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GAS TANKER OPERATING MANUAL

VMS/GAS/01

COPY NO.__________

NOTES

1. This Manual is valid from the issue date.
2. This Manual is to be used only on V Ships managed vessels.
3. This Manual is not to be marked up.
4. Review of this Manual or any suggested alteration is to be referred to the appropriate management office.
5. Further revisions of this Manual will be recorded on the Revision Sheet (Page 2).

MANAGING DIRECTOR	DIVISIONAL DIRECTOR GROUP RISK, SAFETY & QUALITY

REVISION SHEET

1. When it becomes necessary to revise this manual revision will be made by the issue of the new relevant section.

2. These revised pages will bear a new revision number that must be entered on this revision sheet and initialled by the Master or responsible manager after insertion into this book

Document Number	Section	Revision Number	Date Inserted	Manager's or Master's Initials

Contents

1. GENERAL

1.1 DEFINITIONS

V Ships

- VMS - V Ships Management System
- V Ships - Refers to the group of V Ships Companies.
- Client - The Company or individual to whom V Ships is providing a service (i.e. the Purchaser of the Service).
- "The Company" - Refers to V Ships.
- "The Group" - Refers to the group of V Ships Division i.e
  Ship Management Division
  Leisure Division
  Commercial Division
- Management Office - Refers to the company office which manages the relevant vessel.
- Crew Manning Office - Refers to the Company office which supplies the shipstaff to the relevant management office for the managed vessel.
- Manual - A compilation of VMS procedures, instructions and information within an V Ships identified Binder.
- Vendor/Supplier - A Company or individual who is supplying Subcontractor material or a service to V Ships.

Auditing

- Audit - A method of checking that procedures (as written down) are being followed, and that any amendments required have been carried out to maintain a quality service.
- Controlled Copy - A copy of the manual or procedures which will be issued for working to, and will be updated with all the modifications, corrective actions and revisions of the procedure.

- Corrective Action - Actions taken to correct non-compliances.
- DTF - Document Transmittal Form.
- Non-compliance - A deviation from a procedure i.e. a part of the procedure part of which is not being operated accordingly.

Classification Society

- DNV - Det Norske Veritas.

Standards

- DNV SEP - Det Norske Veritas Classification AS requirements for the Management of Safe Ship Operation and Pollution Prevention.
- IMO ISM - International Maritime Organisation. International Safety Management Code.
- ISO 9001:2000 - International Standards Organisation Standards for Quality Systems in a Service Industry.
- ISO 14001 International Standards Organisation environmental and emissions standard.

System

- He - The use of the term "he" is to be interpreted as meaning "he" or "she".
- "SEP" - Refers to Safety and Environmental Protection.
- S.O.P.E.P. - Shipboard Oil Pollution Emergency Plan.

1.2 INTRODUCTION

This Manual is issued in accordance with the Company's VMS and contains specific instructions etc. based on V Ships operating experience.

The subject matter was selected where the Company considered that emphasis had to be placed on the relevant operational procedures, precautions, instructions etc.

The following procedures are to be adhered to in order to achieve safe and effective Company Operating Standards. Adoptions of other unapproved procedures may lead to a breach of the Company's Instructions and could result in disciplinary action being taken against the individual.

This manual is controlled under the Company's VMS and will be revised as required. Copying of the relevant sections of this manual is permitted, for operational purposes, but all copies are to be considered as **"uncontrolled"** documents, and must be destroyed following use.

Revisions will be issued annually and the date of insertion of the revised section is to be recorded with the Manager or Master's initials. The pages of the section rendered obsolete, are to be immediately destroyed.

An updated CD Rom will be issued in conjunction with the abovementioned revision and is to be entered into the relevant on board computer on receipt. The obsolete CD Rom is to be immediately destroyed.

When referencing the VMS manuals, the Document and Revision numbers must always be used.

It is the Master's responsibility to ensure that any amendments received, are inserted within this manual and the appropriate electronic entries made. Any procedure which he considers cannot be adhered to, must be brought to the Company's attention.

This manual remains the property of the Company and in the event of the ship leaving the Company's Management, all copies of this manual and the relevant CD Rom are to be destroyed, unless instructions are received to the contrary.

1.3 DEPARTURE FROM THESE PROCEDURES

The first consideration of the Master and every Officer must be the safety of the lives on board and that of the ship, her cargo and the environment.

Where a deviation from the Company's Instructions/procedures is found to be necessary the Master will report this to the Company at the first opportunity.

1.4 VMS MANUALS

Reference is to be made to the following VMS system "core" manuals which are issued to all types of vessels:

♦	V Ships Management Manual	VMS/VMM/01
♦	Fleet Operating Manual	VMS/FOM/01
♦	Crew Manual	VMS/CRW/01
♦	Safety and Environmental Manual	VMS/SEM/01
♦	Ship Forms Manual	VMS/FMS/01

* The V Ships Management Manual is the umbrella manual of the VMS, and its purpose is to describe the structure by which the VMS is implemented and maintained. It relates to all the requirements of the applicable standards DNV SEP and the IMO ISM code and ISO 14001.

1.5 CHECKLISTS

The Company recognises the importance of operational checklists to assist the Master, Chief Engineer and all Officers in the routine operation of the ships concerned. The Operations checklists fully embrace the Company's Instructions, Procedures and Documentation for the safe technical operation of the vessel, the safety of the crew, the cargo and the environment. These checklists are to be used when required, and whenever completed, a log entry is to be made which must include the checklist number, description and completing officer's signature.

It is emphasised that the checklists are to assist the relevant Officer, and do not detract from his responsibility towards the safety of the vessel, her crew, her cargo and the environment.

1.6 REFERENCE PUBLICATIONS

The Company recognises the importance of certain reference publications and these are listed as appropriate. These publications are to be made available to all on board.

The recommendations of these publications are to be adopted as standard procedures, and are to be read in conjunction with this manual.

Each publication is to be given a Company Reference Number, and is to be kept in the recommended location.

Reference publications will be updated through the Company's Chart and Publication New Edition scheme. Superseded publications are to be removed and destroyed.

1.7 GAS TANKER CHECKLISTS

The Company recognises the importance of operational checklists to assist the Master and Officers in the routine operation of their ship. These check lists fully embrace the Company Operating Instructions, Procedures and Documentation.

The checklists are only to assist in the compliance with the Company's Instructions, Procedures and Documentation for the safe operation of the vessel, the safety of the crew, the cargo and the environment. Company Form Checklists are to be used when required and once completed a log entry is to be made i.e.:

The following Company Form Checklists are applicable to this manual

GAS 01 - Pre-arrival and commencement of cargo operations checklist
GAS 02 - Loading cargo checklist
GAS 03 - Discharging cargo checklist
GAS 04 - Changing non compatible cargoes checklist
GAS 05 Liquified Gases Calculation Sheet
GAS 06 Monitor Gas Carrier Equipment Report

It is emphasised that checklists are only to assist the Officer and does not detract from his responsibility towards the safety of the vessel, her crew, her cargo and the environment.
The above checklists are in addition to any other checklist required by the terminal.

2. RESPONSIBILITIES

2.1 GENERAL

In the operation of any vessel it is essential that good co-operation exists between all ranks on board. The Job Descriptions contained in the Crew Manual are to be expounded as follows:

2.2 MASTER

The Master is responsible for:

- Ensuring that the voyage orders are fully understood and complied with.
- Advising the Chief Engineer and Chief Officer of the relevant details of the intended voyage.
- Providing the Company and Charterers with accurate information regarding the cargo operations.
- Advising the Company when instructions cannot be complied with or he is unsure of the intended voyage instructions.
- Overall supervision of the operation of Cargo System.
- Checking and Verification of Cargo Plans prepared by the Chief Officer.
- Overall supervision of all Cargo and Ballast Operations onboard.
- Completion, checking and signing as applicable of Cargo Documents.
- Maintaining the expertise of all ships staff in the Gas Carrier Field.

2.3 CHIEF OFFICER

Under the supervision of the Master the Chief Officer is responsible for:

- Preparation of the Cargo Plan in compliance with the Voyage Orders.
- Checking of the Cargo System to ensure that the intended plan will be followed.
- Preparation of the ship's Cargo and Ballast Operations onboard and personal supervision of these operations.
- Operation and control of all Cargo Equipment.
- Producing his own written Standing Orders concerning the Cargo Operations which are to be well understood and signed by each Deck Officer.
- For Monitoring of the vessel's stress and stability throughout the Cargo and Ballast Operations and during the voyage to ensure that they remain within the required limits.

- Maintaining Cargo Records as required by the Company, Charterers and International Regulations.
- Calculation of the Cargo Quantity on board and preparation of Cargo Documentation as required.
- Checking of all compartments on a daily basis and recording the sounding in the Deck Log Book.
- For monitoring of Toxic Gases Vapours Concentration in ship's compartments as required.
- Maintaining the records required in conjunction with the Chief Engineer as required.
- Applying the Ballast Water Management Practices required and maintaining records.

2.4 SECOND OFFICER AND THIRD OFFICER

The Second and Third Officers are responsible to the Chief Officer for:

- Assisting in all Cargo, Ballast Systems preparation.
- Monitoring of Cargo and Ballast Operations as instructed by the Chief Officer.
- Ensuring that a proper Deck and Security Watch is maintained.
- Ensuring that the vessel remains securely moored at all times.

2.5 CHIEF ENGINEER

The Chief Engineer is responsible for the maintenance and repair of all the ship's Cargo and Ballast related equipment. He is to assist the Chief Officer in the operation of the ship's cargo equipment. He is to keep the Chief Officer advised of any bunker, lubricating oils or sludge transfers which may affect the ship's trim, stress and/or stability.

2.6 RATINGS

The Deck Ratings are responsible to the Deck Officers for maintaining a safe Deck Watch and ensuring that the vessel remains securely moored. They are to assist in Cargo Operations as required by the responsible officer.

3. INTRODUCTION TO GAS TANKERS

3.1 DEFINITIONS

The ICS publication "Tanker Safety Guide – Liquified Gas" is carried on board all managed gas tankers. This publication should be read in conjunction with this manual.

3.2 PHYSICAL PROPERTIES

The physical properties of a liquefied gas depend on its molecular structure. Some compounds have the same molecular formula but a different arrangement within the structure. These different compounds of the same basic substance are called ISOMERS for example N-BUTANE x ISO-BUTANE.

The single most important physical property of a liquefied gas is its saturated vapour pressure/temperature relationship. This property governs the design of the containment system suitable for each cargo.

3.3 SOURCES OF IGNITION

- Smoking

There are frequently local regulations about smoking which must be rigidly observed. Smoking may be permitted but only under controlled conditions at times and in places specified by the Master.

Personnel when working aboard the ship must not carry matches or more particularly lighters, and the risk of doing so is to be impressed on all, (see the Safety and Environmental Manual.

- Portable Electrical Equipment.

  Only approved Safety torches or hand lamps are to be used.

Portable Electric Equipment self contained or on extension cables are not to be used in a gas dangerous place or zone as specified in paragraph 2.1 and the IMO IGC code unless the equipment is intrinsically safe.

Portable domestic radios, electronic calculators, tape recorders and other non-approved battery equipment <u>are not to be used</u> in a gas dangerous place or zone.

- Communication Equipment.

When berthed the ships normal communication equipment is not to be used unless certified safe.

  Main radio transmitters are not to be used during cargo operations.
  This does not apply to permanently and correctly installed VHF equipment
  or Satellite communication systems

- Hot work, hammering, chipping and power tools

Before any hot work, hammering, chipping, or power tools including shot blasting are used the responsible officer is to examine the area to be worked and satisfy himself that such work can be safely undertaken and a hot work certificate Form SAF 04 issued.

Non - sparking tools are not to be used as they do not significantly reduce the risk of igniting a flammable vapour.

Aluminium paint is not to be smeared across steel. A heavy smear of aluminium on rusty, steel if struck can cause an incandescent spark.

- Ship to Shore Bonding

On some jetties this may be required but it is considered to be of minimal benefit. Cargo hoses and loading arms are to be fitted with an insulating flange to ensure discontinuity between ship and shore.

- Auto - Ignition

The vapours from flammable liquids including fuel and lubricating oil may ignite if the liquid comes into contact with any surface heated above the auto - ignition temperature e.g. steam lines, exhaust manifolds, over heated equipment.

Immediate steps are to be taken to rectify any leakage and to remove any soaked rags on other material including lagging.

- Static Electricity

Static Electricity can cause sparks capable of igniting a flammable gas.

The cargo system of a gas carrier is electrically bonded to the ships hull to prevent any build up of charges, bonding connections must be maintained in good order.

- Steam

A jet of steam may become charged in passing through a nozzle. Steam is not to be injected into a tank compartment or piping system which may contain a flammable mixture.

- Carbon Dioxide

Liquid Carbon Dioxide when released under pressure may form particles of solid carbon dioxide these may become electrostatically charged. For this reason it must not be released into tanks or spaces which contain flammable mixture.

3.4 PRINCIPLES OF REFRIGERATION

See Appendix I for the basic components in a simple refrigerator.

Cold liquid refrigerant (Liquid Gas Cargo) is evaporated in an evaporator coil (Cargo tank) which being cooler than its surroundings draws heat to provide the latent heat of vaporisation. The cool vapour is drawn off by a compressor which raises both the pressure and the temperature of the vapour and passes it to the condenser.

The pressure of the vapour having been increased the vapour now has a temperature of condensation greater than the temperature of the condenser cooling fluid (sea water).

The vapour is condensed to a high pressure liquid and the sensible heat of desuperheating the vapour together with the latent heat of condensation is removed via the condenser coolant which is warmed up in the process.

The high pressure liquid then passes through an expansion valve to the low pressure side of the cycle, in doing so flash evaporates to a mixture of cold liquid and vapour. The mixture passes to the evaporator (cargo tank) to continue the cycle.

3.5 CRITICAL TEMPERATURES & PRESSURES

The critical pressure of a gas is the pressure required to compress a gas to its liquid state at its critical temperature.

Critical Temperatures and pressures are listed in the table of Physical Properties (see Appendix I.

For the carriage or storage of ethane or ethylene as a liquid some additional refrigeration is required often in the form of a cascade system.

3.6 BASIC THERMODYNAMIC THEORY

Cargo and Deck Officers must be familiar with Basic Thermodynamic Theory. Section 13.4 and A3.5 of the Tanker Safety Guide, Liquified Gas deals with the most important points and these sections are to be read in conjunction with this manual.

3.7 FLAMMABILITY AND EXPLOSION

The three requirements for combustion to take place are fuel, oxygen and ignition.

The proportions of flammable vapour to Air must be within the flammable limits.

See Appendix 1 for the ignition/flammability properties of liquefied gas.

3.8 TYPES OF GAS CARRIERS

a. Fully pressurised ships

These ships are the simplest of all gas carriers in terms of containment systems and cargo-handling equipment and carry their cargoes at ambient temperature. Type C tanks - pressure vessels fabricated in carbon steel with a typical design pressure of 17.5 barg, corresponding to the vapour pressure of propane at 45°C, must be used. Ships with higher design pressures are in service: 18 barg is quite common - a few ships can accept up to 20 barg. No thermal insulation or reliquefaction plant is necessary and cargo can be discharged using either pumps or compressors.

Because of their design pressure tanks are extremely heavy. As a result, fully pressurised ships tend to be small with maximum cargo capabilities of about 4,000m^3 and they are used to carry primarily LPG and ammonia. Ballast is carried in double bottoms and in top wing tanks. Because these ships utilise Type C containment systems, no secondary barrier is required and the hold space may be ventilated with air, Appendix 1, shows a section through a typical fully pressurised ship.

b. Semi-refrigerated ships

These ships are similar to fully pressurised ships in that they incorporate Type C tanks - in this case pressure vessels designed typically for a maximum working pressure of 5.7 barg. The ship's range in size up to 7,500m^3 and are primarily used to carry LPG. Compared to fully pressurised ships, a reduction in tank thickness is possible due to the reduced pressure, but at the cost of the addition of a refrigeration plant and tank insulation. Tanks on these ships are constructed of steels capable of withstanding temperatures as low as -10°C. They can be cylindrical, conical, spherical or bi-lobe in shape.

c. Semi-pressurised/fully refrigerated ships

Constructed in the size range 1,500 to 30,000m^3, this type of gas carrier has evolved as the optimum means of transporting the wide variety of gases from LPG and VCM to propylene and butadiene.

Like the previous two types of ship, SP/FR gas tankers use Type C pressure vessel tanks and therefore do not require a secondary barrier

The tanks are made either from low temperature steels to provide for carriage of -48°C which is suitable for most LPG and chemical gas cargoes or from special alloys which allow the carriage of ethylene at -104°C (see also ethylene ships). The SP/FR ship's flexible cargo-handling system is designed to be able to load from, or discharge to, both pressurised and refrigerated storage facilities.

d. Fully refrigerated LPG ships

Fully refrigerated (FR) ships carry their cargoes at approximately atmospheric pressure and are generally designed to transport large quantities of LPG and ammonia. Four different cargo containment systems have been used in FR ships: independent tanks with double hull, independent tanks with single side shell but double bottom and hopper tanks, integral tanks and semi-membrane tanks, both these latter having a double hull. The most widely used arrangement is the independent tank with single side shell with the tank itself a Type A prismatic free-standing unit capable of withstanding a maximum working pressure of 0.7 barg (Appendix I). The tanks are constructed of low-temperature steels to permit carriage temperatures as low as -48°C. FR ships range in size from 10,000 to 100,000m^3.

A typical fully refrigerated LPG carrier would have up to six cargo tanks, each tank fitted with transverse wash plates, and a centre line longitudinal bulkhead to improve stability. The tanks are usually supported on wooden chocks and are keyed to the hull to allow expansion and contraction as well as prevent tank movement under static and dynamic loads. The tanks are also provided with anti-flotation chocks. Because of the low-temperature carriage conditions, thermal insulation and reliquefaction plant must be fitted.

The FR gas carrier is limited with respect to operational flexibility. However, cargo heaters and booster pumps are often used to allow discharge into pressurised storage facilities.

Where Type A tanks are fitted, a complete secondary barrier is required. The hold spaces must be inerted when carrying flammable cargoes. Ballast is carried in double bottoms and in top side tanks, or when fitted, side ballast tanks.

e. Ethylene ships

Ethylene ships tend to be built for specific trades and have capacities ranging from 1000 to 30,000m^3. This gas is normally carried fully refrigerated at its atmospheric pressure boiling point of -104°C. If type C pressure vessel tanks are used, no secondary barrier is required; Type B tanks require a partial secondary barrier; Type A tanks require a full secondary barrier and because of the cargo carriage temperature of -104°C the hull cannot be used as a secondary barrier, so in this case a separate secondary barrier must be fitted.

Thermal insulation and a high capacity reliquefaction plant is fitted on this type of vessel.

Many ethylene carriers can also carry LPG cargoes thus increasing their versatility. Ballast is carried in the double bottom and wing ballast tanks and a complete double hull is required for all cargoes carried below -55°C whether the tanks be of Type A, B or C.

3.9 COMMUNICATIONS

Reliable and effective communications between the ship and terminal are essential for safe and efficient cargo operations while the gas carrier is alongside.

3.10 CARGO INFORMATION

The IMO Codes require that the following information is available to every ship and for each cargo:

- a full description of the physical and chemical properties necessary for the safe containment of the cargo;
- action to be taken in the event of spills or leaks;
- counter-measures against accidental personal contact;
- fire-fighting procedures and fire-extinguishing agents;
- procedures for cargo transfer, gas-freeing, ballasting, tank cleaning and changing cargoes;
- special equipment needed for the safe handling of the particular cargo;
- minimum inner hull steel temperatures;
- emergency procedures;
- compatibility;
- details of the maximum filling limits allowed for each cargo that may be carried at each loading temperature, the maximum reference temperature, and the set pressure of each relief valve.

The Master is to request the correct technical name of the cargo to be loaded as soon as possible before loading. If the cargo is not adequately covered by a data sheet, he is to obtain sufficient additional information necessary for its safe carriage.

The Master and all those concerned are to use the data sheet and any other relevant information to acquaint themselves with the characteristics of each cargo to be loaded. If the cargo to be loaded is a mixture (e.g. LPG), information on the composition of the mixture is to be sought; the temperature and pressure readings in the shore tank can be used to verify this information.

If the information necessary for safe carriage is not available, loading is to be refused; loading must also be refused if a cargo has to be inhibited but no certificate is available.

Special note is to be made of any contaminants that may be present in the cargo, e.g. water.

3.11 GENERAL PRECAUTIONS AT LOADING/DISCHARGE BERTH

a. Moorings

The safe mooring of a vessel requires close co-operation between the ship and the shore. The principles of good mooring, including the dangers associated with mixed moorings, is to be understood by ships personnel. Particular attention must be given to the correct application of winch brakes as well as the maintenance of moorings, winch brakes and associated equipment.

Excessive loads in individual mooring ropes can lead to straining or even the eventual parting of a mooring rope or wire and are to be avoided.

The relevant publications listed in the Reference Publications Index are to be consulted for more comprehensive guidance on safe mooring.

b. Craft Alongside

Unauthorised craft are to be prohibited from securing alongside the ship.

No tugs or other self-propelled vessels are to be allowed alongside during operations which involve the venting of cargo vapours.

Regulations against smoking and naked lights are to be strictly enforced on any craft permitted alongside and on shore if applicable. Operations are to be stopped if these rules are violated and are not to be restarted until the situation has been made safe.

c. Dispersal of Vented Cargo Vapours

Any cargo vapour, whether toxic or flammable, is to be vented to atmosphere with extreme caution, taking account of regulations and weather conditions. In some cases venting may be prohibited.

If the vented vapour is at a temperature below atmospheric dewpoint, clouds of water vapour will form and these are heavier than air; the cargo vapour may or may not be heavier than air, depending on temperature. It is never to be assumed that the cargo vapour is contained entirely within the boundaries of the water vapour cloud. The cargo vapour cloud is likely to be oxygen-deficient and is only to be entered by personnel wearing breathing apparatus.

If the cargo vapour is heavier than air it may accumulate on deck and enter the accommodation. In some cases it may be possible to heat vapour before venting to reduce its vapour density and assist dispersion, if such facilities are provided they are to be used.

d. Openings in Deckhouses and Superstructures

Regulations require that superstructures are designed with certain portholes fixed shut and openings positioned to minimise the possibility of vapour entry. These design features are not be impaired in any way.

All doors, portholes and other openings (including all those in the poop front first tier) must be kept closed during cargo operations. Doors are to be clearly marked if they have to be kept closed, but in no circumstances are they to be locked. It is particularly important that air lock doors are opened one at a time only, opening both doors together will activate an alarm and cause shutdown of equipment.

Mechanical ventilation should be stopped and air conditioning units operated on closed cycle or stopped if there is any possibility of vapour being drawn into the accommodation.

3.12 WEATHER PRECAUTIONS

a. Wind Conditions

If there is little wind movement, vapour may persist on deck. When there is a wind it may, in crossing a deckhouse or structure, create a low pressure on the lee side thereby causing vapour to be carried towards the deckhouse or structure.

Either of these wind conditions may result in high local vapour concentrations and, if so, it may be necessary to stop cargo handling or gas-freeing while the conditions persist.

b. Electrical storms

Cargo operations involving the venting of flammable cargoes should be stopped during electrical storms in the immediate vicinity of the ship.

If a vent mast is struck by lightning during venting operations, ignition can occur. To extinguish the flame the source of fuel should be isolated and, if possible, inert gas should be injected into the vent mast. Venting should not be resumed until the temperature at the mast head has returned to normal.

3.13 ENGINE AND BOILER ROOM PRECAUTIONS

a. Combustion Equipment

Boiler tubes, uptakes, exhaust manifolds and combustion equipment are to be maintained in good condition as a precaution against funnel fires and sparks. In the event of a funnel fire, or if sparks are emitted from the funnel, cargo operations are to be stopped and, at sea, the course is to be altered as soon as possible to prevent sparks falling onto the tank deck.

b. Blowing Boiler Tubes

Funnel uptakes and boiler tubes are not to be blown in port. At sea they are only to be blown in conditions where soot will be blown clear of the tank deck.

c. Flammable Liquids

Flammable liquids or other volatile liquids for cleaning or other purposes are to be kept in closed, unbreakable and correctly labelled containers in a suitable compartment when not in use. Direct skin contact with cleaning liquids is to be avoided. Cleaning liquids should preferably be non-flammable and non-toxic.

d. Oil Spillage and Leakage

Oil spillage and leakages are to be avoided and the floor plates are to be kept clean.

e. Fuel and Lubricating Oil

Fuel or lubricating oils can be ignited by contact with hot surfaces even in the absence of an external flame or spark. Care is to be taken to ensure that fuel or lubricating oil does not touch hot surfaces; if leakage causes oil to spray or fall on to a hot surface, the source of oil is to be isolated immediately.

f. Cargo Vapour

Care is to be taken to ensure that cargo vapour does not enter the engine or boiler room from any source. Particular care is necessary if LNG cargo vapour is used as a fuel.

If, as a result of malfunction of equipment, explosion, collision or grounding damage, cargo vapour is likely to enter the machinery space, immediate consideration is to be given to its possible effect on the operation of any equipment. Any necessary action is to be taken; e.g. isolating the source, closing access doors, hatches and skylights, shutting down auxiliary and main machinery, evacuation.

Apart from the obvious hazards, diesel engines are liable to over-speed and destroy themselves if flammable vapour is present in the air supply, even at concentrations well below the lower flammable limit (LFL).

3.14 GALLEY PRECAUTIONS

The interpretation of this section may be subject to local regulations.

Galley stoves are not to be used when the Master considers that an undue hazard exists. Galley personnel are to be made aware of the potential dangers from galley equipment and of the safeguards to be taken:-

- flues and grease filters are to be cleaned at regular intervals,
- Oily rags and fat are not to be allowed to accumulate in galleys or in their vicinity,
- the trunking of extractor fans are to be kept clean,
- appropriate fire extinguishers are always to be available in galleys.

While berthed, galley stoves and cooking appliances with non-immersed elements, such as electric hot-plates and toasters, may be used in galleys, pantries and accommodation subject to the agreement of the Master and the terminal representative that no hazard exists. Any doors or ports opening directly onto or overlooking the deck are to be kept shut.

Galley stoves and cooking appliances with non-immersed elements are not to be in use in the galley when the stern cargo line (where fitted) is in use. Cookers and other equipment heated by steam may be used at all times.

3.15 CARGO MACHINERY ROOM PRECAUTIONS

Cargo vapour may be present in the compressor room and a gas detection system is installed to warn of its presence. Some ships can carry cargoes (e.g. ammonia and LPG) whose vapours are either lighter or heavier than air; in such cases gas detectors are fitted at high and low levels and the relevant detectors are to be used for the cargo carried.

Ventilation systems are provided to disperse any vapour that may collect in the compressor room. The supply and exhaust ducts are fitted with supply openings at high and low levels and the respective flaps are to be open/closed depending on the cargo carried. The space is to be ventilated for at least ten minutes before cargo operations begin and throughout their duration. If liquid or vapour leakage is suspected cargo operations should be stopped, space ventilated and leakage rectified. Ventilation systems are to be maintained carefully; if the fans fitted are of a non-sparking design it must be ensured that their design features are not impaired in any way.

Lighting systems in the cargo machinery room may be certified safe, and it is essential to ensure that these are properly maintained. If additional lighting is required this is to be of a suitable safe type.

Means such as gas-tight bulkhead gland seals and air lock doors are provided to ensure that cargo vapour does not enter the cargo machinery electric motor rooms. Care is to be taken to ensure that these function correctly and are maintained properly.

Electric motors for driving cargo compressors are normally separated from those spaces by a gas tight bulkhead or deck.

However, the IMO code permits, where operational or structural requirements are such as to make it impossible to fit gastight bulkheads, that electric motors of the following certified safety type may be installed.

- Increased safety type with flameproof enclosure, and
- Pressurised type

3.16 TRIM, STABILITY, STRESS AND READINESS TO MOVE

During discharge, loading and ballasting operations the ship must at all times be adequately stable and in good trim to allow for departure at short notice in the event of an emergency.

The information contained in the ship's Loading and Stability Booklet is to be taken into account. Care is to be taken to ensure that the distribution of cargo and ballast at no time creates excessive stress on the hull; stress measuring devices if fitted, are to be used to verify this. While berthed at a terminal the ship's boilers, main engines, steering machinery and other essential equipment is normally to be kept ready to permit the ship to move from the berth at short notice.

Repairs and other work which may immobilise the ship must not be undertaken at a berth without prior written agreement of the terminal. It may also be necessary to obtain permission from the local port Authority before carrying out such repairs or work.

3.17 HELICOPTERS

Helicopters must not be landed on board liquefied gas carriers unless they have the approval of the Administration, and on an approved landing area. In special circumstances "hovering" for the purposes of personnel and/or stores may be permitted. In either of the above cases operators must comply with the safety measures and procedures required and the advice contained in the ICS Guide to Helicopter/Ship Operations must be taken into account.

3.18 CHEMICAL PROPERTIES

Chemical compounds with the same chemical structure are often known by different names. The alternative names given to the same compound is called a synonym. The table below gives a list of the synonyms of the liquefied gases against each common name and its simple formula. The more complex compounds tend to have a larger number of synonyms than the simple compounds.

