Standard Marine Services

GUIDELINES FOR THE MEASUREMENT OF LIQUEFIED GASES ON SEAGOING SHIPS & INLANDWATERWAY BARGES

Prepared on behalf of

Exxon Chemical Europe Inc.
Basic Chemicals Europe

These guidelines were developed in 1998/99 for Exxon Chemical Europe Inc., Basic Chemicals Europe by Captain C. Allport of Standard Marine Services Limited and replace earlier guidance. They are based upon the report and advice from an LPG Measurement Survey conducted by Srini Sivaraman of ER&E in May/June 1997 and incorporate the earlier guidelines for Liquefied Gas Cargo Measurement and Calculation, produced in 1987 for Exxon Chemicals International by the Centre for Advanced Maritime Studies, Edinburgh. The earlier guidelines were adopted by Exxon Chemical International Inc. and approved by Regional Audit in 1988.

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Preface **:-**

The key to accurate cargo measurement based upon ship's figures depends on the precision of the tank calibration and calibration of associated level, temperature and pressure measuring devices in addition to the use of consistent methodology. Conformance to the recommendations made in these guidelines will result in transfer custody quality that is within the expectation of Exxon Corporation controls.

SECTION I - INTRODUCTION & GENERAL PRINCIPALS

1.1 INTRODUCTION

The practices and procedures described in this document provide guidance for improving or maintaining liquefied gas measurement level of uncertainty within the accuracy requirements of Exxon's Hydrocarbon Measurement Practices (HMP) . Contrary to the general recommendations contained in the HMP, these practices and procedures will demonstrate that quantity determination can be based upon ship or barge measurement. Custody transfer integrity is comparable to and in some cases can be better than shore systems and match HMP requirements.

This document incorporates recommendations made by Srini Sivaraman (ER&E Consultant) in his report of June 1997, following a survey of the measurement practices observed during a number of Exxon Basic Chemical Liquefied Gas shipping operations. A review of liquefied gas transfers by sea-going vessels and inlandwaterway barges at various ports within Europe was undertaken with the primary objective of evaluating the use of vessels for the determination of the custody quantities.

1.2 PURPOSE

(a) The aim of this document is to provide a textbook to acquaint Vessel owners, ship and barge crews, vessel despatchers, product flow and marine operations co-ordinators, marine terminal personnel, marine and chartering advisors and independent surveyors, with consistent guidance for the quantification of liquefied gases based upon ship/barge measurements.

(b) The purpose of the practices is to document the requirements to be applied to ships and inlandwaterway barges to enable quantity determinations based upon vessel measurements to be used for custody transfers of liquefied gases . This will achieve the level of accuracy required by HMP, and standardise the measurement and calculation process.

1.3 APPLICATION

These guidelines apply to pure liquefied petroleum gases and chemicals with constant density but can apply to liquefied gas / LNG mixtures that have varying densities, being carried by seagoing ship or inlandwaterway barge, providing that a representative density can be established. All pure chemicals are assumed to be in equilibrium conditions.

Representitive densities of mixtures can be established by reference to density tables from API MPMS Chapter 11 Table E or the Vapour Density calculation methodology in Appendix VI and/or reference to either ASTM D 2598 for the liquid density or use of the Francis Formula and Cosald Equation(These are described in the SIGTTO publication "Quantity Calculations - LPG and Chemical Gases").

1.4 SCOPE

Practices covering the measurement of both quantity and quality of liquefied gases on seagoing ships and inlandwaterway barges. The guidelines cover the following topics:-

- measurement accuracy and levels of uncertainty

- measurement techniques (equipment, installation, procedures, operational checks, data conversion and computation methodolgy)
- proving and calibration (frequency, equipment accuracy, procedures)
- sampling

1.5 GENERAL PRINCIPALS

In general liquefied gas cargo quantities delivered to or discharged from ships or barges are measured and calculated basically in a similar manner to that of other bulk liquid cargoes such as crude oils and petroleum products. That is to say by measuring cargo volume and cargo density and, after correcting both to the same temperature, multiplying these factors to obtain the cargo quantity.

However, unlike the generality of bulk liquids carried by sea, liquefied gases are carried as boiling liquids in equilibrium with their vapours in close containment systems. This leads to more complicated measurements and calculation procedures than in the case of other bulk liquids.

(i) The inclusion of vapour.

Ullage spaces at all times, when cargo is in the tank, contain saturated vapour of the cargo liquid and very little, if any, of other gases. The vapour may evaporate from, or may condense back into, the liquid during the process of cargo handling and the containment and handling processes generally ensure that the vapour is not lost to atmosphere. The vapour is, therefore, an intrinsic and significant part of the cargo and must be accounted for in the cargo quantification.

(ii) Net quantities of cargo transferred are the difference between "before" and "after" quantities.

It is common practice on discharge to retain on board a significant quantity of liquid (heel) and its associated vapour to keep tanks cool on the ballast voyage and to provide refrigerant for cooldown before loading the next cargo. At loading, the new cargo is added to the heel or, if the ship has arrived with uncooled tanks, to the product put on board for tank cooldown purpose. Thus, at both discharge and loading it is necessary to quantify the ship's tanks content both before handling, known as 'On-board quantity' (OBQ) and after handling, known as 'Remaining on-board' (ROB), in order to ascertain the cargo discharged or the cargo loaded.

(iii) Temperature and liquid level measurements.

Cargo being loaded may arrive in the ship's tanks at temperatures which may vary over the loading period. This may be due to cargo being taken from different shore tanks at varying temperatures or to initial cooling of shore pipelines or to varying pump power input to flowing cargo. Liquefied gases have comparatively large coefficients of volume expansion with temperature. The result in variation in the density of the arriving cargo may therefore be sufficient to give rise to some stratification of a ship's tank content after loading. A number of temperature sensors are usually provided at different tank levels and it is important that all these temperature readings are taken into account in order to assess more accurately the average temperatures of the liquid and of the vapour and from which the appropriate temperature corrections may be applied.

Also, by boil-off or by condensation, a tank's liquid and vapour content will adjust themselves to saturated equilibrium; this equilibrium may not be achieved immediately after loading. It is desirable therefore to delay cargo measurement and sampling for as long a time as possible subject to the constraints of ship's departure, etc..

1.6 CARGO TANK FILLING LIMITS

The IMO, BGC and IGC Codes recognise the large thermal coefficient of expansion of liquefied gas and gives requirements for maximum allowable loading limits for cargo tanks. This is to avoid tanks becoming liquid-full under conditions of surrounding fire.

The maximum volume to which a cargo tank may be filled is determined by the following formula:

$$LL = FL \frac{\rho R}{\rho L}$$

where:

LL =Loading limit expressed in per cent which means the maximum liquid volume relative to the tank volume to which the tank may be loaded.
FL =filling limit = 98 percent unless certain exceptions apply.
ρR =relative density of cargo at the reference temperature
ρL =relative density of cargo at the loading temperature and pressure

In this context "reference temperature" means:

(i) For fully pressurised the temperature corresponding to the vapour pressure of the cargo at the set pressure of the pressure relief valves when no cargo vapour pressure / temperature control is provided.

(ii) For semi pressurised and fully refrigerated the temperature of the cargo upon termination of loading, during transport, or at unloading, whichever is the greatest, when a cargo vapour pressure / temperature control is provided.

