action to be taken.
- Comprehensive and reliable control procedures are required if the ship is to demonstrate non-liability in incidents which occurred outboard of the manifold, such as an undetected or unreported pre-shipment problem resulting in the loading of an off-specification material.

In any shipment, contamination sources or mechanisms can occur either ashore or on board the ship. Shore-side contamination can happen either at the loading terminal or the discharge terminal, though the scope for problems is usually considerably higher at the load port.

Before considering possible contamination sources, it is worth briefly reviewing the various processes which are used in the production of petroleum products (see Fig. 11).

Crude oil comprises a complex mixture of compounds, primarily hydrocarbons. The processing of crude oil involves fractional distillation, by which the wide range of carbon number (C1 to C60+) is separated into streams of narrower carbon number ranges on the basis of their different boiling points. Such streams can be identified as

- LPG (C1 to C4)
- gasoline (C4 to C12)
- kerosene (C10 to C18)
- gas oil (diesel)
- heavier fuel oils.

Having partitioned the crude oil into various streams by atmospheric distillation, secondary processing and further blending is then carried out to produce a range of finished products as might be loaded onto tankers for export.

The individual products are isolated and stored separately in advance of transfer on to ships (or rail and road tankers). Each grade represents a potential contaminant of other products if inadvertent mixing occurs or if poor fractionation in the distillation unit results in a carry-over from one product stream to another.

Oil refineries invariably have the ready means of reprocessing cross-contaminated products.

It is sometimes the case that cargoes will be blended on board a ship from separate storage facilities ashore. In such cases, the final product quality should be the onus of the supplier, purchaser or charterer and no responsibility for poor homogeneity should be placed on the ship.

