WORLD MARITIME UNIVERSITY
MALMOE, SWEDEN



# SAFETY ASPECTS ON LNG CARRIERS
# EXAMPLE OF ALGERIAN GAS FLEET

by

Sadek Benaissa

ALGERIA

A paper submitted to the faculty of the World Maritime University in partial satisfaction for the award of a

## Master of Science Degree
## in
## Maritime Safety Administration (Nautical)

The contents of this paper reflect my own personal views and are not necessarily endorsed by the World Maritime University or the International Maritime Organization.

Signature: Benaissa

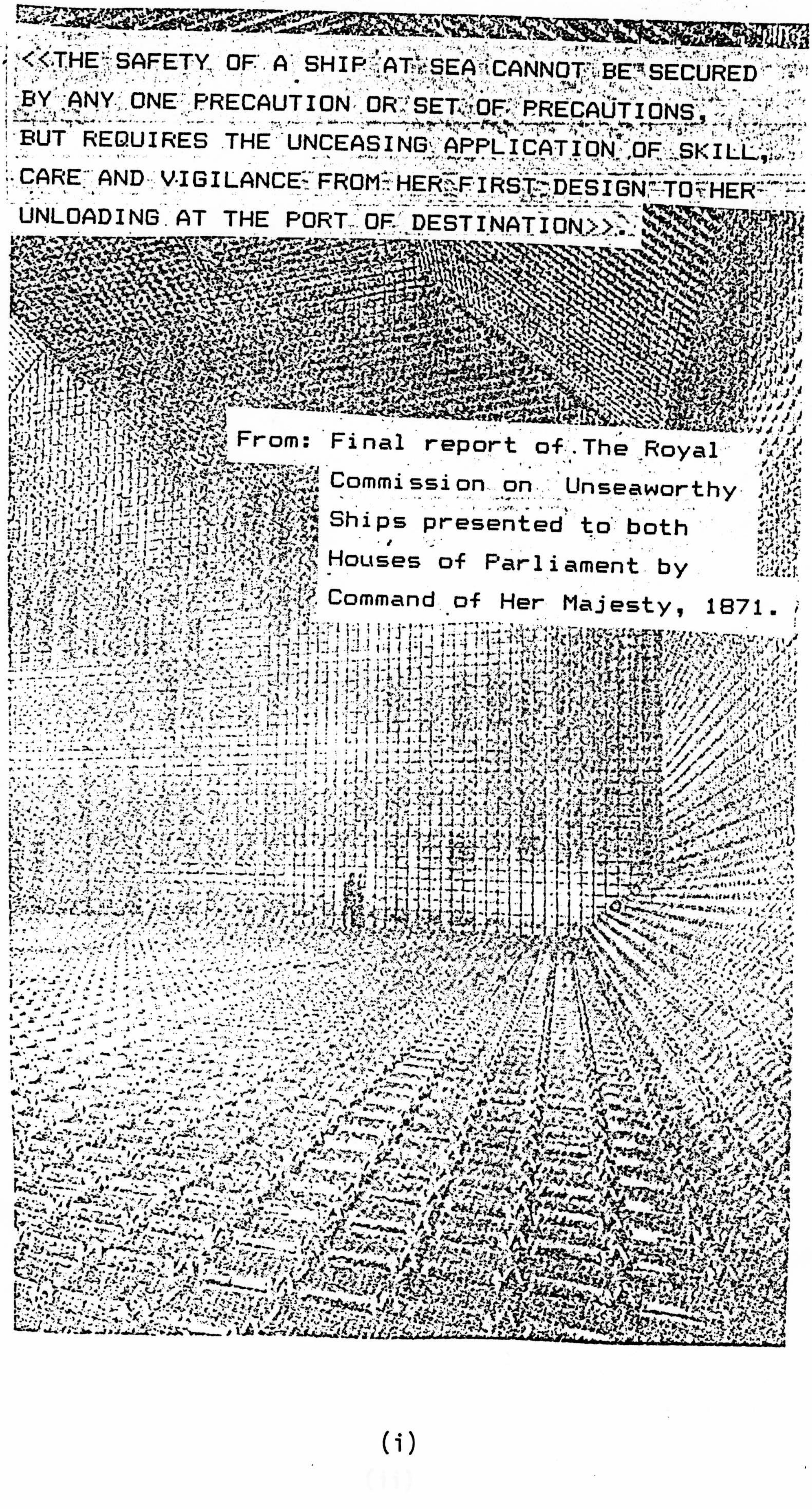
Date: 16 Octobre 1990

Directed and assessed by:

Professor Bjorn Vedeler
Dr. Tech.,
Resident Professor
World Maritime University

Co-assessed by:

Professor P.S. Vanchiswar
Ph.D., Extra Master
Resident Professor
World Maritime University


<<THE SAFETY OF A SHIP AT SEA CANNOT BE SECURED BY ANY ONE PRECAUTION OR SET OF PRECAUTIONS, BUT REQUIRES THE UNCEASING APPLICATION OF SKILL, CARE AND VIGILANCE FROM HER FIRST DESIGN TO HER UNLOADING AT THE PORT OF DESTINATION>>.
From: Final report of The Royal Commission on Unseaworthy Ships presented to both Houses of Parliament by Command of Her Majesty, 1871.