The maximum allowable tank filling limits for each cargo tank should be indicated for each product which may be carried, for each loading temperature which may be applied for the applicable maximum reference temperature, on list to be approved by the Flag Administration. A copy of the list should be permanently kept on board by the master

1.7 SAFETY

Notwithstanding any guidance contained in these criteria, the safety of personnel and equipment is paramount and must not be compromised, therefore careful attention to the attendant hazards on board ships and barges is required. The procedures required to conduct these activities safely are described in the joint ICS/OCIMF/IAPHA publication "International Safety Guide for Oil Tankers and Terminals" (ISGOTT), the SIGTTO publication "Liquefied Gas Handling Principles on Ships and in Terminals", and the ICS publication "Tanker Safety Guide Liquefied Gases", which should be referred to on all occasions.

1.8 CUSTODY TRANSFER PARAMETERS

The term custody is applicable to transfers between separate Exxon affiliates and those involving third parties, hence all waterborne movements which are in third party vessels are to be considered as custody transfers and are accountable to these guidelines.

All third party sea going vessels and inlandwaterway barges in liquefied gas service should comply with the requirement parameters as stipulated in TABLE 1 to maintain custody transfer integrity.

CARGO CUSTODY PARAMETERS

	Parameter	Accuracy	Read-out	Calibration Frequency	Pseudo electronic verification	Remarks
1.	Cargo Tank calibration	+/- 0.3%	3 mm	12 years (Ref;Annex IX)		Approved Certificate
2.	Liquid Level Gauge	+/- 3mm	1 mm local & remote	3 years	3 months to +/- 3mm	
3.	Reference Height/zero gauge height	+/- 5mm		3 months		
4.	Trim	+/- 100 mm				
5.	Heel	+/- 1°				
6.	Temperature probes	+/- 0.1°C	+/- 0.1°C	3 years	3 months to +/- 0.5°C	Located close to level gauge
7.	Application of bias error correction for temperature					Not permittted
8.	Max-Min temperature variation	+/- 1°C				
9.	Pressure gauge	+/- 0.01 bar		3 years	3 months to +/- 0.01 bar	
10.	Cooling system isolated from tank					Yes

TABLE 1

Liquefied gas measurement systems lend themselves easily for automation with very minimal investment and Shipowners are encouraged to consider such enhancement at the next period of major overhaul.

1.9 STANDARDISATION

All reports relating to quantity determination within Exxon and from third parties must use identical reporting format that will facilitate stewardship and control (Ref.Section 5 and Appendix II).

All sea going vessels and inlandwaterway barges in Exxon Chemical service must use standard calculation procedures for the determination of custody (both vapour and liquid) quantities, as stipulated in this report (Sections 4, 5 and Appendix II).

The Bill of Lading (B.O.L) quantity as currently specified under commercial contract is the total quantity loaded on board the vessel. However, material left on board after unloading may be as much as 1 % of total cargo loaded. For a true mass balance for transportation/acquisition loss this should be factored into the calculations.

The B.O.L. shall always be based on primary system. This system can either be the shore or the ship at loading port.

The B.O.L shall be reported in vacuum and at standard conditions of 15 deg C. All other local conditions may be complied with independently.

1.10 RECONCILIATION LIMITS

Quantification of liquefied gases either on ship or shore is based upon the measurement accuracy of the various devices employed and the proving and calibration uncertainty of these devices. An estimate of the current conditions prevailing on well operated vessels compared with what are the best practical conditions which can be achieved are tabulated below. From these conditions one can reconcile measurement based upon ships figures with the accuracy requirements of HMP.

1.10.1 Factors impacting ship mass determination

- Volume depending on calibration procedure
- Level measurement
- Temperature
- Trim impact due to weather
- Pressure variations on vapour mass
- Density variation

1.10.2. Current conditions to best practical

Parameter	Current conditions	Best practical conditions
Cargo Tank Calibration	+/- 0.3 % to 0.6 %	to +/- 0.2 %
Level	+/- 10 mm	to +/- 5 mm
Trim	+/- 2 meters	to +/- 0.5meter
Temperature	+/- 1°C to 1.5°C	to +/- 1°C
Pressure(on vapour mass)	+/- 10 %	to +/- 10 %
Density	+/- 0.005 to 0.01 in 0.5 gravity	

TABLE 2

1.10.3. Current/best practical Precision of Vessel (approximate) : (ie: capability of system)

By definition vessels are afloat and therefore in constant motion adding to levels of uncertainty when conducting measurements. Tabulated below is an estimation of the current and best precision which can be attained, dependent upon the environmental conditions effecting the vessel at time of measurement.

Vessel	Heavy Swell		Normal sea	
	Current	Best	Current	Best
Average vessel (approx.)	+/- 0.5 %	+/- 0.3 %	+/- 0.4 %	+/- 0.2 %

TABLE 3

- The above includes uncertainty in calibration
- To move from current best, recalibration may be necessary
- Level impact not significant

NOTE:- *The above estimates are approx. and have an uncertainty of approx. 15 to 20 % in themselves.*

1.10.4. As the ship capacity increases i.e. tank volumes are larger; the impact as a percent of total mass is smaller.

1.10.5. Effect of level error is much smaller compared to trim and overall calibration error.

1.10.6. To achieve a reconciliation of +/- 0.5 % between ship/shore, the shore measurements variability by definition has to be in the range of vessel variability under best conditions.

1.10.7 It should be noted that in relation to the above uncertainties (that includes calibration impact) an orifice meter may have an uncertainty of +/- 1% under ideal conditions, conventional PD/turbine meters may have an MF drift of 0.5% to 0.75%(on LPG) and tankage uncertainty may be as large as 0.5% for 1 to 2 metre displacements.

1.10.8 On comparison, once the recommendations of this report are fully implemented, overall precision of ship can equal and or exceed shore tanks.

1.11 PHYSICAL LOSS

The material left on board after discharge(ROB) as and when is flared or purged, shall be reported as physical loss and shall be accounted accordingly. Although it is recognised that such flaring/purging is infrequent as vapours are generally condensed and retained on board, it is an aspect of operations which can lead to physical loss.

1.12 RESPONSIBILITIES

1.12.1 THE SHIPOWNER

Shipowners are responsible for:-

1. The tank calibration (Ref. 2.5) of all ships under their control and to provide all such ships with properly approved Certificate of Tank Calibration (Ref.2.6), approved Capacity (Calibration) tables for each cargo tank (Ref.2.7) in addition to the equipment necessary for accurate measurement of the cargo carried and procedures which address re-calibration and proving of such equipment.
2. For ensuring that appropriate maintenance procedures are in place to ensure that the measurement devices are kept in a satisfactory condition and that all key personnel are trained in the correct use of such equipment and the quantification process.
3. For maintaining all vessel records relating to tank calibration, certification of vessel instruments, repairs and repair history.

1.12.2 THE MASTER

Masters are responsible for:-

1. The accurate measurement of liquefied gases carried aboard their vessel and for the delivery of the full cargo loaded as recorded in the Bill of Lading.
2. For ensuring that an approved Certificate of Tank Calibration and Capacity Tables are on board and that all the measurement equipment is in satisfactory condition at all times, proved or re-calibrated as required and records maintained.