Synonyms of liquefied gases

Common Name	Simple Formula	Synonyms
Methane	CH^4	Fire damp; marsh gas; natural gas; LNG
Ethane	C_2H_6	Bimethyl; dimethyl; methyl methane
Propane	C_3H_8	-
n-Butane	C_4H_{10}	Normal butane
i-Butane	C_4H_{10}	Iso-butane; 2-methlypropane
Ethylene	C_2H_4	Ethene
Propylene	C_3H_6	Propene
a-Butylene	C_4H_8	But-1-ene; ethyl ethylen
β - Butylene	C_4H_8	But-2-ene; dimethyl ethylene; pseudo butylene
y-Butylene	C_4H_8	Isobutene; 2-methylprop-2 -ene
Butadiene	C_4H_6	b.d.; bivinyl; 1,3 butadiene; butadiene 1-3; bivinyl; biethylene; erythrene; vinyl ethylene
Isoprene	C_5H_8	3-methyl - 1,3 butadiene; 2-methyl - 1,3 butadiene; 2-methylbutadiene - 1,3
Vinyl chloride monomer	CH_2CHC_1	Chloroethene; chloroethylene; VCM

Common Name	Simple Formula	Synonyms
Ethylene oxide	C_2H_4O	Dimethylene oxide; EO; 1,2 epoxyethane; oxirane
Propylene oxide	C_3H_60	1,2 epoxy propane; methyl oxirane; propene oxide
Ammonia	NH^3	Anhydrous ammonia; ammonia gas; liquefied ammonia; liquid ammonia

Note: Commercial propane contains some butane; similarly commercial butane contains some propane. Both may contain impurities such as ethane and pentane, depending on their permitted commercial specification.

- **Saturated hydrocarbons**

The saturated hydrocarbons methane, ethane, propane and butane are all colourless and odourless liquids under normal conditions of carriage.

They are all flammable gases and will burn in air and/or oxygen to produce carbon dioxide and water vapour. As they are chemically non-reactive they do not present chemical compatibility problems with materials commonly used in handling. In the presence of moisture however, the saturated hydrocarbons may form hydrates.

Sulphur compounds such as mercaptans are often added as odorisers prior to sale to aid the detection of these vapours. This process is referred to as "stenching". Mercaptans are considered to be hazardous in some forms and must be handled with care when on board the vessel.

- **Unsaturated hydrocarbons**

The unsaturated hydrocarbons ethylene, propylene, butylene, butadiene and isoprene are colourless liquids with a faint, sweetish characteristic odour. They are, like the saturated hydrocarbons, all flammable in air and/or oxygen, producing carbon dioxide and water vapour. They are chemically more reactive than the saturated hydrocarbons and may react dangerously with chlorine. Ethylene, propylene and butylene do not present chemical compatibility problems with materials of constructions, whereas butadiene and isoprene, each having two pairs of double bonds, are by far the most chemically reactive within this family group. They may react with air to form peroxides which are unstable and tend to induce polymerisation. Butadiene is incompatible in the chemical sense with copper, silver, mercury, magnesium, aluminium and monel. Butadiene streams often contain traces of acetylene which can react to form explosive acetylides with brass and copper.

Water is soluble in butadiene, particularly at elevated temperatures. The figures quoted are for the purpose of illustration only. On cooling water-saturated butadiene the solubility of the water decreases and water will separate out as droplets which will settle as a layer on the bottom of the tank. for instance, on cooling water-saturated butadiene from +15°C to + 5°C approximately 100 ppm of free water would separate out. On this basis, for a 1,000m^3 tank, 100cc of free water would require to be drained from the bottom of the tank. On further cooling to below 0°C this layer of water would increase in depth and freeze.

- **Chemical gases**

The chemical gases commonly transported in liquefied gas carriers are ammonia, vinyl chloride monomer, ethylene oxide, propylene oxide and chlorine. Since these gases do not belong to one particular family their chemical properties vary.

Liquid ammonia is a colourless alkaline liquid with a pungent odour. The vapours of ammonia are flammable and burn with a yellow flame forming water vapour and nitrogen, however, the vapour in air requires a high concentration (16-25 per cent) to be flammable, has a high ignition energy requirement (600 times that for propane) and burns with low combustion energy. For these reasons the IMO Codes, while requiring full attention to the avoidance of ignition sources, do not require flammable gas detection in the hold or interbarrier spaces of carrying ships. Nevertheless, ammonia must always be regarded as a flammable cargo.

Ammonia is also toxic and highly reactive. It can form explosive compounds with mercury, chlorine, iodine, bromine, calcium, silver oxide and silver hypochlorite. Ammonia vapour is extremely soluble in water and will be absorbed rapidly and exothermically to produce a strongly alkaline solution of ammonium hydroxide. One volume of water will absorb approximately 200 volumes of ammonia vapour. For this reason it is extremely undesirable to introduce water into a tank containing ammonia vapour as this can result in vacuum condition rapidly developing within the tank.

Since ammonia is alkaline, ammonia vapour/air mixtures may cause stress corrosion. Because of its highly reactive nature copper alloys, aluminium alloys, galvanised surfaces, phenolic resins, polyvinyl chloride, polyesters and viton rubbers are unsuitable for ammonia service. Mild steel, stainless steel, neoprene rubber and polythene are, however, suitable.

Vinyl chloride monomer (VCM) is a colourless liquid with a characteristic sweet odour. It is highly reactive, though not with water, and may polymerise in the presence of oxygen, heat and light. Its vapours are both toxic and flammable. Aluminium alloys, copper, silver, mercury and magnesium are unsuitable for vinyl chloride service. Steels are, however, chemically compatible.

***Ethylene oxide and propylene oxide** are colourless liquids with an ether-like odour. They are flammable, toxic and highly reactive. Both polymerise, ethylene oxide more readily than propylene oxide, particularly in the presence of air or impurities. Both gases may react dangerously with ammonia.

Cast iron, mercury, aluminium alloys, copper and alloys of copper, silver and its alloys, magnesium and some stainless steels are unsuitable for the handling of ethylene oxide. Mild steel and certain other stainless steels are suitable as materials of construction for both ethylene and propylene oxides.

***N.B.** NITROGEN PADDING IS REQUIRED

Chlorine is a yellow liquid which evolves a green vapour. It has a pungent and irritating odour. It is highly toxic but is non-flammable though it should be noted that chlorine can support combustion of other flammable materials in much the same way as oxygen. It is soluble in water forming a highly corrosive acid solution and can form dangerous reactions with all the other liquefied gases. In the moist condition, because of its corrosivity, it is difficult to contain. Dry chlorine is compatible with mild steel, stainless steel, monel and copper. Chlorine is very soluble in caustic soda solution which can be used to absorb chlorine vapour.

4. INERT GAS

4.1 GENERAL

The composition of inert gas depends on its method of production. On gas carriers Inert Gas is normally produced by combustion of a fuel in a purpose built inert gas generator but very rarely from the ships main boilers.

The Inert Gas produced is washed and filtered to remove soluble acid gases and to remove solid particles. It is then cooled and dried and delivered under pressure to the cargo tanks. Some vessels may be equipped to produce high purity Nitrogen by fractional distillation of air or by pressure swing absorption.

Chemical gases will require the use of Nitrogen Note:- Inert Gas must not be used with Ammonia due to the chemical reaction between it and the CO_2 contained in the inert gas.

In general use:-

- Nitrogen for VCM, Butadiene, PO-EO mixes
- Inert Gas for Hydrocarbons.

4.2 INERT GAS COMPOSITIONS

Inert gas is principally used to control cargo tank atmospheres and so prevent the formation of flammable mixtures. The primary requirement for an inert gas is low oxygen content. Its composition can, however, be extremely variable as can be seen from the Table below which gives an approximate indication of inert gas components as a percentage by volume.

A Component	B Inert Gas by stoichiometric combustion (by calculation)	C Flue Gas from Main Boilers	D Nitrogen by fractional distillation or by Pressure Swing Absorption
Nitrogen (N_2)	85%	83%	99.9%
Carbon dioxide ($C0_2$)	14%	13%	1 ppm
Carbon monoxide (C0)	0.2%	present	1 ppm
Oxygen (0_2)	0.3%	4%	4 ppm
Sulphur dioxide (SO_2)	<0.1%	300 ppm	-
Oxides of nitrogen (N0)	3 ppm	present	-
Water vapour (H_20)	present	present	5 ppm
Ash and soot(C)	present	present	-
Dewpoint	- 50°C	may be high if not dried	<-70°C
Density (Air=1.00)	1.035	1.044	0.9672

4.3 SHIPBOARD NITROGEN GENERATORS

4.3.1 GENERAL

Gas carriers may be equipped with plant to strip the CO_2 from the Inert Gas produced by the vessels Inert Gas Plant.

This equipment will normally produce nitrogen to the following composition:-

NITROGEN:	up to	99.8%
OXYGEN:	less than	0.2%
CO_2 less than:	1000 ppm	
CO less than	1000 ppm	
Dew Point:	down to -60^{o}C	

5. IMO GAS CODE

Three IMO codes are presently applicable to gas carriers:

- The Code for Existing Ships Carrying Liquified Gases in Bulk (Res A.329ix of 12 Nov. 1975) is applicable to gas carriers built before 31st October 1976. This was accepted by most countries except U.S.C.G

- The Code for the Construction and Equipment of Ships carrying Liquified Gases in Bulk (Res A328ix of 12 November 1975) is applicable to gas carriers built between the 31st October 1976 and 1st July 1986.

- The International Code for the Construction and Equipment of Ships Carrying Liquified Gases in Bulk (IGC) - (Res MSC 5(48) of 17th June 1983 as amendment to SOLAS) is applicable to gas carriers built after 1st July 1986.

You are advised to ascertain into which category your vessel falls and rely upon the appropriate code thereof. The first two IMO codes are not mandatory although most countries and/or charterers require compliance. The IMO International Code IGC is mandatory for new ships. However you may also find it possible that a vessel coming into our management might not comply with any Code because it may have been built to operate exclusively in countries which do not implement these IMO codes. Please obtain a copy of the relevant Code applicable to your vessel and advise V Ships of special remarks if any.

The code also lists the type of liquefied gases to which it applies, and the ship type for an application, and any special requirements for certain cargoes.

5.1 IMO SHIP TYPES

Type 1G - intended for the transport of products which require maximum preventative measures to prevent the escape of such cargo.

Type 2G - intended for the transport of products which require significant preventative measures to prevent the escape of such cargo.

Type 2PG - is a vessel of 150M in length or less intended to carry products as indicated in Chapter 19 of the IGC code and which is fitted with Type C tanks designed for a MARVS (maximum allowable relief valve setting of a cargo tank) of at least 7 Bar gauge and a containment system design temperature of -55°C or above.

Type 3G - is a vessel which require moderate preventative measures to prevent the escape of cargo.

5.2 SURVIVAL CAPABILITIES

The Master of the ship will be supplied with a loading and stability book. This will contain details of typical service conditions, loading, unloading and ballasting operations, provisions for evaluating other conditions of loading and a summary of the ship's survival capabilities.

The booklet will contain sufficient information to enable the Master to load and operate the ship in a safe and seaworthy manner.

5.3 CARGO CONTAINMENT

Type A tanks are constructed of plain surfaces and suitable for low pressures only 0.7 Bar gauge i.e. fully refrigerated cargoes.

Type B tanks may be constructed of plain surfaces or pressure vessel type but to a much more stringent stress analysis than required for Type A.

Type C tanks are normally spherical or cylindrical pressure vessels with design vapour pressure higher than 2 bar gauge. Cylindrical vessels may be vertically or horizontally mounted. This type of containment system is always used in semi-refrigerated and fully pressurised liquid gas carriers; it is also commonly used for fully refrigerated transport provided appropriate low temperature steels are used in the tank construction. Type C tanks are designed and built to conventional pressure vessel codes and, as a result, can be subjected to accurate stress analysis.

Furthermore, design stresses are kept reasonably low so, where this type of system is used, no secondary barrier is required and the hold space can be filled with either inert gas or air.

In the case of a typical fully pressurised ship, i.e. where the cargo is carried at ambient temperature, the tanks may be designed for a maximum working pressure of 17 barg or more. For a semi-pressurised/fully refrigerated ship the cargo tanks and associated equipment are designed for a maximum working pressure of approximately 5-7 barg and upto 50 per cent vacuum. The tank steels are typically capable of withstanding carriage temperatures of -48°C for LPG and -104°C for ethylene and LPG.

5.4 IMO SURVEYS

- An initial survey before the ship is put into service.
- A periodic survey not exceeding 5 years.
- A minimum of one intermediate survey
- A mandatory annual survey within three months before or after the anniversary date of the IMO Certificate of Fitness.
- An additional survey general or partial whenever any important repairs or renewals are made.

The above surveys are additional to normal ship surveys.

5.5 GENERAL

These General International standards for the construction and equipment of ships carrying dangerous chemicals in bulk are defined in the IBC Code.

When carriers have the capability of transporting chemical cargoes then the vessel must meet the requirements of both IGC and IBC codes as designated in Chapter 19 of the IGC Code.

6. TYPICAL CARGO EQUIPMENT

The cargo handling equipment can vary in range from a simple manual system with no reliquifaction plant as fitted to a small fully pressurised ship, or a complicated fully automatic cascade type reliquifaction plant.

This chapter is not intended to cover every system and is for general information only, for individual ships please refer to the Shipbuilders Cargo Operations Manual.

6.1 CARGO PUMPS

6.1.1 GENERAL ARRANGEMENT

Deepwell Pumps are normally installed on smaller vessels, with electrical submerged pumps on larger vessels

One or two booster pumps are normally fitted on deck.

In general, the booster pumps are operated in series with the deep well pumps - two deep well pumps to share one booster pump, or a booster pump plus a deep well pump.

With booster pumps in operation it is important to ensure that the manifold pressure must not exceed the set pressure of the manifold relief valves..

6.1.2 DEEPWELL PUMPS

The pumps are normally of the multi-stage segment type with inducer, multi-bearing supported shaft, double mechanical sealing of tandem design with sealing liquid forming the shaft seal. The leaking sealing liquid is collected and cannot contaminate cargo.

6.2 PRODUCT LINE SYSTEMS

6.2.1 GENERAL ARRANGEMENT

There are normally two separate pipe systems on the main deck, each comprising the following:

- Liquid loading/unloading line
- Vapour suction line
- Stripping/condensate return line
- Common purge line
- Vent/drain line

Note

All flange connections must be electrically conducting. If this cannot be guaranteed bonding straps are to be fitted and a measure of the conductivity made.

6.2.2 PRODUCT SYSTEM SEGREGATION

Product lines can normally be separated into two segregated systems - spool pieces, bends, line blanks are provided to effect the segregation. Spool pieces and mating pipe sections are numbered.

The method of segregation and connection of the system will depend on the system fitted, for details refer to the Builders Manual.

Notes

The following purge arrangements are normally possible:

- Tanks grouped into two segregated systems.
- One tank individually or in series or in parallel with other tanks.
- With inert gas (dry air) from the inert gas generator.
- With nitrogen or gas from shore, compressor or vaporiser.
- To the shore line or vent mast.

6.2.3 VENTING AND DRAIN SYSTEM

A separate venting and drain system is fitted to each cargo system.

The vent/drain lines are connected to liquid collectors which have a free flow to the mast. Residues collected in the collectors can be discharged to a tank or ashore via the crossovers and hose/connectors provided for this purpose, using gas pressure in the collector. Each collector has a relief valve which discharges to the mast and each collector is fitted with a high level alarm.

If liquid quantities in excess of the designed limit flow to the mast, a level switch will shut down the plant and close all hydraulic valves. The cause of this excessive flow is to be investigated before attempting to re-start the plant.

Drain valves are located at the lowest points in the blow off lines, and purge connections are provided in the lines adjacent to the relief valves.

Blow off lines must be purged with nitrogen or inert gas <u>before</u> a thunderstorm.

Flame screens are fitted to the vent masts.

6.3 MEASURING AND CONTROL SYSTEM

6.3.1 GENERAL ARRANGEMENT

Operation of the cargo system is both manually at local stations, and from the cargo control room. In the event of any operational parameters going outside set limits plant will be shut down and cargo operations suspended.

6.3.2 CARGO TANK LEVEL GAUGING

The gauges must be used in conjunction with the tank calibration tables and the correction made for cargoes of varying Specific Gravities.

The gauges are only to be activated during loading and discharging operations. When not in use the gauges should be lifted and locked in place.

6.3.3 CARGO TANK LEVEL SWITCHES

One alarm will normally be at 98% ie high level. This alarm will normally close the loading valve..

6.3.4 CARGO TANK SAMPLE LINES

These are permanently installed sampling pipes which can be used for sampling of liquid cargo or vapour/inert gas/air concentrations when inerting or purging. On some vessels they may also be used in the event of a level gauge failure for tank level gauging. There are normally three per cargo tank, measuring the levels in the tank bottom, middle and top.

6.3.5 RELIQUEFACTION PLANT

There are many types of reliquefaction systems in use on board vessels and Masters and Officers must consult their Manufacturers Manuals for details of the operation.

6.3.6 CARGO HEATER

The cargo heater is operated during cargo discharge when a heated cargo is required by the receiving terminal. The heater uses sea water as the heat source.

Cargo flows in the shell side of the exchanger and sea water flows in the tubes.

NOTE In order to prevent freezing of the heater and the associated damage which occurs during freezing, it is essential that the heater is operated at all times with the designed Sea Water flow and that flow is maintained until cargo operations have been completed and all remaining liquid has been boiled off on completion of cargo operations.

6.8 AUXILIARY EQUIPMENT AND SYSTEMS

6.8.1 HYDRAULIC OR PNEUMATIC QUICK CLOSING SYSTEM

All connections to the tank domes (except for instruments), and shore connections on the manifold cross over lines, are fitted with hydraulically or pneumatically operated, fail safe, ball valves. The system is part of the on-board safety system and causes selected valves to close after release of hydraulic or pneumatic pressure. It also provides the power to activate the valves when operating normally.

Valve Closing Times

The closing time of the valves should be agreed with shore operations, and calculated in accordance with IMO, IGC Code 18.8.2, i.e. "The closing time of the valve .... (i.e. time from shut-down signal initiation to complete valve closure) should not be longer than

T = (3,600 x U)/LR seconds, where,
U = ullage volume at operating signal level in cubic metres
LR = max loading rate agreed between ship and shore installation in cubic metres/hour.

The loading rate must be adjusted to limit surge pressure on valve closure to an acceptable level, taking into account the loading hose or arm, the ship and the shore piping system where relevant.

If the pressure in the hydraulic/pneumatic system is released all valves close. This is initiated by the following:

- Activating an onboard emergency shut down push-button, or if activated from ashore;

- A fusible plug melting in the pneumatic system, (melting temperature 98-104°C)
- Instrument air supply failure
- Electrical power failure
- Activation of one of the mast blow-off high level switches

Tank dome valves close if:

- The 98% full level switch is activated, (many vessels are fitted with an override switch which will prevent the valve from closing, this override is only to be used with the express permission of the Master)

On some vessels this may be limited to filling valves only.
This design is not accepted at Dow Chemical Terminals where a separate switch is required which when activated closes all actuated valves on all cargo lines and also stops the cargo pumps.

6.8.2 AIR BLOWER

A separate air blower may also be fitted for the supply of atmospheric air to the purge system. It is connected to the purge line by a spool piece and two non-return valves.

The use of the blower may cause condensation at 'cold spots', e.g. tank walls and therefore careful drying is a necessity after purging.

6.8.3 DECK SPRAY SYSTEM

The deck spray system is a safety system used for spraying and cooling cargo tank domes, superstructure and housings. Sea water is distributed as follows:

Exposed cargo tank domes.

Exposed on deck storage vessels for flammable or toxic products.

Cargo liquid and vapour manifolds.

Boundaries of superstructures and deck houses normally manned, cargo compressor rooms and pump rooms store rooms containing high fire risk items and cargo control room, all facing the cargo area.

6.8.4 EMERGENCY SHUT DOWN SYSTEM (ESD)

The emergency shut down system may comprises of two separate systems - an electrical loop with operating buttons located at strategic points on the ship and/or a pneumatic loop containing fusible plugs. The two systems may be interconnected by a pressure switch in the electrical loop.

If the electrical circuit is broken by operation of a push button, or the air pressure drops by the melting of a fusible plug, the following action is initiated:

- Electrical power supply to the gas plant is shut down stopping all pumps, compressors and ventilation systems in the electrical and compressor rooms

The immediate effect of this action is to release pneumatic pressure and activate the spray system if fusible plugs have melted and the deck spray system is set to 'Automatic'.

This results in the immediate closure of all hydraulically operated valves and shut down of the gas plant.

6.8.5 PERMANENT GAS DETECTOR SYSTEM

A fixed gas detection consists of a series of sensors, alarm module and measuring unit situated in the cargo control room or on the bridge continuously monitoring the concentration of gases in the specific areas of the vessel.

The gas detection system must always be in operation when the cargo tanks or gas plant contain cargo.

The system must be checked regularly for correct operation, and it must be reset whenever a new cargo is introduced.

THE SYSTEM MUST BE RE-CALIBRATED MONTHLY

All checks and changes to settings must be recorded in the Log Book.

Toxic Gas Detection

Detectors may be installed in the air conditioning system intakes to monitor the presence of toxic gases, e.g. vinyl chloride, ammonia. These will detect concentrations of gas in air down to 2 ppm. The instruments and controls are normally housed in the cargo control room.

The recommended alarm levels are 10 ppm for vinyl chloride and 50 ppm for ammonia.

6.8.6 EQUIPMENT CONDITION MONITORING

To maintain the efficiency of the plant the condition must be monitored on the monthly return form GAS 06.

7. CARRIAGE OF CARGOES

7.1 INTRODUCTION

During the loaded passage, the cargo is warmed by heat input from sea water and atmosphere, causing the temperature and saturation pressure (cargo tank) to rise. It is therefore necessary to maintain strict control of the cargo temperature and pressure at all times during the loaded passage. On vessels other than pressurised LPG carriers this is achieved by reliquefying the boil-off and returning it to the tanks.

Also, there are frequent occasions when it is necessary to reduce the temperature of the cargo on passage so that the ship can arrive at the delivery terminal with her cargo temperature below that of the shore tanks, thus minimising the amount of "flash gas" discharged during the discharge operation. This is achieved by use of the reliquefaction plant on board. It can often take several days to cool by 0.5°C, but this may be sufficient.

Heavy weather can sometimes present problems as there is always a risk that slugs of liquid can be carried over into the compressor. For this reason, it is preferable not to run the compressors during heavy weather

Where weather conditions are calm, it is possible that, because of the small vapour space in the tank and the absence of liquid circulation in the tank, a cold layer of liquid can form at the surface when the condensate returns from the reliquefaction plant through the top sprays. This, in turn, enables the compressors to reduce the vapour pressure after only a few hours running, when in fact the bulk of the liquid has not been cooled at all. In order to avoid this, full reliquefaction plant capacity should be run on each tank separately and the condensate returned from the cargo condenser should be returned through the bottom connection to ensure circulation of the tank contents. After the cargo has been cooled, the reliquefaction plant capacity can be reduced to a level sufficient to balance the heat flow through the tank insulation. If the reliquefaction plant is being run on more than one tank simultaneously, it is important to ensure that the condensate returns are carefully monitored and controlled to avoid overfilling.

NOTE: **It is very important to regularly check and equalise tank levels.**

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

7.2. RELIQUEFACTION

- The reliquefaction plant is designed to maintain a constant tank pressure at a maximum ambient air and sea water temperatures.

The method of operation will depend on the design of the plant installed.

Refer to the Builders Cargo Manual for the correct operation of the plant.

The plant may be capable of being operated in a number of ways.
Selection depends upon the grade of cargo, suction and discharge temperatures of the LPG compressors, and suction and discharge pressure differential across the LPG compressors. In general, reliquefaction without desuperheating between the first and stage compression is possible only if the 2nd stage suction temperature is less than +150°C.

For Butadiene the temperature of the compressor discharge must be less than +60°C. With VCM this must not be allowed to exceed +90°C. This is to prevent polymerisation.

With ammonia it is usual to run the compressors with desuperheating between the first and second stages.

- Most hydrocarbons are reliquefied without intercooling, although the thermal reliquefaction capacity using this method is between 5% and 10% lower than with intercooling.

- During cooling the operating parameters of the compressors change - suction pressure decreases, pressure ratio and discharge temperature increases, and during the latter stages of reliquefaction it is possible that intercooling may be required.

When reliquefying Propylene and Propane using two stage compression with intercooling, control of the 1st stage discharge temperature can be affected by changing the level of the liquid in the intercooler. Increasing the level reduces the temperature.

- An accumulation of non-condensable gases in the condenser will reduce the refrigerating capacity of the plant. These should be separated out in the purge condenser and blown to atmosphere. If, for any reason, the non-condensable gases comprise mainly hydrocarbons (methane, ethane, ethylene) or cargo gas, and it is not possible to vent via then masts, they can be injected back to the cargo tanks via the stripping/condensate lines.

Purge control should always be done slowly, carefully and under supervision. Pressure fluctuations can lead to high temperatures at the compressor causing automatic shut down of the plant.

- Throughout the voyage, including reliquefaction, the level of liquid in the cargo tanks must be monitored and controlled. to prevent overfilling.

- Difficulties can arise with some cargoes containing water or unsuitable inhibitors, at temperatures below +5°C, due to the formation of hydrates which can block the deep well cargo pumps.

To prevent this the following precautions are recommended.

- During loading, the cross-over filter is to be regularly drained.

- Inspect the cargo via the stripping line and the sump sampling line for water content after loading, and regularly thereafter. Water is to be evacuated.

During the voyage periodically turn the cargo pump shaft. If movement is difficult the motor is to be rotated for some time to clear. If the pump is blocked methanol injection can be tried, although this is an expensive and not altogether reliable method of clearing a blockage. There is no guarantee that injecting an anti-freeze liquid onto a block of frozen material will cause it to unfreeze any more than the immediate contact surface.

7.2.1 RELIQUEFACTION WITH INTERCOOLING

Intercooling is used in conjunction with two stage compression. The first stage discharge is de-superheated in the intercooler and returned to the 2nd stage The discharge from the 2nd stage is condensed in the condenser, and thence to the intercooler for further cooling. The condensate is returned to the cargo tank.

Non-condensable gases are separated out in the purge condenser and transferred by the cross over line to the collector and mast, or via the stripping or bottom distribution lines back into the cargo tank.

If two or more tanks are being reliquefied simultaneously via one cargo system the distribution of condensate between the tanks is to be controlled manually.

If, during intercooling, there is insufficient condensate in the intercooler drum, additional liquid can be transferred from the cargo tank using the stripping/condensate line and a cargo pump. This is more likely to occur during the early stages of intercooling, or if the 2nd stage compression temperature is too high.

The condenser pressure is to be maintained at approximately 1 bar above the saturation pressure of condensate at the condensate temperature.

7.2.2 RELIQUEFACTION WITHOUT INTERCOOLING

Gas is drawn into the 1st stage of the compressor from the tank, via the surge drum (if fitted), compressed and discharged through the intercooler, but without cooling. The gas is liquefied in the condenser, expanded to tank pressure and returned via the spray or stripping/condensate line.

When several tanks are being cooled simultaneously by one reliquefaction plant, the operation should start with the tank having the highest pressure. Pressure is to be equalised before the tanks are interconnected. Also, when several tanks are being cooled simultaneously a careful watch must be kept on the liquid return to ensure equal filling.

7.3 VCM AND BUTADIENE

VCM and Butadiene have a tendency to polymerise during transportation and require the use of an inhibitor.

During cooling the reliquefaction selector switch is always be set to "VCM/Butadiene".

The compressor suction pressure is not to exceed 1.5 bar with these gases. If the tank pressure before starting the compressors is greater than 1.5 bar, set the suction pressure controller on the compressor and after stabilisation of the suction pressure, manual operation can be resumed.

Condensates produced by reliquefaction do not contain any inhibitor, and as polymerisation is accelerated by high temperatures, this is most likely to occur downstream of the compressor discharges, in the condenser, and in the lines to the cargo tank.

To counter this tendency, inhibited liquid cargo is to be circulated from the tank to the condenser and back to the tank using a deep well cargo running at reduced capacity.

The condenser level should not exceed 50% full, thus maintaining the ability of the incoming gas to blow inhibited liquid back to the tank. Care must be taken to ensure that the level does not rise above 50% otherwise the condenser and/or intercooler may be flooded. The level can be controlled manually or automatically.

For the reliquifaction of Butadiene or VCM intercooling is not normally required. For Butadiene the temperature of the compressor discharge should be less than +60 deg.C. With VCM this should not be allowed to exceed +90 deg C. If above these limits intercooling may be required. This is to prevent the possibility of polymerisation.

Normally, it is not necessary to use the purge condenser with these cargoes.

7.4 ETHYLENE

7.4.1 GENERAL

LPG Ships have in many cases ethylene capability. The gas is carried fully refrigerated at its atmospheric pressure boiling point of -104C. When IMO Type 'C' pressure vessel tanks are fitted, no secondary barrier is required. High value thermal insulation and high capacity reliquefaction plant is fitted to vessels with this capability.

The maximum practical pressure of which ethylene can be compressed is about 15 bar and at this pressure the condensate temperature would be -40°C. Therefore some other cooling medium other than sea water must be used.

7.4.2 CASCADE CYCLE

This system uses a refrigerant to condense cargo vapour .

The compression of cargo vapour is similar to the direct cycle however the cargo condenser is cooled using the refrigerant in place of sea water. The cargo in condensing evaporates the liquid refrigerant and the vapours are then taken through a conventional closed refrigeration cycle condensed by sea water - hence the term cascade.