SAFETY ASPECTS ON LNG CARRIERS

EXAMPLE OF ALGERIAN GAS FLEET

## ACKNOWLEDGEMENTS

I owe my gratitude and sincere thanks to all those who provided me with encouragement, guidance and information and made it possible for me to produce this paper. In particular, I would like to express my sincere thanks to:

TheInternational Maritime Organization for establishing WMU and for nurturing it to its present academic eminence.

The United nations development programme for awarding me the followship to pursue the two year Master of Science Degree Course at World Maritime University.

The people and country who nominated me to attend this course,especially the Director of "Direction Navigation Maritime" in the Ministry of Transport and all staff of the company "CALTRAM".

Professor P.S.Vanchisvar for providing information and guidance whilst directing and assessing the paper.

Professor Bjorn Vedeler for his very kind agreement to co-assess and to give constant guidance in this paper.

All distinguished resident and visiting professors for their dedicated lecture and knowledge imparted during the period of study.

The Maritime Admnistrations of Denmark, Finland, Norway,Sweden, The United Kingdom and The Federal Republic of Germany for their co-operation and assistance during various field training and Job training activities.

Librarians Richard Poisson, Cecilia Denne and other staff who gave much of their valuable time to provide me with many important materials, information, and research documents concerned with my paper.

English Lecturer Clive Cole for helping in correcting and upgrading my English to an acceptable level.

Algerian colleagues at WMU, in particular Said Amrouche and Kaddour Abderezzak who helped me during the two year course.

The City of Malmo for the most remarkable host facilities.

Friends of mine, Inger Sverud and Ranto Finn, who provided me with housing facilities during the two years in Malmo.

My Father-in-law for standing as a guarantor, supporting my wife and son during my abscence.

Finally my wife for providing support and encouragment during this period of hardship to make it possible for me to pursue my studies at WMU.

## Table of contents

## LIST OF FIGURES

## LIST OF TABLES

## LIST OF APPENDICES

## LIST OF ABBREVIATIONS

| | | |
|---|---|---|
| B.V | = | Bureau Veritas |
| CMA | = | Code Maritime Algerien |
| CNAN | = | Compagnie Nationale Algerienne de Navigation |
| DnV | = | Dets norsk Veritas |
| ESDS | = | Emergency Shut Down System |
| LNG | = | Liquefied Natural Gas |
| LPG | = | Liquefied Propane Gas |
| IACS | = | International Association Classification Societies |
| ICS | = | International Chamber of Shipping |
| ILO | = | International Labour Organisation |
| IMO | = | International Maritime Organisation |
| ISL | = | International Safety of Labour |
| MARAD | = | Maritime Admnistration |
| MARPOL 1973/78 | = | The International Convention for the Prevention of Marine Pollution from Ships (as amended) |
| MSA | = | Maritime Safety Admnistration |
| SIGTTO | = | Society of International Gas Tanker and Terminal Operation Ltd. |
| SNTM Hyproc | = | Societe National des Transports Maritime des Hydrocarbures et des Produits Chimiques. |
| STCW | = | International Convention on the Standards of Training and Watchkeeping for Seaferers, 1978. |
| Solas 1974 | = | The International Convention on the Safety of Life at Sea (as amended). |
| TLV | = | Threshold Limit Value. |
| USCG | = | United States Coast Guard. |

# CHAPTER ONE

# INTRODUCTION

Since the early 1940's natural gas has been revealed as one of the most bountiful products of nature's chemistery.

Much of the production of gas occurs in the developing countries where, because of distance or intervening seas, it cannot be transported economically by pipeline to the great industrial complexes of the world.

The crucial requirements have centered on the design and construction of a tanker for the safe and economic transport of low temperature natural gas cargoes.

Basically, it is necessary to isolate the product Liquified Natural Gas (LNG) in insulated and separate containers from contact with the tanker's hull structure. If the product were allowed to contact the hull, or its steel structural members, the steel would be subject to brittle fracture.

Finally, the LNG tanker is reviewed in its present state (1973), setting forward the intricate insulation barriers and methods of supporting and isolating the LNG tanks from the tanker hull.

The world wide Liquefied Natural Gas trades climbed well ahead of the previous year's levels in 1988 However the increase in LNG gas shipped on board vessels which are registered in developing countries and handled in the ports of the developing world will require the application of new technologies and the introduction of internationally accepted safety standards. This, however, can only be achieved by employing highly trained and skilled seamen and terminal workers who are led by a well-educated management and who work within an excellent organizational structure.

It is hard to find fault with the safety record compiled by the Liquefied Natural Gas (LNG) transport and even with storage over the years. An acute awareness of the hazards associated with handling vast amounts of flammable gas, condensed at cryogenic temperatures, has led to high standards of engineering performance and stringent operational procedures. Together they underpin the commendably high safety record.

Since the start up of commercial scale deliveries of LNG by sea in 1964, there have been no accidents involving the breaching of a gas carrier's cargo tank or a major spillage of product.