1.12.3 LOADING TERMINAL/CARGO SHIPPER

The loading terminal is responsible for:-

1. Ensuring that safe ship/shore conditions exist whilst cargo measurement and sampling activities are being carried out onboard whilst the vessel is moored at the terminal.
2. Witnessing or perform with the ship's officer, the measurement and sampling of the cargo onboard.
3. Reconciliation of the quantity of cargo loaded according to the ship's measurements and the preparation of the Bill of Lading.
4. Proving & calibration of all shore measurements.
5. Verification of Inspector/Surveyor practice in conformance with Surveyor Instructions.

1.12.4 UNLOADING TERMINAL/CARGO RECEIVER

The receiving terminal is responsible for:-

1. Ensuring that safe ship/shore conditions exist whilst cargo measurement and sampling activities are being carried out onboard whilst the vessel is moored at the terminal.
2. Witnessing or perform with the ship's officer, the measurement and sampling activities before and after unloading.
3. Reconciliation of the quantity of cargo received compared with the BOL quantity, based upon the ship's or shore measurements.
4. Proving & calibration of all shore measurements.
5. Initiating claim procedures in the event of gross ship/shore differences. Ensure ontime collection of documented evidence.
6. Verification of Inspector/Surveyor practice in conformance with Surveyor Instructions.

1.12.5 INDEPENDENT CARGO SURVEYOR/INSPECTOR

The independent cargo surveyor/inspector, who may be appointed by the seller, charterer, shipowner or receiver or jointly, is responsible to his principals for :-

1. Compliance with the Surveyor Instructions (see Specification Manual)
2. Recording all raw data (level, temperatures, trim pressures as part of the custody report
3. Report reading from each individual temperature sensor.
4. Verifying Reference Height/zero gauge heights and report any deviations.
5. Confirming all calibration & verification records are maintained onboard vessel.
6. Obtaining from Master the reasons for such deviations and forward the same to Principals with necessary recommendations.

7. Independently from ship, measuring and calculating quantity on board.
8. Reconciliation of any differences between ship and independent determination of quantities.
9. Reporting repair/ dry dock history and reconfirming integrity of capacities, reference height, zero gauge height and review calibration records for level, temperature and pressure (see APPENDIX V Check List).

SECTION II - MEASUREMENT PARAMETERS

2.1 INTRODUCTION

The term custody is applicable to transfers involving third parties, hence all waterborne movements which are in third party vessels are to be considered as custody transfers and are accountable to custody standards as detailed in HMP (Ref. Section 1.8).

All custody volumes shall be computed as Mass in vacuum and at 15°C with volumes and densities all at the same temperature conditions.

All parties in question (loading/shipping terminal, unloading/receiving terminal, seagoing ships & inlandwaterway barges, independent inspection, Exxon sites, Third parties) shall use same equations and constants.

2.2 GENERAL

2.2.1 Cargo tank capacity

All ships are provided with a capacity/calibration table for each cargo tank by means of which the tanks liquid and vapour volume may be calculated from a measurement of the liquid level. A capacity or calibration table is obtained from careful measurement taken at ambient temperature and pressure after the ship is constructed and the basic values given in the tables normally referred to volume with the ship upright and with no trim. The capacity or calibration tables therefore contain correction factors with which to adjust the liquid level measurements in accordance with the actual conditions of the ship's list and trim and with the cargo tank temperatures at the time of cargo measurements.

2.2.2 Trim Correction:-

Cargo Tank capacity tables are calibrated with the ship/barge on even keel and upright. When not on even keel the vessel is said to be trimmed. When not upright the vessel has a heel(list).

See Fig. 1.

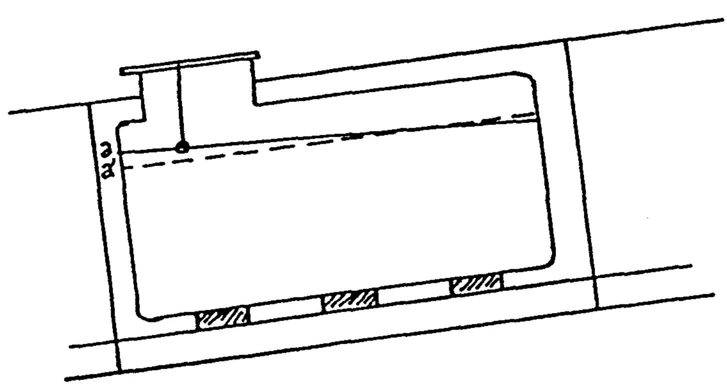

FIGURE 1

In a trimmed condition there will be an apparent change in liquid level from ‘a’ to ‘a1’. The trim correction rectifies this apparent change.

2.2.3 Heel/list correction:-

See Fig. 2.

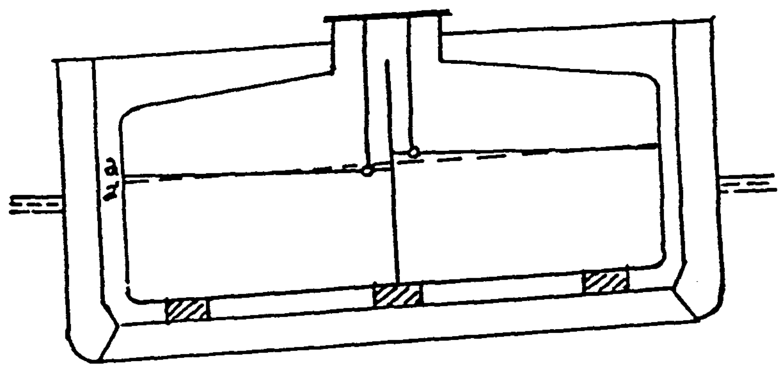

FIGURE 2

When the ship is listed the level gauge in one side tank reads low and in the opposite side reads high for the same liquid level. The correction rectifies these apparent changes.

2.2.4 Measurement Parameters

Volume of liquid and vapour in cargo tanks, temperature of the cargo and pressure into the cargo tank are the basic parameters required for the measurement and calculation of cargoes. The means of measuring these parameters are:-

(i) Volume: Each cargo tank must be provided with at least one liquid level gauge. All level gauge instruments will have an inherent accuracy of 3 mm..The capacity/calibration tables are designed to give in addition to the total volume of the tank itself, the volume of the liquid contained in the cargo tank at any level indicated by the liquid level gauging device.

(ii) Temperature: Each cargo tank must be provided with at least two devices for indicating cargo temperatures, one placed at the bottom of the cargo tank and the second near the top of the tank, below the highest allowable liquid level, as required by IMO Codes. Most of the tanks are fitted with more than two sensors, to give also the temperature of the vapour phase. All temperature measuring instruments will have an inherent accuracy of of 0.1°C.

(iii) Pressure: The vapour space of each cargo tank is provide with a pressure gauge which should incorporate an indicator (and alarms) for high and low pressure alarms. The inherent accuracy of all pressure measuring instruments will be 0.01 bar.

2.3 MEASUREMENT OF CARGO VOLUME

2.3.1 Level measurement

The height of liquid level in the cargo tank is measured by liquid level gauge.
The IMO Codes require that each cargo tank should be fitted with at least one liquid level gauging device designed for temperatures within the cargo operating temperature range. Only proven technology level devices must be used. devices shall allow periodic calibration/reference checks as per the table of Cargo custody Parameters in section 1.8.

Readings from the liquid level gauge can be read either as:

ULLAGE: where the height of the reference point above the liquid surface is measured, or

INNAGE: where the depth of the liquid (height of the liquid level from the bottom of the tank) is measured.