7.4.3 R22 SYSTEM OPERATION

- Start R22 system before cargo plant.
- Ensure liquid separator is not flooded.
- Ensure R22 compressor discharge valve is open.
- The compressor is started and the suction valve opened slowly to prevent cut out due over load.
- Check that compressor oil level and crankcase pressures are within manufacturer's limits.
- Check R22 liquid levels for correct operation during reliquefaction.
- On stopping R22 compressor ensure oil separator return to the crankcase is closed.

8. DISCHARGING CARGO

8.1 INTRODUCTION

When the vessel arrives at the discharge terminal, cargo tank pressures and temperatures must be at values appropriate to the terminal requirements to allow maximum discharge rates to be achieved. Before the discharge operation begins, the pre-operational ship/shore procedures must be carried out, i.e. ship/shore information exchange, ship/shore safety check list.

The following information will be required to set the principle discharge plant parameters:

- Which side is the ship to berth?
- Will there be a vapour return line?
- What size are the vapour and discharge lines?
- What are the normal and maximum permitted back pressures?
- Required temperature of the cargo.
- Slow down, speed up and emergency procedures.

NOTE: THE COMPANY AND CHARTERER ARE ALWAYS TO BE ADVISED PRIOR TO USING A SHORE VAPOUR RETURN AS THIS MAY HAVE IMPORTANT IMPLICATIONS AFFECTING THE CHARTER PARTY OR OTHER COMMERCIAL CONSIDERATIONS.

Three basic methods may be used to discharge cargo:

- Vapour pressure.
- Cargo pumps with our without boosters.
- Cargo pumps through a cargo heater and a booster pump.

Discharge by vapour pressure is unlikely to be used.

All unused manifolds are to be blanked.

When discharging using the cargo pumps running in parallel, it should be noted that trying to increase the rate of discharge by running all the pumps may not result in the expected increase due to constraints in the overall system. Also, the increased energy imparted to the cargo is dissipated as heat and results in an increase in liquid temperature, which in turn increases the flash gas produced when the cargo discharges into the shore terminal. This may cause the terminal to ask for a reduction in the flow.

Observing the manifold pressure gauges will provide a good indication of whether or not the correct number of pumps is being used. The discharge rate must not be reduced by throttling the valves at the crossover if the shore cannot accept the discharge rate. This will only heat up the cargo. The principle method of flow control is by throttling the booster pump discharge or the main pump circulation or by a combination of the two. Control of flow solely by throttling the main pump discharge may cause loss of booster pump suction.

The required NPSH (Net Positive Suction Head) valve of the cargo pumps is relatively low due to the fitted inducer, and it is possible to unload down to a level of approximately 65cm. For further unloading, the capacity of the pumps must be throttled or the pressure of the gas pad above the liquid increased, otherwise the tank pressure can fall below atmospheric pressure causing the pump to stop.

Replacement of the unloaded liquid in the tank by additional gas is normally not necessary, except for a cargo under atmospheric pressure, and this only at the end of the discharge.

Where cargo is being transferred into pressurised storage, it will almost certainly be necessary to warm the cargo on discharge.

8.2 CARGO PUMPS

Deep well and booster pumps are fitted with differential pressure switches which shut down the pumps if the pressure difference across the pumps and/or the outflow falls below set limits.

The maximum capacity when all deep well pumps are running, is a rated figure which is unlikely to be achieved throughout a total discharge when pumping against shore pressure.

The upper pressure limit switch is set to approximately 22 barg and when this is reached, the quick closing valves on the cross over line will close, initiating the shutting down of both deep well and booster pumps. Therefore, it is necessary to set the maximum operating pressure to below 22 barg, using the pressure controllers between the pump suctions and discharged.

When running two deep well pumps in conjunction with a booster pump, the hand controlled discharge valve must not be throttled because this may have a detrimental effect on the suction pressure of the booster pump. Instead, the discharge valves on the deep well pumps are to be used to control the discharge from the two tank compartments.

To avoid cavitation or gassing-up of a pump when handling boiling liquids, the pressure at the pump suction must exceed the saturated vapour pressure (SVP) of the liquid by an amount termed the Net Positive Suction Head (NPSH). The required minimum NPSH, expressed as an equivalent head of liquid above the pump suction, may vary from 1 metre at maximum pump capacity to 200mm at practical reduced flow. If the vapour space pressure can be increased above the SVP by the supply of extra vapour from shore vapour return or shipboard vaporiser, the onset of cavitation as the liquid level approaches the bottom of the tank can be delayed. This procedure is most frequently used where maximum possible cargo outturn is required prior to gas freeing.

Before starting booster pumps, ensure that the combined pressure produced by the main plus booster pumps will not exceed the maximum system operating pressure, otherwise the pumps will be stopped automatically and the relief valves may lift.

VCM must not be unloaded with deep well and booster pumps running in series, because the high density of VCM may cause overpressure. The booster pumps on their own can be used to discharge VCM in emergency conditions.

8.3 DISCHARGING CARGO

Prior to commencing the discharge, all preparatory liaison with terminal staff is to have been completed, including communications systems, safety and emergency procedures, inspections and preparation of an agreed discharge plan. After the manifold valves are opened, the first pump should be started discharging back to the tank. When it is running satisfactorily the discharge valve can be opened slowly and the cargo discharged ashore. The other pumps can then be started in sequence.

If booster pumps are used to increase the discharge pressure they must be primed from a deep well pump. Booster pumps can be used to discharge at low rates of flow.

8.4 CARGO HEATING DURING THE DISCHARGE

When cargo is being transferred into pressurised storage, it may be necessary to warm the cargo on discharge; this means running the cargo booster pump and cargo heater in series with the main cargo pump. To operate the booster pump and heater, it is necessary to first establish the correct sea water flow through the heater.

Thereafter, to avoid thermal shocks, the pump and heater may be slowly cooled down prior to operation by carefully bleeding in liquid from the main cargo pump discharge. Once cooled down, the discharge valve can be opened until the desired outlet temperature is reached.

It is important to ensure that the main cargo pumps maintain adequate suction to the booster pump at all times

Cargo heating always carries with it the risk of freezing the heater circulating water. As well as checking the cargo outlet temperature and the booster pump suction during operation, attention is to be paid to the sea water inlet and outlet temperatures and pressure.

A minimum sea water temperature of $+10^0$C is normally required to provide satisfactory cargo heating. In the case of a lower temperature, it <u>may</u> be possible to achieve satisfactory heating by slowing the rate of discharge, but under these circumstances great care will be required if freezing of water in the heater tubes is to be prevented.

The heat exchanger is protected by a temperature switch which stops the flow of cargo if the sea water drops below $+5^0$C.

Water for the heater is supplied by the condenser cooling water system.

The main danger with cargo heating is water freezing in the heat exchanger tubes. This can be prevented by maintaining a high rate of sea water flow through the tubes.

The minimum discharge temperature of the cargo is set by the transmitter controller and limiting valve. Control of the cargo temperature above the minimum temperature is made by controlling the flow through the heater by pass line.

For cargoes with an inlet temperature at the heater warmer than -15^0C, the sea water temperature must not be less than $+5^0$C; for cargoes with a temperature colder than -15^0C the sea water temperature is not to be less than $+10^0$C.

On completion of cargo heating, the heater is to be drained back to a cargo tank. When it is confirmed that all liquid has totally evaporated the flow of seawater can be stopped.

8.5 CARGO TANK STRIPPING

8.5.1 NORMAL STRIPPING

The following procedures are used when the loading of a <u>compatible</u> cargo follows the discharge.

With the deep well pumps running at full capacity, the tank can be emptied down to approximately 65cm from the bottom of the discharge well. At this level, the discharge is to be throttled at the discharge control valve, to maintain suction. Pressure above the liquid may be increased by shore supplied vapour or by using the compressors. When using compressors vapour can be drawn from an already discharged tank, or from the vaporiser.

When using this method to strip a tank containing VCM the pressure difference between the two tanks should be 2.5 bar, 1.5 bar when stripping propane and 1.7 bar for ammonia.

For a short time during the early stages of stripping, the compressed vapour will condense on the cold tank walls and tend to inhibit the stripping process, but as the tank walls begin to warm condensation stops and stripping proceeds.

A calculated minimum quantity of liquid is to remain in the tanks to keep the tanks cold during the ballast passage.

On completion of the cargo discharge and stripping, liquid must be drained from all deck lines, cargo hoses or hard arms. This can be done either from ship to shore using a cargo compressor, or from shore to ship, normally by blowing the liquid into the ship's tanks using nitrogen injected at the base of the hard area. Only after depressurising all deck lines is the ship/shore connection to be broken.

If, during this operation, liquid quantities in excess of the designed amount flow to the mast, a level switch will shut down the plant and close all hydraulic valves. The cause of this excessive flow must be investigated before attempting to re-start the plant.

8.5.2 STRIPPING FOR COMPLETE DISCHARGE

Stripping for complete discharge is required prior to changing between incompatible cargoes, when gas freeing and when specific instructions are given to avoid any mixing of previous and new cargoes.

It is important not to under-estimate the quantity of vapour remaining in the tanks after total unloading of all liquid.

The tanks are to have pressure restored to above the SVP before the cargo pumps start to drain the tanks to delay the onset of pump cavitation. Pressure above the liquid is to be increased by introducing vapour from the vapour return line or by running the compressors. Vapour can also be drawn from an already emptied tank or from the vaporiser.

When using this method to strip a tank containing VCM the pressure difference between the two tanks should be 2.5 bar, 1.5 bar when stripping propane and 1.7 bar for ammonia.

For a short time during the early stages of stripping, the compressed vapour will condense on the cold tank walls and tend to inhibit the stripping process, but as the tank walls begin to warm condensation stops and stripping proceeds. Final clearance of liquid will be accomplished by vaporising the remainders - this will also help to warm the tank walls.

Vapour is drawn from the tank, heated in the superheater section of the vaporiser and returned to the tank sump through the stripping line or the bottom distribution line. The warm vapour jet sprays onto the liquid collected in the sump which quickly vaporises. An increase in the temperature of the tank sump signals the completion of vaporisation.

THIS PROCEDURE MUST NOT BE HURRIED. During boiling off it is important to obtain a positive temperature reading on the sump thermometer. Any subsequent drop in temperature indicates that liquid may still be present hence it is important to monitor the temperature even after the flow of hot gas has stopped.

If there is insufficient cargo in the system to support this closed cycle operation, this will result in low pressure, and in this case a quantity of liquid cargo from ashore or the deck tank is to be vaporised and injected into the circuit. Inert gas or nitrogen can also be used to accelerate this procedure, but it must be remembered that the total contents of the tank, (nitrogen/inert gas and cargo vapour mix) will be lost.

When all liquid has finally been cleared from the tank the vapour sucked on by the compressors can be condensed and unloaded to shore or the deck tank.

On completion of the cargo discharge and stripping liquid must be drained from all deck lines, cargo hoses or hard arms. This is usually done from ship to shore using a cargo compressor. Only after depressurising all deck lines is the ship/shore connection to be broken.

Liquid quantities in excess of the designed amount flowing to the mast will cause a level switch to stop all machines and close all hydraulic valves. To restart the system the drainings are to be drained to atmosphere via the bottom valve and a flexible hose, and allowed to evaporate or hosed with water.

One of the following procedures will follow the unloading:

- Loading of the same or compatible cargo
- Purging and/or gas freeing for an incompatible cargo, tank inspection or dry docking. (Tanks must be totally unloaded, vapour from tanks liquefied and unloaded to shore or deck tank).
- Ballast voyage. (A quantity of cargo should remain in the tanks to maintain tank temperature).

8.6 ICE IN SUSPENSION

With some cargoes ice can be held in suspension, and some ice can remain in the tank atmosphere after the discharge. This will cause little or no problem providing the tank temperature is maintained below 0^0C on the ballast voyage.

Serious problems can occur if the tank temperature is allowed to rise above freezing point - ice held in suspension will melt and collect in the sump, this water will then refreeze in the sump when cooled below zero. This may cause problems with the guaging system.

Methanol can be injected into the pump discharge tube but this is not always completely successful.

If the tanks are allowed to warm-up above 0^0C the sump sampling line is to be used to drain off any accumulated water.

9. CHANGING CARGOES, COMPATIBLE CARGOES

9.1 INTRODUCTION

Compatible cargoes are those substances which can be loaded consecutively without prior need to gas free the tanks. However, care must be taken to fully comply with Charter Party, shippers or other stated requirements for the cargo changeover, as these may require more stringent procedures.

When cargo grades are changed the Company Form GAS 04 Changing from Non Compatible Cargoes Checklist is to be completed.

On completion of the discharge the amount of liquid stripped from the tanks will depend on the information available on the next cargo. If no prior information is received then normal stripping will be carried out manually.

The conditions then required in the cargo tanks for loading the next grade of cargo will depend on the degree of contamination acceptable to the shippers/charterers between the last cargo and the next.

If the degree of contamination is of no importance, it may only be necessary to retain the remaining liquid and maintain the cargo tank temperatures on the ballast passage by use of the reliquefaction plant. If contamination has to be kept to a minimum it may be necessary to remove the remaining liquid in the sumps by boiling off and by venting the remaining vapour to atmosphere whilst on passage.

It is emphasised that the final decision depends on the requirements of the charterer/shipper and the required maximum level of contamination.

See Appendix 1 for cargo compatibility.

9.2 LIQUID VAPORISING OF RESIDUES

The deepwell pumps can normally be used to remove liquid residues, but if the level is not sufficient for them to operate satisfactorily the residues can be cleared by drawing vapour from the tank, heating it in the LPG compressor or vaporiser, and returning it to the tank sump through the stripping line or the puddle heating line. The warm vapour heats the liquid collected in the sump which quickly vaporises. An increase in the temperature of the tank sump signals the completion of vaporisation.

THIS PROCEDURE MUST NOT BE HURRIED. During boiling off it is important to obtain a positive temperature reading on the sump thermometer. Any subsequent drop in temperature indicates that liquid may still be present hence it is important to monitor the temperature even after the flow of hot gas has stopped.

10. CHANGING CARGOES – NON COMPATIBLE GRADES AND PREPARING FOR REPAIRS OR DRYDOCK

Gas freeing is necessary when changing between incompatible cargoes, and when preparing the ship for dry-dock or repairs.

Liquid residues can be removed by the total tank heating procedure or by boiling off procedure.

10.1 TOTAL TANK HEATING

A total tank heating process may be achieved by drawing off the vapour with the compressors and the upper distribution line. The compressed vapour is passed through the vaporiser and returned to the tank via the lower distribution line. The Vaporiser may be heated by thermal oil steam or sea water.

10.2 BOILING OFF

Vapour is drawn from the tanks via the vapour suction line, compressed, where it receives a moderate degree of superheat, and returned to the sump through the stripping line.

A higher degree of superheat can be achieved by passing the compressed vapour from the compressors through the vaporiser prior to returning it to the sumps via the stripping line.

Overheating the vapour can be counter productive and must be avoided as it has a tendency to blow the liquid out of the sumps on emerging from the stripping lines.

Completion of the boiling off process will be indicated by an increase in the temperature of the sump.

*On completion of boiling off, it is important to obtain a positive temperature reading in the sump before shutting off the flow of hot gas as any liquid remaining will greatly increase the time taken to complete the following inerting stage. The temperature should continue to be monitored to ensure that there is no liquid present.

During this period any remaining liquid is to be drained from the cargo pipe system via the drain system.

If during this process, liquid quantities in excess of the designed amount flow through the drain system to the vent mast, a level alarm will be activated and cause the cargo plant to shut down.

***NB No inerting is to be carried out until it is confirmed that boiling off is completed.**

10.3 VENTING EXCESS VAPOUR

During the above vaporisation processes the vapour pressure will slowly increase. This excess pressure may be reduced by the following methods:

- If the excess vapour is to be retained it can be drawn off by using the compressors, reliquefied and returned to another tank, or to the deck tank;
- Returned ashore as liquid;

- Returned ashore as vapour to flare or shore storage tank, either using a compressor or by pressure transfer direct from the tank.

- If at sea on passage, vapour can be vented to atmosphere via vent masts.

During this process wind conditions must be taken into account to ensure that there is no possibility of vapour entering either accommodation or machinery spaces.

10.4 INERTING

Note: Inert gas must not be used with **AMMONIA** due to the chemical reaction between it and the CO2 contained in the inert gas. Dry air must always be used.

Inerting is achieved by **displacement** of the cargo vapour or by **dilution** of the cargo vapour.

10.4.1 INERTING BY DISPLACEMENT

Displacement is the most economical method and is achieved by the introduction of the inert gas/air with the higher density to the tank bottom distribution line and displacing the lighter cargo vapour from the top distribution line, or vice versa.

Therefore, the ratio of the specific gravities between the inert gas/air and the cargo vapour, and the temperature difference between the two has an important influence in determining the efficiency of the interface created.

Upper and lower distribution lines are provided in order to distribute the incoming inert gas/air and to collect the outgoing cargo vapours. This process must be started slowly to avoid high velocity at the inlet nozzles which will cause turbulence ,and prevent the formation of the interface.

In an ideal displacement process the interface between the incoming and outgoing gases would be perfect, with no mixing above or below the interface. The minimum amount of inert gas/air required to displace the outgoing cargo vapour would then be equivalent to one tank volume.

The higher the degree of mixing that occurs at the interface, the higher will be the quantity of incoming inert gas/air required to achieve satisfactory inerting.

Any liquid cargo remaining in the sump from the boiling-off process will greatly increase the time taken and the quantity of inert gas/air required to complete the inerting process.

Tanks can be inerted in series or in parallel, with series inerting being the most economical of the two.

The outgoing cargo vapour is sent either to shore flare or, if at sea, vented to atmosphere via the vent mast.

When inerting in series with gas from the on board inert gas generator, the sequences must be in accordance with gas plant suppliers manual. The inert gas generator may also be used to blow air for purging.

During inerting frequent checks of the dew point are to be made as near to tank entry as possible. Maintaining a low dew point will help prevent the formation of water and ice during the subsequent cool down.

Drying can be accomplished simultaneously with inerting either using nitrogen from shore or, alternatively, the inert gas generator on board. The generator is provided with drying facilities.

Whichever method is used, time and care must be spent on the drying operation. Malfunction of pumps and valves due to ice or hydrate formation can often follow from an inadequately dried system and, while methanol addition facilities are available to allow freezing point depression at deep well suctions, etc., this may not be regarded as a substitute for thorough drying. Methanol is only used on cargoes down to -48^{0}C; propanol is used as a de-icer down to -108^{0}C, below which temperature no de-icer is effective

10.4.2 INERTING BY DILUTION

In the dilution method of inerting the incoming gas mixes with the vapour already in the tank. This can be done in several ways depending on the type of vessel:

Repeated pressurisation

Dilution can be achieved by a process of repeated pressurisation of the tank with inert gas using a compressor, followed by a release of the compressed contents to atmosphere. Each repetition will bring the tank contents nearer to the oxygen concentration level of the injected inert gas. Thus to bring the tank contents to a level of 5% oxygen within a reasonable number of repetitions, an inert gas quality better than 5% oxygen content is required.

Quicker results will be achieved by more numerous repetitions each at a lower pressurisation levels than by fewer repetitions using the higher pressurisation levels of which the tank and compressor may be capable.

Continuous Dilution

Inerting by dilution can be a continuous process. An increased flow of inert gas, hence the better mixing and a reduction in overall time may be achieved by maintaining the tank under vacuum by passing the diluted efflux through the compressor. Care must be take to ensure continued good quality inert gas under the increased output flow conditions of the inert gas generator.

The locations of the inert gas inlet and tank outlet are not important provided that good mixing is achieved. It is generally found more satisfactory to introduce the inert gas at high speed through the vapour line and exit through the liquid loading line.

Where several tanks are to be inerted it may be possible to achieve a reduction in the total quantity of inert gas used, and in the overall time, by inerting two or more tanks in series. This procedure also provides a ready way of inerting pipework and equipment at the same time.

10.5 GAS-FREEING WITH AIR

When the following cargo is not compatible with the previous one it may be necessary for the tanks to be gas freed after inerting as part of the process of preparing the tanks for next cargo. This is commonly the case when loading chemical gases such as VCM, ethylene, butadiene, etc. When preparing tanks for dry docking or repairs gas freeing with air after inerting is always required.

A table in Appendix 1 provides guidelines for the required tank condition when changing cargoes.

10.5.1 GAS FREEING PROCEDURE

Gas freeing can take place with tanks connected in series or in parallel, and with a vapour flow within the tanks from either top or bottom or bottom to top. A table of relative densities is included in appendix 1.

The procedure is continued until the tanks are completely gas-free, i.e. the oxygen content is restored to 21%.

10.5.2 GAS FREEING TANKS CONTAINING AMMONIA

Ammonia is always gas-freed with fresh air, and this is swept through the cargo system once tank temperatures have increased above the dew point of the air so as to avoid condensation.

The air, being heavier than ammonia vapour, is fed to the bottom of the tanks and ammonia vapour displaced from the top, being released up the mast. Flushing through with air must continue until the concentration of ammonia vapour is reduced to below 20 ppm. The tanks can then be considered gas-free.

10.6 CARGO TANK WASHING

Water washing cargo tanks will be required when changing from certain cargoes, particularly ammonia and polypropylene oxide, and before dry docking.

Washing can commence after gas-freeing.

In the context of the requirements of MARPOL Annex II, provided the tanks have been properly stripped and ventilated, any water introduced into the tank for preparing the tank to receive the next cargo can be regarded as being clean, and not subject to the discharge restrictions included in Annex II.

10.6.1 PROCEDURE

The correct procedure will depend on the tank washing system fitted to individual vessels.

Refer to the builders Cargo Manual for the correct procedure.

10.6.2 WASHING TANKS WHICH HAVE CONTAINED AMMONIA

Unlike other cargoes ammonia requires considerable quantities of water to effectively wash the tanks.

Special attention should be paid to the avoidance of tank corrosion.

When water is sprayed into a tank containing ammonia the tank pressure will fall rapidly due to the ammonia vapour being absorbed in the water, and the temperature will rise as a result of exothermic reaction. **To avoid a vacuum forming in the tank, the upper distribution lines must be opened to atmosphere.**

Ships staff must keep clear of ammonia venting to atmosphere

11. CARGO TANK INERTING PRIOR TO GASSING UP

Reminder

- use air for ammonia cargoes
- Nitrogen for VCM/Butadiene/PO, PO-EO mixes, Ethylene
- Inert gas for hydrocarbons

11.1 GENERAL INFORMATION

Inerting cargo tanks and pipework systems is undertaken primarily to ensure a non-flammable condition in the subsequent gassing up with the vapour of the cargo to be loaded. For this purpose a reduction in the oxygen concentration to 5% by volume is generally judged to be adequate, although lower values are usually obtainable and preferred.

For some of the more active chemical gases, VCM or butadiene, oxygen levels as low as 0.1% may be required to avoid chemical reaction with the incoming gassing-up vapour. This level will be difficult to achieve using shipboard inert gas plant.

11.2 INERTING BY DISPLACEMENT

This is generally considered to be the most efficient method of inerting tanks. It relies on stratification in the tank as a result of the difference in vapour densities between the gas entering the tanks and the gas already in the tank. The heavier gas is introduced beneath the lighter gas, and at a low velocity to minimise turbulence. If perfect stratification could be achieved with no mixing at the interface, then one tank volume of the inert gas would completely displace the gas already in the tank. In practice some mixing does occur and it will be necessary to use more than one tank volume of inert gas. This may vary from 1.25 to 4 times the tank volume, depending upon the relative densities and tank and piping configurations. There is little density difference between air and inert gas; inert gas from a combustion generator is slightly heavier than air while nitrogen is slightly lighter. These small density differences make inerting by displacement alone very difficult to achieve, and usually the process becomes partly displacement, partly dilution.

Before introducing nitrogen a purge with dry air is usual. The relative densities of nitrogen and air are similar which makes the change over from air to nitrogen, and the clearance of all air from the tank difficult. In order to improve the separation during this process the dry air in the tank should be as cold as possible, and the nitrogen as warm as possible.

The nitrogen must be introduced through the upper distribution line with displacement taking place in the direction top to bottom.

This process must not be hurried. Nitrogen gas is expensive, and the need to re-inert following an unsuccessful first attempt is costly and time consuming.

Tanks can be inerted in parallel or series, and with flow within the tanks or either top to bottom or bottom to top, depending on the relative densities of the two gases.

11.3 INERTING BY DILUTION

In the dilution method the incoming gas mixes with the vapour already in the tank. This can be done in several ways depending on the type of the vessel:

11.3.1 REPEATED PRESSURISATION (not on fully refrigerated vessels)

Dilution can be achieved by a process of repeated pressurisation of the tank with inert gas using a compressor, followed by a release of the compressed contents to atmosphere. Each repetition will bring the tank contents nearer to the oxygen concentration level of the injected inert gas. Thus to bring the tank contents to a level of 5% oxygen within a reasonable number of repetitions, an inert gas quality better than 5% oxygen content is required.

Quicker results will be achieved by more numerous repetitions each at a lower pressurisation level, than by fewer repetitions using the higher pressurisation levels, of which the tank and compressor may be capable.

11.3.2 REPEATED VACUUM (not on fully refrigerated vessels)

Inerting by successive dilutions may be carried out by repeatedly drawing a vacuum on the tank by the compressors, and then breaking the vacuum using inert gas. If, for instance a 50% vacuum can be drawn then on each vacuum cycle half the oxygen content of the tank will be withdrawn. Some of the withdrawn oxygen will, of course, be replaced by the oxygen content of the subsequent vacuum breaking inert gas but, if the quality of inert gas is good, this method is probably the most economical in the use of minimum inert gas quantity in order to achieve the desired inerting level in the tank. The overall time taken may be longer than with pressurisation because of the reduction in capacity of the compressor on vacuum, and the limitation of the rate of vacuum breaking output capacity of the inert gas generator.

11.3.3 CONTINUOUS DILUTION

Inerting by dilution can be a continuous process. An increased flow of inert gas and hence better mixing and a reduction in overall time may be achieved by maintaining the tank under vacuum by passing the diluted efflux through the compressor. Care must be taken to ensure continued good quality inert gas under the increased outflow conditions of the inert gas generator.

It is immaterial where the inert gas inlet or the tank outlet are located provided that good mixing is achieved. It is generally found more satisfactory to introduce the inert gas at high speed through the vapour line and exit through the liquid loading line. Where several tanks are to be inerted it may be possible to achieve a reduction in the total quantity of inert gas used, and in the overall time, but inerting two or more tanks in series. This procedure also provides a ready way of inerting pipework and equipment at the same time.

11.4 AMMONIA

Inert gas from a combustion type generator <u>must never be used</u> in preparation for carrying ammonia because of the reaction of ammonia vapour with the carbon dioxide content of such inert gas to form carbamates. Normally, however, inerting prior to loading ammonia is not required because it is recognised that ammonia vapour, though flammable, is not readily ignited. Liquid ammonia must never be sprayed into a tank containing air as there is a risk of creating a static charge which would cause ignition, and the conditions for ammonia stress corrosion cracking. If the ship's Flag Administration or the loading terminal require inerting prior to loading ammonia then nitrogen should be used.

11.5 COMPRESSORS AND RELIQUEFACTION

If the compressors are used to create vacuum in the tanks, they are to be connected on the suction side to the tank gas suction lines on deck, and on the discharge side to the gas discharge lines on deck.

If condensable gas is drawn from the tanks this may be reliquefied and discharged ashore via the condesate and liquid cross over lines, or to the deck tank or another cargo tank.

When using the compressors care must be taken to avoid raising the level of non-condensable gases (nitrogen/inert gas) thus causing an increase in the temperature and pressure in the condenser, and overheating at the compressor outlet as this will stop the reliquefaction process.

11.6 PREPARATION FOR GASSING UP AND COOLING DOWN

If possible a quantity of the next, or compatible, cargo should be taken into a deck tank for the voyage to the loading port. This will enable the gassing up and cooling down process to be started during the ballast passage. The limited quantity of cargo may mean that only one or two tanks can be prepared, but this would be a useful contribution to minimising port time.

12. CARGO TANK PURGING (GASSING UP)

12.1 GENERAL INFORMATION

Neither nitrogen nor C02, the main components of inert gas, can be condensed by the ship's liquefaction plant because at cargo temperatures they are above their critical temperatures. Purging the inert gas out of the cargo tank with vapour of the cargo to be loaded is necessary so that the reliquefaction plant can operate continuously and efficiently.

Similarly, on change of cargo without inerting, it may be necessary to purge out the vapour of the previous cargo with vapour of the cargo to be loaded.

12.1.1 PURGING AT SEA

Liquid can be taken directly from the deck tank (if fitted) through the tank sprays (with the exception of ammonia) at a carefully controlled rate to avoid cold liquid impinging on warm tank surfaces. In this case mixing tends to predominate and the mixed cargo/inert gas mixture can be taken into other tanks or vented up the vent riser.

Alternatively, liquid from the deck tank can be vaporised in the cargo vaporiser and the vapour introduced gradually into the top or bottom of the cargo tank, depending on the relative densities, to displace the existing inert gas or vapour to other tanks or to the vent riser.

Only when the concentration of cargo vapour in the tanks has reached approximately 90% should the reliquefaction plant be started and cooldown of the system begin.

Due to the limited quantity available from the deck tank, it may not be possible to gas-up all the tanks, but it should be possible for the ship to arrive at the loading terminal with at least one tank gassed-up and partially cooled.

12.1.2 PURGING ALONGSIDE

If the ship arrives at the loading terminal fully or partially inerted, gassing-up will be completed using cargo supplied from ashore. At certain terminals facilities exist to allow the operation to be carried out alongside but these tend to be the exception as venting hydrocarbon vapours alongside may present a hazard and is therefore prohibited by most terminals and port authorities.