Although cargo carried by LNG tankers frequently is hazardous in nature, accidents are infrequent. LNG carriers are constructed according to stringent requirements contained in the IMO liquefied Gas Carriers Code, which also addresses handling and stowage. Consequently, great emphasis is placed on safety in the cargo area onboard a LNG carrier. This emphasis carriers over into other areas of safety, which complicates normal safety practice and planning.

Finally, for a complete understanding of the importance and complexity safety onboard LNG tankers, we have to define the word safety so that it will not be lost from our vocabulary because it is rather abstract and perplexing.

The safety of an LNG tanker is a manifestation of the state of safety of shipping as whole .

The scope of safety does not stop with the ship designers and the onboard ship operators; it continues with the shore management. Ship owners have the responsability of ensuring that their ships are built to a required safety standard and manned by competent and experienced crews. Classifications societies and Maritime Administrations have the responsability of laying down rules and regulations to regulate shipping and at the same time they have to make sure that the rules and regulations are adhered to.

The cycle of safety mentioned above has become a success for most of countries involved in LNG transport. But in many developing countries there is a serious reason to think that the system of safety is not clear. An example of transport by sea of LNG in Algeria will be presented later in this paper showing a lack of safety which can compromise the operations of the LNG fleet that represents an integral part of the country's economy.

# CHAPTER TWO

# Ship Safety

## 2.1 General.

The scientific definition of safety is not the objective of this paper but it is necessary to approach the concept of safety. In order to understand what safety is on board an LNG carrier?

The safety as defined in the Collins Cobuild dictionary is "the state of being safe". Another definition more precise is given Acceptable Risk, Science and the Detemination of Safety, a research dissertation by William W. Lawrance : " Safety is defined as judgement of the acceptability of risk, and risk, in turn, as a measure of the probability and severity of harm to human health". And he continues his statement as follows: "Notice that this definition emphasizes the relativity and judgemental nature of the concept of safety. It also implies that two very different activities are required for determining how safe things are: measuring risk, an objective but probabilistic pursuit, and judging the acceptability of that risk (judging safety), a matter of personnel and social value judgement".

It is recognized that hazards always exist everywhere and anywhere. Consequently, the risks are there which can be evaluated through exact sciences or the empirical sciences. Then the safety is estimated according to the evaluation of risks calculated or estimated by probability or consequences of events. However, the evaluation of risks can be interpreted by judgement.

Therefore the safety of LNG ships in this paper will be based on the judgement of acceptable risks to assess.

The solution proposed in turn leads to the enhancement of the safety of company operations, the reduction of the cost of accidents and the increase in the effectiveness and economy of company operations.

Because the safety of LNG carriers is the prime concern of the ship itself and its crew, of Terminals, plant operators and contractors (most LNG carriage is linked by long contract between the deliverer and receiver), of manufacturers of sophisticated and expensive equipment, and finally of local authorities and the general public.

However, safety standards are under continuous review and revisions of safety requirements are reducing the risk to life and property.

## 2.2 Importance of safety:

An LNG ship is a scene where gas is handled, stored in tanks and carried on the sea. She becomes exposed to various hazards and consequently the context of safety will be exposed in several aspects.

The importance of safety is based on the risks of losing worthy ship, and exposing the crew to death or injury by accident, on the permanent potential of hazard to the port, and finally on the link between economic and accident risk reduction.

### 2.2.1 Economic aspects:

In shipping generally, safety and economy are closely related to each other.

The relation between economy and safety is based on the factors influencing the overall economy of shipping. However,in this paper we need only to identify some economic factors which are involved in LNG carrier operation and they are as following:

- Direct operation costs including cost of crews, stores, maintenance, insurance, bunkers, port charges overheads and boil-off gas used for propulsion.

- The indirect operation costs incurred through loss of carrying capacity of the vessel due to reasons connected with the vessel itself.

**How do theses factors influence safety?**

Firstly, there are obviously potential hazards associated with the transportation and handling of liquefied natural gas and these risks are continuouosly present.

Secondly, the lack of safety may arise from many other reasons such as human error (it is the most common reason encountered in casualty stastics) or failure in equipment aiding the ship in its operation.

Finally, the consequences comming from any lack of safety may affect a part of or all factors mentionned in this chapter and lead to serious financial losses for the parties involved in the carriage of the liquefied natural gas.

To illustrate the philosophy of this chapter there is an excellent paper by Professor P.S. Vanchisvar in his volume entitled Maritime Admnistration /Maritime Safety Admnistration (revised 1987/1989). From the point of view of a Maritime Administration (MARAD) he examined both the developmental and regulatory functions, where the first contributes directly to maritime development and the second - usually the responsibility of a Maritime Safety

Admnistration - contribuates to such development and economic advantages. It is understood largely through his paper that safety has a contribution in the economic aspects inter-alia:

(a)- In the maximum efficiency in ship operations with consequent economic advantages.

(b)- In the reduction of the maintenance costs for ships.

(c)- In the conservation of foreign exchange.

(d)- In the avoidance of disasters and consequent loss or damage to life, property, and marine resources involving heavy expenditures.