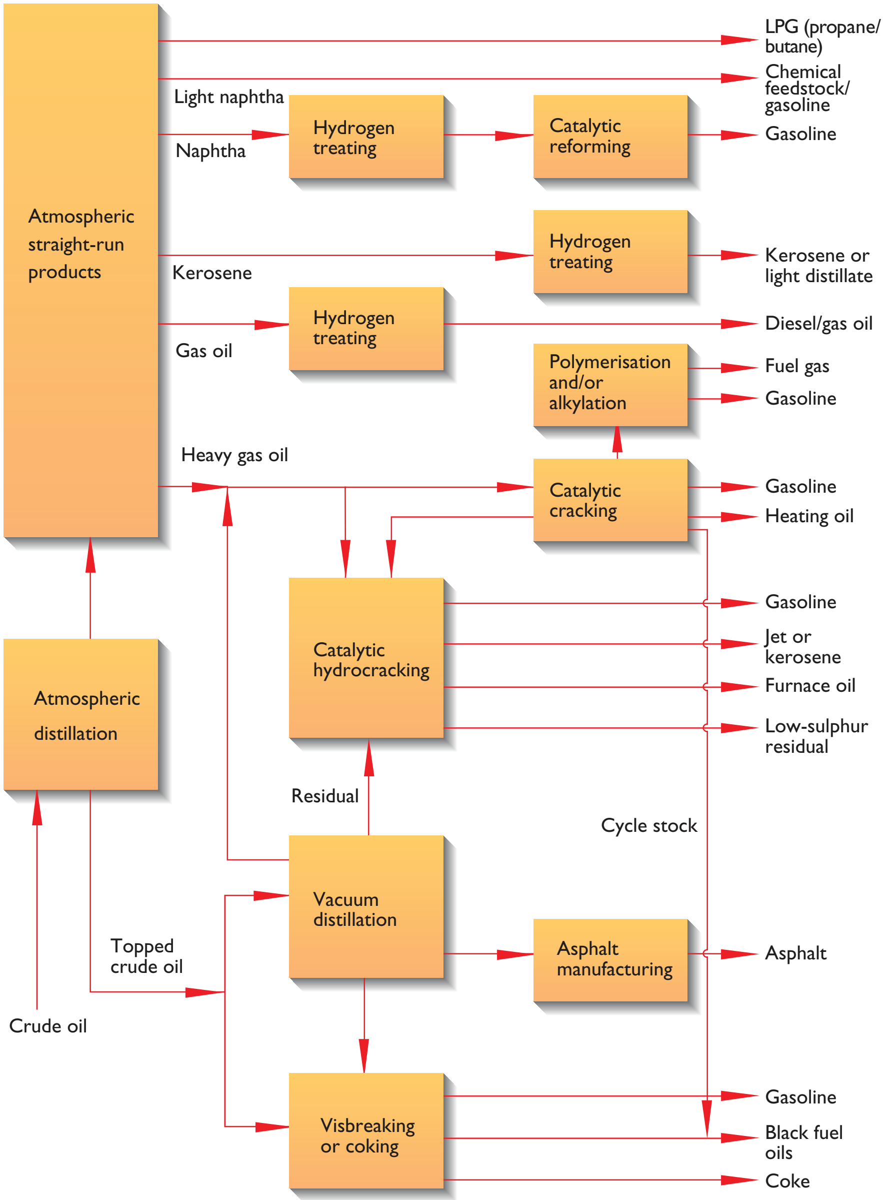


Fig. 11. Petroleum refinery processes

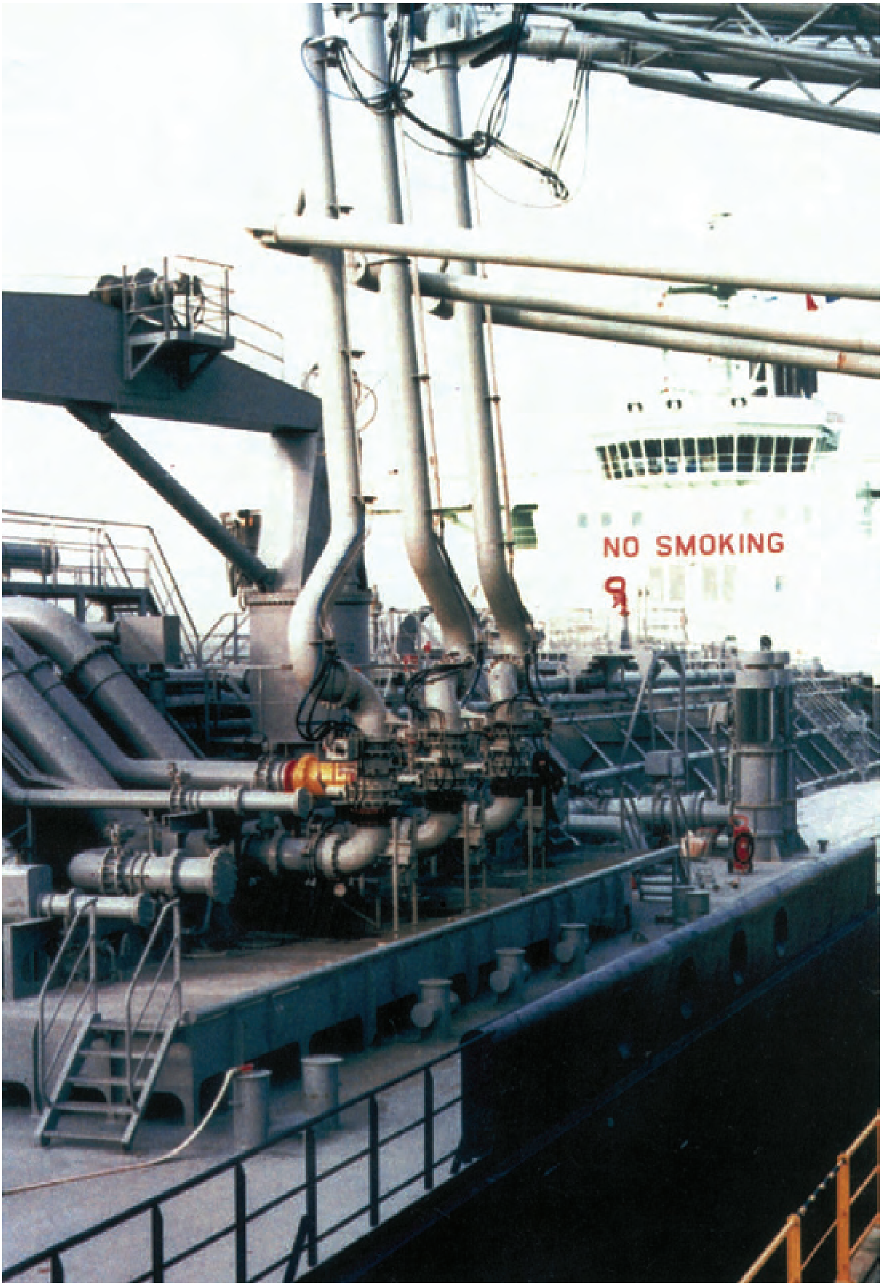


Fig. 12. Jetty headers and loading arms are a potential source of shore-side contamination

Possible shore-side contamination causes include

- cross-contamination between different products due to valve leakage (let-by) or mis-operation
- carry-over during processing operations
- contamination by residues of other products in a (supposedly) empty shore tank
- presence of alien product within the shore pipeline system, including jetty headers and loading arms/hoses in cases when non-dedicated systems are in use (Fig. 12)
- water from line/tank cleaning and line flushing operations, leaking heating coils and leaking tank roofs (rainwater).

Possible shipboard contamination causes include

- cross-contamination between different products due to valve leakage or mis-operation (including retained ballast)
- cross-contamination due to structural deficiency (such as cracks in bulkheads)
- presence of an alien product within a (supposedly) empty cargo tank (particularly adhering to bulkhead or contained within badly deteriorated coating blisters – see Fig. 13)
- presence of an alien product within the ship's cargo handling system (pumps, pipes, valves and so on)
- water from line/tank cleaning and flushing operations, adjacent ballast, leaking heating coils, poorly sealed hatches/ access plates
- cross-contamination via the installed inert gas system.

There are other aspects which may also result in problems arising, particularly when commercial pressures induce the rushed fixing of a ship which is unsuitable for a particular cargo, or the cargo grade is changed at the last minute. For example, a ship which previously

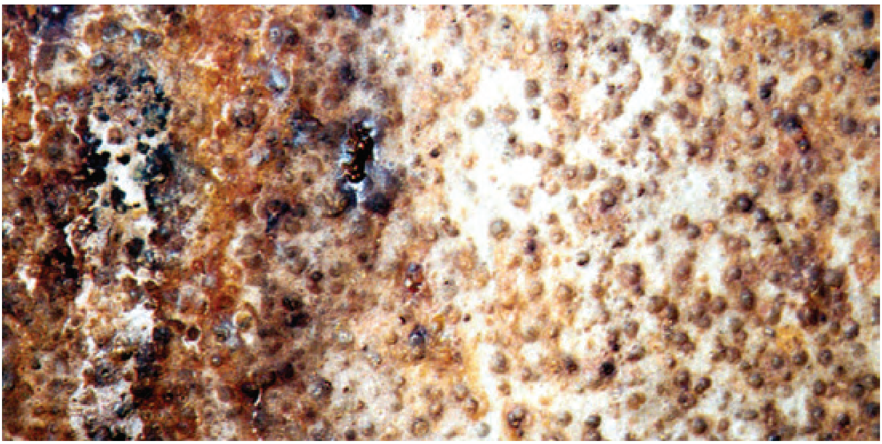


Fig. 13. Seepage of previous cargo from tank coating blister

was engaged in the carriage of dirty petroleum products may be fixed to carry a colour sensitive cargo. If insufficient preparation is carried out, or if the ship's tanks are in a poor condition (coating breakdown), then leaching problems might occur giving rise to a drop in colour and a consequent dispute with the cargo receivers.

PROTECTIVE MEASURES

For retrospective claims management, the procedure of sampling and sample retention is probably the most crucially important factor in the ultimate determination of liability and, as appropriate, rebuttal of spurious claims.

Prevention is the best cure and this adage applies throughout all operations. The key aspects to be considered prior to loading are

- tank cleanliness
- cargo pumps, lines and fittings
- adjacent cargo, slops and ballast
- key meeting.

Tank cleanliness

The tanks should be cleaned in accordance with industry guidelines or in compliance with the specific requirements of the charterer's written instructions. Care must be taken to load a cargo that is compatible with previous cargoes and any detergents used in the cleaning operation should be fully rinsed away.

In cases where the ship is fixed to load a clean product with a specified colour limit incorporated in the charterparty (typically 'un-darker than 2·5 NPA'), a buffer cargo (such as dirty condensate) should ideally be carried if the previous cargo was a dirty cargo (such as fuel oil and crude oil). Otherwise additional tank cleaning procedures may be required involving hot wash regimes, use of detergents and chemical cleaning agents, collection and removal of any sludge, scale, sediment and so on.

Controlled experiments adding small amounts of residual fuel oil to water-white kerosene demonstrate that only very small amounts of fuel oil are required to discolour the kerosene – thus contaminating the cargo (see Table 5).

Table 5. Colour drop in water-white kerosene due to adding residual fuel oil (RFO)

RFO content: ppm	Colour ASTM D1500	Approximate description
100	< 1·0	Lily white
200	1·0	
500	2·0	
1,000	3·0	Lemon pale
1,500	4·0	
2,200	5·0	
3,000	6·0	Light red
4,000	7·0	
5,000	8·0	
10,000	> 8·0	Black

In cases where the ship's tanks are coated, the suitability of the coating should be checked from the manufacturer's resistance lists, and the condition of the coating be assessed (Fig. 14). An example tank condition report is provided in Appendix IV.