Thus, before a vessel arrives alongside with tanks inerted, the following points must be considered:-

- Is venting allowed alongside? If so, what is permissible?
- Is a vapour return facility available?
- Is liquid or vapour provided for purging?
- Will only one tank be purged and cooled down initially from the shore? How much liquid must be taken on board to purge and cooldown the remaining tanks?

Before commencing purging operations alongside, the terminal will normally require to sample the tank atmosphere to check that the oxygen is less than 5% for LPG gases (some terminals require as low as 2%) or the much lower concentration required for chemical gases such as VCM.

Where no venting to atmosphere is permitted, a vapour return line must be provided and used throughout the purging operation. Either the ship's cargo compressors or a jetty vapour blower can be used to handle the efflux. Some terminals while prohibiting the venting of cargo vapours, permit the efflux to atmosphere of inert gas. Thus if a displacement method of purging is used, the need for the vapour return flow to shore may be postponed until cargo vapours are detected in the mast vented efflux. This point may be considerably postponed if tanks are purged in series.

Where a terminal supplies a cargo liquid for purging, it is to be taken on board at a carefully controlled rate and passed through the ship's vaporiser or allowed to vaporise in the tanks. If the supply is of vapour, this can be introduced into the tanks at the top or bottom depending on the vapour density.

Where a vessel arrives alongside with its tanks containing a cargo vapour which requires to be replaced with the vapour of a different cargo to be loaded, then the terminal will normally provide a vapour return line. The vapours taken ashore will be flared until the desired vapour quality is achieved, at which point cooldown can begin.

If no facilities (return line) are available for the ship to purge alongside, it is common practice for the ship to prepare one cargo tank and to take sufficient liquid on board so that the vessel can leave the berth, purge and cooldown the remaining cargo tanks using this liquid and then return ready for loading.

12.2 PURGING OPERATIONS

If a liquid product is received it will have to be vaporised in the vaporisers, heated by sea water.

If two cargoes are to be carried and sufficient heat is obtained in the vaporiser from sea water, the two purges can be done simultaneously.

For purging all tanks with a common gas the ship's two gas handling systems can be integrated by inserting spool pieces and removing line blinds. If two gases are to be used the systems must be segregated by removal of the spool pieces and insertion of line blinds.

Purging may be done with the tanks connected in parallel or in series, with the flow of gas in the tanks either from top to bottom or from bottom to top, using the tank upper and lower distribution lines and the gas suction line, as appropriate.

The compressors may be required to boost the pressure of the purge gas to the cargo tanks. Single or two stage compression may be used, but intercooling is seldom necessary.

If the source of the liquid is a deck tank and there is insufficient pressure differential between the deck tank and the evaporator the deck tank must be pressurised by the compressors.

Before purging with the new gas all tank, plant and equipment should be drained, gases expanded and liquids vaporised.

The Officer with overall responsibility for cargo operations should check with his opposite number ashore if waste gas is allowed to be blown off at the mast.

Allow the cargo tanks to expend to atmospheric pressure before purging.

Blow off from the mast is strictly prohibited during a thunderstorm, or if a thunderstorm is imminent.

Butadiene and VCM <u>must not</u> be vented to atmosphere.

12.2.1 LIQUID SUPPLIED BY A DECK TANK

When the source of liquid is a deck tank the compressors are to be used to raise the pressure in the deck tank. One of the following methods should be used:

- With high vaporisation pressures, i.e. high sea water temperature, liquid with low boiling point, the main body of the purge gas from the vaporiser is let to the cargo tanks with the balance going to the compressor to pressurise the deck tank.

- With low vaporisation pressure, i.e. low sea water temperatures, liquid with high boiling point the compressors may be used to pressurise both the deck tank and cargo tanks simultaneously. The main body of purge gas from the vaporiser is led to the cargo tanks with the balance going to pressurise the deck tank.

13. CARGO TANK COOLING

13.1 INTRODUCTION

Before loading a refrigerated cargo, the tanks must be adequately cooled down in order to minimise thermal stresses and excessive tank pressure during loading. Cooldown consists of introducing cargo liquid into a tank at a low and carefully controlled rate. The lower the cargo carriage temperature, the more important the cool down procedure becomes.

The rates at which cargo tanks can be cooled without creating undue thermal stresses depend on the design of the containment system, and are typically a maximum of 10 deg c/hour.

Normally the cooling down has been included, or at least started, during gassing-up which commenced during the latter stages of the ballast voyage, or at the terminal if the ship arrived with the cargo tanks inerted.

The procedure is for cargo liquid from shore or from a deck storage tank to be gradually introduced into the tanks through the spray lines. The vapours produced by the rapid evaporation of this liquid may be taken ashore or handled in the ship's reliquefaction plant and returned to the tanks for continued cooling. Additional liquid is introduced at a controlled rate depending on the tank pressure and temperatures resulting. If vapour is being handled in the ship's reliquefaction plant, difficulties may be experienced with "incondensibles" remaining from the inert gas. A close watch must be kept on compressor discharge temperatures, and the incondensible gases vented from the top of the reliquefaction condenser as required.

As the cargo containment system cools down watch should be maintained to ensure that associated pressures are maintained within operational limits. Normally pressure control systems supplying air or inert gas will maintain these pressures but watch should be kept on them as the cooldown proceeds.

Cool down must continue until liquid begins to form in the bottom of the tanks. This can be seen from the temperature sensors. At this stage, in the case of cool down of cargo tanks for fully refrigerated ammonia for example, the pool of liquid formed will be of approximately -34°C while the top of the tank may still be at about - 14°C, i.e. at temperature gradient of approximately 20°C on cooldown. The actual temperature gradient depends on the size of the cargo tanks, position of sprays etc.

Many of the difficulties that occur during the cool down operation result from inadequate purging by inert gas or from inadequate drying. In the latter case, ice or hydrates may form and ice-up valves, pump shafts, etc. Methanol can be added as anti-freeze provided that cargo is not put off specification.

It is necessary always to maintain a pressure within the cargo tank at least equal to saturated vapour pressure. This can be done by vaporising liquid using the vaporiser and introducing vapour into the tank with a compressor. Alternatively, vapour can be provided from shore.

13.2 COOLING WITH VAPOUR RETURN ASHORE

Note: head office must always be advised prior to using a shore vapour return as this may have important implications affecting the charter party or other commercial considerations.

Tanks are cooled by spraying liquid cargo, supplied from shore, a deck tank or another cargo tank, via the spray line. This need not be refrigerated as long as the tank pressure is kept at or below the saturation pressure of the intended liquid pressure after expansion. Flash gas and evaporated cargo should be led ashore directly or via a compressor. During this operation maintenance of an adequate pressure difference is essential as it can significantly affect the rate of cooling.

This should not exceed 10°C/hour.

Vaporised product is swept on by a compressor and discharged ashore via the vapour return line or condensed and re-injected into the tank. The vapour can also be transferred into the next tank to be cooled.

As a precaution against cargo pumps freezing they must be rotated periodically.

13.3 COOLING WITHOUT VAPOUR RETURN

Cargo liquid is sprayed into the tanks via the spray line. The vaporised cargo is then reliquefied in the reliquefaction plant and returned to the tank as liquid. By the intermittent operation of the spray valves a homogeneous cooldown is achievable.

Compressors must be controlled so that the tank temperature decreases slowly.

This should not exceed 10°C/hour.

If the source of cargo liquid is a deck tank or cargo tank remainders, the available quantity will be limited.

Bear in mind that some of the remaining cargo may have been used for tank purging and is not, therefore, available for cooling down. In this case tanks must be cooled sequentially.

The first tank must be pressurised with vapour via the vaporiser until the desired pressure is achieved, or all the cargo has been used. The reliquefaction plant is then to be operated, and the cargo recirculated to the tank as liquid. During intermittent stops in the spraying operation the compressors are to be set to discharge into the next tank. When the first tank has been cooled vapour will be stored in the next tank and cooling can commence by a similar process.

If these conditions are not achievable when sourcing from the deck tank or cargo tank residues, cool down will have to start from a reduced pressure and lower spray temperature. During this operation special attention will need to be paid to the temperature gradient, and care taken with intermittent opening and closing of the spray valves.

As a precaution against cargo pumps freezing they must be rotated periodically.

14. CARGO LOADING

14.1 INTRODUCTION

Before the loading operation begins, the pre-operational ship / shore procedures must be thoroughly discussed and subsequently carried out. The appropriate information exchange is required and the relevant ship / shore safety check list must be completed.

Particular attention must be paid to the conditions and setting of cargo relief valves, reliquefaction plant, gas detection system, alarms and controls and to the maximum loading rate, taking into account restrictions in ship / shore systems, etc. Lines are to be pressurised to the maximum working pressure, and checked for leaks.

The terminal must provide the necessary information on the cargo, including inhibitor certificates where inhibited cargoes are loaded. Any other special precautions for specific cargoes are to be made known to ship personnel, e.g. the lower setting of the compressor discharge temperature cut-out switch required for some chemical cargoes. Variable setting pressure valves and gas detection sample valves must be correctly set.

Either the terminal or the shippers will advise the required cargo tank temperatures / pressure which are required for arrival at the load port.

Cargo loading can be carried out using either a vapour return line, the ship's reliquefaction plant, or both. Where loading is carried out with a vapour return facility, liquid is taken on board through the liquid header and directed into the appropriate tanks. Vapours generated are returned ashore via the vapour return line using the compressor or jetty blower. Under these conditions the loading rate is independent of the ship's reliquefaction plant and governed by the rate at which the terminal can handle the vapour; it may also be constrained by velocity through the ship's piping system. Where no vapour return is provided then the loading rate is governed by the capacity of the ship's reliquefaction plant. In most cases the terminal reliquefaction plant capacity will be much larger than that on board the vessel and, as a result, loading rates where vapour return is provided will normally be higher than without vapour return.

NOTE: THE COMPANY MUST ALWAYS BE ADVISED PRIOR TO USING A SHORE VAPOUR RETURN AS THIS MAY HAVE IMPORTANT IMPLICATIONS AFFECTING THE CHARTER PARTY OR OTHER COMMERCIAL CONSIDERATIONS.

All unused manifolds are to be blanked.

When liquefied gas is being loaded from terminal to ship, it is necessary to consider the location, pressure, temperature and volume of the stored product on shore as well as the pumping requirements of the transfer facility. Ship loading will normally be from fully refrigerated storage where the tanks typically operate at a pressure of approximately 60 mbar; this pressure will allow the propane at the bottom of a full shore tank to sustain a temperature perhaps 1°C above the atmospheric boiling point, i.e. -44°C as against -45°C.

When LPG is pumped to the jetty head, the pumping energy required for transfer is dissipated in the liquid as heat, to which must be added the heat flow into the liquid through the pipework. The propane may therefore arrive at the ship's rail at a temperature of -43.5°C. When loading without vapour return, the vapour which is displaced by the incoming liquid must be liquefied by the reliquefaction plant; the capacity required for this, plus the heat loss through the insulation, may leave little or no capacity for cooling of the cargo during loading.

The early stages of loading are critical, particularly where significant distances exist between storage tank and jetty. Ship's tank pressures must be regularly observed and on no account should relief valves be allowed to lift. Loading rates must be reduced and, if necessary, stopped when difficulties are experienced in maintaining acceptable tank pressures. Ship's tank pressure rise in the early stages of loading can also be controlled to a certain extent by taking liquid into the cargo tank via the top sprays so condensing part of the cargo vapour.

Depending on the efficiency of the purging operation, significant quantities of incondensibles may be present and without vapour return to shore these incondensibles will have to be vented from the condenser. Care must be taken when venting incondensibles to minimise venting of cargo vapours to the atmosphere. As the incondensibles are vented, the condenser pressure will drop and the vent valve should be throttled and eventually closed.

A close watch must be kept on ship's cargo tank pressure, temperatures, liquid levels, inter-barrier space pressures etc., throughout the loading operation. Monitoring of liquid levels may present difficulties when the reliquefaction plant is in operation. This is because the liquid in the tank is boiling and as a result vapour bubbles within the liquid increasing the volume of the liquid, thus giving false reading with float-type ullage gauges. An accurate level monitoring can be achieved by temporarily suppressing boiling, i.e. by closing the vapour suction from the tank.

Towards the end of the loading operation, loading rates must be reduced to an appropriate rate as previously agreed with shore staff in order to accurately "top-off" tanks.

At this time the vapour suction valve is also to be closed to prevent the surface of the liquid boiling as explained above. This boiling and the resulting increase in liquid volume due to the vapour bubbles may give a false reading on the level gauge and result in a lesser amount of cargo being loaded.

On completion of the loading operation, ship's pipework is to be drained back to the cargo tanks. The liquid remaining can be cleared by blowing ashore with vapour using the ship's compressor or by nitrogen injected into the loading arm to blow the liquid into the ship's tanks. Once liquid has been cleared and lines depressurised, manifold valves should be closed and the hose or loading arm disconnected from the manifold flange.

The ballast handling arrangements are quite independent of the cargo system. Deballasting can therefore take place simultaneously with loading subject to regulations. Ship stability and stress are of primary importance during loading and deballasting and procedures are in accordance with normal tanker practice.

14.2 LOADING PROCEDURES

(a) The reliquefaction plant is usually to be kept running and the tank pressure maintained as low as possible throughout the loading.

(b) It may be possible to load two cargoes simultaneously by segregating the two cargo systems, the two systems being separated by spool pieces.

(c) To avoid thermal shocks it is important to ensure that the temperature of the incoming gas is not at variance with the receiving tank temperature by more than 10 deg. Also, the temperature of the gas must be constant throughout loading to prevent stratification and the possible development of an unstable situation ('roll-over').

If this occurs the loading operation must be stopped immediately.

NOTE: "ROLL-OVER"

If cargo is stored for any length of time and the boil off removed to maintain tank pressure this will cause a slight increase in density and reduction in temperature near the liquid

surface. The static head will create a marginally higher temperature and lower density at the tank bottom.

This unstable equilibrium may exist until some disturbance occurs, such as the addition of new liquid. Spontaneous mixing can take place with violent evolution of large quantities of vapour. This phenomenon is called "roll-over".

(d) A deck tank may be loaded simultaneously with cargo tanks, or separately.

(e) Safety Relief Valves must be set in accordance with requirements of Flag Administration or USCG.

The maximum transport pressure of the incoming gas should be at least 0.1 bar below the relief valve settings. If the pressure of the incoming gas is higher than the relief valve settings, flow must be throttled to prevent the valves lifting.

(f) Cargo tanks must not be filled to more than 98% of the tank capacity, measured after necessary adjustments to the temperature of the cargo have been completed.

The maximum volume to which tanks may be filled is calculated using the following formula:-

	VL	=	0.98 x V x dr/dl
where	VL	=	maximum loading capacity
	V	=	tank volume

Variable 0.98 x dr/dl is obtained from tables for various cargoes at varying loading temperatures and safety valve settings.

If overfilling occurs this must be corrected immediately by transferring the liquid to another tank, or the deck tank using the deep well pump.

A sudden closing of the quick closing valves, caused by overfilling, can cause problems at the terminal because they may not be able to react quickly to the situation.

(g) When cargo is loaded without vapour return, with the reliquefaction plant in operation, the following points apply:-

- Attention must be paid to possible water content of the cargo. This will collect in the filter during reliquefaction and should be drained as necessary.

- During loading, gas displaced from the cargo tanks is led to the reliquefication plant and re-circulated to the tanks via the spray lines. Non-condensable purge gases collected in the purge condenser should be blown off from the mast.

- In addition to the gas displaced from the tank the reliquefaction plant has to reliquefy flash gas.

Where high cooling capacities are required the capacity of the reliquefaction plant is the limiting factor; for low capacities the only constraint is the available shore pressure.

(h) During loading the vessel has to be deballasted. This must be done in accordance with conditions in the vessel's Loading Booklet and loading instrument.

Care must be taken to keep the vessel upright at all times, which means keeping the cargo even and the ballast even. If the vessel does develop a list during cargo operations, it must be corrected to bring the vessel upright immediately. This can be down by adjusting the cargo, ballast or both.

N.B. Vessels with spherical or cylindrical tanks can only use ballast to correct list.

14.3 LOADING BUTANE / BUTADIENE

When loading butane and butadiene it is important to have a dry atmosphere in the tanks to avoid the possibility of ice forming in the cargo. If water is allowed into the tank methanol injection must be used.

As a precaution against cargo pumps becoming blocked with ice they must be rotated periodically.

15. VCM/BUTADIENE

Because of their specific characteristics, VCM and butadiene require special attention during cargo operations. This section of the manual highlights characteristics and procedures of the two cargoes which differ from the procedures included in the other sections of the manual.

15.1 VINYL CHLORIDE MONOMER (VCM)

Vinyl Chloride Monomer (V.C.M.) is carried as a liquid in certain LPG ships, which have been converted or built for the purpose.

V.C.M. is a chlorinated hydrocarbon and has flammability limit of 4 - 33% by volume and toxicity characteristics similar to many cargoes of hydrocarbon origin. In addition, however, long-term exposure to high concentrations has been linked with a rare form of cancer, the TLV has therefore been set at 10 ppm - a level well below the bottom of the flammable range. **V.C.M. has an odour threshold of 2000 ppm and therefore smell cannot be relied upon as a means of detection**.

It must be noted however, that to date no cases have been recorded relating to exposure to the monomer. The only cases have been linked with production processes, and in particular to cleaning of the autoclaves used in the production of PVC.

Nevertheless, it is policy that exposure levels should not exceed 10 ppm unless suitable protection such as CABA and possibly chemical suits are used.

Ships, which are in the VCM trade for all or part of the time, have specialised detection and protective equipment. In addition, modified emergency procedures have been developed to deal with the problems, which may arise from the presence of the gas.

(a) VCM is a colourless liquid with a characteristic sweet odour. It is highly reactive, though not with water, and may polymerise in the presence of oxygen, heat and light. Its vapours are both toxic and flammable. Aluminium alloys, copper, silver, mercury and magnesium are unsuitable for vinyl chloride service. Steels are, however, chemically compatible.

(b) Extract from I.M.O. Regulations / USCG

With VCM - the person in charge of cargo transfer operations shall ensure that:-

- Cargo vapours are returned to the cargo tank or shore installation for reclamation or destruction during cargo transfer;

- Continuous monitoring for vapour leaks takes place during all cargo transfer operations. Fixed or portable instruments may be utilised to ensure that personnel are not exposed to VCM vapour concentrations in excess of 1 ppm averaged over any 8 hours period or 5 ppm averaged over any period not exceeding 15 minutes. The method of monitoring and measurement must have an accuracy (with confidence level of 95%) of not less than plus or minus 50% from 0.25 through 0.5 ppm, plus or minus 35% from over 0.5 ppm through 1.0 ppm, and plus or minus 25% over 1.0 ppm.

- Cargo transfer operation is discontinued or corrective action is initiated by the person in charge to minimise exposure to personnel whenever a VCM vapour concentration exceeds 5 ppm for over 15 minutes, action to reduce the leak can be continued only if the respiratory protection requirements of 29 CFR 1910.93q (g) are met by all personnel in the area of the leak.

- Those portions of cargo lines which will be open to the atmosphere after piping is disconnected are free of VCM liquid and that the VCM vapour concentration in the area of the cargo piping disconnect points is not greater than 5 ppm.

- Any restricted gauge fitted on a tank containing VCM is effectively out of service by locking or sealing that device so that it cannot be used; and

- A restricted gauge is neither to be used as a “check” on the required closed gauge nor as a means of sampling.

  - Sign bearing the legend:

    "DANGER - SUSPECT AGENT IN THIS AREA"
    "PROTECTIVE EQUIPMENT REQUIRED"
    "AUTHORISED PERSONNEL ONLY"

must be posted whenever hazardous operations, such as tank cleaning, are in operation.

- A tank ship undergoing cargo transfer operations must be designated a "**regulated area**" having access limited to authorised persons and requiring a daily roster of authorised persons who may board the ship.

- Employees engaged in hazardous operations, such as tank cleaning, must be provided and required to wear and use respiratory protection in accordance with the provisions of 29 CFR 1910.93q (g) and protective garments, provided clean and dry for each use, to prevent skin contact with liquid VCM.

15.2 BUTADIENE

Butadiene is an unsaturated hydrocarbon. It is a colourless liquid with a faint, sweetish characteristic odour.

Water is soluble in butadiene, particularly at elevated temperatures. On cooling water-saturated butadiene the solubility of the water decreases and the water will separate out as droplets which will settle as a layer in the bottom of the tank. For instance, on this basis, for a 1,000 cu metres tank, 100 cc of free water would require to be drained from the bottom of the tank. On further cooling to below 0°C this layer of water would increase in depth and freeze.

Butadiene is chemically more reactive than saturated hydrocarbons and may act dangerously with chlorine. It can be chemically reactive with materials of construction. It is chemically incompatible with copper, silver, mercury, magnesium, aluminium and monal. Butadiene streams often contain traces of acetylene which can react to form explosive acetylides with brass and copper.

15.3 CARGO OPERATIONS SPECIFIC TO VCM AND BUTADIENE

15.3.1 LOADING

(a) All inhibited liquid must be removed before a ballast passage between consecutive cargoes. If a second cargo is to be carried between such consecutive cargoes the reliquefaction plant must be thoroughly drained and purged before loading the second cargo, if compatible. Practical steps are to be taken to ensure that polymers do not accumulate in the ship’s system.

(b) Before loading VCM / butadiene all air is to be excluded from the tanks by purging with nitrogen. The quality of the nitrogen is to be sampled and demonstrated to have an oxygen content not exceeding 0.1% by volume.

(c) All connections are to be purged with nitrogen.

(d) When loading butadiene it is important to have a dry atmosphere in the tanks to avoid the possibility of ice forming in the cargo. If water is allowed into the tank methanol injection is to be used.

As a precaution against cargo pumps becoming blocked with ice, they must be rotated periodically.

15.3.2 COOLING

(a) When carrying VCM and butadiene cargo temperatures are to be controlled so as to maintain a positive pressure in the tanks.

(b) VCM and butadiene cargoes are carried with inhibitors to prevent polymerisation.

(c) During cargo loading, the reliquefaction plant can normally be operated without intercooling, but if the gas temperatures are approaching their upper limit, VCM 90°C; butadiene 60°C; intercooling will be necessary. If incondensibles cause an unacceptable increase in condenser pressure, these are to be returned with the condensate into the tank, or discharged ashore.

(d) During reliquefaction the inhibitor is present only in the liquid phase, i.e. it will not be present in the condenser during a normal open reliquefaction cycle, and the condensate will not contain it either, and as polymerisation is accelerated by high temperatures, polymerisation will occur downstream from the compressor discharge, which includes the condenser, piping and cargo tanks. Prevention is to supply stabilised liquid, i.e. one containing inhibitor into the condensers using the following procedure: After cooling down, inhibited cargo liquid can be circulated with a deep well pump via the liquid line to the condenser, returning to the tank via the condensate line - the condenser is to be kept approximately half full during this operation.

At the same time, gas is swept from another tank by a compressor into the condenser to pressurise the inhibited liquid back to the tank. During this operation a careful watch must be maintained on the distribution of condensates back to the tanks to avoid overfilling.

Normally it is possible to reliquefy VCM and butadiene without the need for intercooling.

On completion of this operation the lines must be emptied into the tanks and blown through with gas.

NOTE 1 : The solubility of VCM in lubricating oil increases as temperature rises and pressure drops. Pressure in the compressor crankcase must not exceed 1 bar - achieved by controlling the first stage compressor suction pressure to a maximum of 0.5 bar, and the glycol heating system must be in operation to prevent condensation, even if the compressors are shut down. Temperatures should be maintained at approximately +40°C.

Ensure lubricating oil is compatible.

NOTE 2 : When compressing VCM and butadiene, the compressor discharge temperatures must not exceed 90°C and 60°C respectively. The compressor suction pressure is not to be allowed to exceed 1.5 barg in either case.

15.3.3 DISCHARGE VCM

Prior to discharging, all connections must be purged with nitrogen. Due to its high density VCM must not be discharged with deepwell pumps running in series with booster pumps.

If, during stripping, it becomes necessary to increase pressure above the liquid residues by introducing gas from another tank, the pressure difference between the two tanks is to be approximately 2.5 bar

16 PROPYLENE OXIDE & ETHYLENE OXIDE – PROPYLENE OXIDE MIXTURES

16.1

Propylene oxide (PO) is an eserine with wide flammable limits of 2.8 - 37% by volume. The TLV of this product is 100 ppm whilst its odour threshold is 10 ppm. Exposure to the liquid or high concentrations of the vapour can lead to eye burns, skin irritation and blistering, vomiting, lack of co-ordination and depression

16.2 INTRODUCTION

(a) Because of their specific characteristics P.O. and E.O./P.O. mixes require special attention during cargo operations. This section of the manual highlights characteristics and procedures of these cargoes which differ from the procedures for products included in the other sections of the manual.

In the following descriptions the term ‘P.O.’ is used for both P.O. and E.O./P.O. mixes.

(b) The transport of P.O. is only permitted with a valid certificate issued by the responsible authority, (e.g. USCG). The certificate is only issued after inspection of the tanks and plant, for which they will need to be gas-free and clean. During transport the deck spray system must be ready for use at all times.

(c) Residues of previous cargoes have to be completely removed before loading P.O. as they can cause a dangerous reaction. Rust and encrustations, which may contain gas pockets must be removed, and all tank filters and pipes are to be cleaned and thoroughly dried.

(d) Cargo holds must be purged with inert gas having an oxygen content <0.2%, or nitrogen, until the atmosphere contains <0.3% oxygen. The cargo is carried under a padding of 99.9% nitrogen. The Charterer’s requirements must be noted in this respect.

(e) The only other cargoes allowed to be carried simultaneously with P.O. are propane and butane.

(f) P.O. must only be loaded and unloaded directly, i.e. with this plant it must not:

- **Be loaded by the compressors, or**
- **Heated with the heat exchangers or cooled by the compressors.**

This is affected by removing spool pieces so that there is only a liquid line into the tanks and a gas line out. All other lines and plant, is then isolated.

16.3 EXTRACT FROM I.M.O. REGULATIONS

(a) Flame Screens on Vent Outlets

Cargo tank vent outlets are to be provided with readily renewable and effective flame screens or safety heads of an approved type when carrying a cargo referenced to this section. Due attention is to be paid to the design of the flame screens and vent heads to the possibility of the blockage of these devices by the freezing of cargo vapour or by icing up in adverse weather conditions. Ordinary protection screens are to be fitted after removal of the flame screens.

(b) Maximum Allowable Quantity of Cargo per Tank

When carrying a cargo referenced to this section, the quantity of the cargo is not to exceed 3,000 cu mtrs in any one tank, (tank means tank compartment).

(c) Propylene Oxide and Mixtures of Ethylene Oxide-Propylene Oxide with Ethylene Oxide content of not more than 30% by weight

- Products carried under the provisions of this section must be acetylene-free.

- Unless cargo tanks are properly cleaned, these products are not to be carried in tanks which have contained as one of the three previous cargoes any product known to catalyse polymerisation, such as:

  Ammonia, anhydrous and ammonia solutions;
  Amines, and amine solutions;
  Oxidising substances, e.g. chlorine.

- Before loading, the tanks are to be thoroughly and effectively cleaned to remove all traces of previous cargoes from tanks and associated pipework, except where the immediate prior cargo has been P.O. or P.O./E.O. mixtures.

- In all cases, the effectiveness of cleaning procedures for tanks and associated acidic or alkaline materials remain that might create hazardous situations in the presence of these products.

- Tanks must be entered and inspected prior to each initial loading of these products to ensure freedom of contamination, heavy rust deposits and any visible structural defects. When cargo tanks are in continuous service for these products, such inspections are to be performed at intervals of not more than two years.

- Tanks for the carriage of these products must be of steel or stainless steel construction.

- Tanks which have contained these products may be used for other cargoes after thorough cleaning of tanks and associated pipework systems by washing or purging.

- All valves, flanges, fittings, and accessory equipment must be of a type suitable for use with these products and are to be constructed of steel or stainless steel or other material acceptable to the Administration. The chemical composition of all material used is to be submitted to the Administration for approval prior to fabrication. Discs or disc faces, seats and other wearing parts of valves must be made of stainless steel containing not less than 11% chromium.

- Gaskets must be constructed of materials which do not react with, dissolve in, or lower the auto-ignition temperature of these products and which are fire-resistant and possess adequate mechanical behaviour. The surface presented to the cargo should be **POLYTETRAFLUORETHYLENE** (PTFE) or materials given a similar degree of safety by their inertness. Spirally wound stainless steel with a filler of PTFE or similar fluorinated **POLYMER** may be accepted by the Administration.

  Spirally wound gaskets are required to be fitted to cargo tank lids by the U.S.C.G.

- The following materials are generally found unsatisfactory for gaskets, packing and similar uses in containment systems. These products would require testing before being approved by the Administration:

- **NEOPRENE** or **NATURAL RUBBER**, if it comes in contact with the products;

- **ASBESTOS** or binders used with **ASBESTOS;**

- Materials containing **OXIDES of MAGNESIUM**, such as mineral wools.

- Filling and discharge piping is to extend to within 100 mm of the bottom of the tank or any sump pit.

- The products are to be loaded and discharged in such a manner that venting of the tanks to atmosphere does not occur. If vapour return to shore is used during tank loading, the vapour return system connected to a containment system for the product is to be independent of all other containment systems.