2.3.2 Trim measurement

Tank capacity/calibration tables are calibrated with the ship upright and with no trim.

Trim correction tables are prepared for each cargo tank and should be entered with gauge reading and trim, to obtain the correction to be applied to gauge reading.

The trim of the ship is the arithmetical difference between the draught forward and the draught aft and is measured in metres. (see Figure 1)

The trim can be :

(i) "by the stern" (B/S) when the draught aft is greater than the draught forward.

(ii) "by the head" (B/H) when the draught forward is greater than the draught aft.

2.3.3 Heel/list measurement

If the ship is listed/heeling either on port or starboard side, correction to reading should be supplied as related in Sec.2, Fig. 2. The correction rectifies this apparent change. *The listing/heeling of the ship is the arithmetical difference in metres between the draft* readings (port and starboard) amidship, divided by two, or can be expressed in degrees as read at the ship clinometer.

2.3.4 Tape correction

The float gauge wire and materials pass through the cold tank vapour and depending on the actual temperature will be subject generally to thermal contraction and therefore measure "short".
For temperatures below the calibration temperature, a small correction must be added for the reading of the liquid level gauge, float type.

2.3.5 Float correction

The zero of the float gauge is determined by the manufacturers, but is normally at 50% immersion in liquid, corresponding to the density of the cargo normally carried (Typically Propane). As the density and temperature vary so the float will change level from zero. Hence a small correction will be required to the liquid level gauge reading.

2.3.6 Tank shell contraction/expansion

In the way that the cold temperatures in the cargo tank affect the length of the tape, the entire cargo tank is able to expand and contract as the "cold" shrinks the tank material. Cargo tanks calibrated at an ambient temperature of (say) 20°C will require a factor to reduce the volume to reflect the cargo temperature.

2.4 PARAMETERS

All custody transfers will be conducted using the criteria as specified in Section 1.8 TABLE 1.

This table lists the parameters which require addressing to minimise the uncertainty in measurement of liquefied gases based upon ship's figures. Addressed is the frequency of cargo tank calibration, equipment resolution and frequency of calibration and proving (verification). These criteria must be adhered to if the levels of accuracy required by HMG are to be achieved .

2.5 CALIBRATION

All vessels and barges with bullet tanks shall be calibrated in future using an approved API or ISO standard method or preferably the Optical Distance Ranging or equivalent method. For spheres the above method is still applicable and recommended in conjunction with API Standard 2552.

All vessels and inlandwaterway barges in Intra-European service should also comply with the EU directive 71/ 349 / EEC (calibration of vessel tanks).

Vessels or barges which undergo structural changes re-calibration must be conducted of the tanks affected.

All vessels and barges shall be calibrated to a standard condition at 15 deg C in addition to any other reference temperature that may be required by local authorities.

If there are reference height and zero gauge height variations from the original certification, a re- calibration of the same would be required and revised certification must be made available.

The tank calibration undertaken outside the vessel must be checked for inclination after installation on the vessel and slope correction shall be applied using API standard 2551 (latest method for slope correction is the use of Coats equation which will be included in ISO CD 12917 - 1).

Any and all changes that impact tank volumes and or reference height must be notified and reported prior to any field modifications.

2.6 CERTIFICATE OF CARGO TANK CALIBRATION

The Certificate of Cargo Tank Calibration shall carry the following data in addition to the standard information contained presently :

+ Reference standard used for calibration
+ Reference temperature at which the capacity table is developed
+ Reference gauge height, zero gauge height, zero gauge volume clearly indicated with a drawing
+ Location of the temperature devices in relation to the level device and clearly indicated with a drawing
+ Original certificate of calibration of level and temperature devices
+ Overall uncertainty of the calibration procedures.

2.7 CARGO TANK CAPACITY (CALIBRATION) TABLES

All vessels in Exxon Chemical service are required to carry a Cargo Tank Capacity Table tabulated to permit volumes in litres to be determined for every 3mm of the reference height of each tank.

In addition to the standard corrections for trim and heel/list, all tables shall carry tank shrinkage and expansion factors from the reference temperature of 15°C.

2.8 LEVEL GAUGE CALIBRATION

All level devices used for gauging shall have a scale resolution of 1 mm. Those gauges that have a resolution of 5 mm or higher must be replaced as soon as possible if the integrity of custody measurement is to be maintained.

Both remote and local gauges shall be calibrated to within +/ - 3 mm using manual reference method or by any alternate method with traceability. (ref: HMP 2.2.6)

Such calibration shall be undertaken at every intermediate class survey/dry dock operation or at least once every three years which ever comes first.

Both reference height and zero gauge height shall be verified once every 3 months to within + / - 5 mm. This includes full reference height and the height at the closed block valve. The zero gauge height shall reflect the float depth at the bottom and clearly indicated in the capacity table.

2.9 TEMPERATURE PROBE CALIBRATION

Each temperature probe shall be calibrated using liquid bath as close to the operating conditions as possible and at standard conditions (15, 20°C) every intermediate class survey/dry dock or at least once every three years whichever comes first.

The temperature probes shall be calibrated to within + / - 0.1°C. No correction factors table shall be developed for systems that cannot be calibrated to within 0.1°C. Those that cannot be calibrated shall be replaced.

On site pseudo electronic verification shall be undertaken once every quarter to within + / -0.5°C. If this limit is exceeded in any specific probe, use of that probe shall be discontinued till it is replaced.

All devices shall be capable of reading to within + / - 0.1°C.

2.10 PRESSURE SENSOR/PROBE CALIBRATION

Each pressure sensor/gauge shall be calibrated to +/- 0.01 bar accuracy using bench tests every intermediate class survey/dry dock or at least once every three years whichever comes first. This shall be veryfied every 3 months.

2.11 WITHDRAWAL FROM SERVICE - OUT OF SERVICE REPAIRS

Failure of all liquid temperature probes in any single tank would call for the vessel to be withdrawn from service for repair and re-calibration as soon as possible. Meanwhile the adjoining tank temperature shall be used for custody calculations, providing that homogenous cargo is carried in both tanks..

Failure or breakdown of level device in any tank would call for immediate repair or the vessel to be withdrawn from service for repair as soon as possible.

Failure of pressure gauges do not require vessels to be withdrawn from service as long as the pressure gauges / transmitters can be replaced on deck with a calibrated unit.

In the absence of any failures, a survey frequency of at least once every three years shall be required in order to prove the calibration/re-calibration of the instrumentation.

SECTION III - MEASUREMENT PROCESS

3.1 AT THE LOADING TERMINAL

Follow all the steps noted in Check List No.1 (APPENDIX III). These address all activities prior to loading, particularly the determination of OBQ, measurement activities after loading and the calculation process. Sampling is addressed separately in Section VII.

3.2 AT SEA

For all refrigerated and semi-pressurised gas carriers it is necessary to maintain strict control of cargo temperature and pressure throughout the loaded voyage. This is achieved by reliquefying cargo boil-off and returning it to the tanks. During these operations incondensibles must be vented as necessary to minimise compressor discharge pressures and temperatures.

Frequently, there are occasions when it is required to reduce the temperature of a liquefied gas cargo on voyage. This is necessary so that the ship can arrive at the discharge port with the cargo temperature below that of the shore tanks, thus minimising the amount of 'flash gas'.