(e)- In the maintenance of Marine insurance premia at an advantageous level.

For some economists, safety becomes important in terms of the way operating the ship itsel. P. Alderton in his book "Sea transport operation and economics". He states that the economic advantages for each method depend fundamentally on the distance the gas has to be carried. The methods in question are:

a- carrying the LNG in liquefied form as this reduces the volume about 600 times. Or reducing the temperature to - 160 degrees celcius when it has to be carried in fast well insulated and expensive ships or

b- converting it into methyl alcohol and carryino it in conventional tankers.

Of these two methods, Prof. P. Alderton states that the latter method is :"better for longer distances and it is also inherently safer".

**2.2.2 Ship and port aspects:**

Since a vast quantity of gas is moved by sea in the world, there is a need to build LNG vessels and also to construct ports which include liquefied gas terminals. They are both involved in specific gas transportation project and they work in ship/shore interface.

LNG vessels and Terminals are involved in the same objectives of safety because of the common risk. Operations and handling of such a cargo are extremely hazardous because the gas is subject to the risk of explosion. Therefore a very stringent safety policy in all possible forms is imposed.

**Why is safety important in the port and on board the ship?**

Before answering this question, the importance of safety is generally observed from many angles which are potential risks, casualties and losses.
I will briefly discuss in this paper the losses which could arise from small or severe casualties and through permanent hazards which exist in places such as the ship and the LNG terminal and its vicinity.

I was mentioned earlier that safety is defined as judgement of acceptable risk into which includes losses. Then what kind of possible losses can occur on the scene considered?

**In the port:**

The Terminal cannot be made harmeless or operationnaly totally safe. It is exposed to many risks which are hidden in the energy potential. Because if any disaster happens, then numerous losses might occur as follows:

(a)- In the area of Terminal:

- Obstruction of access from the sea to the terminal caused by a collision between two ships or other objects, which consequently cripples the port infrastructure.

(b)- In the land Terminal :

A chain process of any accident may lead to heavy losses to:

- Industrial constructions.
- Facilities.
- Storage tanks.
- Cryogenic pipe -work on the surface of the land.
- Vessels in the vicinity of loading/ discharging
- People working in the Terminal (deaths or injuries).
- Living quarters for people working in the terminal.

(c)- In the environment:

Generally, the Terminal is constructed an area at least several kilometers from populous urban areas. If any accident happens near the Terminal which is caused by liquefied natural gas, whatever the reason, will be threated.

(d) On board the vessel:

Fortunately, on board LNG vessels, the maintenance record is good, so is the safety standards. These contribute to low accidents rates and the turn round of the vessel is not adversely affected.

The latest edition of LNG Log published by SIGTO shows that by the end of 1982 LNG ships had together made 6865 voyages, sailed over 12 1/2 millions miles and delivered about 390 millions cubic meters of cargo.

Therefore this information tells us that a well maintained vessel has a quick turn round.

### 2.2.3 Human aspects:

In this paper, human aspects is a reference to the human element which may be identified as a shipping community involved- closely or not -in the chain of transport of LNG by sea.

The human element plays an important role in safety by improving all efforts to reduce potential risks and accident on board LNG carriers.

(i)- The crew on board have the responsibility:
- to prevent cargo fires which result from cargo vapour, oxygen and sources of ignition coming together. Also all possible sources of ignition should be eliminated from areas such as cargo tanks, cargo machinery spaces and on deck.

- To take initial action in handling a distress situation caused by grounding, collision, fire, explosion or engine break-down because in any emergency response timely action can prevent a minor casualty from becoming a major disaster.

(ii)- The shipowner has the responsibility inter-alia:

- to keep the ship in a seaworthy condition all the time.
- to manage a safety policy by training the crew on board to think about safety and to be aware of safe practises.
- to assist and support the ship in time of distress.

(iii)- The shore crew in the terminal have the responsibility to observe the same strict handling precautions.

(iv)- Other people such as designers and shipbuilders, classification societies and authorities are also important, in safety. Designers are assigned to safety design and construction, while the rules and legislation are setled by the classification society and enforced by the authorities.

Human behaviour in LNG carriers:

The factors that influence performance to avoid human error are inter-alia:

- Proper education and kowledge about the trade.
- Sufficient time and advice to be skilled in the

operations of handling the cargo.

- Normal working hours to avoid fatigue.
- Clear instructions and information on who is resposible for what in the organizational structure on board the ship.
- Updated clear information.
- Motivation.

# CHAPTER THREE

## COMPLEXITY OF SAFETY

There are different components constituing the complexity of safety on board the LNG carrier. They are combined to enhance total safety and are classified into the kinds of extreme values they offer. These components belong to the following structures:

- the technical aspects of safety in design and construction,
- the Cargo itself and its handling,
- the persons on ship- i.e crew, stevedores for operations and ship maintenance, and
- the differents regulations in the form of:
  *IMO Recommendations and Codes,
  *Solas 1974, Ammendements and Protocoles of Solas 1974,
  *Marpol 1973/1974,
  *National regulations,
  *Rules of classification societies, and
  *Principles/Guidelines for handling the cargo elaborated by shipping Industry.