- During discharging operations, the pressure in the cargo tank must be maintained above 0.07 bar gauge.

- The cargo is to be discharged only by deep well pumps, hydraulically operated submerged pumps, or inert gas displacement. Each cargo pump is to be arranged to ensure that the product does not heat significantly, if the discharge line of the pump is shut off or otherwise blocked.

- Tanks carrying these products must be vented independently of tanks carrying other products. Facilities are to be provided for sampling the tank contents without opening the tank to atmosphere.

- Cargo hoses used for transfer of these products must be marked.

  “ FOR ALKALINE OXIDE TRANSFER ONLY ”

- Hold spaces are to be monitored for these products.

- Prior to disconnecting shore-lines, the pressure in liquid and vapour lines must be relieved through suitable valves installed at the loading header. Liquid and vapour from these lines is not to be discharged to atmosphere. All connections must be purged with nitrogen.

- Pressure relief valve settings must not be less than 0.2 bar gauge and for type C independent cargo tanks not greater than 7.0 bar gauge for the carriage of propylene and not greater than 5.3 bar gauge for the carriage of Ethylene Oxide-propylene Oxide mixtures.

- The piping system for tanks to be loaded with these products is to be completely separated from the piping systems for all other tanks, including empty tanks, and from all cargo compressors. If the piping system for the tanks to be loaded with the product is not independent, the required piping separation must be accomplished by the removal of spool pieces, blank flanges, or other pipe sections and the installation of blank flanges at these locations. The required separation applies to all liquid and vapour piping, liquid and vapour vent lines and any other possible connections such as common inert gas supply lines.

- The products are to be transported only in accordance with the cargo handling plans that have been approved by the Administration. Each intended loading arrangement is to be shown on a separate cargo handling plan. Cargo handling plans must show the entire cargo piping system and the locations for installation of blank flanges needed to meet the above piping separation requirements. A copy of each approved cargo handling plan is to be kept on board the ship. The Certificate of fitness for the Carriage of Liquefied Gases in Bulk is to be endorsed to include reference to the approved handling plan.

- Before each initial loading of these products, and before every subsequent return to such service, certification verifying the required piping separation has been achieved is to be obtained from a responsible person acceptable to the port administration and carried on board the ship. Each connection between a blank flange and pipeline flange must be fitted with wire, and sealed by the responsible person to ensure that inadvertent removal of the blank flange is impossible.

The "responsible person" may be, for example, the ship's master or the society's local surveyor.

- The maximum allowable tank filling limits for each cargo tank are to be indicated for each loading temperature which may be applied and for the applicable maximum reference temperature, on a list to be approved by the Administration. A copy of the list is to be permanently kept on board by the master.

- The cargo must be carried under a suitable protective padding of nitrogen gas. An automatic nitrogen make-up system is to be installed to prevent the tank pressure falling below 0.07 bar gauge in the event of product temperature falling due to ambient conditions or malfunctioning of the refrigeration system. Sufficient nitrogen must be available on board to satisfy the demand of the automatic pressure control. Nitrogen of commercially pure quality (99.9% by volume) is to be used for padding. A battery of nitrogen bottles connected to the cargo tanks through a pressure reduction valve satisfies the intention of the expression "Automatic" in this context.

- The cargo tank vapour space must be tested prior to and after loading to ensure that the oxygen content is 2% by volume or less.

- A water spray system of sufficient capacity is to be provided to blanket effectively the area surrounding the loading manifold, exposed deck piping associated with product handling and the tank domes. The arrangement of piping and nozzles is to be such as to give a uniform distribution rate of 10 litres / sq metre / minute. The water spray system is to be capable of both local and remote manual operation and the arrangement should ensure that any spilled cargo is washed away. Additionally, a water hose with pressure to the nozzle, when ambient temperatures permit, shall be connected ready for immediate use during loading and unloading operations.

For ships trading to the territorial waters of the USA the relevant requirements of the USCG must be complied with, i.e. the water spray system required by 17.20.17 must operate automatically in case of fire.

16.4 LOADING P.O. / P.O. - E.O. MIXES

The following conditions must be observed before loading P.O.:

(a) P.O. must not be loaded into tanks which contained during one of the last three voyages either ammonia, amines, caustic solutions or other products above to react with P.O. A proof of the last ten cargoes must be kept on board.

(b) Washing water used in the tanks must not contain dissolvents or additives which have not been authorised by a competent technical supervision authority. The last washing has to be done with clear, pure water. Samples of the last purge water are to be handed to the responsible person or to the terminal before loading.

(c) The ship must have her own independent nitrogen system for padding the tank after loading. There is to be sufficient nitrogen available on board to guarantee a minimum tank pressure of 5 psi, (0.35 bar).

(d) Sealing material has to be approved and controlled by the competent technical supervision authority. All tanks and pipes are to be clean, dry and prepared for inspection after arrival at the loading port. Before loading the tanks and pipes have to be inspected and approved by the responsible person of the shore terminal or by the marine inspector.

(e) All air must be purged from the tanks and pipes with pure nitrogen or inert gas, so that the oxygen content is <0.3%, and the carbon dioxide content <1%.

On board generated Co2 must not be used.

The quality of the inert gas must be confirmed by laboratory analysis and approved by the responsible person of the shore terminal.

(f) All open connections or pipes and valves must be closed or equipped with blind flanges.

Loading hoses must be approved and marked by the responsible authorities.

They must not be used for any other product.

(g) The pipe systems to be used for loading cargo, including the return lines for liquids and gases must be entirely segregated from the main cargo handling system on board ship.

(h) Cargo tanks must not be filled to more than 98% of the tank capacity, relative to the density of the gas at the set pressures of the safety valves.

For P.O./E.O. mixtures the pressure <u>must</u> be not greater than 5.3 barg.

The maximum volume to which tanks may be filled is calculated using the following formula:

VL = 0.98V pr/pl

Where
VL = Maximum volume to which tank may be loaded.

V = Volume of the tank.

PR = Relative density of cargo at the reference temperature.

PL = Relative density of cargo at the loading temperature and pressure.

NOTE : Reference temperature defined as per paragraph 15.1.4 IMO code.

(i) On completion of cargo loading, and after blowing liquid residues from the piping system ashore with nitrogen, the system must be purged with nitrogen from a shore supply or the on board bottles. Finally the tank nitrogen padding is introduced.

16.5 TRANSPORT OF P.O. / P.O. - E.O. MIXES

P.O. must be transported under a padding of nitrogen, and because it has a relatively high boiling temperature of +34°C at atmospheric pressure, pressure in the tanks should be at least 0.35 barg above atmospheric. Pressure is to remain constant throughout the loaded voyage by feeding nitrogen as required. A nitrogen supply system is installed for this purpose.

Safety valve setting for transportation of P.O. / P.O. mixes must be in accordance with gas plant supplier's instruction manual, usually USCG requirements.

16.6 DISCHARGING

During discharging operations the following conditions must be observed:

(a) The tanks and piping system must be segregated from all other cargo systems on board ship.

(b) Over-pressure in the tank must not fall below 0.07 bar. Unloaded liquid is replaced with inert gas or nitrogen from shore.

(c) Cargo is discharged using deep well pumps and possibly the boosters. Total discharge can be achieved by displacement with nitrogen and by using the 2" stripping line. Draining and purging of lines requires a high purge gas speed, which is best obtained by using the nitrogen accumulated in the tank.

(d) Liquid residues in the deck lines are to be drained into the collectors and discharged ashore.

(e) When changing cargo grades, tanks must be totally discharged, water washed and ventilated for inspection.

The inert gas from the stripping phase can be retained in the tanks because washing must be done in an inerted atmosphere. This is to offset the possible formation of static charges during washing, due to the relatively high boiling temperature of the cargo.

(f) Tank washing is to be carried out in accordance with the approved Annex II Procedures and Arrangements manual, a copy of which is retained on board the ship.

In the context of the requirements of MARPOL Annex II, provided the tanks have been properly stripped and ventilated dry, any water introduced into the tank for preparing the tank to receive the next cargo can be regarded as being clean, and not subject to the discharge restrictions included in Annex II.

*The water for tank washing is supplied from ashore or from an on board soft water generator and will normally be at ambient temperature. Pressure at the spray line connection is to be at least 3 barg above tank pressure. (At 3 bar the flow rate will be approximately 28 cu mtrs/hr/tank). Water can be pumped from the bottom of the tanks by deep well pumps into adjacent tanks, or recirculated, and finally ashore, or discharged to sea. This procedure is to be repeated several times.

After completely drying and ventilating tanks and pipe systems, the system shall be inspected and the appropriate certificates issued.

17. CARGO MEASUREMENT AND CALCULATION

17.1 GENERAL

Liquefied gas cargoes are measured and calculated in a similar manner to that of other bulk liquid cargoes such as crude oils and petroleum products. However, as liquefied gases are carried as boiling liquids in a closed containment system the quantity of vapour has also to be measured when calculating the total quantity onboard.

It is common practice for gas tankers on a regular trade to retain onboard a quantity of liquid (heel) in order to keep tanks cool on the ballast passage. In this way the vessel arrives at the load port ready to commence loading with no cool down time necessary. At the loadport the new cargo is added to the heel. Equally if the ship has arrived with uncooled tanks a quantity is usually put onboard for tank coldown purposes. It is therefore extremely important that a full survey of all tanks is carried out before and after every operation.

17.2 MEASUREMENT

Temperature

Cargo being loaded may arrive at the manifold at various temperatures during loading. This may be due to cargo being taken from different shore tanks or the initial cooling of ship/shore lines. It is possible that because of this some stratification in the vessel’s tanks can occur. It is very important therefore that temperatures are taken at all available points in order to accurately assess the actual average liquid temperature. Ships temperature sensors are usually provided at a number of different levels. This is equally important for vapour temperature where temperatures in the tank dome are usually higher than that of the vapour near the surface of the liquid. The positions of temperature probes must be accurately known in order that only those actually submerged in the liquid are used for liquid temperature and similarly for vapour temperature.

Density

Density is by definition measured in vacuum at 15°C.

Density x volume M3 (at 15°C gives metric tonnes in vacuum).

The measurement of liquid gas density requires laboratory facilities or equipment not available on ships. Modern terminals usually calculate this form from an analysis of liquid composition obtained from a gas liquid chromatograph. The results of this are provided to the ship in order to carry out the cargo calculations.

It is necessary to correct the density for the actual observed temperature of the cargo. For specialised chemical gases the storage facility normally provide their own density table for the cargo showing the density for a range of temperatures. Some ports provide the density at a standard temperature of 60°F or 15°C. This has to be corrected to the density for the observed cargo temperature.

Density can be quoted as either being in air or in vacuum.

For a density quoted in vacuum subtract 0.0011 to obtain the density in air, i.e. 0.5074 in vacuum corresponds to a density of 0.5063 in air.

Cargo's quantities worked out in vacuum are always heavier than those worked out in air. Liquid gas quantification is more commonly expressed in terms of weight in air and indeed this is a requirement of most customs authorities. It is extremely important that when a density is provided to the vessel it is ascertained whether the density is in air or vacuum.

Liquid Level

The liquid level is read direct from the tank level gauge on the tank dome. The remote readout must not be used for cargo calculations. It is necessary to apply corrections to this figure before entering the tables. These corrections are for tape shrinkage and float immersion. The float gauge tape passes through the cold vapour space and depending on the space temperature contracts thus indicating a higher liquid level than actually present. Float immersion will depend on the density of the cargo and this will usually be different from the manufacturer's initial determination. A small correction is necessary for both these items to obtain the correct gauge reading before entering the tables.

Liquid Volume

All ships are provided with a calibration table for each tank by means of which the tank's liquid (and vapour) volume can be calculated from the measurement of the liquid level. These tables are obtained from careful measurement of the tanks during the ship's construction. These tables normally refer to an upright vessel with no list. Corrections are therefore necessary for trim and list and these will be included with the tank calibration tables. Instruction for use will be included with the tables.

The cargo tank volume will have been calculated at ambient temperature and the tables calculated for a standard temperature of say 20°C. Cold cargo temperature will result in tank shrinkage and a reduction in volume. A correction therefore is necessary and this is normally expressed as the Tank Shrinkage factor.

Vapour Quantity

The volume of vapour is found by subtracting the volume of liquid from the tanks 100% capacity. This is at the calibration temperature for the tank before the Volume Correction Factor has been applied. It is necessary to apply a Volume Correction Factor (tank shrinkage factor) to this figure and this correction is obtained using the average vapour temperature.

17.3 CALCULATION

On completion of measurement calculation of the total cargo quantity can be carried out.

There is no internationally agreed standard for gas cargo calculations and procedures can vary particularly with the chemical gases.

In the absence of any instructions concerning calculations the following procedure using the standard temperature of 15°C which is widely used should be followed.

17.4 CALCULATION PROCEDURE (TYPICAL)

a. Determine by measurement the average liquid and vapour space temperature (degrees C) and the vapour space pressure (barg or mbarg).

b. Read the tank liquid level and calculate the liquid volume (V1) at tank conditions using the ship's calibration tables for that tank and making all necessary corrections for temperatures, list and trim.

c. Determine the liquid density noting the temperature at which it is determined and using ASTM* table 53 convert this to liquid density at 15°C.

d. Using the liquid density at 15°C and the measured average liquid temperature, enter ASTM* table 54 to derive the appropriate volume correction factor to convert to the volume at 15°C.

e. Calculate the liquid mass. Volume x Density.

f. Calculate the vapour volume at tank conditions by subtracting the apparent liquid volume (liquid quantity before applying tank shrinkage factor) from the tank total volume.

* N.B. ASTM tables 53 & 54 have been revised for densities in the range 610.0 to 1076.0 kg/m^3 however below this range covering LPG no revision has been carried out and ASTM-IP tables 53 & 54 are to be used.

g. Using the average vapour temperature correct the apparent volume of vapour for tank shrinkage.

h. Determine the vapour density at vapour space conditions using the following formula.

$$\text{Density of Vapour} = \frac{Ts \times Pv \times Mm}{Tv \times Ps \times I} \quad Kg/m^3$$

Where Ts is standard temperature of 288 K

Tv is average temperature of vapour in K

Pv is absolute pressure of vapour space in bars

Ps is standard pressure of 1.013 bar

Mm is molecular mass of vapour mixture in Kg/Kmol (sometimes called molecular weight)

I is ideal gaseous molar volume at standard temperature (288K) and standard pressure (1.013 bar). This is 23.645 m^3 / Kmo1).

i. Calculate the vapour mass by multiplying vapour volume and vapour density.

j. Add the liquid mass and the vapour mass to give the total cargo mass in the tank.

k. Convert the total to weight in air.

17.5 EXAMPLE CALCULATION

The following numeral example demonstrates in detail the typical procedure for the calculation of the contents of a ship's tank.

Measurement Data

Tank No. 3 Port	
Product - Propane	
Gauge reading	10.020 metres
Ship's Trim	2.0 metres by stern
Ship's List	0.5 degrees to port
Average liquid temperature	- 43°C
Average vapour temperature	- 38°C
Vapour space pressure	59 mbarg
Molecular weight of liquid	4.097
Density of liquid	511 Kg / m³

From Ship's Calibration Tables for 3P Tank

Tank gauge reading	10020 mm
Correction for trim	- 127 mm
Correction for list	+ 46 mm
Level gauge correction	+ 1 mm
Float immersion correction	0 mm

Corrected liquid depth 9940 mm

Liquid volume (uncorrected)	5441.88 m³
100% tank volume	9893.63 m³
Vapour volume (uncorrected)	4451.75 m³
Tank shrinkage factor (liquid)	0.99773 (- 43°C)
Tank shrinkage factor (vapour)	0.99791 (- 38°C)

Liquid Calculation

Volume of liquid (uncorrected)	5441.88 m³
Tank shrinkage factor	x 0.99773
Volume of liquid at - 43°C	5429.52 m³
VRF from - 43°C to 15°C (table 54)	x 1.145
Volume of liquid at 15°C	6216.8 m³
Liquid density at 15°C (from shore)	x 511 Kg / m³
Mass of liquid	3176785 Kg

Vapour Calculation

Volume of liquid (uncorrected)	5441.88 m^3
100% tank volume	9893.63 m^3
Vapour volume (uncorrected)	4451.75 m^3
Tank shrinkage factor	x 0.99791
Volume of vapour at - 38°C	4442.45 m^3

Density of vapour at - 38°C:

$$\frac{Ts \times Pv \times Mm}{Tv \times Ps \times I} = \frac{288 \times 1.059 \times 44.097}{(273-38) \times 1.013 \times 23.645} = 2.389$$

Mass of Vapour 10613 Kg

Total Mass

Mass of liquid 3176785 kg
Mass of vapour 10613 kg

Total Mass 3187398 Kg

Weight in Air

Factor for converting mass to weight in air for liquid of 511 Kg / m^3 density at 15°C (Table 56) x 0.99775

Total weight in air 3180226 Kg = 3180.23 MT

17.6 CARGO DOCUMENTATION

The transportation of liquefied gases is subject to the same commercial documentation as applies to oil cargoes. Documents accompanying a liquid gas cargo will generally include the following.

Bill of Lading

This is the most important document. It is a receipt for the cargo on board and is normally signed by the Master on behalf of the shipowner or time charterer. It will state the quantity of cargo shipped, that it was received onboard in apparently good order and condition and will indicate the terms and conditions under which the ship will carry the cargo to its destination. In some ports which operate early departure procedures the Agents will sign the Bills and the Master will be required to furnish the agents with a letter authorising them to do this.

The Bill of Lading is usually issued in three “originals” of equal standing, each separately stamped and signed. One of these goes to the shipper, one to the carrier (shipowner or time charterer) and one to the intended receiver of the cargo. A copy will be retained onboard and normally the Master will only deliver the cargo on presentation of the receivers “original”.

Refer the commercial section of the Fleet Operating Manual for company policy on Bills of Lading.

Certificate of Quantity

This is issued by the loading terminal and is the cargo quantities declared as loaded usually established by an independent surveyor.

Certificate of Quality

This provides the product specification and quality in terms of physical characteristics and component constituents. It is again issued by the loading terminal.

Certificate of Origin

This is a document issued by the manufacturer or shipper, countersigned by the custom's authorities and attesting to the country in which the cargo was produced.

Time Sheet

This records all timing details of the ship's movements and operations from the ships entry to its final departure from the port. This is usually prepared by the vessel's agents and is countersigned by the Master. Its purpose is to provide an agreed statement of facts relating to timing of events and any delays.

Cargo Manifest

This document is again usually prepared by the vessel's agents at the loading port and lists the cargo according to the Bill of Lading(s) and the disposition of the cargo within the ship. Its purpose is to provide readily available data for Customs authorities etc., at the discharge port.

Certificate of Tank Fitness

This is issued by independent chemists or surveyors where particular tank conditions are required prior to loading.

Certificate of Inhibitor Addition

Certain gases require an inhibitor added for transportation and the certificate will show the quantity added and the length of time the inhibitor will last for.

17.7 MOLECULAR WEIGHTS

The following are the molecular weights for various standard gases. In the absence of data from the loading terminal these figures should be used for calculating the vapour mass.

Ammonia	44.05
Butadiene	54.10
Butane	58.12
Butene	56.10
Chlorine	70.91
Ethane	30.10
Ethylene	28.05
Methane	16.04
Methyl Chloride	50.49
Propane	44.10
Propylene	42.08
R12	120.92
R22	86.48
Sulphur Dioxide	64.07
Vinyl Chloride	62.50

17.8 SAMPLING

Cargo is normally sampled by shippers' or receivers' personnel, or by authorised petroleum inspectors. The responsible officer must, however, be present when sampling is carried out to ensure that samples are taken from correct sampling points and that this is performed in a correct and safe manner. He is to also make a proper record of the samples taken as these may be of considerable value subsequently. A good rule is to request samples to be taken from the liquid shore connections at the start of loading to safeguard against possible contamination of shore transfer lines.

The following precautions are to be observed when sampling cargo liquid or vapour:-

17.9 LIQUID SAMPLES

(a) The sample container must be completely clean and compatible with the cargo to be sampled and is to be able to withstand the extremes of temperature and pressure anticipated.

(b) Sample containers must be purged of air by pure nitrogen before use with flammable cargoes.

(c) If the sample is to be representative its container has to be purged thoroughly with cargo from the sampling connection. Sufficient cargo must be passed through the container to cool it down to liquid temperature. If the cargo is a mixture (which is often the case) the most volatile components will evaporate more rapidly than the heavier fractions as the container is cooled down; this will leave the sample with a higher concentration of the heavy fraction than present in the cargo, and it will therefore be unrepresentative. To counteract this, sample containers are to be turned with the vent valve downwards during cooldown, to drain off the liquid that first collects. For the same reason, samples from the bottom of cargo tanks at the beginning of, or just after, loading may not be representative. It is recommended that the cargo is circulated using the cargo pump, if possible, before taking bottom samples.

(d) It is imperative that sufficient ullage or vapour space is left in the sample container to allow for the liquid expansion that will occur when the temperature increases to ambient. Ullage is obtained by holding the full sample container upright after disconnecting it from the sample connection and draining some liquid by opening the bottom valve for a moment.

(e) Unless the sample container is free of cargo vapour, it should not be stored in an unventilated space.

(f) Gloves, goggles and protective clothing must be worn when sampling cold cargoes.

(g) If the cargo is toxic, a suitable respirator, or preferably self-contained breathing apparatus, must be worn. If sampling in an enclosed space, a respirator is unsuitable, due to the possibility of asphyxiation, then breathing apparatus is necessary.

(h) If electrical equipment is used when taking samples this is to be of the certified-safe type.

17.10 VAPOUR SAMPLES

(a) The precautions given in 16.9 (a), (b), (c), (f), (g) and (h) are to be observed when sampling cargo vapour or inert gas.

(b) Plastic sample bags are sometimes used for collecting vapour samples. These must be handled carefully, never used for liquid samples and always purged after use.

18. EMERGENCY PROCEDURES

The following procedures are those associated with action due to a failure of plant or an emergency situation particular to gas carriers. The overall safety procedures associated with health and safety, and major hazards are included in the Safety And Environmental Manual.

18.1 UNLOADING WITHOUT DEEP WELL PUMPS

Chapter 7 of the Tanker Safety Guide – Liquifidied Gases must be read in conjunction with this section.

With the exception of fully refrigerated vessels and in the event of a failure of a main cargo pump the tank may be discharged using vapour pressure to transfer cargo directly ashore or to another tank, or to the suction of a booster pump. Vapour for this procedure can be supplied from another tank, produced in the vaporiser or LPG Compressor, onboard inert gas generator, or received from shore.

Discharging by displacement with vapour is a much slower process than by using deep well pumps; the actual rate being dependent upon the physical properties of the cargo, cargo temperature, gas temperature, and available overpressure.

If cargo gas is used, it is estimated that between 30% and 50% will condense out, thus lowering the discharge rate still further.

The pressure above the liquid is to be kept constant throughout the discharge, which may not be easy as the level approaches the bottom of the tank. Frequent adjustments to the discharge rate will be necessary to maintain pressure.

18.2 FREEZING (HYDRATES IN THE CARGO)

Water loaded with the cargo, or loaded into tanks which have not been thoroughly dried, can result in ice forming at the following key locations:-

- Manifold cargo filter
- Main and purge condensers
- The vaporiser, during vaporising
- condensate expansion valves

Problems will occur if the water has not been drained off and the cargo is cooled down below + 5°C during the voyage, as it can block deep well pumps, and expansion valves. Methanol injection points are located at most of the vulnerable locations**, <u>but methanol can contaminate the cargo, and in some cases is not allowed to be used</u>**.

(a) A blocked cargo manifold filter catcher will be signalled by a high pressure drop and reduced flow. During loading regular draining is to occur to remove water. If it is blocked by ice the inlet and outlet valves are to be closed and the vessel pressurised with cargo or inlet gas. Warm gas can be used if necessary.

(b) A blocked deep well pump will probably need to be cleared by methanol injection if it cannot be turned. If the sump is frozen as well this may require considerable quantities of methanol, and attention should be given to the acceptable levels of methanol-in-cargo contamination. If this method of defrosting is not successful, or methanol is not allowed, the tank will have to be unloaded by displacement with cargo or inert gas - see paragraph 16.1.

18.3 FLAMMABILITY

All liquefied gases presently transported in bulk by sea, with the exception of chlorine and nitrogen, are flammable. The vapours of liquefied gases are generally as easily ignited as those of oil cargoes. The exception to this is ammonia vapour, which requires considerably higher ignition source energy to ignite than the other flammable vapours. Statistically, therefore, fires following ammonia leakage are less likely than those with other cargoes but it would be unwise to discount thereby the possibility of an ammonia fire.

Because of the high vapour pressure and rapid vaporisation of spilled liquefied gases, the spread of flammable vapour is likely to be more extensive than in the case of a similar liquid spillage of oil. The chances of ignition following a spill of liquefied gas is thereby greater. Radiation from liquefied gas fires, because of the rapidity of vapour production, may be intense and no fire-fighting should be attempted without full fire-fighting protective clothing.

Leakage of a liquid or vapour from a pipeline under pressure will burn as a jet if ignited which will continue as long as fuel is supplied.

A particularly destructive form of vapour burn associated with the transportation of liquefied gas in pressurised containers is the BLEVE (Boiling Liquid Expanding Vapour Explosion). This arises from the rise in pressure within the container together with the weakening of the uninsulated and uncooled part of the container shell due to surrounding fire or due to radiation from the ignited vapour emission from the safety relief valve. As a result, the container suddenly splits open, releasing the pressurised liquid to atmospheric pressure. The consequent flash of liquid vapour provides fuel for a rising fireball and parts of the ruptured container may be projected apart with considerable violence. The BLEVE is a well known occurrence in road and rail transportation but has never occurred in marine transportation and is unlikely so to occur for the following reasons:

- the likelihood of surrounding fire is small,
- safety relief valve emissions are piped away to mast head vents
- shipboard pressurised tanks are provided with water sprays and water for cooling purposes is readily available.

18.4 VAPORISATION OF SPILLED LIQUID

When a gas is stored as a liquid, whether under pressure or refrigeration, it will vaporise when released to the atmosphere, taking heat from its surroundings in so doing. Depending upon the liquid spilled, the spill size and whether the spill is on land or water, the rate of vaporisation and the temperature and density of the ensuing vapour cloud will vary. Almost certainly the cloud will be low lying (only methane when warmer than -100°C, ethylene and ammonia are lighter than air), will be initially cold, and will drift downwind; its occurrence will, in general, be visible as a white 'cloud' which is condensed atmospheric water vapour.

18.5 TOXICITY AND TOXIC PRODUCTS OF COMBUSTION

Some liquefied gases present toxic hazards principally if the vapours are inhaled. Four of these toxic gases, ammonia, chlorine, ethylene oxide and propylene oxide, are also irritants to the skin and mucous membrane. Incomplete combustion of hydrocarbon vapours may produce the toxic gas carbon monoxide which is found on occasion in inert gas. Combustion of vinyl chloride may produce toxic carbonyl chloride.

18.6 BRITTLE FRACTURE

Liquefied gas spilled onto constructional steel such as ship's decks not designed for low temperatures may cool this steel to temperatures where it becomes brittle. Stress already within the steel together with that resulting from differential contraction may cause fracture of the steel in the cooled areas. The resultant fractures are generally fine and unlikely to propagate beyond the cooled areas. Detailed investigations have suggested that even with shipboard spills, the integrity of the ship is unlikely to be affected and that the seepage of liquid through the fine fractures is unlikely to have any significant consequences.

18.7 COLLISION

The SOPEP/Contingency plan is to be used in the event of a collision but special considerations on board gas carriers are:

- Issue protective clothing ensure all persons on board have to hand their self contained breathing apparatus.
- Implement initial fire fighting.
- Alert all departments to dangers.
- Mount large scale fire fighting if necessary.
- Assess hull damage and stability.
- Assess effect on cargo system.

18.9 GROUNDING

The SOPEP/Contingency plan is to be used in the event of a grounding

18.10 FIRE FIGHTING

The SOPEP/Contingency plan is to be used in the event of a fire but the following points must in addtion be considered.

18.10.1 CARGO AREA FIRE

The fire may affect the cargo and increase the boil off and subsequent cargo tank pressure. Cool area by actuating water spray system. Use reliquefaction plant.

The source of fuel should be cut off and the initial attack should be with dry powder. If necessary use fixed fire fighting system - Foam, CO_2, Halon ensuring area has been evacuated.

Consider:

- Isolating the source of fuel.
- The initial attack
- Shutting down all cargo operations.

- Closing all tank valves (ESD System).
- Activate water system.
- Large scale attack (fire fighters can advance behind water spray from hoses).
- Continue cooling area when fire is out.

18.10.2 VENT MAST FIRE

Ignition can be caused by a lightning strike or other source of ignition when venting.

Consider:

- Stop venting.
- Inject inert gas into the vent if possible.
- Spray mast head with water.
- Resume venting when mast head and surroundings are cool and electrical storm is over

18.10.3 FIRE ON SHIP OR VICINITY

It is the duty of any person on board who discovers an outbreak of fire to raise the alarm immediately. Thereafter they should attempt to control the fire using the nearest available appropriate means until an organised party takes over.

In port, shore assistance must be called immediately, if possible all cargo hoses should be isolated and disconnected. Bring main engines to readiness.

At sea the ship should be manoeuvred so as to minimise the risk of fire spreading. Consider stopping mechanical ventilation in affected area.