Fig. 14. New coating completely destroyed by an incompatible, aggressive cargo. The coating resistance was not referred to in this instance

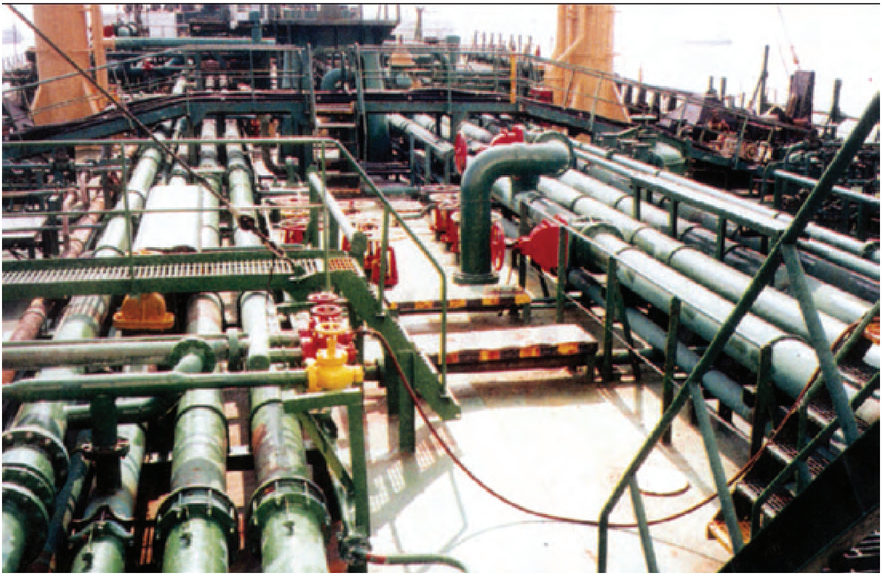


Fig. 15. The ship must ensure that all its cargo pumps, lines and fittings are free of potential contaminants

Cargo pumps, lines and fittings

Inspection of the ship's cargo handling system is part of the pre-loading survey for determining a ship's suitability to load a particular product (Fig. 15).

Independent inspectors are unable to check fully the cleanliness or suitability of the cargo system and it is important that the ship's crew are confident that the system is acceptable. Special care must be taken to ensure that any dead ends and branch lines are free of potential contaminants. If heating coils are to be used, these should be tested for leaks prior to loading. Such leaks may result in the ingress of fresh water to the loaded product, but might also mean that the coils themselves contain residues of previous cargoes. When more than one grade of cargo is to be loaded, or simultaneous loading and de-ballasting or discharging or ballasting operations are anticipated, a full valve pressure test should be carried out on all segregating valves – tanks, pump room and main deck/manifold.

Adjacent cargo, slops and ballast

It is essential that any other material on the ship is kept segregated from the cargo being loaded, unless pre-arranged on-board blending operations are being carried out. Segregation should extend to the cargo lines as well as the cargo tanks and, as necessary, blank flanges inserted where possible. In the case of crude cargoes, load-on-top operations should only be carried out on the explicit instructions of the charterer.

Key meeting

Prior to any transfer of cargo, the ship's officers should ensure that they are fully aware of the procedures to be adopted during the transfer operation, particularly when more than one grade is to be transferred.

A meeting should be held with representatives of the ship, the terminal and the independent surveyor of record to discuss all aspects of the intended transfer. In practical terms, from the ship's point of view, there is a limit to the amount of information which is required from ashore although the independent inspector will require a complete overview of the ship and shore. From the ship's point of view, the following items should be clarified before any cargo transfer operation takes place.

Key meeting checklist
Quantity and quality of the cargo to be transferred.
Order of loading by grade and by tank, segregation between grades, installation of blind flanges as appropriate.
Identity of nominated loading arm or hose and manifold.
Ship's previous cargo (by tank), if a low lead product is to be loaded, the previous five cargoes must be established and approved.
Operational history of the nominated cargo line or pump, nature of any residues contained therein.
Details of tank washing carried out, including line flushing.
Type and condition of coating, suitability for nominated cargo.
Proposed loading and discharge rate.
Status of inert gas (IG) system if appropriate, management of IG system for gauging and sampling tanks, suitability of IG for nominated cargo.

Segregation of venting system for multi-grade cargoes.
Quantity and quality of retained slops, segregation of slops or requirement to LOT, status of system utilised if slops to be discharged separately from the cargo (suitability for subsequent cargo transfer).
Need to ballast and de-ballast during cargo operations, segregation of cargo and ballast systems.
Identity of gauging points and corresponding tank calibration tables, trim and list tables to be available as necessary.
Ship to shore communication, exchange of hourly figures to be agreed if possible.
Quality control procedures to be employed including shoreline, manifold, first-foot sampling and slopping (discharge).

SAMPLING

Sampling is a vitally important factor in the monitoring of crude and product quality during transfer and transportation (Figs 16, 17 and 18). Acquisition and subsequent care and retention of representative samples is probably the most potent device available to ship's officers in the rebuttal of unfounded contamination claims. This applies to petroleum products and also to crude cargoes, where disputes concerning the water content of the cargo may lead to allegations of ingress during the voyage.

Because of the inability of the ship's officers to undertake analysis of samples, only the most obvious contamination problems will be apparent at the outset. Such problems will manifest themselves immediately as a change in colour or the presence of water or of a foreign particulate matter.

Whenever possible, all samples drawn by the ship's crew, or on behalf of the ship by an attending surveyor, should be clearly labelled with the following information.

Sample label checklist
Ship name.
Operational status • before discharge • after loading • before loading.
Product.
Sample source • tank number • manifold number • pump number.
Sample type • top • middle • bottom • dead-bottom • running • composite.

Fig. 16. (top) Multi-level sampling can

Fig. 17. (above) Bottle cage sampler for clean products

Fig. 18. (right) Gas-tight sampling device (no vapour release to atmosphere)

Identity of sampler • surveyor • crew member.
Date and time of sampling.
Location • port • berth number • anchorage.
Seal number.

The seal number would normally apply to those seals placed on a sample by an independent inspector. However, it is increasingly common for ships to be equipped with their own seals which are easily obtained and relatively inexpensive (Fig. 20).

Any samples drawn for shipboard purposes should be noted in a separate sampling log. A list of samples drawn and retained by the ship should be prepared and handed to the shore representatives or independent inspectors for acknowledgement and signature. It is important that the samples are drawn in compliance with industry practice as set out

Fig. 19. Samples should be sealed and clearly labelled

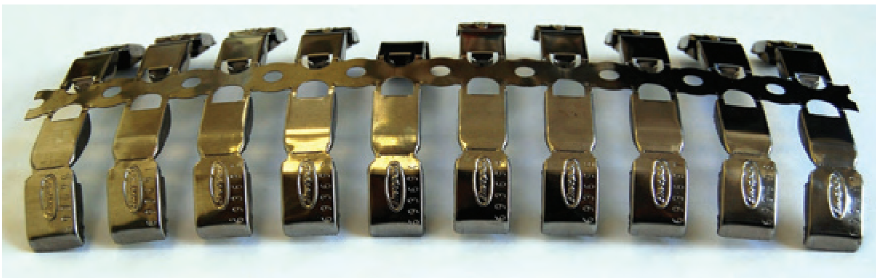


Fig. 20. Simple, individually numbered sample seals are readily obtainable

in publications such as those by ASTM, API, IP and the International Organization for Standardization (ISO). The most difficult aspect of sampling is obtaining a representative sample, particularly in the case of non-homogenous cargoes such as fuel oils which may be prone to stratification within the cargo tank.