Throughout the loaded voyage regular checks should be made to ensure there are no defects in cargo equipment and no leaks in the nitrogen or air supply lines.

3.3 AT THE UNLOADING/RECEIVING TERMINAL

Follow all the steps noted in Check List No.2 (APPENDIX IV). These address all measurement activities prior to unloading/discharge and the calculation process, and activities after discharge, particularly the determination of ROB. Sampling is addressed separately in Section VII.

3.4 LEVEL MEASUREMENTS

The reading of the "sounding height" (liquid level) from the liquid level gauge,to a resolution of +/- 1 mm, for each tank is entered into the tank capacity/calibration table, and the corresponding volume in litres, interpolating where necessary, is extracted. This may be either an 'Ullage' or an 'Innage', dependant upon how the tables have been formatted.

The remote digital read out in the cargo control room shall be used in preference to the local gauge on the deck for each tank. [Providing that the local/remote difference is within the tolerance limits of +/- 3mm]

Level readings shall be taken with the tank isolated from the cooling system.

Level gauge swings, due the movement of the vessel, shall be within + / - 5 mm at the time of measurement.

3.5 TEMPERATURE MEASUREMENTS

At the same time as ullages are being taken, determine the cargo temperatures in each tank. Report the reading from each individual temperature sensor. An overall average ship temperature must never be used.

The remote digital read out in the cargo control room shall be used in preference to the local gauge on the deck for each tank. [Providing that the local/remote difference is within the tolerance limits of +/- 0.5°C.]

The custody temperatures shall agree within + / - 1°C (for ethylene) for liquid. The middle probe shall be within 1°C of the equilibrium temperature derived from the vapour pressure/temperature relationship (assuming full tank).
The temperatures shall not be used if they fall outside this criteria and shall not be included for averaging.

For other pure chemical gases, such calibration is presently set at +/- 2°C.

OBQ and ROB shall be based on the following:

++ Use only the top two or three temperature sensors for vapour and not the bottom temperature sensor.

All temperature sensors within the tank shall be located as close to the gauging location as possible.

3.6 PRESSURE MEASUREMENTS

All devices shall be capable of reading up to 0.01 bar and the measurements shall be based on the cargo control room display and local devices shall be used for back up only.

3.7 TRIM and HEEL(LIST) MEASUREMENTS

Immediately before, or after measurement of the cargo the draught of the vessel, forward, aft and amidships port and starboard will be read and the trim and heel(list) calculated.

Cargo Tank capacity tables are calibrated with the ship/barge on even keel and upright. When not on even keel the vessel is said to be trimmed. When not upright the vessel has a heel(list).

The trim of the ship/barge is the arithmetical difference between the draught forward and the draught aft. The heel(list) of the ship/barge is the arithmetical difference in metres between the draught readings (port & starboard) amidships, divided by two, or can be expressed in degrees as read at the ship clinometer.

NOTE:- The majority of corrections applied to volume and density are temperature related.
It is therefore of the utmost importance to ensure that temperature observations are accurate in both liquid and vapour phases.
Similarly the correction for list and trim are sizeable and must be accurately applied.

SECTION IV - CARGO CALCULATION PROCEDURES

4.1 GENERAL

Calculation procedures to arrive finally at the weight-in-vacuum of cargo delivered or received vary in detail both on shipboard and on shore and it is not possible or useful here to deal with any variation. The purpose of this guideline is to provide a proposed standard to be used for shipboard calculations.
There is no internationally agreed standard but all calculation procedures should meet the following basic requirements:

a) Account must be taken of product in board before loading (OBQ) or left on board after discharge (ROB).

b) Account must be taken of the vapour quantity in all calculations. In determining the contribution of the vapour quantity to the weight-in-vacuum of the total product quantified, the vapour is converted to a liquid equivalent

c) Where direct weighing is not possible, the mass of liquid or vapour is determined essentially by multiplying the volume (Vt), at a stated temperature (t), by the density (Dt) at the same temperature.
If volume and density are not physically measured or calculated at the same temperature, one or the other, or both, of these must be converted to the same temperature before multiplication.

4.2 DOCUMENTATION

The measured values (level, temperature, pressure, trim) shall be reported as measured without any adjustments as part of the custody raw data per suggested format presented (Appendix III).

All corrections for gauge tape, float, trim, list shall also be reported as part of the custody report.

Documented records will be maintained on board vessels of all calibration of tanks, level gauging, temperature and pressure measuring equipment used on the vessel.

4.3 CALCULATION METHODOLOGY

Custody report based on the following and other standard computations shall be reported in the format presented (Appendix III).

Tank shell expansion and contraction factor shall be applied in all cases when the liquid temperature varies by more than 5C from the reference temperature.

The average tank shell temperature, Ts, for such a correction shall be based on a weighted average of liquid and vapour volumes and temperatures (Appendix III). For a tank 98 % full, use of liquid temperature would be sufficient.

$$Ts = \frac{VL \times TL + Vv \times Tv}{Vt}$$

VL, TL = liquid vol., temp.
Vv, Tv = vapour vol. temp.
Vt = total tank volume

Liquid Mass shall be computed using density tables from API MPMS Chapter 11, Table E, or pure product tables as defined by the supplier and agreed to by both parties.

$M_L = V'_L x\ P_L$	V'_L	=	liquid volume at temp. corrected for shrinkage
	P_L	=	liquid density from tables

Vapour mass shall be computed using natural gas laws assuming a compressibility factor of one for all vapours and for both loading and unloading operations as indicated below. The MW for vapour shall be based on the data provided by the supplier.

	MW	=	molecular weight
$M_v = V'v \times v$	V'v	=	vapour volume corrected for shrinkage/expansion
	v	=	density of vapour Kg/m3 at15°C
	t	=	average vapour temp.

$$\rho v = \frac{288.15}{273+t(°C)} \times \frac{1.013 + P(bars)}{1.013} \times \frac{Mw}{23.55}$$

NOTE:- *Always use this formula for vapour calculations and not the equilibrium tables. Assume compressibility factor of 1 all the time.*

All computations shall be undertaken at standard condition of 15°C and total custody mass shall be reported in vacuum for all chemicals and all transfers.

Bill of Lading quantity based on vessels and barges shall comply with commercial contract specifications as agreed to by both parties :

\+ Net quantity as defined below shall also be reported at the discharge port :

Net Quantity $= (M_v + M_L)_{LP} - (M_v + M_L)_{DP}$ LP = loading port
DP = discharge port

NOTE:- *The vapour remaining on board after discharge shall be reported as physical loss if the vessel is scheduled for purging operations or directed to a third party terminal.*

4.4 UNITS OF MEASUREMENT

Whilst measurement and calculation have been described in terms of metric units it is quite possible to find ships with tables necessitating the use of Imperial units. The basic calculations remain the same, but the user must take care to see that all data conforms to the same system i.e. temperatures in °F, Relative Density at 60°/60°F, volumes in ft^3 and weight in tons.

Equally, in some countries cargo stems are made in U.S. barrels and densities may be quoted at +20°C.

Whatever the units used by a terminal, and especially where these differ from those in use on the ship or at the receiver's terminal, one thing is certain:

- *failure to understand the proper definition of the units employed,*

- *failure to ensure that units are properly defined on documentation,*

will result in failure to correctly calculate the cargo quantity on board and confusion between seller, shipper and buyer.