### 3.1 LNG Containment Systems:

### 3.1.1 Introduction:

The development of Marine LNG transport started in 1959, when the "Methane Pioneer" gas carrier transported by sea about 5000 cubic meters of LNG from Lakes Charles (USA) to Canvay Island (UK). As a consequence, the first commercial project began in 1964 with two ships: Methane Princess and Methane Progress from Algeria to the United Kingdom followed later by Jule Verne in 1965 operating between Algeria and France. Finally the shipment of gas experienced rapid growth and at the same time the technology of LNG transport evolved.

Nowadays liquefied natural gas is transported in large vessels in big quantities. The vessel is called and LNG Carrier, which is defined by Mc Guire and White in their book "Liquefied Gas Handling Principle on Ships and in Terminals" as " specialised vessels built to transport large volumes of LNG at its atmospheric pressure boiling point of -163 degrees Celsius". These ships are now typically of between 120,000 cm and 130,000 cm capacity and are normally dedicated to a specific project where they will remain for their entire contract life, which may be around 20-25 years. In recent years these ships have been of three types:

(i)- Gas transport membrane.
(ii)- Technigaz membrane.
(iii)- Kvoerner Moss Spherical-Independant type.

**3.1.2 What kind of containment systems are found in LNG carriers?**

During the development of LNG transport several containments system designs were approved. They are divided in two general categories which are the independent or self-supporting and the membrane type.

**What is the indepedent containment system?**

The incorporated tanks are independent of vessel the hull; they are supporting their own weight and the static and the dynamic loads of the liquid cargo.

**What is the membrane containment system?**

It consists of the membrane tanks which are made of thin metallic materials and are non-self-supporting. The tanks are attached indirectly to the ship's structure through a load-bearing insulation. Beyond the types mentionned by Mc Guire in the beginning of this chapter, there are several other containment systems.

Some of them are deleted for reasons of technical failure like Conch (independant,Type A). While the others are nowadays in commercial service like Esso (Independant, type A); Hitachi Zosen Esso (Independant, TypeB sphere and typa A-Prismatic); Sener (Independant , typeB) .

And the last group are under development like IHI (Semi-membrane, type B), Ocean Phoenix (Independant , typeC), Zellentank (Independant, type C), IHI, Hitachi and others (Independant primatic, type B).

The three independant tanks mentionned repectively above (type A, B, and C) are defined in the IMO-Intenational Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk Volume III and they are as follows:

**Type A independant tanks:**

They are tanks which are designed primarily using Recognized Standards (for this purpose, the Recognised Standards are standards laid down and maintained by classification societies recognized by the Administration) of classical ship-structural analysis procedure where such tanks are primarily constructed of plane surfaces (gravity tank), andthe design vapour pressure Po should be less than 0.7 bar.

**Type B independent tanks:**

They are tanks which are designed using model tests, refined analytical tools and analysis methods to determine stress levels, fatigue life and crack propagation characteristics. Where such tanks are primarly constructed of plane surfaces (gravity tanks) the design vapour pressure Po should be less than o.7 bar.

**Type C independent tank:**

(Also referred to as pressure vessels) they are tanks meeting pressure vessel criteria and having a design vapour pressure not less than Po. given under the following formula:

$$Po = 2 + A\,C\,(Er)^{1.5} \text{ (bar)} \quad \text{Where: } A = 0.0185 \left(\frac{Om}{DOA}\right)^{2}$$

With:

Om = design primary membrane stress

DOA = allowable dynamic membrane stress (double amplitude at probability level Q = 10 )
55 N/mm2 for ferritic/martensitic steel
25 N/mm2 for aluminium Alloy (5083-0)

C = a characteristic tank dimension to be taken as the greatest of the following h; 0.75 b; or 0.45 l
with:
h = height of tank ( dimension in ship's vertical direction) (m).

b = width of tank (dimension in ship's transverse direction) (m).

l = length of tank (dimension in ship's longitudinal direction) (m).

Er = the relative density of the cargo (Er = 1 for fresh water) at the design water.

It is not the objective of this chapter to describe all the techniques of all containment systems used nowadays in commercial service.

The following technical descriptions are more or less same in differents articles of LNG carriers from many authors.

b=width of tank (dimension in ship's transverse direction ) (m).

l= lenght of tank (dimension in ship's longitudinal direction ) (m).

Er= the relative density of the cargo (Er=1 for fresh water ) at the design water.

It is not the objective of this chapter to describe all the specifications of all containment systems used nowadays in commercial service.

The following technical descriptions are adapted from differents articles about LNG carriers by many authors.

### 3.1.2.1 Gas transport membrane:

The description given in many articles relative to the technique of gas carrier construction says that this system was developed in 1967 by Gas transport.

It consists of using 36 % nickel-iron low-expansion alloy (invar) for both the primary and secondary barriers.

Invar was chosen as the cryogenics material for the primary and secondary barriers because of its low coefficient of thermal expansion which makes corrugations in the tank structure unecessary.