In the case of petroleum products, it is the normal practice to test the cleanliness of ships' lines by taking 'first-foot' samples. Loading should be stopped as a sample is drawn from the nominated tank(s) and taken ashore for key test analysis. In cases where some doubt exists as to the quality of the first-foot sample, further samples should be taken for the ship's own reference purposes. It is obviously important to confirm the integrity of the line and tank system in use to ensure that any such quality doubt is not attributable to shipboard factors such as adjacent and different grade products.

In some instances, the inspector will draw first-foot samples while loading continues uninterrupted. These samples necessarily are subjected to only a very basic visual analysis, that is a lesser degree of quality control, and this practice should be discouraged if possible.

At start of loading, it is strongly recommended that samples are drawn at the ship's manifold so that such samples can be compared with the first-foot samples subsequently drawn from the cargo spaces. It is sometimes the case that shore facilities are designed with a common jetty header which causes co-mingling of various products at the loading arm or hose until the header is flushed though with the cargo being loaded.

Samples should be drawn from the manifold whenever some doubt exists as to the quality of the supplied or discharged product or after scheduled and unscheduled stoppages for shore reasons. In any event, manifold samples should be taken at the start of loading or discharging of all grades.

Whenever sampling from an installed sample point, it is very important that this has been flushed of any previous residues prior to start of cargo operations and before obtaining a reference sample.

In many cases, particularly in the case of high purity products (such as lubricating oil), the ship's lines and pumps will be checked for cleanliness at the discharge port by slopping a small quantity into a reception container. During such slopping operations, a sample should be drawn at the manifold for reference and retention purposes.

The safe-keeping of samples in a suitable locker is of paramount importance. Depending on the prevailing circumstances, the samples should be retained for at least a year, by which time notification of any claim should have been made. It is recommended that samples are retained for more than this period if there was clearly a problem or doubt concerning the product quality during the voyage. In most cases, cargoes will be loaded and delivered without incident and, in these cases, disposal of samples is a matter of common sense based on the availability of storage space. Ideally the head office should be asked to confirm that sample disposal is in order as it will have notification of any claim arising.

Conversely, as soon as a claim is raised against the ship or the owner is notified of third party involvement in a claim, then the ship should be advised to identify all relevant samples and arrange for these to be landed at a suitable location, into the custody of an owner's (or P&I club's) representative.

No attempt should be made to disguise or ignore any observed comingling or misrouting of on-board cargoes, or any observed or possible contamination. In terms of cost effectiveness, early resolution of such problems is much the preferred approach and reduces the potential exposure to the owner and its P&I club.

APPENDIX I

RECOMMENDED REFERENCES

1. *API Manual of Petroleum Measurement Standards*

Chapter 17	Marine measurement
Section 1	Guidelines for marine cargo inspection
Section 2	Measurement of cargoes on board tank vessels
Section 4	Method for quantification of small volumes on marine vessels
Section 8	Guidelines for pre-loading inspection of marine vessel cargo tanks
Section 9	Vessel experience factor (VEF)

2. *Energy Institute Hydrocarbon Management (HM)*

Procedures for oil cargo measurements by cargo surveyors

HM 28	Crude oil
HM 29	Petroleum products
HM 30	Liquefied petroleum gas (LPG)
HM 40	Guidelines for the crude oil washing of ships' tanks and the heating of crude oil being transported by sea

APPENDIX II

VESSEL EXPERIENCE FACTOR (VEF) CALCULATION

IP method 1

- List all the admissible recordings of vessel load ratio (VLR). The following VLRs are not admissible
  - first voyages after dry dock
  - lightenings
  - voyages where bills of lading are based on shipboard measurement
  - voyages prior to any modifications which have affected the ship's cargo carrying capacity.
- Calculate the mean value, *r*, of all the listed VLRs.
- Calculate 0·003*r* (0·3%) of *r*.
- Delete all of the values of VLR that do not fall into the range r ± 0·003*r*.
- Calculate the mean of the remaining values, *r*'. **This is the VEF.**
- Calculate 0·003*r*' (0·3% of *r*'). **This is the range of accuracy of the VEF.**

Example of IP method 1

Admissible VLRs

Voyage	VLR
1	0·9999
2	1·0119
3	1·0011
4	1·0026
5	1·0023
6	1·0053
7	1·0009
8	0·9989
9	0·9976
10	0·9984

Mean value, *r*, for the listed values of VLR = 1·0019

0·3% of *r* = 1·0019 × 0·003
= 0·003

Range of acceptable values is therefore 0·9989 to 1·0049 meaning that voyages 2, 6, 9 and 10 can be deleted.
Mean value, *r*', for the remaining values of VLR =1·0010

0·3% of *r*' = 1·0010 × 0·003
= 0·003

The VEF is thus 1·0010 with a range of accuracy of ±0·003.

IP method 2

This method only utilises VLRs that are statistically significant at the 95% probability level in the calculation of the VEF.

- For n admissible VLRs (see IP method 1 for typical reasons to omit a VLR) list them in ascending order and label them r_1 to r_n.
- Establish the statistical significance of the selected VLR to the limit outlined in the introductory paragraph. This is done by calculation of the two parameters R_L and R_H which is dependent on the value of n, the number of VLRs being considered.

For $n = 3$ to 7 $\quad R_L = \dfrac{r_2 - r_1}{r_n - r_1} \quad R_H = \dfrac{r_n - r_{n-1}}{r_n - r_1}$

For $n = 8$ to 10 $\quad R_L = \dfrac{r_2 - r_1}{r_{n-1} - r_1} \quad R_H = \dfrac{r_n - r_{n-1}}{r_n - r_2}$

For $n = 11$ to 13 $\quad R_L = \dfrac{r_3 - r_1}{r_{n-1} - r_1} \quad R_H = \dfrac{r_n - r_{n-2}}{r_n - r_2}$

For $n = 14$ to 25 $\quad R_L = \dfrac{r_3 - r_1}{r_{n-2} - r_1} \quad R_H = \dfrac{r_n - r_{n-2}}{r_n - r_3}$

- Compare the two values R_H and R_L with the critical values corresponding to n, a given number of VLRs (Table A).

Table A

n	Critical value
3	0·941
4	0·765
5	0·642
6	0·560
7	0·507
8	0·554
9	0·512
10	0·477
11	0·576
12	0·546
13	0·521
14	0·546

n	Critical value
15	0·525
16	0·507
17	0·490
18	0·475
19	0·462
20	0·450
21	0·440
22	0·430
23	0·421
24	0·413
25	0·406

If R_L is greater than the critical value then r_1 should be deleted.
If R_H is greater than the critical value then r_n should be deleted.