18.10.4 EXTINGUISHING AGENTS

Water

Water must never be applied onto a burning liquefied gas pool since it will provide a heat source for more rapid vaporisation of the liquid and thereby increase the rate of burning. Nevertheless, water remains a prime contributor to liquefied gas firefighting. Being freely available in most circumstances, water is an excellent cooling agent for surfaces exposed to radiation or direct fire impingement. It may be used in spray form as a radiation screen or to deflect an unignited vapour cloud away from ignition sources. In some circumstances, water can be used to extinguish a jet or column of burning gas.

Fixed water deluge systems are fitted for covering ship structures deck tanks and piping.

Water spray from fixed monitors or from hand held hose nozzles can provide radiation protection for personnel in their approach to shut off valves or to leaking jet or vent fires in order more effectively to deliver an attack by dry chemicals to extinguish the flame.

Dry chemical powder

Dry chemical powders such as sodium bicarbonate, potassium bicarbonate and urea potassium bicarbonate can be very rapidly effective in extinguishing small LNG or LPG fires. Gas carriers are required by IMO Codes to be fitted with fixed dry powder systems capable of delivering adequate powder to any part of the cargo area by means of fixed monitors and/or hand held hoses. Jetty manifold areas are also usually provided with substantial portable or fixed dry powder systems. Dry chemical powders are effective in dealing with ignited spills on deck or in manifold drip trays or in extinguishing flames torching from a pipeline flange or fracture and have been used successfully in extinguishing fires at relief valve mast head outlets. Dry chemicals attack the flame by the absorption of free radicals in the combustion process but have a negligible cooling effect. Re-ignition from adjacent hot surfaces, therefore, must be guarded against by cooling any obvious hot areas with water before extinguishing the flame with dry powder.

Inert gas

Inert gas from combustion generators or nitrogen gas provided from insulated liquid nitrogen containers is commonly used on gas carriers and in terminals for permanent inerting of interbarrier spaces or for protective inerting cargo related spaces, such as ships' hold spaces or enclosed plant spaces on shore, which are normally air filled but in which flammable gas may be detected. Because of the comparatively low rate at which such gas can be delivered, it is not normally used for the rapid inerting of an enclosed space in which a fire has already begun. For this, high pressure bottled CO_2 gas or halon is injected through multiple nozzles, the mechanical ventilation system to the space having been first shut off.

While CO_2 injection systems are rapidly effective in enclosed space fire extinguishing, they have two disadvantages. Their fire extinguishing action is achieved by displacing oxygen in the space to a level which will not support combustion and it is therefore essential that all personnel completely evacuate the space before the injection beings. Secondly, the necessarily rapid injection of CO_2 produces electrostatic charging which can be an ignition hazard if CO_2 is injected inadvertently or as a precautionary measure into a flammable atmosphere.

CO_2 or nitrogen injected into safety relief valve vent outlet risers may be used as an alternative to the external use of a dry powder screen as an effective means of extinguishing vapour fires at the vent outlet, particularly once the initial full pressure gas flow has subsided.

Foam

In general foam installations are not provided on gas carriers for liquefied gas fire fighting. However when the vessel has the capability of carrying cargoes also covered by the IBC code then the flag administration may require a foam installation.

18.11 PERSONAL PROTECTION

Breathing Apparatus

It is always preferable to achieve a gas free condition in a tank or enclosed space prior to entry. Where this is not possible, entry should only be permitted in exceptional circumstances and when there is no practical alternative. In this case breathing apparatus must be worn and if necessary protective clothing must be worn also.

There are three types of respiratory protection.

- Canister filter respirators
- Fresh air respirators
- Compressed air breathing apparatus

Canister filter respirators

These consist of a mask with a replaceable canister filter attached through which contaminated air is drawn by the normal breathing of the wearer. They are simple to operate and maintain, can be put on quickly and have been used extensively as personal protection for emergency escape purposes on ships certified for carrying toxic cargoes.

They are, however, only suitable for relatively low concentrations of gas, once used there is no simple means of assessing the remaining capacity of the filter, filter materials are specific to a limited range of gases and, of course, the respirator gives no protection in atmospheres of reduced oxygen content. For these reasons, the IMO Code requirement for emergency escape protection is now met by lightweight portable package self-contained breathing apparatus.

Fresh air respirators

These consist of a helmet or face mask linked by a flexible hose (maximum length 120 feet) to an uncontaminated atmosphere from which air is supplied by a manual bellow or rotary blower. The equipment is simple to operate and maintain and its operational duration is limited only by the stamina of the bellows or blower operators. However, movement of the user is limited by the weight and length of hose and great care must be taken to ensure that the hose does not become trapped and kinked. While in general this respirator has been superseded by the self-contained or air line compressed air breathing apparatus, it will be found on many ships as an always available backup to that equipment.

Compressed air breathing apparatus

In the self-contained version (SCBA), the wearer carries his air for breathing in a compressed air cylinder at an initial pressure of between 135 and 200 bars. The pressure is reduced at the outlet from the cylinder to about 5 bars and fed to the face mask as required through a demand valve providing a slight positive pressure within the mask. Working duration depends upon the capacity of the air cylinder and the respiratory demand. Indicator and alarm features are usually provided to warn of air supply depletion.

A typical set, providing approximately 30 minutes operation with physical exertion, may weigh about 13kg and the bulk of the cylinder on the back of the wearer imposes some restriction on his manoeuvrability in confined spaces. Although when properly adjusted, the SCBA is simple and automatic in operation, its maintenance requires care and skill. To ensure their serviceability when required, all such breathing sets must be checked monthly and worn and operated during appropriate exercises preferably using special exercise air cylinders in order to keep the operational cylinders always fully charged.

Although modern demand valves are designed to maintain a slight positive pressure within the face mask, it must not be assumed that this feature will prevent leaks from the contaminated atmosphere into an ill-fitting face mask. While face mask materials and contours are designed to accommodate a range of typical facial shapes and sizes, it is essential that, before entry to a dangerous space, the air tightness of the mask on the wearer's face be thoroughly checked in accordance with the manufacturer's instructions. Comprehensive practical tests have shown that it is virtually impossible to ensure continued leak tightness in operational conditions on a bearded face.

Most compressed air breathing sets may be used in the air line version (ALBA) whereby the compressed air cylinder and pressure reducing valve are placed outside the contaminated atmosphere and connected to the face mask and demand valve by a trailed air hose. At the expense of decreased rangeability and the need for extra care in guiding the trailing air hose, the wearer is relieved of the weight and bulk of the air cylinder and his operational duration may be extended by the use of large air cylinders of continuous supply cylinder changeover arrangements.

Short duration breathing apparatus may be provided in accommodation spaces for each crew member or for carrying slung in its easy-to-open package on inspection of non-contaminated and gas-free enclosed spaces as an insurance against encountering a foul atmosphere. These sets consist of a small compressed air cylinder and a polythene hood which may be rapidly placed over the head. Their duration is limited to 15 minutes of comparatively non-exertive effort and the sets may be used purely for escape purposes.

18.15 PROTECTIVE CLOTHING

In addition to breathing apparatus full protective clothing should be worn when entering an area where contact with cargo is a possibility. Types of protective clothing vary from those providing protection against liquid splashes to a full positive pressure gas-tight suit which will normally incorporate helmet, gloves and boots. Such clothing is also to be resistant to low temperatures and solvents.

Full protective clothing is particularly important when entering a space which has contained toxic gas such as ammonia, chlorine, ethylene oxide, VCM or butadiene.

One complete set of protective clothing is to consist of:

One self-contained air breathing apparatus not using stored oxygen having a capacity of at least 1200L of free air.

Protective clothing, boots, gloves and tight fitting goggles.

Steel-covered rescue line with belt.

Explosion proof lamp.

Suitably marked decontamination showers and eyewash should be available on deck in convenient locations. The showers and eyewash should be operable in all ambient conditions.

18.16 GENERAL

This is to be read in conjunction with the relevant publications listed in the Reference Publications Index of the Fleet Operations Manual.

Speed of response is crucial, and particular attention must be paid to Emergency Party drills and the training of substitutes.

Prior to cargo operations dry powder hoses and fire-fighting equipment must be run out ready for use and sited close to the manifold being used.

The Emergency Organisation is to react according to the contents of the SOPEP/Contingency plan, except that:

a) Members of the ship's company are to muster at a point inside the accommodation.

b) Provision must be made for wives and supernumeraries to muster at a point inside the accommodation where lifejackets and escape breathing apparatus sets are stowed for their use.

18.17 ESCAPE OF GAS ON DECK

Whether a spillage of liquid or a leak of vapour, the priorities of the Emergency Party are to:

a) Stop the flow of gas

b) Prevent ignition

c) Disperse the vapour cloud

The flow of gas from a source which is between two valves on the Emergency Shut Down system will be limited. However, personnel advancing to close a valve manually close to the source of a spillage or leak must:

a) Wear breathing apparatus and protective clothing.

b) Be protected by a massive water wall

Care must be taken to avoid cargo coming into contact with the skin.

Any leak of LPG will produce a rapidly expanding cloud of explosive vapour, which must be prevented from coming into contact with a source of ignition. It is imperative therefore to isolate any source of ignition and ensure that no vapours enter the accommodation. Early consideration must be given to altering course and/or speed, and if necessary to stopping ventilation fans. Personnel who have to leave the accommodation to close vent intakes must wear breathing apparatus and protective clothing.

If a vapour cloud approaches a known source of ignition, consideration must be given to attempting to "bend" its path by putting up a solid water wall.

The rate of dispersal of a vapour cloud will depend on climatic conditions. However, the use of liberal quantities of water in spray form will increase the rate of vaporisation, and, in the case of liquid spillage, reduce the risk of cold fractures of steel. Solid water jets must not be used on liquid spills, as they will result in splashing of cold liquid. Fixed water sprays may also assist in vapour dispersal if near enough to the cloud.

18.18 FIRES INVOLVING LPG

The highest priority of action must be given to stopping the gas flow to limit the amount of flammable material available, and contain the fire in as small an area as possible. This may happen automatically with the operation of the Emergency Shut Down System. Fire fighters must wear protective clothing and self-contained compressed air breathing apparatus. Tackling the fire requires the use of two media, water and dry powder.

Large quantities of water spray are to be used:

a) To protect fire fighters and those assisting the rescue of trapped personnel from spaces.

b) To cool surfaces exposed to heat.

c) To prevent heat radiation through steel bulkheads.

The normal extinguishing medium for LPG fires is dry powder, which is propelled by nitrogen. The Master is to ensure that all Officers are familiar with the operation of this equipment, and the technique to be used in fighting a LPG fire.

The best results are achieved by applying dry powder at a maximum rate by using as many guns as possible from upwind. The guns must sweep rapidly backwards and forwards over the fire area. If a liquid spillage is involved, the surface of the spillage must not be disturbed by direct impact.

Dry powder guns discharge at not less than 4 kilos per second. The initial recoil and subsequent force exerted by discharge means that in order to avoid the wastage of dry powder, a second person may be needed to help the operator maintain control of the gun.

If it is judged preferable to allow a flame to burn from a controlled leak, such as a pipe fracture, water spray is to be used to contain the fire without extinguishing the flame.

Either CO_2 or Halon are fitted to the Cargo Control Room, Compressor Room and Motor Room on LPG ships.

18.19 ABANDONING THE SHIP IN THE PRESENCE OF TOXIC VAPOURS

The Master may have to consider abandoning ship in the presence of toxic gas following, for example, a collision or fracture in the loading line. For this purpose, sufficient escape breathing apparatus of 15 minutes duration are supplied for all on board.

(a) At Sea

If, during cargo operations, the accommodation becomes filled with toxic vapours (e.g. Anhydrous Ammonia) such that it is impossible for personnel to remain therein, the Master may order the ship to be abandoned, or at least to move the ship's company upwind of the source.

In this case, the Emergency Party, wearing full breathing apparatus, is to prepare the most suitable lifeboats, and lower them to the embarkation level.

When instructed, personnel and supernumeraries inside the accommodation are to put on their escape breathing apparatus and man the lifeboats with the minimum of delay. The Officer on the brake is to board the lifeboat by way of the ladder when the boat is in the water. Some types of fully enclosed boats may be lowered from inside the boat.

The lifeboat is to be manoeuvred upwind, clear of the vapour before the engine is started. This restriction may not be necessary with enclosed lifeboats. This operation is to be undertaken by personnel wearing full breathing apparatus, with their own escape breathing apparatus as standby.

Once the escape breathing apparatus has been put on, action must be swift and completed well within the 15 minutes duration of the sets.

This is a difficult operation and is only to be attempted if there are no alternatives. Whenever a suitable opportunity presents itself, the Master is to conduct exercises as outlined involving the whole ship's company.

(b) In Port

Circumstances may arise where the Master has to order the ship to be abandoned when the accommodation area is enveloped in a cloud of toxic vapour. In this case, the Emergency Party, wearing full breathing apparatus, will be responsible for indicating the route to be taken by personnel (wearing their escape breathing apparatus).

18.20 EXPOSURE TO GAS CARGOES

18.20.1 PRECAUTIONS TO AVOID EXPOSURE

During cargo operations, the number of personnel allowed on deck forward of the accommodation must be kept to the minimum. Under normal circumstances they are to be restricted to those persons directly concerned with the loading/discharging operation.

During all cargo and gas freeing operations the Master is to consider the risk to personnel on deck encountering a concentration of cargo vapour. If the cargo is particularly hazardous, he is to ensure that personnel working on deck carry the Emergency Life Support Apparatus.

In vessels carrying Vinyl Chloride Monomer or Propylene Oxide where there is a possibility of vapour of liquid escaping, all operations such as hose disconnection and cargo sampling will be carried out or supervised by personnel wearing full CABA and totally enclosed protective clothing.

18.20.2ACTION IN THE EVENT OF EXPOSURE

The action to be taken will depend on whether exposure has resulted in:

a) liquid in the eye
b) liquid on the skin
c) vapour being inhaled

Action in each case is similar for many types of cargo carried in LPG ships, but chemical data sheets (MSDS's) must be checked before handling begins.

Decontamination centres and eye wash facilities are provided to assist persons who have been contaminated by cargo.

a) If liquid has entered the eye, it must be flooded gently with clean water for at least 15 minutes (30 minutes for ammonia). It will probably be necessary to force the eye open.

b) Skin contact with liquid from most hydrocarbon cargoes will produce immediate FROSTBITE and remedial action must be rapid and well practised, since medical assistance may not be readily available. Contaminated clothing must be swiftly removed and the affected area immersed in water.

c) Where vapour inhalation occurs, the victim must be removed upwind to fresh air. If breathing has stopped mouth-to-mouth resuscitation must be started at once, pending arrival of the 'Resusepac', if available.

Immediate medical advice and assistance should be sought in all cases of exposure to gas cargoes.

18.20.3ESCAPE BREATHING SETS

The Master is to ensure that all personnel onboard are familiar with the operation and the limitations of these sets. In particular, newly joined personnel are to be instructed in the use of these sets when they sign on.

It is the responsibility of the Second Officer to ensure that the compressed air cylinders are full and that they are checked monthly or more frequently if required. On no account are these sets to be used for operational use, inspection, rescue or fire-fighting support. They have duration of 15 minutes and are to be used only to assist personnel escape from concentrations of toxic vapours.

18.20.4FILTER MASKS

Some vessels carry these masks and have in the past used them around the deck, particularly with ammonia cargoes.

They are safe for use in atmospheres with less than 0.5% by vol., and then only for 30 minutes duration. The period of effectiveness reduces as the concentration rises.

From the above, it can be seen that at very high concentrations these masks become useless. It is the Company's policy that CABA sets be used where concentrations of gas may be expected, particularly in operations such as connecting and disconnecting hoses or in the fitting removing purge pipes.

19. LPG CARRIERS

19.1 EMERGENCY PROCEDURE

19.1.1 GENERAL

This is to be read in conjunction with the relevant publications listed in the Reference Publications Index of the Fleet Standing Instructions Manual.

Speed of response is crucial, and particular attention must be paid to Emergency Party drills and the training of substitutes.

Prior to cargo operations dry powder hoses and fire-fighting equipment must be run out ready for use and sited close to the manifold being used.

The Emergency Organisation will react according to the plan described in Section 2, except that:

a) Members of the ship's company will muster at a point inside the accommodation.

b) Provision must be made for wives and supernumeraries to muster at a point inside the accommodation where lifejackets and escape breathing apparatus sets are stowed for their use.

19.1.2 ESCAPE OF GAS ON DECK

Whether a spillage of liquid or a leak of vapour, the priorities of the Emergency Party are to:

a) Stop the flow of gas

b) Prevent ignition

c) Disperse the vapour cloud

The flow of gas from a source which is between two valves on the Emergency Shut Down system will be limited. However, personnel advancing to close a valve manually close to the source of a spillage or leak must:

a) Wear breathing apparatus and protective clothing.

b) Be protected by a massive water wall

Care must be taken to avoid cargo coming into contact with the skin.

Any leak of LPG will produce a rapidly expanding cloud of explosive vapour, which must be prevented from coming into contact with a source of ignition. It is imperative therefore to isolate any source of ignition and ensure that no vapours enter the accommodation. Early consideration must be given to altering course and/or speed, and if necessary to stopping ventilation fans. Personnel who have to leave the accommodation to close vent intakes must wear breathing apparatus and protective clothing.

If a vapour cloud approaches a known source of ignition, consideration must be given to attempting to "bend" its patch by putting up a solid water wall.

The rate of dispersal of a vapour cloud will depend on climatic conditions. However, the use of liberal quantities of water in spray form will increase the rate of vaporisation, and, in the case of liquid spillage, reduce the risk of cold fractures of steel. Solid water jets must not be used on liquid spills, as they will result in splashing of cold liquid. Fixed water sprays may also assist in vapour dispersal if near enough to the cloud.

19.1.3 FIRES INVOLVING LPG

The highest priority of action must be given to stopping the gas flow to limit the amount of flammable material available, and contain the fire in as small an area as possible. This may happen automatically with the operation of the Emergency Shut Down System. Fire fighters must wear protective clothing and self-contained compressed air breathing apparatus. Tackling the fire requires the use of two media, water and dry powder.

Large quantities of water spray are to be used:

a) To protect fire fighters and those assisting the rescue of trapped personnel from spaces.

b) To cool surfaces exposed to heat.

c) To prevent heat radiation through steel bulkheads.

The normal extinguishing medium for LPG fires is dry powder, which is propelled by nitrogen. The Master is to ensure that all Officers are familiar with the operation of this equipment, and the technique to be used in fighting a LPG fire.

The best results are achieved by applying dry powder at a maximum rate by using as many guns as possible from upwind. The guns must sweep rapidly backwards and forwards over the fire area. If a liquid spillage is involved, the surface of the spillage must not be disturbed by direct impact.

Dry powder guns discharge at not less than 4 kilos per second. The initial recoil and subsequent force exerted by discharge means that in order to avoid the wastage of dry powder, a second person may be needed to help the operator maintain control of the gun.

If it is judged preferable to allow a flame to burn from a controlled leak, such as a pipe fracture, water spray is to be used to contain the fire without extinguishing the flame.

Either CO_2 or Halon are fitted to the Cargo Control Room, Compressor Room and Motor Room on LPG ships.

19.1.4 ABANDONING THE SHIP IN THE PRESENCE OF TOXIC VAPOURS

The Master may have to consider abandoning ship in the presence of toxic gas following, for example, a collision or fracture in the loading line. For this purpose, sufficient escape breathing apparatus of 15 minutes duration are supplied for all on board.

(a) **At Sea**

If, during cargo operations, the accommodation becomes filled with toxic vapours (e.g. Anhydrous Ammonia) such that it is impossible for personnel to remain therein, the Master may order the ship to be abandoned, or at least to move the ship's company upwind of the source.

In this case, the Emergency Party, wearing full breathing apparatus, is to prepare the most suitable lifeboats, and lower them to the embarkation level.

When instructed, personnel and supernumeraries inside the accommodation are to put on their escape breathing apparatus and man the lifeboats with the minimum of delay. The Officer on the brake is to board the lifeboat by way of the ladder when the boat is in the water. Some types of fully enclosed boats may be lowered from inside the boat.

The lifeboat is to be manoeuvred upwind, clear of the vapour before the engine is started. This restriction may not be necessary with enclosed lifeboats. This operation is to be undertaken by personnel wearing full breathing apparatus, with their own escape breathing apparatus as standby.

Once the escape breathing apparatus has been put on, action must be swift and completed well within the 15 minutes duration of the sets.

This is a difficult operation and is only to be attempted if there are no alternatives. Whenever a suitable opportunity presents itself, the Master is to conduct exercises as outlined involving the whole ship's company.

(b) **In Port**

Circumstances may arise where the Master has to order the ship to be abandoned when the accommodation area is enveloped in a cloud of toxic vapour. In this case, the Emergency Party, wearing full breathing apparatus, will be responsible for indicating the route to be taken by personnel (wearing their escape breathing apparatus).

19.1.5 EMERGENCY SHUT DOWN SYSTEM

All members of the ship's company must be aware of the methods of activating the Emergency Shut Down System.

The Emergency Shut Down System is a quick closing system, which may be activated automatically or manually. It will close all deck valves and shut down all cargo machinery.

The automatic system is an airline, which is constantly pressurised. Activation results in the release of the air in the line and a pressure switch detects the resulting drop in pressure. There are three consequences of this:

a) The Emergency Alarm sounds.

b) Air is exhausted which activates a pressure switch from the supply line, which allows the valves to close.

c) Electrical relays operate to stop cargo pumps, LPG compressors and R22 compressors.

To avoid unacceptable pressure surges in the pipelines, there is a time lag in closing valves. From activation of the system to valves being completely closed will take from 20-30 seconds.

a) Automatic Operation

b) At each tank dome and manifold, the Emergency Shut Down System contains a fusible plug. In the event of a fire, the plug will melt to allow the air in the system to evacuate.

c) Manual Operation

I. Electrical push-button switches are situated in the Cargo Control Room, the Engine Control Room and the Wheelhouse.

II. Push buttons, painted red, are situated at strategic points around the deck.

19.2 EXPOSURE TO GAS CARGOES

19.2.1 PRECAUTIONS TO AVOID EXPOSURE

During cargo operations, the number of personnel allowed on deck forward of the accommodation must be kept to the minimum. Under normal circumstances they are to be restricted to those persons directly concerned with the loading/discharging operation.

During all cargo and gas freeing operations the Master is to consider the risk to personnel on deck encountering a concentration of cargo vapour. If the cargo is particularly hazardous, he is to ensure that personnel working on deck wear the Emergency Life Support Apparatus.

In vessels carrying Vinyl Chloride Monomer or Propylene Oxide where there is a possibility of vaporisation and during all cargo and gas freeing operations the Master is to consider the risk to personnel on deck encountering a concentration of cargo vapour. If the cargo is particularly hazardous, he is to ensure that personnel working on deck wear the Emergency Life Support Apparatus.

In vessels carrying Vinyl Chloride Monomer or Propylene Oxide where there is a possibility of vapour of liquid escaping all operations such as hose disconnection and cargo sampling will be carried out or supervised by personnel wearing full CABA and totally enclosed protective clothing.

19.2.2 ACTION IN THE EVENT OF EXPOSURE

The action to be taken will depend on whether exposure has resulted in:

a) liquid in the eye
b) liquid on the skin
c) vapour being inhaled

Action in each case is similar for many types of cargo carried in LPG ships, but chemical data sheets (MSDS's) must be checked before handling begins.

Decontamination centres and eye wash facilities are provided to assist persons who have been contaminated by cargo.

a) If liquid has entered the eye, it must be flooded gently with clean water for at least 15 minutes (30 minutes for ammonia). It will probably be necessary to force the eye open.

b) Skin contact with liquid from most hydrocarbon cargoes will produce immediate FROSTBITE and remedial action must be rapid and well practised, since medical assistance may not be readily available. Contaminated clothing must be swiftly removed and the affected area immersed in water.

c) Where vapour inhalation occurs, the victim must be removed upwind to fresh air. If breathing has stopped mouth-to-mouth resuscitation must be started at once, pending arrival of the 'Resusipac', if available.

Immediate medical advice and assistance should be sought in all cases of exposure to gas cargoes.

19.2.3 VINYL CHLORIDE MONOMER

Vinyl Chloride Monomer (V.C.M.) is carried as a liquid in certain LPG ships, which have been converted or built for the purpose.

V.C.M. is a chlorinated hydrocarbon and has flammability limit of 4 - 33% by volume and toxicity characteristics similar to many cargoes of hydrocarbon origin. **In addition, however, long-term**

exposure to <u>high concentrations</u> has been linked with a rare form of cancer, the TLV has therefore been set at 10 ppm - a level well below the bottom of the flammable range. V.C.M. has an odour threshold of 2000 ppm and therefore smell cannot be relied upon as a means of detection.

It should be noted however that to date no cases have been recorded relating to exposure to the monomer. The only cases have been linked with production processes, and in particular to cleaning of the autoclaves used in the production of PVC.

Nevertheless, it is policy that exposure levels should not exceed 10 ppm unless suitable protection such as CABA, ELSA and possible chemical suits are used.

Ships, which are in the VCM trade for all or part of the time, have specialised detection and protective equipment. In addition, modified emergency procedures have been developed to deal with the problems, which may arise from the presence of the gas.

19.2.4 PROPYLENE OXIDE

Propylene oxide (PO) is an eserine with wide flammable limits of 2.8 - 37% by volume. The TLV of this product is 100 ppm whilst its odour threshold is 10 ppm. Exposure to the liquid or high concentrations of the vapour can lead to eye burns, skin irritation and blistering, vomiting, lack of co-ordination and depression.

19.2.5 ESCAPE BREATHING SETS

One short-duration escape breathing apparatus is provided in the Company's LPG ships for each person on board. The total number of sets onboard is equal to the number of persons the ship is certified to carry.

The Master is to ensure that all personnel onboard are familiar with the operation and the limitations of these sets. In particular, newly joined personnel are to be instructed in the use of these sets when they sign on.

It is the responsibility of the Second Officer to ensure that the compressed air cylinders are full and that they are checked monthly or more frequently if required. On no account are these sets to be used for operational use, inspection, rescue or fire-fighting support. They have duration of 15 minutes and are to be used only to assist personnel escape from concentrations of toxic vapours.

19.2.6 FILTER MASKS

Some vessels carry these masks and have in the past used them around the deck, particularly with ammonia cargoes. These filter masks are not part of the ship' safety equipment and are not to be used on board.

The following is true of these filter masks:

a) They are safe for use in atmospheres with less than 0.5% by vol., and then only for 30 minutes duration. The period of effectiveness reduces as the concentration rises.

From the above, it can be seen that at very low concentrations these masks become useless. It is the Company's policy that CABA sets be used where concentrations of gas may be expected, particularly in operations such as connecting and disconnecting hoses or in the fitting removing purge pipes.

19.2.7 PROTECTIVE CLOTHING

At least 5 suits of fire protective clothing, consisting of trousers, jackets, helmet, gloves, boots, CABA set, fire axe and safety line are supplied to the Company's LPG ships and these should be stowed:

*	Emergency Headquarters	-	3
	Cargo Control Room	-	2

When wearing protective clothing it is important to ensure that neither the sleeves are tucked into the gloves, not the trousers into the boots. This is to avoid low temperature cargo falling into the gloves and boots of personnel working in areas where splashing of cargo of spillage is possible.

Sleeves are to pass over gloves and trousers over the boots of all protective clothing.

- In some ships, the construction, size or type may necessitate a departure from this distribution.

Where this is the case, the location of equipment will be established by the Superintendent and noted in the ship's Safety Set.

20. PERSONAL SAFETY AND HEALTH

Gas tankers are designed such that in normal operation, personnel need at no time be exposed to hazard from the products being transported, provided that the ship and its equipment are properly maintained and operating instructions are observed.

Hazard avoidance depends on:

1. Hazard removal
2. Hazard control
3. Reliance on personal protection
4. Training

Liquefied gas relate to the following hazards asphyxia, toxicity, low temperature and flammability.

*See Health Data Liquids and Vapour/Gases

20.1 ASPHYXIA

Normal breathing requires air with an oxygen content of 20.8%. At 19.5% there is in general a rapid onset of impairment of activity and reasoning power. At levels below 16% oxygen, the onset of unconsciousness may be rapid. At lower levels exposure time for ultimate survival shortens rapidly. A victim removed from this situation before death may suffer permanent brain damage.

20.2 TOXICITY

Toxicity is the ability of a substance to cause damage to living tissue, the nervous system, illness and in extreme cases death when ingested, inhaled or absorbed through the skin.

20.3 THRESHOLD LIMIT VALUES

Given as a guide to vapour concentrations for prolonged exposure, such as might occur in plant operation and usually given in PPM (parts of vapour per million parts of contaminated air by volume).

***HEALTH DATA - LIQUIDS**

Substance	Irritant	Cold burn	Chemical burn	Skin absorption
LNG	-	X	-	-
LPG	-	X	-	-
Methane	-	X	-	-
Ethane	-	X	-	-
Propane	-	X	-	-
Butane	-	X	-	-
Ethylene	-	X	-	-
Propylene	-	X	-	-
Butylene	-	X	-	-

Butadiene	X	X	-	-
VCM	-	X	-	X
Ammonia	X	X	X	-
Chlorine	X	X	X	X
Ethylene oxide	X	X	X	-
Propylene oxide	X	-	X	-
Nitrogen	-	X	-	-

***HEALTH DATA - VAPOURS/GASES**

Substance	**Asphyxiant**	**Narcotic**	**Toxic System**	**Irritant**	**Typical TLV TWA (STEL) ppm by vol**
LNG	X	-	-	-	-
LPG	X	-	-	-	1000(1250)
Methane	X	-	-	-	-
Ethane	X	-	-	-	-
Propane	X	-	-	-	-
Butane	X	-	-	-	800
Ethylene	X	X	-	-	-
Propylene	X	X	-	-	-
Butylene	X	X	-	-	-
Butadiene	X	X	-	-	-
VCM	X	XX	X	-	5
Ammonia	X	-	X	X	25(35)
Chlorine	X	-	X	X	1(3)
Ethylene	X	XX	X	X	1
Propylene oxide	X	XX	X	X	20
Nitrogen	X	-	-	-	-
Flue gas	X	-	X	X	-

X Mild

XX Strong

(i) **TLV-TWA** Time weighted average concentration for an 8 hour day or 40 hour week throughout working life.