This frequently leads to cargo claims and loss of freight for no real reason, other than failure to present accurate documentation. It cannot be stressed sufficiently that a clear understanding must exist between buyer and seller regarding the units of measurement employed and these documented in the purchase contract.

4.5 CALCULATIONS FOR SIMILAR CARGOES

Pressurised LPG is measured exactly in the same way as described for refrigerated products. In calculating liquid quantities, corrections for low temperature effect are not needed but corrections for trim, heel and density must be applied and volume modified for the difference between calibration and carriage temperature. Using the molecular weight to determine the liquid equivalent of vapour, allowances are made for pressure and temperature in the formula.

4.6 QUANTITY RECONCILIATION

Ship/shore reconciliation is a function of both ship and shore measurements. Ideally in the absence of any physical losses, the ship/shore or shore/ship or ship/ship differences shall be nil but can always be expected to fluctuate between certain limits referred to as the reconciliation limits or control band depending upon the type and variability of the measurements involved.

Assuming that full cargoes are being transported.

The factors that impact such reconciliation are:-

1. Shore measurements

- PD/turbine meters, tank gauging, orifice metering
- Displacements in and out of tanks
- Level, temperature calibration
- Flow rate thru meters
- Calibration of tanks, frequency, method used
- Line packing

2. Ship measurements

- Method and frequency of calibration
- Level, temperature calibration
- Trim/heel corrections impact
- Capacity of vessel

Based on the above parameters, the individual uncertainty of the ship and the shore can be established. An example of such analysis is presented in Section 1.10 for current systems and also best achievable if recommendations are fully implemented.

Based on survey evaluations, vessels can be expected to have an overall best precision of +/- 0.25 % that includes the uncertainty of calibration as well (Section 1.10). This is comparable to a shore based system.

As far as ship/shore reconciliation limits, these can only be developed after evaluation of shore measurements. Using a general unsupported criteria of +/- 0.5 % between ship/shore without regard to the type of measurement system and other parameters outlined would be erroneous. Each ship/shore comparison will have its own control limits and may not be generalised. To have one single criteria one would need to have same/similar shore system and this is impractical.

It needs to be recognised that part cargoes will always present reconciliation difficulties as the determination of the vapour quantity and liquid level can be inherently inaccurate.

We can expect intransit ship/shore loss to be around +/- 0.35 % for full cargo reconciliation systems (best practical). However, if it exceeds the contractual 'loss allowance', then a claim should be initiated using the appropriate procedures.

SECTION V - SAMPLING

5.1 GENERAL

Samples of bulk liquefied gases are used for determining the physical and chemical characteristics of the product.

The precautions required to ensure that a truly representative sample is taken are manifold. They depend on the type of cargo being sampled, the tank and its sample drawing fittings, the type of cleanliness of the sample container, the sampling container being used and the sampling procedure adopted.

The basic principle of each procedure is to obtain a sample or a composite of several samples in such a manner and from such a location from the cargo tank that the sample will be truly representative of the cargo liquid.

Many hours of work and expenditure may be incurred to complete the various tests required and all this could be rendered totally useless, if the sample has become contaminated due to incorrect sampling procedure.

From the above it can be easily appreciated that the sampling procedure to be followed to obtain a representative sample may be considered as an extremely important factor both on safety and commercial grounds in the overall operation of handling and transferring liquefied gases.
Sampling is a procedure requiring professional skill, experience and the correct equipment in sampling drawing and laboratory analysis.

5.2 SAMPLING EQUIPMENT AND PROCEDURES

5.2.1 Shipboard equipment

Cargo tanks on liquefied gas carriers are fitted with at least three independent sampling lines,
- line extended from external sampling point to the bottom of the cargo tank
- line extended from external sampling point to the middle height of the cargo tank
- line extended from external sampling point to the top (about 98% of total tank height) of the tank

Sampling points on the tank dome present a stainless steel connection for the sample container.

5.2.2 Shore equipment

As indicated two types of samples can be taken to analyse liquefied gas cargo.

i) a sample of the vapour phase (cargo or cargo tank atmosphere)

ii) a sample of the liquefied gas

5.2.3 Sampling procedures:-

To take samples, the method described in ISO/DIS 257, or equivalent, is recommended.

The method of sampling and equipment to be used may vary according to the cargo to be sampled and the pressure and temperature at which such cargo is carried.

APPENDIX I

LIQUEFIED GAS CARRIERS

All gas carrier cargoes are transported in liquid form and in view of their well known physical properties they are either carried at pressure greater than atmospheric or at temperatures below ambient or a combination of both.
Consequently gas carriers are built and operate to comply with the conditions under which the cargo is carried. Ship's may be categorised by the following types:

i) **Fully pressurised**:-
Cargo at ambient temperature, maximum pressure 17.5 bar (vapour pressure of propane at 45°C).
Cargo containment system is of ordinary grade steel of cylindrical (bullet) shape. No insulation is required. No reliquefaction plant is installed. Vapour return line is mandatory to prevent escape of cargo boil off from vents.
Average maximum size is around 2000 cubic metres.

ii) **Semi-pressurized - Semi refrigerated**:-
Cargo refrigerated to -10°C, pressure 8.5 bar.
Cargo containment system is of cylindrical shape. Insulation is required. Reliquefaction plant is installed as well as heating system for the cargoes. Average maximum size is 5000 cubic metres. It would appear that ships of this type are no longer built.

iii) **Semi-pressurized - Fully refrigerated**:-
They range now up to 30,000 cubic metres. Minimum temperature - 48°C. Pressure from 5 to 7 bars. Insulation is required. Reliquefaction system " Cascade Type" is installed. Cargo containment system is cylindrical or spherical.

The " Ethylene Carrier" belongs to this group of ships which can carry this particular product at temperatures of -103°C, pressure as above.

iv) **Fully refrigerated**:-
The cargo containment system is designed for a maximum working pressure of about 0.28 bar and a minimum working temperature of -50°C.
They are fully insulated and fitted with "Cascade Type" reliquefaction plant.

v) **Fully insulated ships**:-
Maximum working pressures 0.28 bar and a minimum working temperature of -162°C (LNG Carriers).
They are not fitted with reliquefaction plants and are fully insulated.
The boil off is either vented or burned in the ship's boilers. Studies are in progress to install on these ship's a reliquefaction plant, which is more complex than those installed on fully refrigerated ships due to the physical properties of L.N.G.

These ships are built to the highest degree of technology and sophistication, as required by the "Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk" developed by IMO in 1976 as a recommended document and the IMO " International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk" which became mandatory on the 1 July 1986.