- After any deletions have been made new values of R_H and R_L must be calculated using the equation corresponding to the new number of VLRs used. This process is continued until neither R_H nor R_L exceed the critical value.
- The VEF is equal to the mean of the remaining values of VLR, that is

$$r = \frac{\sum_{n=1}^{N} r_n}{N}$$

- Determine the range of accuracy of the VEF by calculating the standard deviation, *d*, of the *N* VLRs about the mean using

$$d = \sqrt{\sum_{n=1}^{N} \frac{(r_n - r)^2}{N - 1}}$$

The range of accuracy can be found by multiplying the standard deviation by the Students Distribution Value at 95% probability value, t_{95} (Table B).

Table B

Degrees of freedom (N-1)	t_{95}	Degrees of freedom (N-1)	t_{95}
1	12·705	13	2·160
2	4·303	14	2·145
3	3·182	15	2·131
4	2·776	16	2·120
5	2·571	17	2·110
6	2·447	18	2·101
7	2·365	19	2·093
8	2·306	20	2·086
9	2·262	21	2·080
10	2·228	22	2·074
11	2·201	23	2·069
12	2·179	24	2·064

Range of accuracy $= \pm\, t_{95} \times d$

Example of IP method 2

Using the VLR data from the previous example

r_n	VLR
r_1	0·9976
r_2	0·9984
r_3	0·9989
r_4	0·9999
r_5	1·0009
r_6	1·0011
r_7	1·0023
r_8	1·0026
r_9	1·0053
r_{10}	1·0119

$$R_L = \frac{r_2 - r_1}{r_9 - r_1} = \frac{0{\cdot}9984 - 0{\cdot}9976}{1{\cdot}0053 - 0{\cdot}9976} = \frac{0{\cdot}0008}{0{\cdot}0077} = 0{\cdot}104$$

$$R_H = \frac{r_{10} - r_9}{r_{10} - r_2} = \frac{1{\cdot}0119 - 1{\cdot}0053}{1{\cdot}0119 - 0{\cdot}9984} = \frac{0{\cdot}0066}{0{\cdot}0135} = 0{\cdot}489$$

$R_L = 0{\cdot}104$ and $R_H = 0{\cdot}489$

From Table A it can be seen that the critical value = 0·477, therefore r_{10} must be discarded and the calculation repeated.

On repeating the calculation it can be seen that no further deletions are required and so the mean and standard deviation can be calculated.

$$\text{Standard deviation} = d = \sqrt{\sum_{n=1}^{9} \frac{(r_n - r)^2}{8}} = 0{\cdot}0024$$

$$\text{Mean} = r = \frac{\sum_{n=1}^{9} r_n}{9} = 1{\cdot}0008$$

Range of accuracy $= \pm\, t_{95} \times d$
$= \pm\, 2{\cdot}306 \times 0{\cdot}0024$ (from Table B)
$= \pm\, 0{\cdot}0055$

The VEF is 1·0008 within a range of accuracy of ± 0·0055.

API form

Vessel: ____________________

Date: ____________________

Vessel experience factor – calculation

Load

1	2	3	4	5	6	7	8	9	10	11	12	13	14
					bbls / m³ / t (use same units for all entries)					Step 1	Step 2	Qualifying voyages	
Cargo	Voyage number	Cargo description	Terminal – port	Date	Vessel sailing TCV	Vessel OBQ TCV	Vessel load TCV	Bill of lading TCV	Vessel load ratio	Gross error > 2%?	Qual. voy. (> 0.3%) Y/N	Vessel TCV	Shore TCV
Last													
2nd													
3rd													
4th													
5th													
6th													
7th													
8th													
9th													
10th													
11th													
12th													
13th													
14th													
15th													
16th													
17th													
18th													
19th													
20th													
						Totals:					Totals:		
							Average TCV ratio:					TCV vessel / TCV shore:	

Qualifying range (excluding gross errors)
L: H:

Vessel experience factor:

Notes:
1. List last voyage first.
2. Do not include load and discharge information on the same form.
3. The average TCV ratio is the total vessel loaded TCV divided by the total shore TCV.

Source: API Manual of Petroleum Measurement Standards, chapter 17 – marine measurement, section 9 – vessel experience factor / IP Hydrocarbon Management HM 49 (November 2005)

APPENDIX III

WEDGE VOLUME CALCULATION

The wedge formula is $V = \frac{LBp^2}{2T}$ where

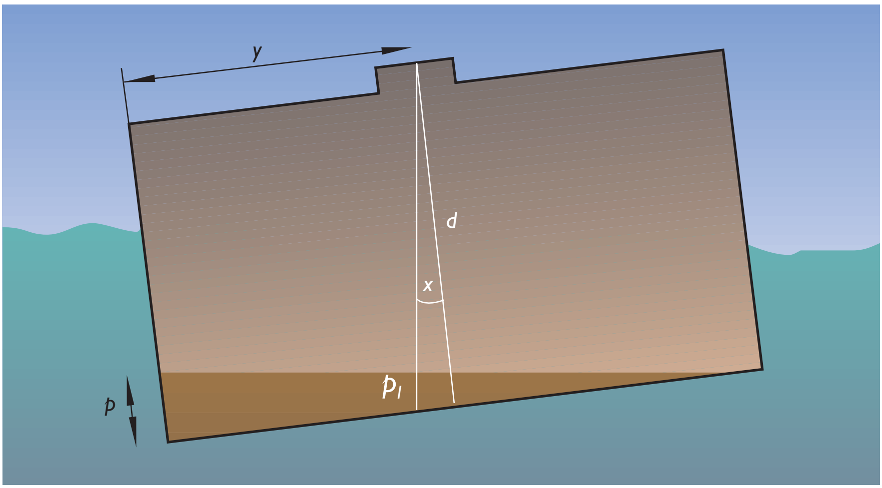
V = volume of liquid in the wedge
L = length between perpendiculars of the ship
B = breadth of the tank
p = corrected dip
T = ship's trim.

The formula assumes that

- the liquid is free flowing
- the ship has zero list
- the units used are consistent.

The calculation for corrected dip is $p = [p_1 \text{cosec} x + (y - d \tan x)] \tan x$, where

p_1 = measured dip
y = distance from sounding position to bulkhead
x = angle of trim
d = depth of tank.

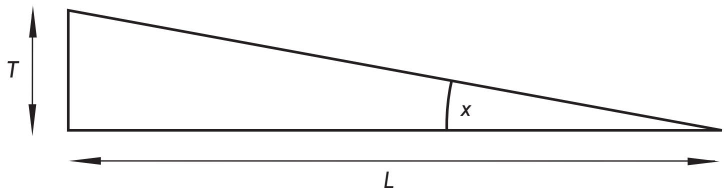


Example of wedge formula calculation

For a ship where

p_1 = 15 cm (0·15 m)
y = 1·7 m
d = 26·89 m
L = 329 m
B = 18 m
T = 1·8 m.