(ii) **TLV-STEL** Short term exposure limit in terms of the maximum concentration allowable for a period of up to 15 minutes duration provided there are no more than 4 such excursions per day and at least 60 minutes between excursions.

(iii) **TLV-C** The ceiling concentration which should not be exceeded even instantaneously.

While most substances that are quoted are allocated a TLV-TWA and a TLV-STEL, only those which are predominantly fast-acting are given a TLV-C.

20.4 COLD AND CHEMICAL BURNS

Skin contact with materials that are very cold compared with human temperature will cause damage similar to that when contact is made with hot materials of similar temperature difference. Some cargoes will cause chemical burning in addition to cold burning. Gases that cause chemical burning are especially dangerous to the eyes!

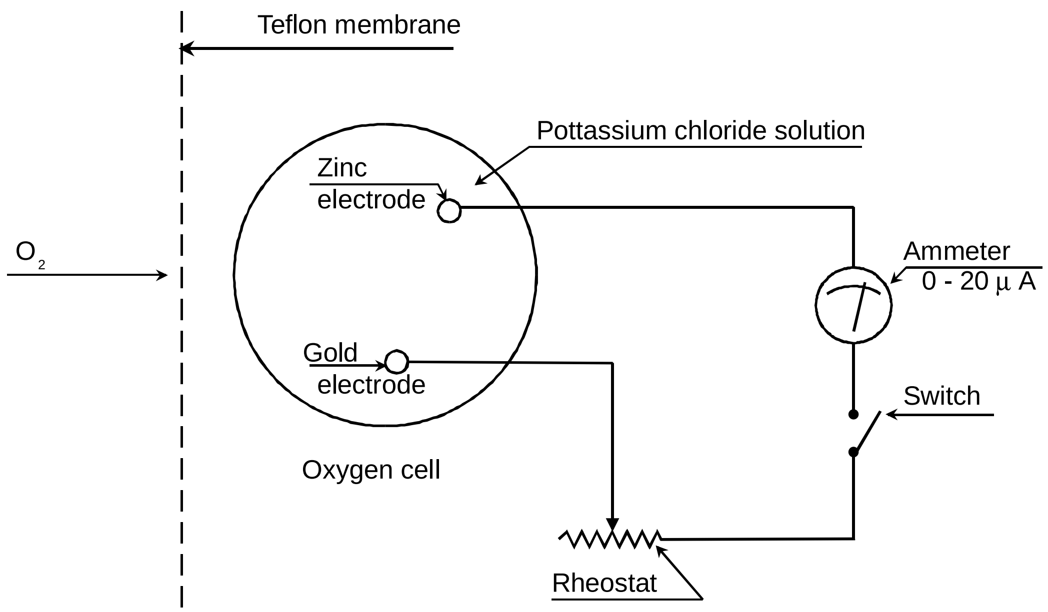
20.5 ATMOSPHERE EVALUATION

Vapour detection equipment is required by IMO codes for a number of reasons.

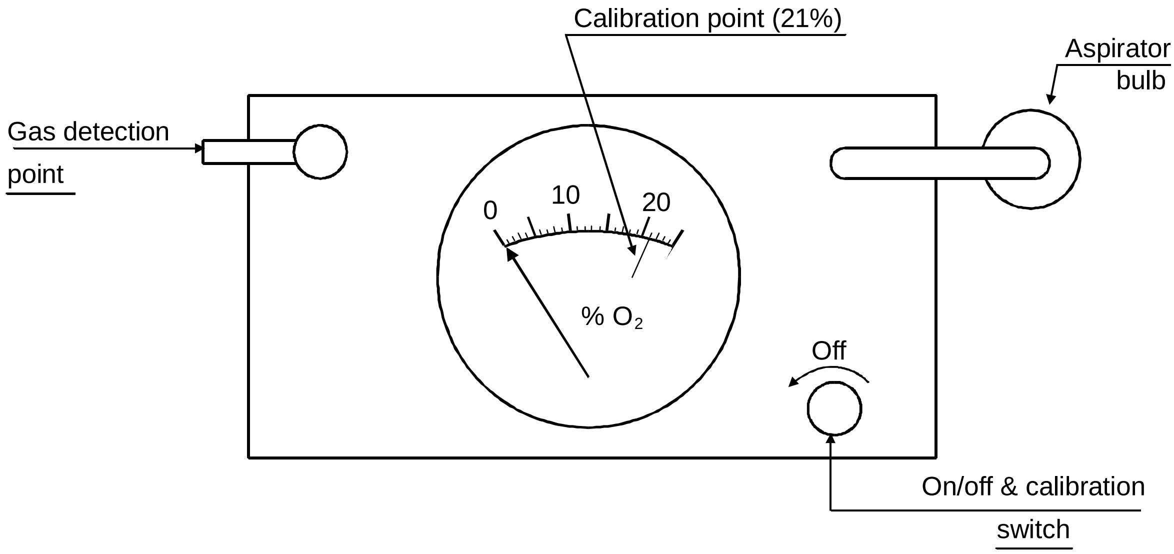
1. Cargo vapour in air, inert gas or the vapour of another cargo.
2. Concentrations of gas in or near the flammable range.
3. Concentrations of oxygen in inert gas, cargo vapour or enclosed spaces.

20.6 OXYGEN ANALYSER/INDICATORS

A typical indicator draws the sample through a teflon membrane into a potassium chloride solution and activates a chemical cell. When the switch is closed current flows round the circuit and deflects the ammeter needle. The more oxygen absorbed by the solution the greater the current and needle deflection indicating the percentage oxygen in the sample.



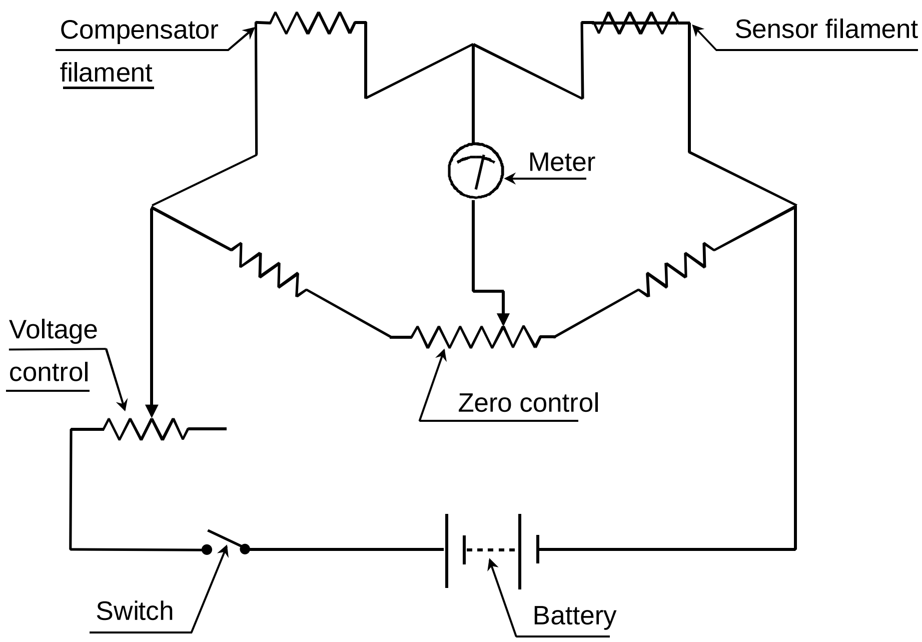
Oxygen indicator



Oxygen indicator (without alarm function)

20.7 COMBUSTIBLE GAS INDICATORS

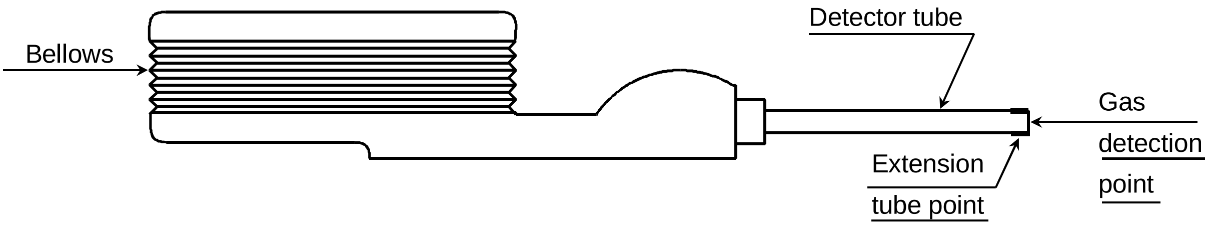
The basic electric circuit (Wheatstone Bridge) of the combustible gas indicator is shown. Sample gas to be measured is aspirated over the specially treated sensor filament which is heated by the bridge current. Although the gas sample may be below the lower flammable limit, it will burn catalytically on the filament surface. In so doing it will raise the temperature of the filament and thereby increase its electrical resistance and so unbalance the bridge. The resultant imbalance current is shown on the meter and is related to the hydrocarbon content of the sample gas.



Combustible gas indicator

20.8 TOXICITY DETECTORS

Toxic gas detectors commonly operate on the principle of absorption of the toxic gas in a chemical tube which results in a colour change. A common type of toxic gas detector is illustrated. Immediately prior to use the ends are broken from a sealed glass tube. This is inserted into the bellows unit, and a sample aspirated through it. The reaction between the gases being sampled and the chemicals contained in the tube causes a colour change. Usually readings are taken from the length of the colour stain against scale indicators marked on the tube and are expressed as parts per million (ppm). Some tubes, however, require the colour change to be matched against a control provided in the instructions. As tubes may have a specific shelf life they are date stamped and also accompanied by an instruction leaflet which lists any different gases which being present may interfere with the accuracy of the indication.

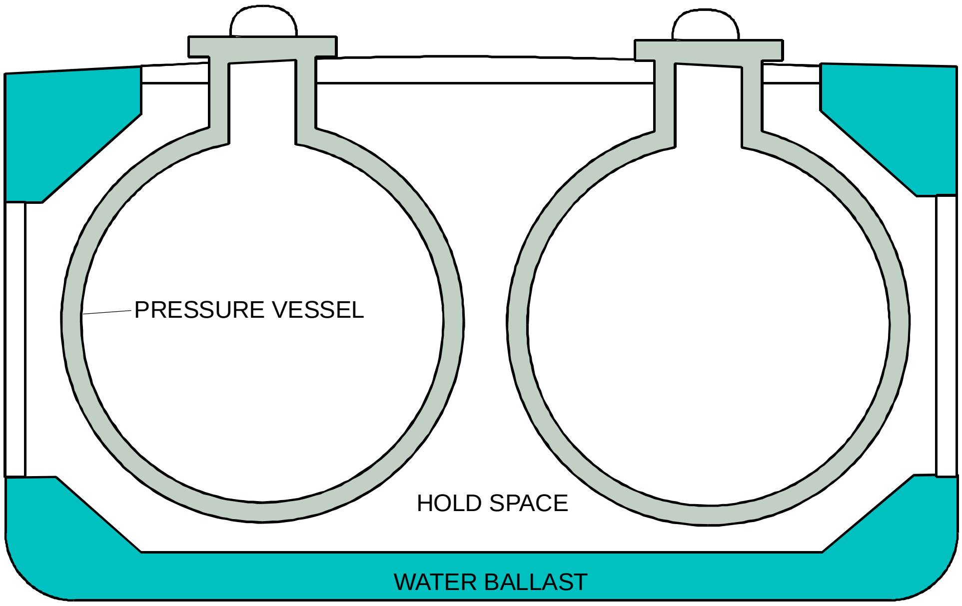


Toxic gas indicator

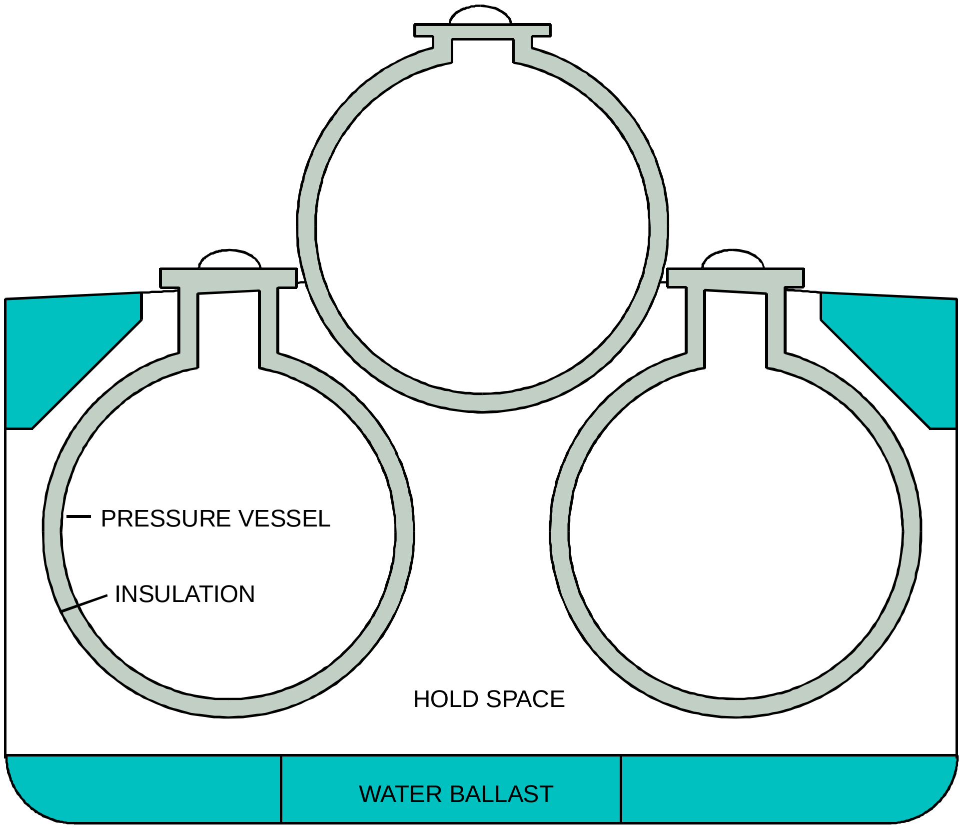
It is important to aspirate the bulb correctly if reliable results are to be obtained. Normally, the bellows are compressed and the unbroken tube inserted. The instrument is then checked for leaks prior to breaking the tube; if found to be faulty it must be replaced at once.

CRITICAL TEMPERATURES AND PRESSURES

Gas	Atmospheric boiling point (°C)	Critical temp (°C)	Critical pressure (bars, absolute)	Condensing ratio $\frac{dm^3 \text{ liquid}}{lm^3 \text{ gas}}$	Liquid relative density at Atm.Boiling Pt (Water= 1)	Vapour relative density (Air = 1)
Methane	-161.5	- 82.5	44.7	0.804	0.427	0.554
Ethane	- 88.6	32.1	48.9	2.453	0.540	1.048
Propane	- 42.3	96.8	42.6	3.380	0.583	1.55
n-Butane	- 0.5	153	38.1	4.32	0.600	2.09
i-Butane	- 11.7	133.7	38.2	4.36	0.596	2.07
Ethylene	-103.9	9.9	50.5	2.20	0.570	0.975
Propylene	- 47.7	92.1	45.6	3.08	0.613	1.48
a-Butylene	- 6.1	146.4	38.9	4.01	0.624	1.94
y-Butylene	- 6.9	144.7	38.7	4.00	0.627	1.94
Butadiene	- 5.0	161.8	43.2	3.81	0.653	1.88
Isoprene	34	211.0	38.5		0.67	2.3
VCM	- 13.8	158.4	52.9	2.87	0.965	2.15
Ethylene oxide	10.73	195.7	74.4	2.13	0.896	1.52
Propylene oxide	34.2	209.1	47.7		0.830	2.00
Ammonia	- 33.4	132.4	113.0	1.12	0.683	0.597
Chlorine	- 34	144	77.1	2.03	1.56	2.49



FULLY PRESSURISED SHIP



SEMI - REFRIGERATED SHIP

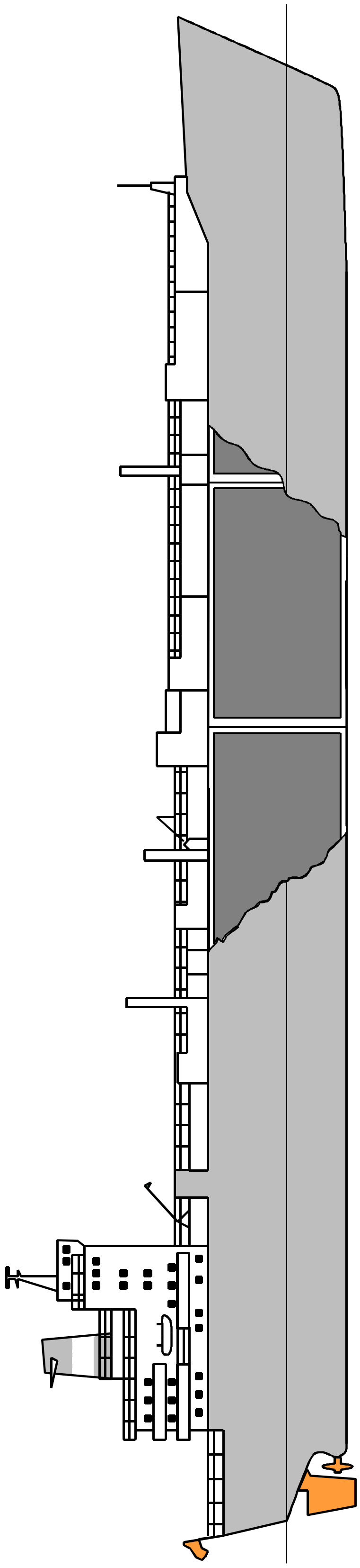


Fig. A.2.5 75,000 m^3 FULLY REFRIGERATED LPG-CARRIER WITH SELF SUPPORTING PRISMATIC TANKS

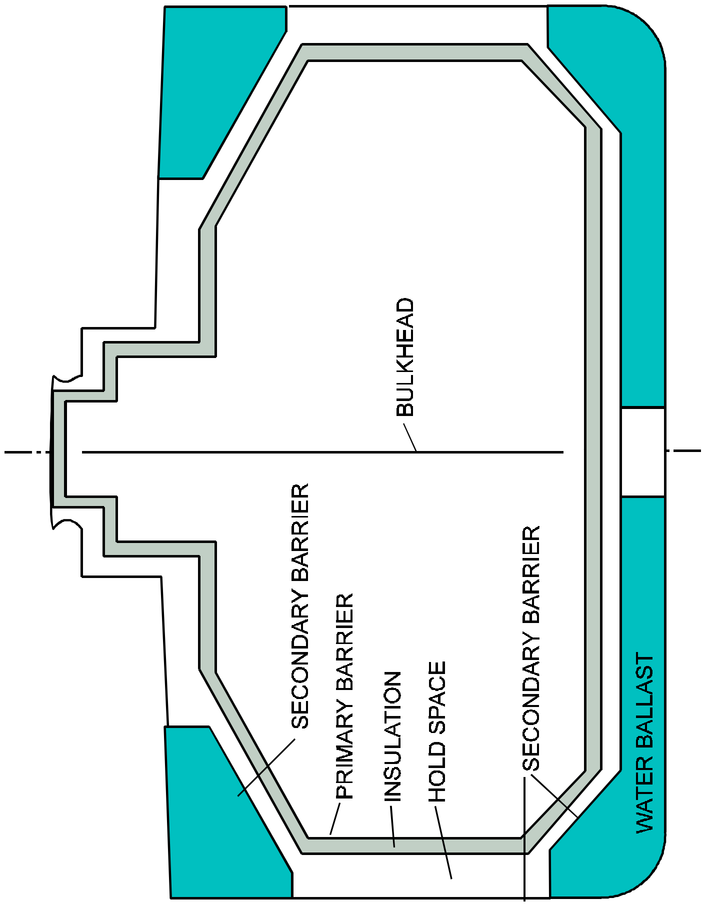
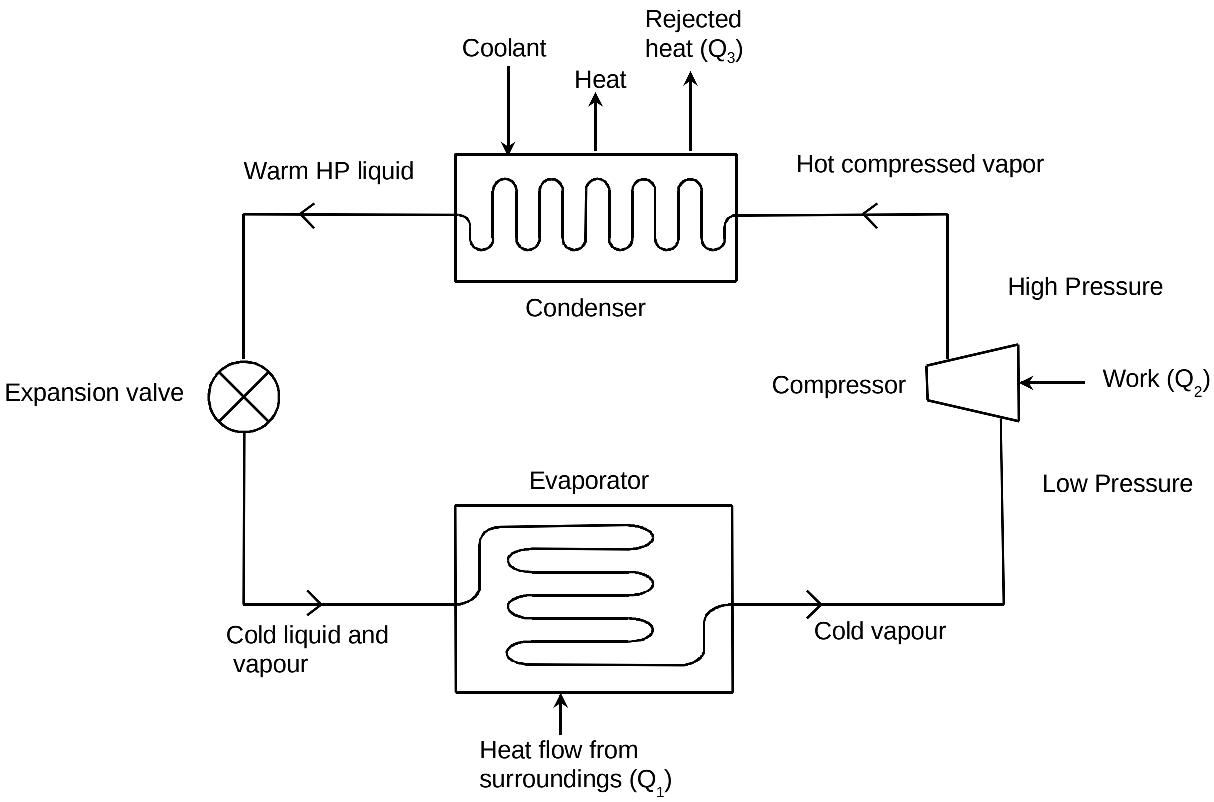
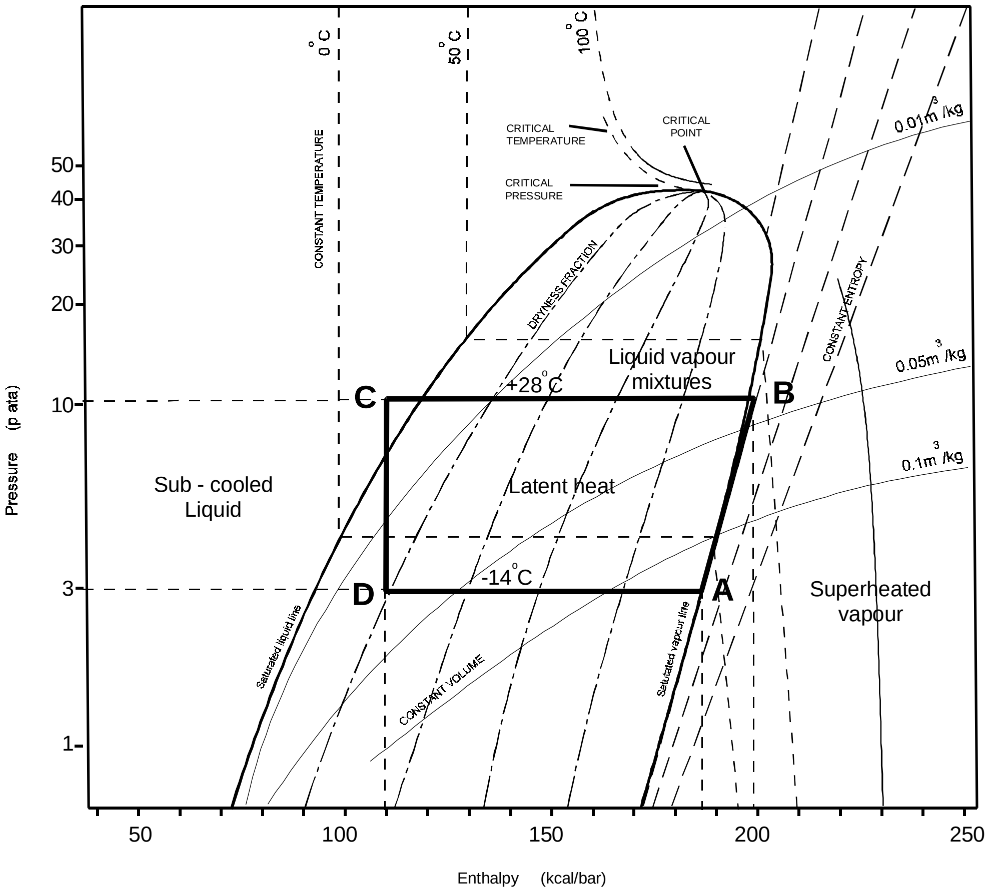


Fig. A.2.6 SELF SUPPORTING PRISMATIC TANK



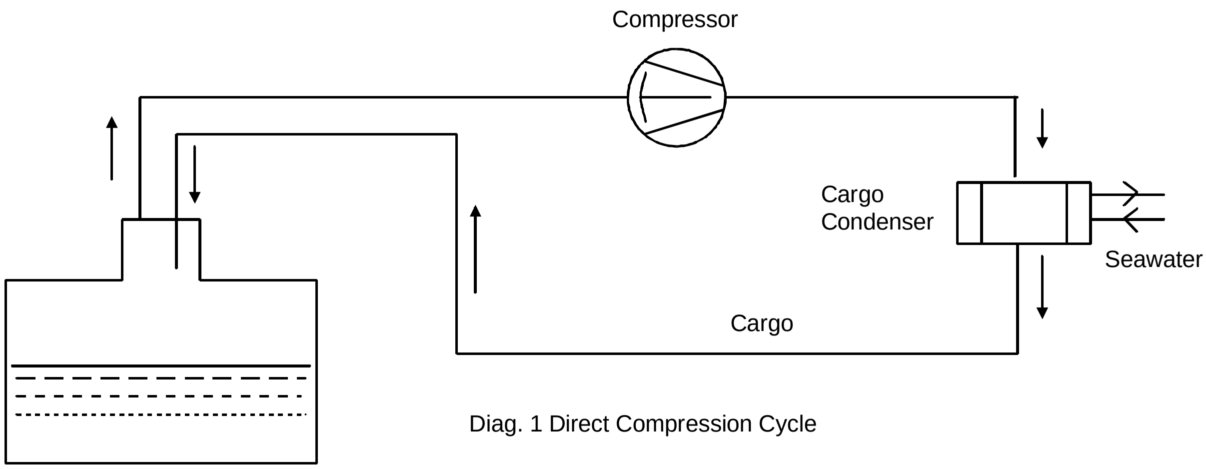
Simple refrigeration evaporation / condensation cycle