Mc Guire, in hi manual (see introduction of Chap. 3.1 of this paper), also mentiones that nowadays the gas transport systems utilise invar membrane of 0.7 mm thickness and strengthened pywood boxes to hold the perlite insulation. The perlite is silicinized to make it impervious to water or moisture (see Figure 1).

### 3.1.2.2 Technigaz membrane:

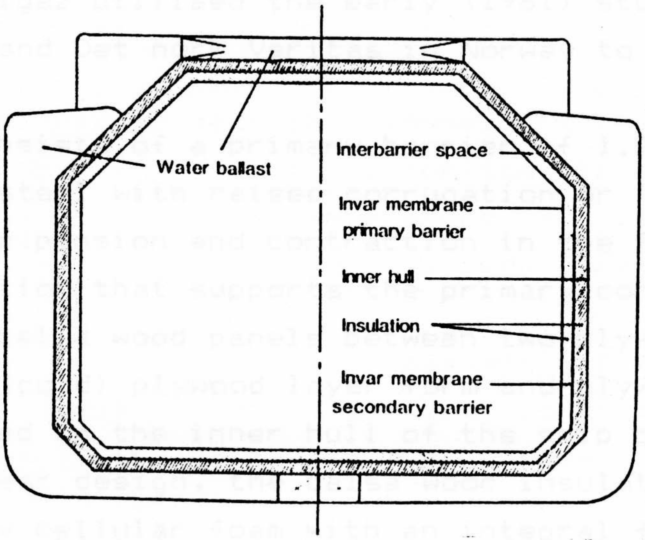



Figure 1 Gaz Transport membrane containment system as utilised on larger-sized LNG carriers.

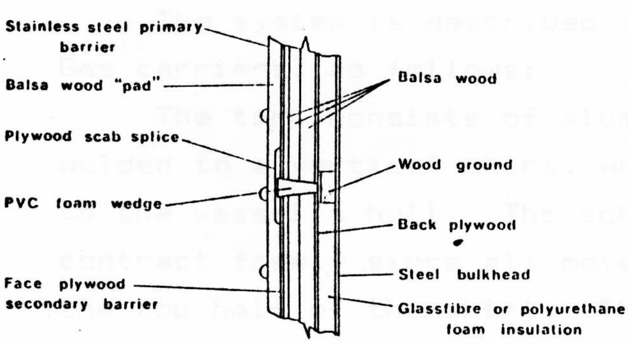



Figure 2 Technigaz membrane containment system as utilised on larger-sized LNG carriers.

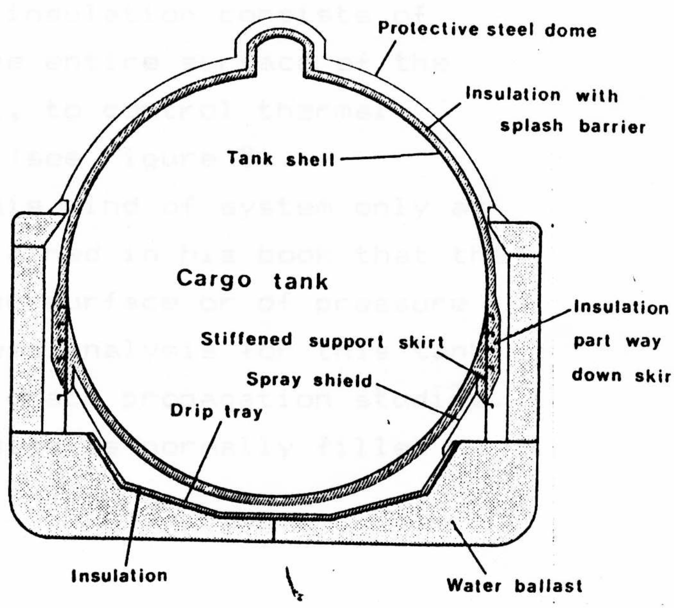



Figure 3 Self-supporting spherical type B tank.

Technigaz utilised the early (1961) studies of Lorentzen and Det nork Veritas in Norway to develop this system.

It consists of a primary barrier of 1.2 mm thick stainless steel with raised corrugation or "wafles", to allow for expansion and contraction in the form of bendin. The insulation that supports the primary consists of laminated balsa wood panels between two plywood layers; the inner (cold) plywood layer form and plywood scale and are supprted on the inner hull of the ship by wood grands. In the latest design, the balsa wood insulation is replaced by cellular foam with an integral fibre glass cloth/aluminium laminate secondary barrier (see Figure 2).

**3.1.2.3 Kvaerner-Moss (independent, type B):**

The system is described in Fairplay article entitled Gas carriers, as follows:

The tank consists of aluminium or 9% nickel sphere welded to a vertical skirt, which is the only connection to the vessel's hull. The sphere can thus expand and contract freely since all movements are compensated for in the top half of the skirt. The insulation consists of Polyurthane foam applied over the entire surface of the sphere, and to part of the skirt, to control thermal stresses and limit heat leakage (see Figure 3).

While Mc Guire qualified this kind of system only as independent tanks type B he explained in his book that the tanks can be constructed of plane surface or of pressure vessel type. The mandatory stress analysis for this tank type comprises fatigue life and crack propagation studies. Also, the hold space in this design is normally filled with dry innert gas.