APPENDIX II

CUSTODY REPORT FORMAT

Note : mass in vac. at 15°C for all

1. Raw data required (see Check Lists in APPENDICES IV;V;VI):
   - Level
   - Temperatures (by tanks) and (by each probe)
   - Reference height
   - Trim
   - Pressure
   - Total tank volume Vt

2. Corrections (all to 15°C)
   - Trim correction
   - Gage tape correction
   - Float correction

3. Corrected level/corresponding volume = V_L

4. Shell temperature = $\frac{V_L \times T_L + V_V \times T_V}{V_t} = T_s$

5. Shrinkage factor at Ts =

6. Volume total (Vt) corrected for shrinkage =

7. Volume liquid (V_L) corrected for shrinkage =

8. Volume (vapor) = $V_t - V_L$

9. Av. liquid temp. = (T1 + T2 + T3)/3 (if Tmax-Tmin < 1°C/2°C, dependent on product)

10. Av. vapor temp = (T1 + T2)/2 (do not use bottom temp. for vapour at anytime)

11. Compute liquid mass = M_L (use density tables)

12. Compute vapour mass := Mv (use gas laws Z = 1)

13. Total mass = $M_L + M_V$

14. **MEASUREMENT REPORT PROFORMA (APPENDIX II)**

LIQUEFIED GAS CARRIERS
CARGO QUANTITY - MEASUREMENTS & CALCULATIONS

PORT________________TERMINAL/BERTH________________DATE________________

SHIP________________OWNER/OPERATOR________________OPERATION: LOADING/DISCHARGE(i)

DRAUGHT: FWD=________AFT=________M=________TRIM=________m by Stern/Bow. LIST________Deg.PT/STB(i)

CARGO CHARACTERISTICS:________________DENSITY:________________AT 15 C MOL. MASS OF VAPOUR:________

ON BOARD BEFORE LOADING / CARGO LOADING / ON BOARD BEFORE DISCHARGE / ON BOARD AFTER DISCHARGE (i)

SHIP TANK	GAUGE READING	P (Abs)	T (LIQUID)	T (VAP)	EXP/CONT LEVEL	VARIAT GAUGE	CORR SOUND	LIQUID						VAPOUR				
No.					GAUGE	IMMERS		CARGO VOLUME at 20C	EXT/ONT FACTOR OF TANK	CARGO VOL at OBS	VOL CONVER FACTOR	VOL at 15C	WT MT (A)	VOL at 20C	EXP/CONT FACTOR of TANK	FACTOR VAPOUR to LIQUID at 15	VOLUME as LIQUID at 15C	WT MT (S)
1																		
2																		
3																		
4																		
5																		
6																		
TOTAL																		

DENSITY (AIR CORRECTED________________AT15C
TRIM CORRECTION ________________

TOTAL WEIGHT LIQUID (A) __________M.TONNE
TOTAL WEIGHT VAPOUR (B) __________M.TONNE

TOTAL CARGO ON BOARD__________M.TONNE

(i) Delete as appropriate

(i) ARRIVAL LOADING PORT / DEPART DISCHARGE PORT CARGO ON BOARD __________M.TONNE

(i) LOADED / DISCHARGED __________M.TONNE

________________ MASTER/CHIEF OFFICER

________________ TERMINAL REPRESENTATIVE

________________ INDEDEPENDENT INSPECTOR

APPENDIX III

Check List No.1 - Cargo Loading Operation

LIQUEFIED GASES
CARGO MEASUREMENT AND CALCULATIONS

Note: Use " Cargo Quantity - Measurement and Calculation" form APPENDIX II

CARGO LOADING OPERATION

A: Before loading commences:-

A1. Take ship draught for'd and aft - calculate trim. ☐
A2. Read list of ship (clinometer) and note it. ☐
A3 Has any cargo been left on board for the purpose of cooling tanks and systems?. ☐
A4. In which cargo tank (s)?. ☐
A5. Are all cargo tanks under cargo vapour atmosphere?. ☐
A6. Read level gauge of cargo tank(s) containing liquid and note. ☐
A7. Read pressure in each cargo tank and note. ☐
A8. Read temperatures of liquid and vapour and note. ☐
A9. Proceed to calculate liquids and vapours as per Sec. C. ☐
A10. Check that a thermometer is placed at the cargo manifold to which cargo transfer equipment is connected. ☐
A11. Check that a pressure gauge is placed at the cargo manifold to which cargo transfer equipment is connected. ☐

B: After loading is completed.

B1. Make sure that all operations have been completed and all cargo valves, including cargo manifold, are secured. ☐
B2. Take ship draught fwd. and aft. Calculate trim. ☐
B3. Read list of ship (clinometer) and note. ☐
B4. Read level gauge at each cargo tank and note. ☐
B5. Read pressure of each cargo tank and note. ☐
B6. Read temperature of liquid phase in each cargo tank and note. ☐
B7. Read temperature of vapour phase in each cargo tank and note. ☐
B8. Obtain from loading terminal density of liquid at 15°C. ☐

Note: All data from item 2 to item 8 to be entered in the "Cargo Measurement and Calculations" form in APPENDIX II

APPENDIX III

C: Cargo Calculations

Note:

1. Tank Calibration Certificate to be available and sighted. Check when issued and approved by Competent Authority.
2. Ship calibration tables to be available. Check they are approved by Competent Authority.
3. Note tables used for cargo calculations.

C1. Calculate trim (Draught Aft - Draught Fwd = Trim.)

C2. From calibration tables:

C i) Obtain value of trim correction.
C ii) Obtain value of list (or heel) correction.
C iii) Obtain value of expansion/contraction of level gauge. (Generally applicable only to float gauge).
C iv) Obtain variation of float immersion (function of density of cargo).
C v) Calculate correct sounding of cargo.
C vi) Enter correct sounding in calibration tables and note cargo volume in m^3. This will be the volume of cargo at 15°C.
C vii) Obtain and note correction factor of expansion / contraction of tank shell, as function of temperatures of liquid and vapour.

C3. Proceed first with liquid calculation.

C a) Multiply volume at 15°C by expansion / contraction of tank factor (Cvii). Volume of liquid at observed temperature will be obtained.
C b) Obtain from Cargo Calculation Tables in use (API, IP, ASTM, ANSI, JIS, Company, etc) the volume conversion factor as a function of density and liquid temperature and multiply by C a), volume at 15°C will be obtained.

C4. Calculation of Vapours:

C e) From calibration tables obtain 100% capacity (at 15°C).
C f) Subtract from e) the cargo volume at 15°C (C vi).
C g) Multiply Cvii) (Vapour) by C f) to obtain volume of vapour at observed temperature.
C n) From tables (b) above) called "factor of vapour to liquid " obtain correction factor to reduce vapour <u>as liquid</u> at 15°C.
C i) Multiply C h) by C g) to obtain volume of vapour <u>as liquid</u> at 15°C.

C5. Add the weight of liquid C d) to the weight of vapour C j) to have total cargo on board.

C6. Subtract from the total as per C5, the cargo quantity on board on arrival (A9) to obtain the actual amount of cargo loaded. (NB: BOL Quantity)

APPENDIX IV

LIQUEFIED GASES
CARGO MEASUREMENTS AND CALCULATIONS

CHECK LIST No. 2

Note: Use " Cargo Quantity - Measurement and Calculation " form APPENDIX II.