To obtain the corrected dip it is first necessary to determine the angle of trim *(x)* from the length between perpendiculars *(L)* and trim (*T*).



$$\tan x = \frac{T}{L} = \frac{1.8}{329} = 0{\cdot}00547$$

Therefore, $x = 0{\cdot}31347$ and $\operatorname{cosec} x = 182{\cdot}78$.
Substituting the values into the equation for the corrected dip gives

$p = [0{\cdot}15 \times 182{\cdot}78 + (1{\cdot}7 - 26{\cdot}89 \times 0{\cdot}00547)] \times 0{\cdot}00457$
$p = (27{\cdot}417 + 1{\cdot}553) \times 0{\cdot}00547$
$p = 0{\cdot}158$ m.

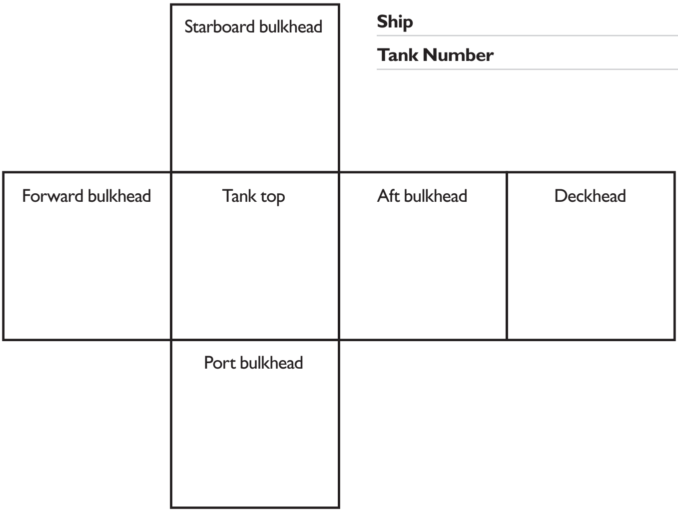
This can then be substituted into the wedge formula

$$V = \frac{329 \times 18 \times (0{\cdot}158)^2}{2 \times 18}$$

V **= 41·06 m³**

APPENDIX IV

CARGO TANK CONDITION REPORT



Ship ______________________

Tank Number ______________________

Coating type ______________________

Total area ______________________ m²

Year coated ______________________

Last repaired ______________________

Inspected by ______________________

Date / /

For stainless steel tanks

Last passivated ______________________

Last pickled ______________________

Steel type ______________________

Condition of:

Ladders ______________________

Coaming ______________________

B/W hatches ______________________

Sump ______________________

Coils ______________________

Hatch packings ______________________

Closed gauging ______________________

High level alarm ______________________

Key for diagram

B = blisters
C = cracks in coating
D = delamination
E = discolouration
P = pittings
R = rust as stains
ES = elephant skin
P = pump
DL = drop line
SK = Skappenord sensors
S = Saab sensor
HL = High level sensor

Overall appearance

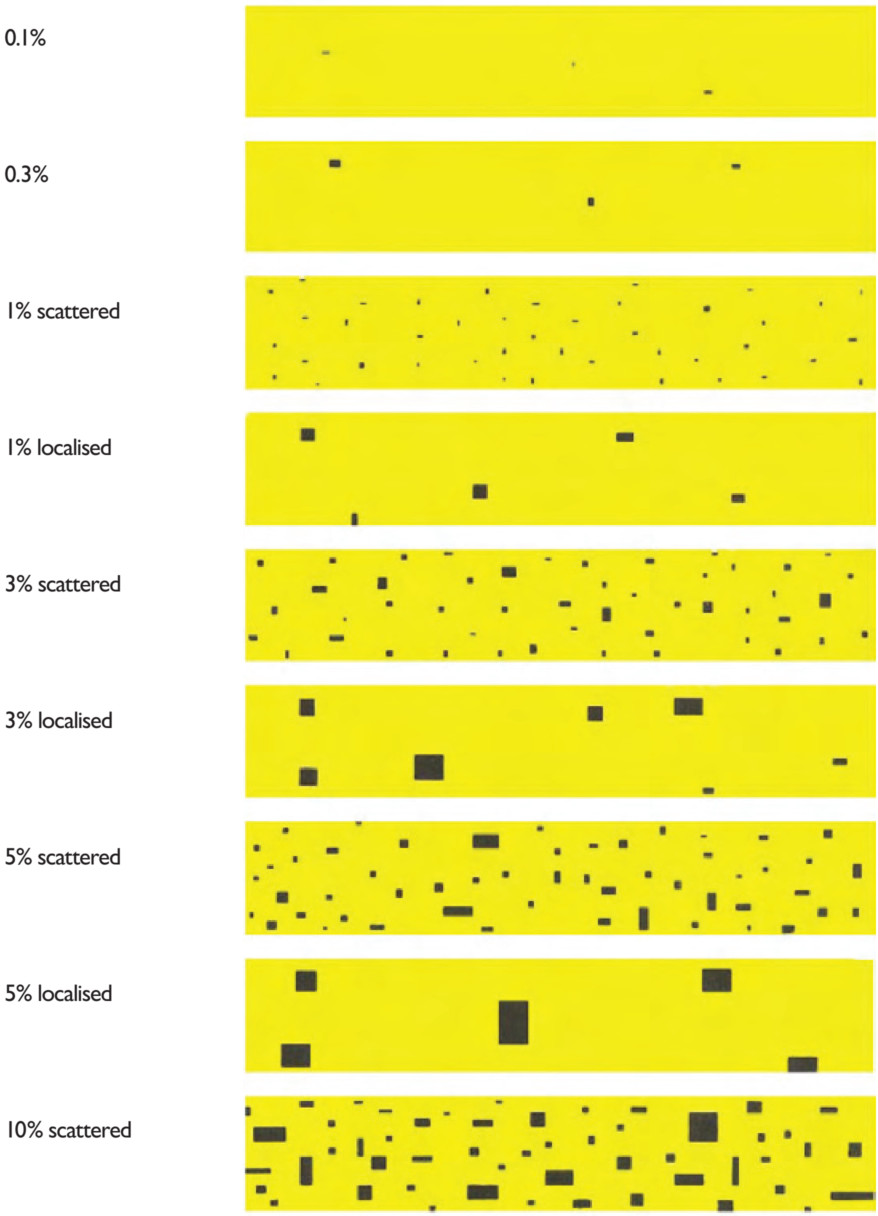
Very good ______________________

Good ______________________

Poor ______________________

Bad ______________________

Fig. 23. Tank coating breakdown extent (source International Paint)