### 3.1.2.4 Comments:

The techniques described above, are designed to solve one common problem which is to contain liquefied natural gas with the low boiling temperature of - 162 degrees Celsius. Therefore measures have been taken to make vessels safe.

However, the containment systems are quite different. Those options might include an effort to reduce the building cost at the same time. Therefore, the selection has a large impact on the final ship design, where many factors are considered like efficiency of cubic utilisation in the ship, the vertical centre of gravity of the tank and the cargo, weight, material cost, need for second barriers, type of insulation, boil off rate, visibility from the bridge, tank cool down and many more criteria.

## 3.2 Ship design and construction:

### 3.2.1 General:

Safety is also considered complex from the aspect of design and construction of LNG carriers.

The hull has a sahpe and strength suitable for the tanks carried. Special steel or aluminium is provided for tanks capable of containing low temperature (-160 degrees Celsius) without becomming brittle.

Naval architects try to design ships to fulfill the conditions of stabiliuty by finding the optimum breadth, draught and body shape.

### 3.2.2 LNG carrier construction:

During the period of evolution of LNG transport, the LNG ships have had a common object, which is to carry a cargo with a low temperature. THerefore these vessels have common basic rules for their construction.

The layout is defined as a mandatory requirement in the Internatiuonal Maritime Organisation's (IMO) "Code for the Constructions and Equipment of Ships Carrying Liquefied Gases in Bulk" which was recomende internationaly in 1976, and made mandatory under Solas 1986.

However we can cover the layout globally as follows:

- all accomodation aft.
- double bottom, which is mandatory for all gas ships,
- double side shell, also mandatory for LNG ships,
- separate ballast tanks,
- cargo tanks spaced a minimum distance from the shell,
- the primary cargo containment system may take ayone of several configuration.

### 3.2.2.1 Construction of hull:

The hull form is chosen proportionally and it runs continuously from the fore to the aft of the cargo tanks and the double hull is in accordance with the LNG rules.

A part from reinforcing appropriately the tanks as required, the hull is arranged so that inspection and manitenace can be out without difficulties .

This feature provides excellent protection for the cargo tanks in the event of collision or grouding. The studies of incident cases show that the damage caused to the side shell or bottom plating was absobed by the internal structure without deformation of the inner hull as on board the following vessels:

- "EL Paso Paul Kayser" grounding in 1976.
- "LNG Taurus" grounding in 1980.
- "Ben Franklin" colliding with a sinking research vessel in 1976.

The steel quality and grades of selected parts of the hull are chosen through studies on hull steel. Local failure spills occurs by over flow on weather deck.

### 3.2.2.2 Construction of tanks:

The cargo tanks along the sides and the bottom of the vessel form the inner hull.

The space along the sides of cargo tanks between the inner hull and the outside hull constitutes the ballast.

The construction of cargo tanks is very complex. If we analyse the envelope of one cargo tank of one kind of containment system, we can find respectively, from the inside of cargo tank to the inner hull of cargo tank, the following (see Figure 4):

- primary membrane,
- primary insulation,
- secondary membrane,
- secondary insulation.

The construction of these membranes is variable from one technique of containment system to another.