CARGO DISCHARGE OPERATIONS

A:) Before Discharge Starts

A1. Take ship draught fwd and aft. Calculate trim. ☐
A2. Read list of ship (clinometer) and note it. ☐
A3. Read level gauge at each cargo tank and note. ☐
A4. Read pressure of each cargo tank and note. ☐
A5. Read temperature of liquid phase in each cargo tank and note. ☐
A6. Read temperature of vapour phase in each cargo tank and note. ☐
A7. Note cargo density at 15°C used at loading port for cargo calculation. ☐
A8. Check that a thermometer is placed at the cargo manifold to which cargo transfer equipment is connected. ☐
A9. Check that a pressure gauge is placed at the cargo manifold to which cargo transfer equipment is connected. ☐
A10. Proceed to calculate cargo as per B) below. ☐

B: Cargo Calculations

B1. Calculate trim (draught aft - draught fwd = trim.)
B2. From calibration tables:

B i) Obtain value of trim correction. ☐
B ii) Obtain value of list (or heel) correction. ☐
B iii) Obtain value of expansion/contraction of level gauge. (Generally applicable only to float gauge). ☐
B iv) Obtain variation of float immersion (function of density of cargo). ☐
B v) Calculate correct sounding of cargo. ☐
B vi) Enter correct sounding in calibration tables and note cargo volume in m^3. This will be the volume of cargo at 15°C. ☐
Bvii) Obtain and note correction factor of expansion/contraction of tank shell, as function of temperatures of liquid and vapour. ☐

APPENDIX IV

B3. Proceed first with liquid calculation

B a) Multiply volume at 15°C by expansion/contraction of tank factor (Cvii). Volume of liquid at observed temperature will be obtained.
B b) JIS, Company, etc.) the volume conversion factor as function of density and liquid temperature and multiply by B a) volume at 15°C will be obtained.

B4. Calculation of Vapours

B e) From calibration tables obtain 100% capacity (at 15°C).
B f) Subtract from e) the cargo volume at 20°C (Cvi).
B g) Multiply Cvii) (Vapour) by C f) to obtain volume of vapour at observed temperature.
B n) From tables (b) above) called "factor of vapour to liquid" obtain correction factor to reduce vapour <u>as liquid</u> at 15°C.
B i) Multiply B h) by B g) to obtain volume of vapour <u>as liquid</u> at 15°C.
B j) Multiply density of liquid at 15°C (air-corrected) by B i) here above to obtain weight of vapour in metric tonnes.

B5. Add the weight of the liquid B d) to the weight of vapour B j) to have total cargo on board.

B6. Compare cargo quantity figures obtained, with those accepted at the loading port. Calculate difference if any.

C: Cargo on board after discharge completed

C1. Take ship draught fwd and aft - Calculate trim.
C2. Read list of ship (clinometer) and note.
C3. Read level gauge of cargo tank(s) and note.
C4. Read pressure in each cargo tank and note.
C5. Read temperature of liquid in tank(s) containing cargo and note.
C6. Read temperature of vapour in each cargo tank and note.
C7. Proceed to calculate liquid and vapour as per B) above.
C8. Subtract C7. from A10. The difference will give the quantity of cargo discharged ashore.

APPENDIX V

Check List No.3 - Calibration verification

LIQUEFIED GASES
CARGO MEASUREMENTS AND CALCULATIONS

INSTRUMENTATION

1. LIQUID LEVEL GAUGE TYPE_________LAST CHECK_______BY______
2. PRESSURE GAUGE TYPE_________LAST CHECK_______BY______
3. TEMPERATURE IND. DEVICE TYPE_________LAST CHECK_______BY______
4. THERMOMETER (MANIFOLD) LAST CHECK_______BY______
5. PRESSURE GAUGE (MANIFOLD) LAST CHECK_______BY______
6. SHIP IS PROVIDED WITH STANDARD THERMOMETER____________________
7. SHIP IS PROVIDED WITH STANDARD PRESSURE GAUGE ____________________
8. INSTRUMENTS ARE CHECKED AT REGULAR INTERVALS____________________
   (AT LEAST EVERY THREE MONTHS)
9. CHECKS ARE REGULARLY RECORDED ______________________________

CARGO TANK CALIBRATION & TABLES

10. SHIP CALIBRATION TABLES ARE APPROVED BY:- ______________
11 CERTIFICATE OF CARGO TANK CALIBRATION ISSUED BY:- ______________
12 CERTIFICATE OF CARGO TANK CALIBRATION DATE:- ______________
13 DATE OF ANY RECALIBRATION ______________
14 REFERENCE STANDARD USED FOR CALIBRATION:- ______________
15 REFERENCE TEMPERATURE USED:- ______°C/______°F
16 REFERENCE GAUGE HEIGHT INDICATED:-(Drawing?) ______________
17 ZERO GAUGE HEIGHT INDICATED:- ______________
18 ZERO GAUGE VOLUME INDICATED:- ______________
19 LOCATION OF TEMPERATURE DEVICES INDICATED:- ______________
20 ORIGINAL CERTIFICATES OF CALIBRATION OF LEVEL & TEMPERATURE DEVICES ATTACHED:- ______________
21 OVERALL UNCERTAINTY (Accuracy) OF THE CALIBRATION PROCESS +/- ________%_____

22 CONVERSION TABLES USED ______________
(SAME TABLES TO BE USED AT BOTH LOADING AND DISCHARGING PORT

APPENDIX VI

VAPOUR DENSITY CALCULATION/METHODOLOGY

For perfect gases, the density is calculated by means of the perfect gas law.

The vapour density is given by:-

$$\rho = \frac{288.15}{273.15 + t(\,^\circ C\,)} \times \frac{1.01325 + p(bar)}{1.01325} \times \frac{M}{23.6451}$$

where,

ρ	: density of a gas (kg/m3)
23.6451 m3/mole	: molar volume of a perfect gas at 15 C and 1 atm.
p(bar)	: relative pressure (bar)
t (°C)	: temperature in degrees Celsius
M	: molar mass (g/mole)

APPENDIX VII

Density Variations

1. Location of ideal sampling point must be established.
2. This involves sampling at shore tank, line, ship tanks and analysed for density.
3. Each sample analysed independently.
4. Analysis by GC/hydrometer.
5. Variability analysed and optimum procedure chosen.
6. If necessary ship composite samples may have to be prepared.
7. Criteria for max. allowable variations may have to be established. A variation of +/- 0.005 to 0.01 in 0.5 gravity be considered as a starting point for analysis.

GLOSSARY OF TERMS

Accuracy The degree to which measurement by a field instrument compares with measurement by a laboratory instrument or other standard reference equipment.

The instrument accuracy's quoted in this document represent an allowable tolerance limit for single readings by a specific device. These tolerances (+ and -) are the maximum ranges of error for recording the product movement.

Calibration of a measuring instrument: Adjusting the equipment to most closely determine the "true" or "actual" quantity being measured, or providing a correction factor or correction curve for the instrument readout.

Critical tanks All tanks used in custody transfer service or any tank which could have a significant product loss.

Custody Transfer

- All Purchases, Sales and Exchanges involving third parties, or separate Exxon affiliated companies.
- Transfers using third party transportation, i.e. where a third party has temporary control over Exxon products.
- Transfers between business functions within an affiliate when there are legal, tax or significant product loss considerations.

Dead-end The variance between the reading of an operating measuring device (e.g. meter) and a reference device (e.g. prover) which is so small that there is no need for recalibration. The dead-end is smaller than the tolerance range. Deadbands are expressed as both + and - around the datum line.

Precision Mechanical or scientific exactness

Proving of a measuring device: Comparing and quantifying the performance of a field instrument versus a known/certified reference device and then recalibrating the field instrument back to the standard value if necessary. Recommendations for proving frequencies are listed in TABLE 3 of Section 2.

Tolerance The range of acceptable accuracy for measuring instrument. Tolerances for acceptable measuring methods are shown in TABLE 3 of Section 2. Tolerances are both + and - around the datum.

Uncertainty Refers to the difference between measurement by a field instrument and the "true" or "actual" quantity being measured.