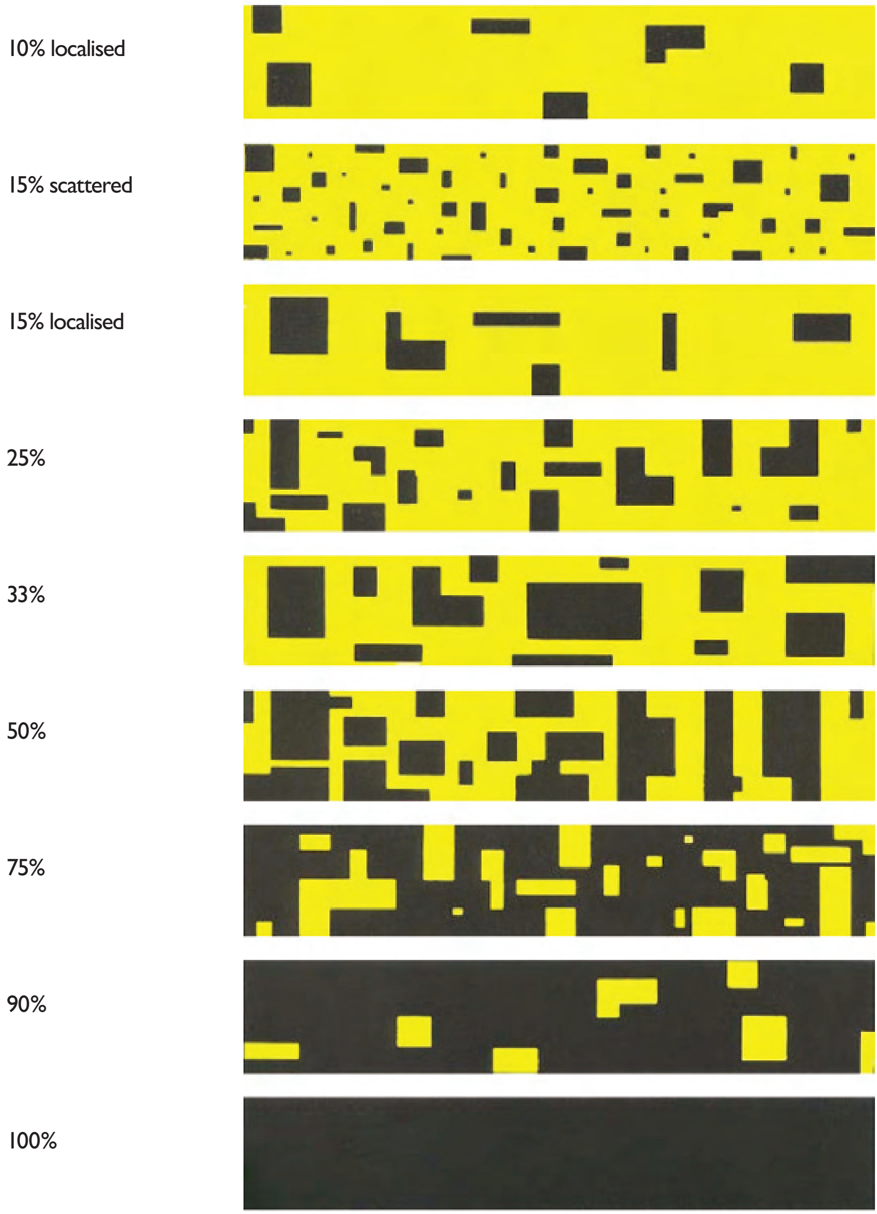
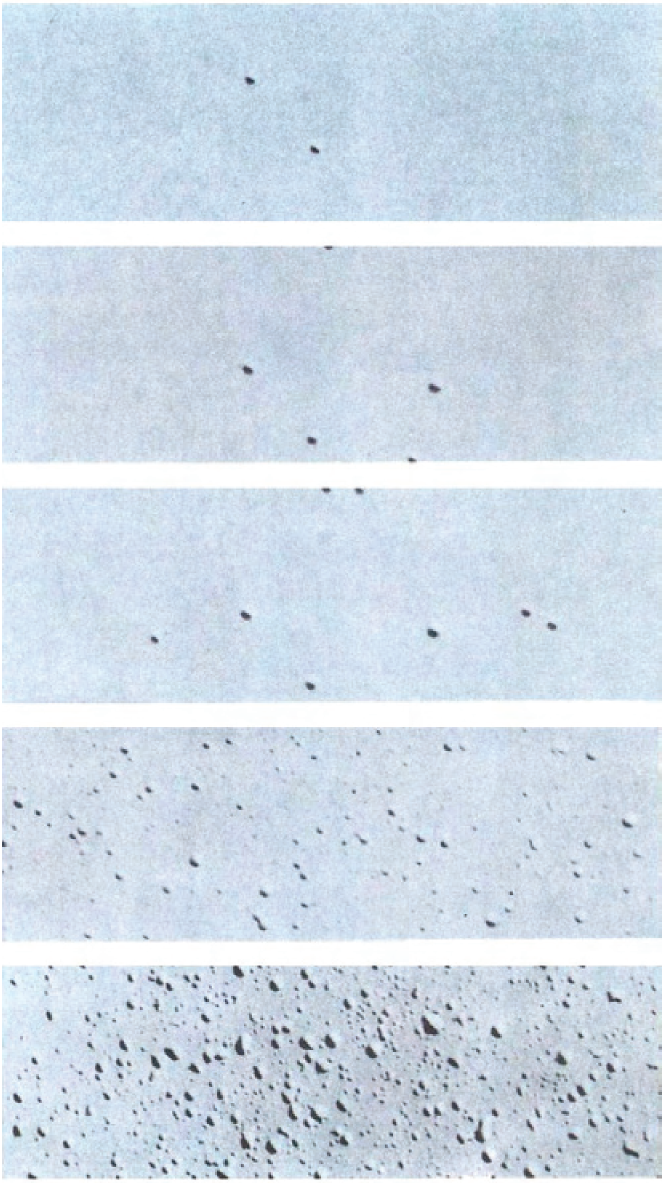

10% localised
15% scattered
15% localised
25%
33%
50%
75%
90%
100%

Fig. 24. Tank coating blistering extent (source International Paint)



Very light

Light

Moderate

Heavy

Very heavy

APPENDIX V

GLOSSARY OF TERMS

API The API gravity is a US industry scale of density introduced by the American Petroleum Institute, defined as degrees API = (141·5/SG 60/60ºF) – 131·5. Crude oils generally fall in the range API 20–40. For water, API = 10. For light distillates, such as gasoline, API is 70 and above.

Asphaltenes The components of the bitumens in petroleum products (especially asphalts) which are soluble in carbon disulphide but insoluble in paraffin naphtha.

ASTM The initials of the American Society for Testing Materials.

Automatic gauging device A device installed in a pipeline to retrieve a 'representative' sample from the liquid flowing in the line. The automatic sampler generally consists of a probe, an extracting mechanism, an associated controller and a sample receiver.

bbls Abbreviation for US barrels.

Blended cargoes A fuel oil which is a mixture of two or more of the other types of fuel oil (residual, distillates or cracked fuel).

Clingage Oil residues which adhere to the surface areas of tank walls and structures on completion of discharge. Clingage films are subject to drainage.

Composite sample A blend of spot samples mixed in volumetric proportion in order to obtain a 'representative' sample of the bulk.