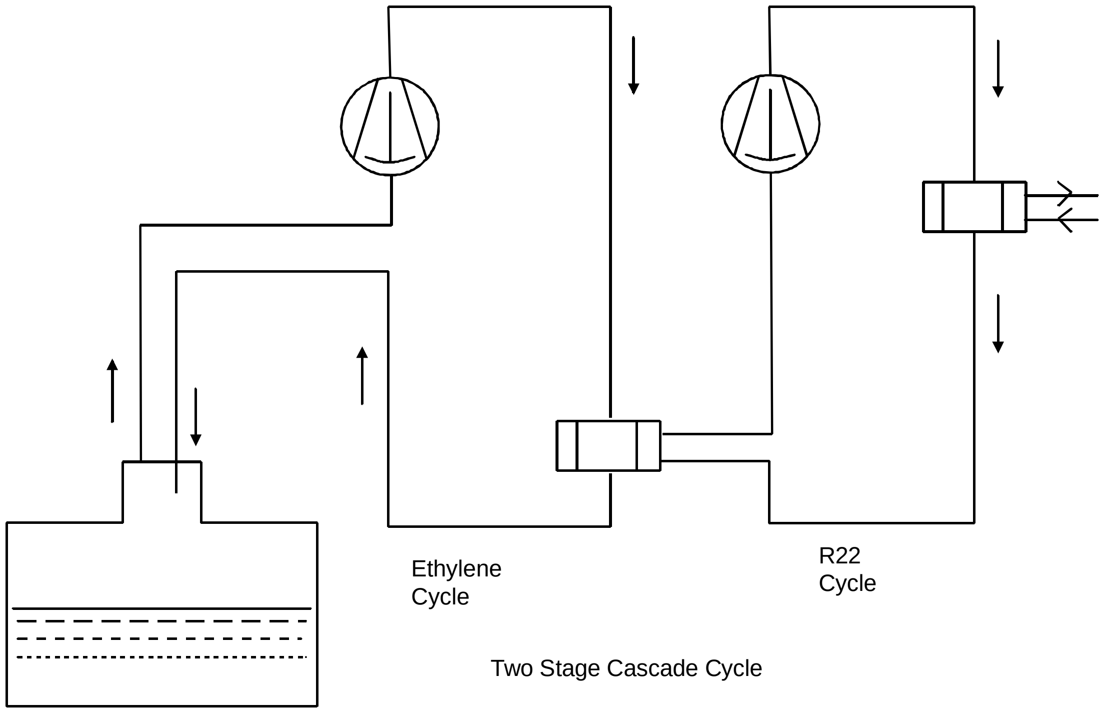
MOLLIER DIAGRAM FOR PROPANE - TYPICAL

Flammability and Explosion

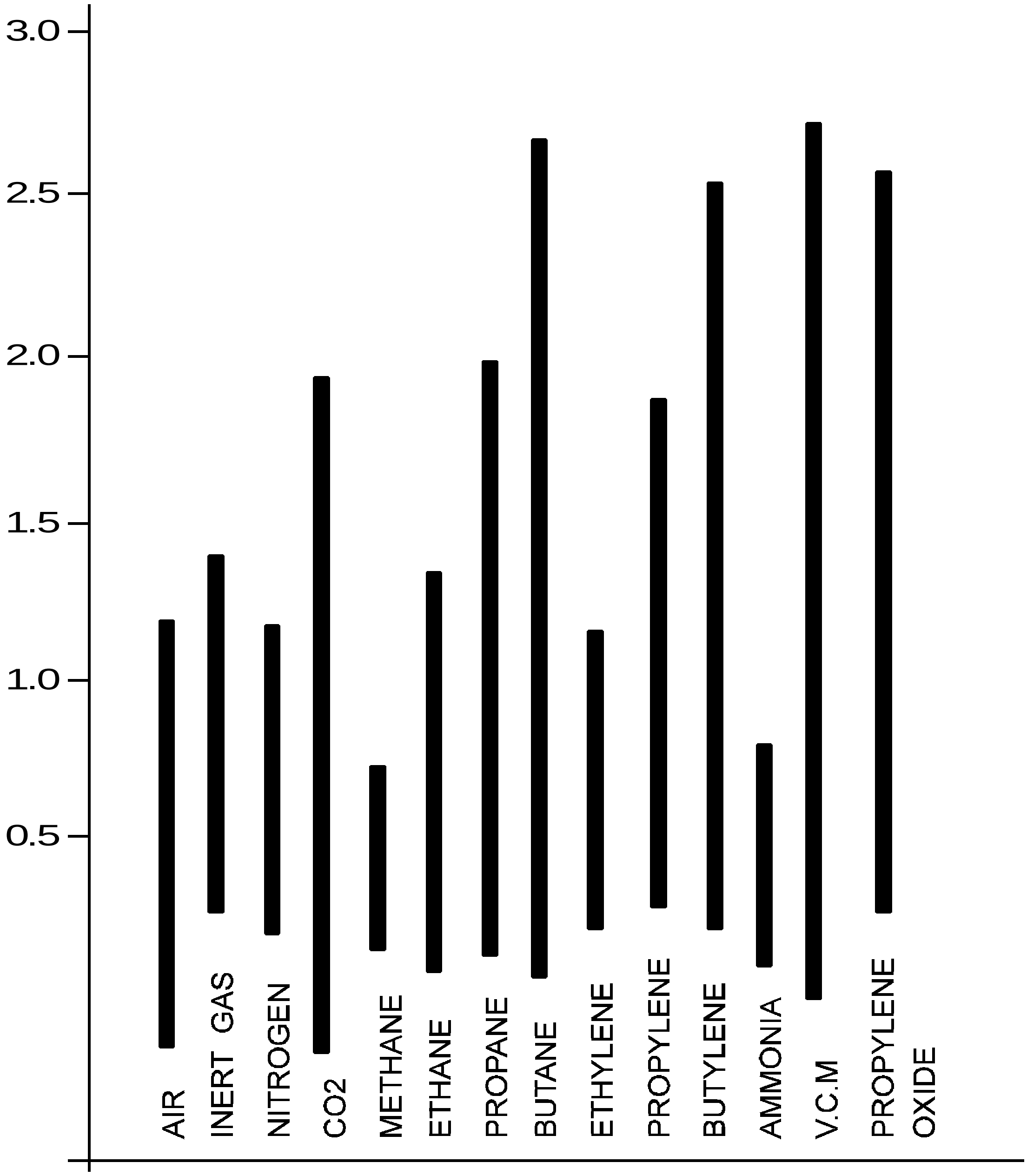
Liquefied Gas	Flash Point (°C)	Flammable range (0% by vol in air)	Auto-ignition temperature (°C)
Methane	- 175	5.3 - 14	595
Ethane	- 125	3.1 - 12.5	510
Propane	- 105	2.1 - 9.5	468
n-Butane	- 60	1.8 - 8.5	365
i-Butane	- 76	1.8 - 8.5	500
Ethylene	- 150	3 - 32	453
Propylene	- 180	2 - 11.1	453
a-Butylene	- 80	1.6 - 9.3	440
B-Butylene	- 72	1.8 - 8.8	465
Butadiene	- 60	2 - 12.6	418
Isoprene	- 50	1 - 9.7	220
VCM	- 78	4 - 33	472
Ethylene oxide	- 18	3 - 100	429
Propylene oxide	- 37	2.8 - 37	465
Ammonia	- 57	16 - 25	615
Chlorine	Non-flammable		



Diag. 1 Direct Compression Cycle



Two Stage Cascade Cycle



GAS DENSITIES IN KG/CU MTR AT STANDARD CONDITIONS - 0 DEG C; 1,033 BAR

GUIDELINES FOR CARGO TANK CONDITIONS PRIOR TO LOADING LPG AND PO

NEXT CARGO →	BUTANE	BUTA-DIENE	BUTY-LENE	C4-RAFF	ETHY-LENE	PROPANE	PROPY-LENE	P.O.	PROMIX	V.C.M	C4-CRUDE
O2 CONTENT	< 0.5%	< 0.2%	< 0.3%	<0.3%	< 0.3%	<0.5%	< 0.3%	< 0.3%	< 0.3%	< 0.1%	< 0.3%
DEW POINT					< -50 C		< -25 C				
PREVIOUS CARGO ↓											
AMMONIA	V,N2/I	W,V,N2	W,V,N2/I	W,V,N2/I	W,V,N2	V,N2/I	W,V,N2	NOT ALLOWED	W,V,N2	W,V,N2	W,V,N2
BUTANE		N2 < 5%	N2/I < 5%	E.T.	V,N2	S	V,N2	V,N2	E.T.	V,N2	E.T.
BUTADIENE	E.T.		N2/I < 25%		V,N2	E.T.	V,N2	V,N2	V,N2	V,N2	E.T.
BUTYLENE	E.T.	N2		E.T.	V,N2	E.T.	V,N2	V,N2	V,N2	V,N2	E.T.
C4-RAFF	E.T.	N2 < 5%	N2/I < 75%		V,N2	E.T.	V,N2	V,N2	V,N2	V,N2	E.T.
ETHYLENE	S HEATING	N2 < 5%	N2/I < 5%	S		S	N2 <3000 PPM	V,N2	E.T. HEATING	N2 <1000 PPM	S HEATING
PROPANE	E.T.	N2 < 5%	N2/I < 5%	E.T.	N2 <1000 PPM		N2 < 5%	V,N2	E.T.	N2 <1000 PPM	S
PROPYLENE	E.T.	N2 < 5%	N2/I < 5%	E.T.	N2 <1000 PPM	E.T.		V,N2	E.T.	N2 <1000 PPM	S
P.O.	W,V,N2/I	W,V,N2	W,V,N2/I	W,V,N2/I	W,V,N2	W,V,N2/I	W,V,N2		W,V,N2	W,V,N2	W,V,N2
PROMIX	E.T.	N2 < 5%	N2/I < 5%	E.T.	V,N2	S	V,N2	V,N2		N2 <1000 PPM	S
V.C.M	V,N2/I	V,N2	V,N2/I	V,N2/I	V,N2	V,N2/I	V,N2	V,N2	V,N2		V,N2
PROPANE & BUTANE WET	S	N2 < 5%	N2/I < 5%	E.T.	V,N2	E.T.	V,N2	V,N2	S	V,N2	
C3/C4 CRUDE C4	E.T. < 5%	N2 < 5%	N2/I	E.T.	V,N2	S	V,N2	V,N2	V,N2	V,N2	

SYMBOLS:

W - WATERWASH
V - VISUAL INSPECTION
N2 - NITROGEN PURGE
N2/I - NITROGEN OR INERT GAS PURGE
E.T. - EMPTY TANK
S - STANDARD REQUIREMENTS
TANKS, PIPING ETC LIQUID FREE
0.5 OVERPRESSURE PRIOR TO LOADING
< X% - ALLOWABLE AMOUNT OF PREVIOUS CARGO, VAPOUR PHASE ON THE BOTTOM OF THE TANK; %AGE BY VOLUME

N.B. WHEN ANY MIXING OF CARGOES WITH LARGE DIFFERENTIALS IN THEIR BOILING POINTS IS CONSIDERED, THEN PRECAUTIONS MUST BE TAKEN TO AVOID THE RESULTANT VACUUM CONDITION IN THE CARGO TANKS.

Previous cargo compatibilities of liquefied gases
(maximum percentage by volume vapour of last cargo before loading, see notes)

Last cargo / Cargo to be loaded	Propylene	Mixed C_4	Iso-butylene	n-Butane	Butene	Butadiene	Ethylene	VCM	Ammonia
Propylene	100	C	C	C	C	C	D	A	B
Mixed C_4	33	100	100	100	100	50	5	A	B
Iso-butylene	1	10	100	10	30	10	5	A	B
n-Butane	100	100	100	100	100	100	2	A	B
Butadiene	1	10	10	10	1	100	5	A	D

Notes:

IMPORTANT: These figures are given as guidance only and are subject to confirmation before each loading [illegible] individual cargo specification requirements.

A. When previous cargo is VCM, concentration in vapours should be < 100 ppm by volume.

B. When previous cargo is ammonia, concentration in vapours should be < 20 ppm by volume.

C. Depending on customer and load port. To be checked each time.

D. Concentration less than 1000 ppm by volume.

Chemical compatibilities of liquefied gases

	Methane	Ethane	Propane	Butane	Ethylene	Propylene	Butylene	Butadiene/isoprene	Ammonia	VCM	Ethylene oxide	Propylene oxide	Chlorine (dry)	Water vapour	Oxygen	Carbon dioxide	Air
Methane													x				
Ethane													x				
Propane													x				
Butane													x				
Ethylene													x				
Propylene													x				
Butylene													x				
Butadiene/isoprene													x	x	x		x
Ammonia											x	x	x	x		x	
Vinyl chloride monomer													x		x		x
Ethylene oxide									x						x		x
Propylene oxide									x								
Chlorine (dry)	x	x	x	x	x	x	x	x	x	x				x			
Water vapour								x	x				x				
Oxygen								x		x	x						
Carbon dioxide									x								
Air								x		x	x						

Note: Reference should be made to the Data Sheets in Appendix 1 to the ICS Tanker Safety Guide (Liquefied Gas) (Ref. 12.2.2) for details of chemical compatibility.
x = incompatible

COMPATIBILITY TABLES

N.B. WHEN ANY MIXING OF CARGOES WITH LARGE DIFFERENTIALS IN THEIR BOILING POINTS IS CONSIDERED, THEN PRECAUTIONS MUST BE TAKEN TO AVOID THE RESULTANT VACUUM CONDITION IN THE CARGO TANKS.

SYNONYMS OF LIQUEFIED GASES

Common Name	Simple Formula	Synonyms
Methane	CH_4	Fire damp; marsh gas; natural gas; LNG
Ethane	C_2H_6	Bimethyl; dimethyl; methyl methane
Propane	C_3H_8	__
n-Butane	C_4H_{10}	Normal-Butane
i-Butane	C_4H_{10}	Iso-butane; 2-methlypropane
Ethylene	C_2H_4	Ethane
Propylene	C_3H_6	Propene
α-Butylene	C_4H_8	But-1-ene; ethyl ethylene
β-Butylene	C_4H_8	But-2-ene;dimethyl ethylene; pseudo butylene
γ-Butylene	C_4H_8	Isobutene; 2-methylprop-2-ene
Butadiene	C_4H_6	b.d.; bivinyl; 1,3 butadiene; butadiene 1-3; divinyl; biethylene; erythrene; vinyl ethylene
Isoprene	C_5H_8	3-methyl — 1,3 butadiene; 2-methyl — 1,3 butadiene; 2-methylbutadiene — 1,3
Vinyl chloride monomer	C_2H_3Cl	Chloroethene; chloroethylene; VCM
Ethylene oxide	C_2H_4O	Dimethylene oxide; EO; 1,2 epoxyethane; oxirane
Propylene oxide	C_3H_6O	1,2 epoxy propane; methyl oxirane; propene oxide
Ammonia	NH_3	Anhydrous ammonia; ammonia gas; liquefied ammonia; liquid ammonia

Note: Commercial propane contains some butane; similarly commercial butane contains some propane. Both may contain impurities such as ethane and pentane, depending on their permitted commercial specification.

CHEMICAL PROPERTIES OF LIQUEFIED GASES

	Methane	Ethane	Propane	Butane	Ethylene	Propylene	Butylene	Butadiene/isoprene	Ammonia	VCM	Ethylene oxide	Propylene oxide	Chlorine (dry)
Flammable	X	X	X	X	X	X	X	X	X	X	X	X	
Toxic									X	X	X	X	X
Polymerisable								X		X	X		

REACTIVE WITH

Magnesium								X			X	X	
Mercury								X	X		X	X	X
Zinc									X				X
Copper								X	X		X	X	
Aluminium								X	X	X	X	X	X
Mild Steel	X				X								
Stainless Steel											X		
Iron											X	X	
PTFE									X				
PVC									X				
Polythene	X	X	X	X			X						
Ethanol													X
Methanol													X

CHEMICAL COMPATIBILITIES OF LIQUEFIED GASES

	Methane	Ethane	Propane	Butane	Ethylene	Propylene	Butylene	Butadiene/isoprene	Ammonia	VCM	Ethylene oxide	Propylene oxide	Chlorine (dry)	Water vapour	Oxygen	Carbon dioxide	Air
Methane													X				
Ethane													X				
Propane													X				
Butane													X				
Ethylene													X				
Propylene													X				
Butylene													X				
Butadiene/isoprene													X	X	X		X
Ammonia											X	X	X	X		X	
Vinyl chloride monomer													X		X		X
Ethylene oxide									X						X		X
Propylene oxide									X								
Chlorine (dry)	X	X	X	X	X	X	X	X	X	X				X			
Water vapour								X	X				X				
Oxygen								X		X	X						
Carbon dioxide									X								
Air								X		X	X						

Note: Reference should be made to the Data Sheets in Appendix I to the ICS Tanker Safety Guide (Liquefied Gas) (Ref. 12.2.2) for details of chemical compatibility.

X = incompatible

PREVIOUS CARGO COMPATIBILITIES OF LIQUEFIED GASES

Last Cargo	Propylene	Mixed C_4	Iso-Butylene	n-Butenes	Butane	Butadiene	Ethylene	VCM	Ammonia
Cargo to be loaded Propylene **1.1.1 NOTE C**	100	C	C	C	C	C	D	A	B
Mixed C_4	20	100	100	100	100	50	5	A	B
Iso-Butylene	1	10	100	10	20	10	5	A	B
n-Butenes	100	100	100	100	100	100	5	A	B
Butadiene **1.1.2 NOTE C**	1	10	10	10	5	100	5	A	D

Notes:

IMPORTANT: These figures are given as a guidance only and are subject to confirmation before each loading as they are dependent upon the individual cargo specification requirements.

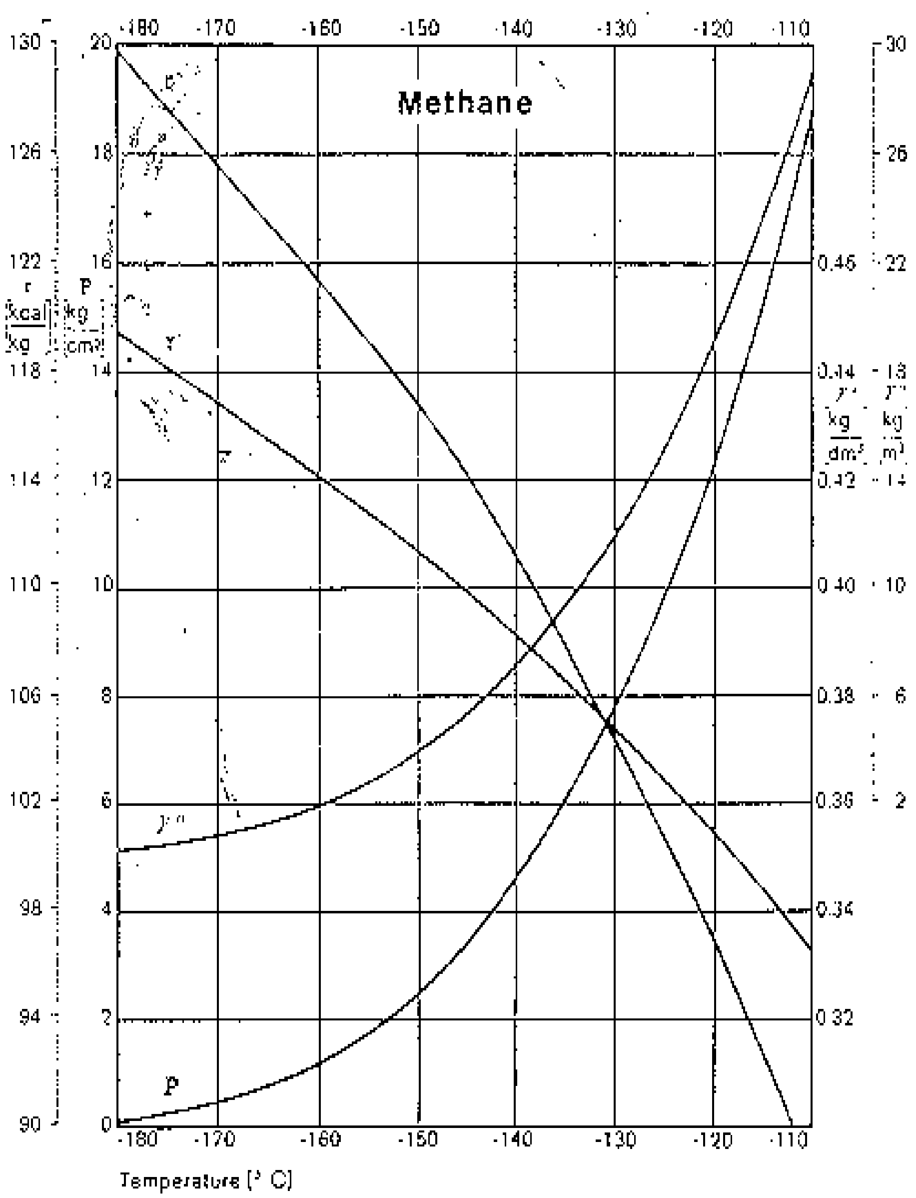
A. When previous cargo is VCM, concentration in vapours should be < 100 ppm by volume.
B. When previous cargo is ammonia, concentration in vapours should be < 20 ppm by volume.
C. Depending on customer and load port. To be checked each time.
D. Concentration less than 1000 ppm by volume.

INERT GAS COMPOSITIONS

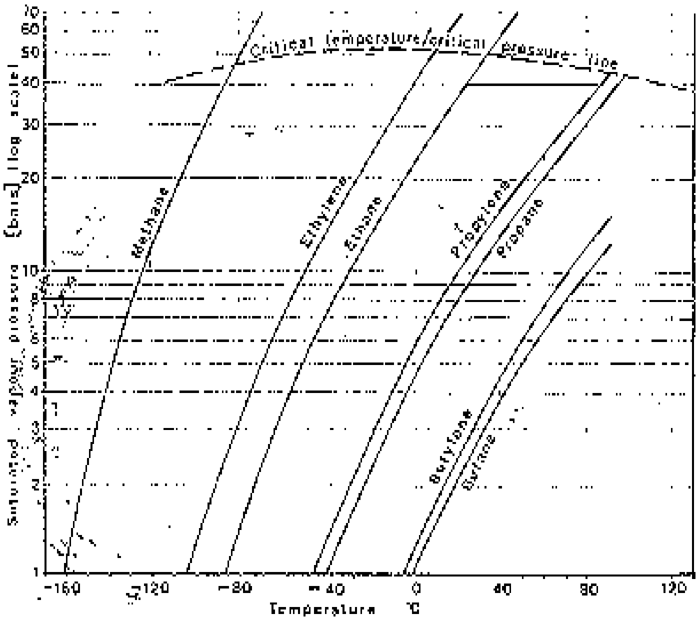
A **Component**	1.2 B Inert gas by stoichiometric Combustion (by calculation)	1.2.1 C Flue gas from main boilers	1.2.2 D Nitrogen by fractional distillation or by Pressure Swing Absorption (psa)
Nitrogen (N_2)	85%	83%	99.9%
Carbon dioxide (CO_2)	14%	13%	1 ppm
Carbon monoxide (CO)	0.2%	present	1 ppm
Oxygen (O_2)	0.3%	4%	4 ppm
Sulphur dioxide (SO_2)	<10%	300 ppm	—
Oxides of nitrogen (NOx)	3 ppm	present	—
Water vapour (H_2O)	present	present	5 ppm
Ash and soot (C)	present	present	—
Dewpoint	-50°C	may be high if not dried	<-70°C
Density (Air = 1.00)	1.035	1.044	0.9672

PHYSICAL PROPERTIES OF GASES

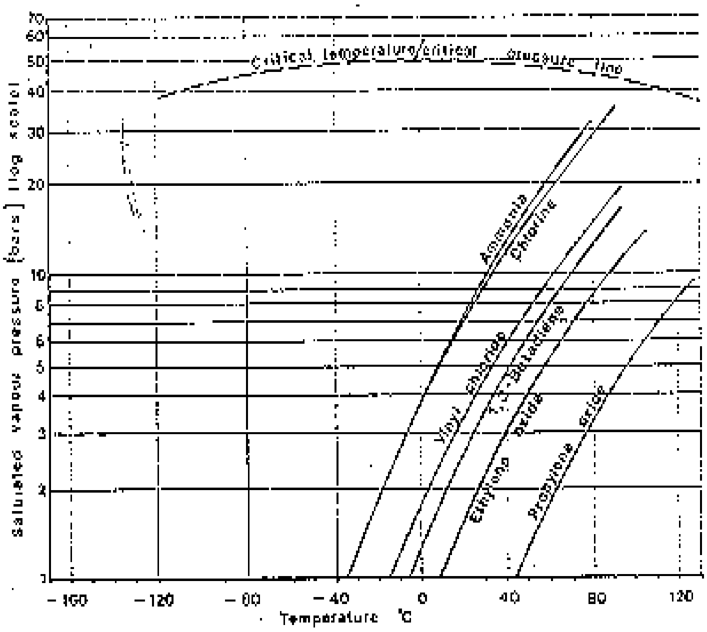
Gas	Atmospheric boiling point (°C)	Critical temp (°C)	Critical pressure (bars, absolute)	Condensing ratio dm³ liquid / 1m³ gas	Liquid relative density at Atm. Boiling Pt. (Water = 1)	Vapour relative density (Air = 1)
Methane	-161.5	-82.5	44.7	0.804	0.427	0.554
Ethane	-88.6	32.1	48.9	2.453	0.540	1.048
Propane	-42.3	96.8	42.6	3.380	0.583	1.55
n-Butane	-0.5	153	38.1	4.32	0.600	2.09
i-Butane	-11.7	133.7	38.2	4.36	0.596	2.07
Ethylene	-103.9	9.9	50.5	2.20	0.570	0.975
Propylene	-47.7	92.1	45.6	3.08	0.613	1.48
α-Butylene	-6.1	146.4	38.9	4.01	0.624	1.94
γ-Butylene	-6.9	144.7	38.7	4.00	0.627	1.94
Butadiene	-5.0	161.8	43.2	3.81	0.653	1.88
Isoprene	34	211.0	38.5		0.67	2.3
VCM	-13.8	158.4	52.9	2.87	0.965	2.15
Ethylene oxide	10.73	195.7	74.4	2.13	0.896	1.52
Propylene oxide	34.2	209.1	47.7		0.830	2.00
Ammonia	-33.4	132.4	113.0	1.12	0.683	0.597
Chlorine	-34	144	77.1	2.03	1.56	2.49



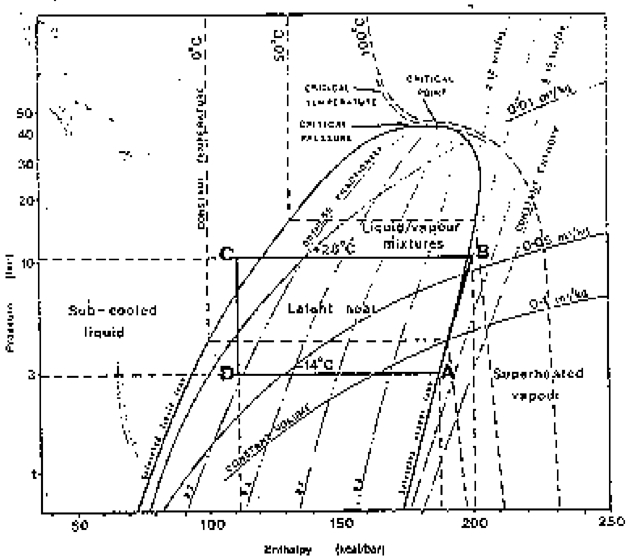
VAPOUR PRESSURE, LIQUID DENSITY, SATURATED VAPOUR DENSITY AND HEAT OF VAPOURISATION FOR METHANE



PRESSURE/TEMPERATURE RELATIONSHIPS FOR SATURATED AND UNSATURATED LIQUEFIED HYDROCARBON GASES



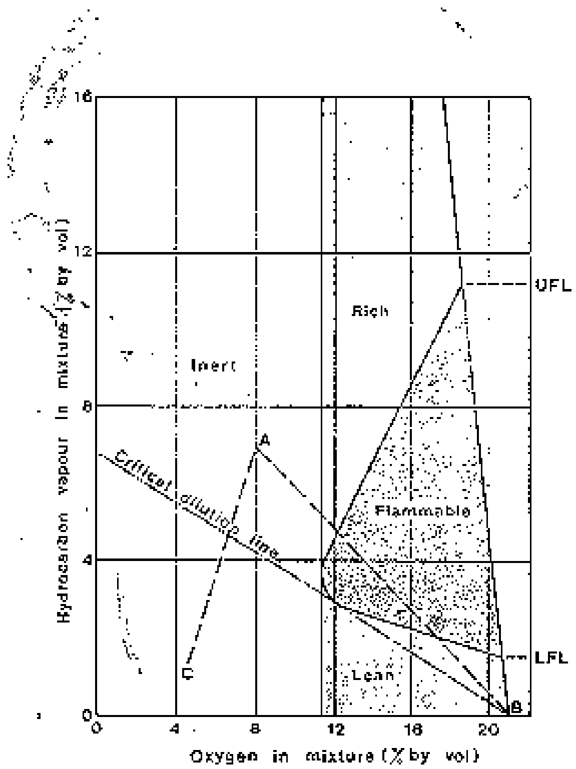
PRESSURE/TEMPERATURE RELATIONSHIPS FOR LIQUEFIED CHEMICAL GASES



MOLLIER DIAGRAM FOR PROPANE

IGNITION PROPERTIES FOR LIQUEFIED GASES

Liquefied gas	1.3 Flash point (°C)	1.3.1 Flammable range (% by vol. in air)	Auto-ignition temperature (°C)
Methane	-175	5.3 — 14	595
Ethane	-125	3.1 — 12.5	510
Propane	-105	2.1 — 9.5	468
n-Butane	-60	1.8 — 8.5	365
i-Butane	-76	1.8 — 8.5	500
Ethylene	-150	3 — 32	453
Propylene	-180	2 — 11.1	453
α-Butylene	-80	1.6 — 9.3	440
β-Butylene	-72	1.8 — 8.8	465
Butadiene	-60	2 — 12.6	418
Isoprene	-50	1 — 9.7	220
VCM	-78	4 — 33	472
Ethylene oxide	-18	3 — 100	429
Propylene oxide	-37	2.8 — 37	465
Ammonia	-57	16 — 25	615
Chlorine	Non-flammable		



FLAMMABLE LIMITS OF A TYPICAL HYDOCARBON GAS IN MIXTURES OF AIR AND NITROGEN