COW: crude oil washing The practice of jet washing cargo tanks with crude oil during the course of discharge operations to reduce clingage and bottom residue. On tankers, COW is performed with permanently installed machines. The tanks must be inerted and reliably monitored to ensure low oxygen content (officially less than 8% but ideally less than 5%).

Density Mass per unit volume of a substance, at a defined temperature. For commercial purposes mass may be equated with weight in vacuum. The important distinction is therefore between weight in vacuum and weight in air. For crude oil and petroleum products, the density is reported at 15°C (tonnes/m^3). The weight in air (usually quoted as kg/l) is reliably estimated to be 11 points less than density (see ASTM D1250 table 56).

De-scaling The removal of encrusted corroded material from cargo tank steel.

Elephant skin Coating breakdown, typified by the coating being loose and wrinkled in appearance.

FW: free water Water layer existing as a separate phase, normally detected by water paste or interface detector and usually settled at the bottom of the tank (depending on relative density of cargo).

GOV: gross observed volume TOV less FW and bottom sediment, being the measured volume of oil and S&W at observed temperature and pressure. In practice, GOV is usually calculated with no deduction for bottom sediment, which is very difficult to quantify.

GSV: gross standard volume Measured volume of oil and S&W at standard conditions of 15ºC and atmospheric pressure. In practice, the GSV is the GOV multiplied by the VCF obtained from the appropriate ASTM/IP *Petroleum Measurement Tables*. The GSV is the primary quantity measured and reported on tankers.

High level sensor An electrical or mechanical device designed to indicate when a cargo tank is filled to maximum level.

Inerting The introduction of a chemically un-reactive gas into cargo or ballast spaces to minimise the risk of explosion.

IP The initials for the Institute of Petroleum.

Light ends The more volatile component of a particular crude or product.

LOT: load on top The procedure of comingling the recovered oil slops with the next cargo.

NSV: net standard volume Only applicable to crude oil, NSV is the GSV minus S&W, being a measurement of the 'dry' oil quantity at standard conditions. For products, S&W is not normally deducted and is included (where appropriate) within the receiver's quality specifications. Whereas samples of crude and product are commonly drawn from ship's tanks after loading (and before discharge), the measured S&W is not advised in time for ship's officers to calculate the NSV on board.

OBO: oil/bulk/ore A combination carrier having holds designed such that they can be used to carry either dry or liquid bulk cargoes.

OBQ: on-board quantity Any material (oil, water, sludge and sediment) in cargo spaces and associated lines and pumps on a tanker after de-ballasting and before start of loading operations. OBQ measurement is restricted to bottom soundings and is usually made under stern trim.

O/O: oil/ore A combination carrier which, unlike an OBO, possesses wing tanks. *Note:* Oil and bulk cargoes are never carried at the same time.

Outturn The quantity of cargo discharged from a tanker, as received by a shore terminal.

Passivated Passivation of stainless steel involves the thickening of its surface layer of chromium oxide to increase corrosion resistance.

Pickled Pickling of stainless steel involves the chemical removal of oxidation products generated during welding.

Pitting Localised corrosion typified by the formation of a cavity.

Pour point The lowest temperature at which an oil can be poured under prescribed conditions of tests.

ROB: remaining on board Residual material (oil, water, sludge and sediment) in cargo spaces and associated lines and pumps on a tanker after completion of discharge operations. ROB measurement is generally restricted to bottom soundings. Clingage cannot be measured directly although clingage values may account for a substantial proportion of the ROB.

RFO: residual fuel oils Fuel oils which are topped crude petroleum or viscous residuum obtained in refinery operation.

Running sample A sample obtained by lowering an un-stoppered sample container from top to bottom and returning to the top at a uniform rate such as to obtain around three-quarters filling of the sample container.

S&W: sediment and water Entrained material within the oil bulk, including solid particles and dispersed water, as measured under standard conditions (ASTM D4006, D4007, D473).

Saab sensor The trade name of a fixed installation ullage sensoring device.

SG: specific gravity The ratio of density of a liquid at a given temperature to that of pure water at a standard temperature. Within the petroleum industry the standard reference temperature for specific gravities is 60°F/60°F. Other reference temperatures are used, such as 15°C/4°C (Japan). Since the density of water at 4°C is 1.000, SG 15°C/4°C is equivalent numerically to density @ 15°C (vac). The SG is dimensionless. SG unqualified by temperature is ambiguous and therefore, for practical purposes, useless.

Skappenord sensor The trade name of a fixed installation ullage sensoring device.

Slops Oily material collected after such operations as stripping, tank washing or dirty ballast separation. It may include oil, water, sediment and emulsions and is usually contained in a tank specifically designed to hold, condition and separate such material.

Spot sample A sample taken at a specific location in a tank or from a pipe at a specific time during flow. Spot samples from tanks include top, upper, middle, lower, bottom, drain and outlet samples.

Topped crude petroleum Residual products remaining after the removal by distillation or other artificial means of an appreciable quantity of the more volatile components of crude petroleum.

TCV: total calculated volume The GSV plus FW.

TOV: total observed volume The measured volume of oil, S&W and FW at observed temperature and pressure.

Ullage A measure of empty cargo space in a ship.

VCF: volume correction factor Coefficient of expansion for petroleum liquids of various densities in relation to a standard volume at standard temperature. Standard volume is obtained by multiplying the observed volume by the VCF.

VDR: vessel discharge ratio Comparison between ship and shore figures on discharge.

VEF *see* VEFL and VEFD.

VEFL: vessel experience factor loading Comparison of ship and shore figures for the quantity of oil loaded. The VEF is commonly expressed as the ratio of the quantity (TCV) of oil measured on board a ship immediately after loading less the OBQ to the quantity (TCV) measured by the loading terminal.

VEFD: vessel experience factor discharge Comparison of ship and shore figures for the quantity of oil discharged. The ratio of the quantity (TCV) of oil measured on board a ship immediately before discharge less the ROB to the quantity (TCV) measured by the receiving terminal. VEFD is rarely reported explicitly.

Viscosity The internal friction of a substance or its resistance to flow.

VLR: vessel load ratio Comparison between ship and shore figures on loading.

Water cut or dip The measured depth of FW lying on the bottom of the tank.

Water-finding paste A paste which is smeared onto a bob or ruler to indicate the free water interface by a change of colour at the cut.

Wedge formula An algebraic relationship to calculate the volume of free-flowing liquid which will accumulate in the aft end of a tank when the ship is trimmed by the stern.

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SHIPBOARD PETROLEUM SURVEYS

A GUIDE TO GOOD PRACTICE
Second Edition

by ANTHONY SEVERN and
North of England P&I Association

This unique guide explains how good shipboard survey practice can significantly reduce the risk of shortage or contamination claims arising from loading or discharging crude oil and petroleum products. A range of quantitative and qualitative monitoring and recording techniques is recommended which should ensure that potential loss or contamination problems are identified at an early stage and can be remedied cost effectively. The guide is aimed at ship's officers, cargo surveyors and all others involved in monitoring cargo operations. The second edition has been updated and revised to reflect the latest industry developments.

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