### 3.2.2.3 Tank insulation:

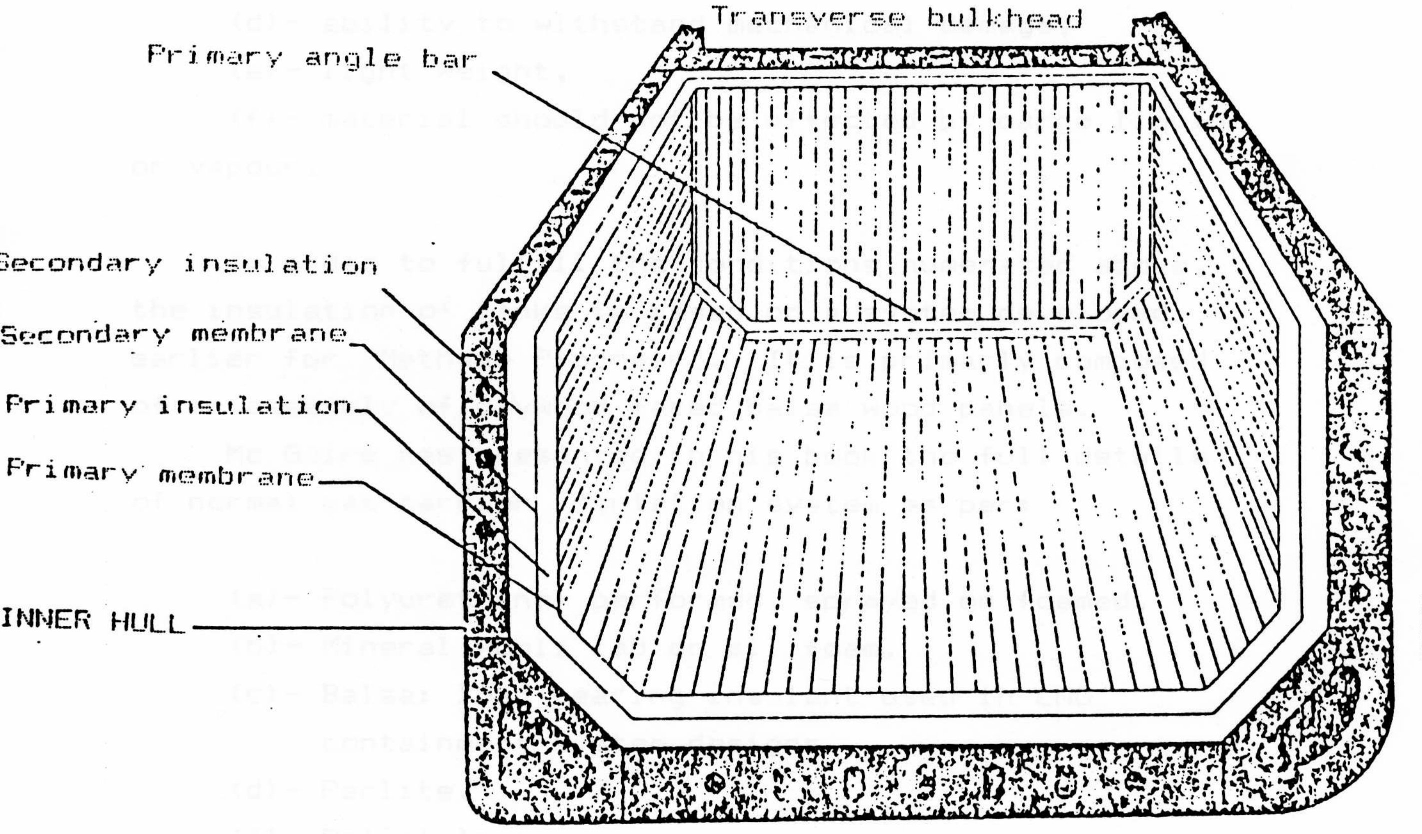
The insulation is fitted to the inside of the inner

Fig. 4. Structural construction of tank.
Gaz-Transport Invar membrane technique.

---

Source: Fatigue test on LNG carriere -Gaz Transport Technique. P. Vercamer and P. Sauve, Gaz de France, St Denis.- Gas Tech. 86 p.226.

---



inner hull of the cargo tanks for two reasons:

- to control heat flow and therefore reduce the boil-off.
- to protect the general ship structure around the cargo tanks from the effects of low temperature of cvargo.

The materials for ionsulation are chosen rationally for their main caracterics as introduced by Mc Guire in his book:

(a)- low thermal conductivity,

(b)- non-flammable or self-extinguishing,

(c)- ability to bear loads,

(d)- ability to withstand mechanical damage,

(e)- light weight,

(f)- material should not be affected by cargo liquid or vapour.

In order to fulfill the conditions numerated above, the insulation of tanks is based on a system developed earlier for "Methane Pionneer". It is primarly composed of an assembly of plywood faced balsa wood panels.

Mc Guire has presented in his book the full details of normal gas carrier insulation system as per:

(a)- Polyurethane: performed, sprayed or foamed.

(b)- Mineral wool: lab or all foam.

(c)- Balsa: load bearing insulant used in LNG containment system designs.

(d)- Perlite.

(f)- Polystylene.

**3.2.2.4 Strenght of material:**

Any physical body subjected to forces or stresses deforms under the action of these forces.

In general gas carriers must have enough strenght to cope with the following forces or combinations thereof:

-Hogging and sagging,

- Rolling, pitching, yawing, heaving,

- Hydrostatic, vibration, propeller forces,

- Grounding or docking,

- Tugs loads,

- Longitudinal load distribution.

The density of cargo carried in the tanks and the boiling temperature constitute the following loads:

- Internal and external pressure,

- Dynamic loads due to the motion of the ship,

- Tank and cargo weight with the correponding reactions in way of supports.

- Insulation weight.

According to the load conditions and associated structural calculations, the strength of a gas carriers will be assured if the analysis can comply with the requirements of authorized organisations.

The classification societies provide the structural safety criteria based upon intensive research of ship structure and materials.

Det nork Veritas gives table for minimum design temperatures for some actual tank materials and they give also a table for design temperatures and densities typical cargoes for liquefied gas carriers ( see Tables 1.1 and 1.2).

In liquefied gas carriers, low temperature service requirements may be encountered in the cargo tanks, secondary barriers and portions of the hull affected by the cargo as shown in Table 1.3.

### 3.2.2.5 Stability:

**(i) - General :**

The ship is designed to float upright in the water and move through the water in safety.

This stability must be considered in 2 phases before the ship is built: the intact stability and damage stability .

An LNG carrier is not different from the other ship from the point of view of stability.

The purpose of this paper is not to give all details of stability for LNG carriers; it is only limited to some information on the existing problem and its solution according the requirement in the IMO Codes.

After 1970 the IMO put forward international recommenadtions for the subdivision of liquefied gas carriers ito categories of ships like tankers for oil, Mobile offshore drilling units, etc...

Later in 1975, IMO adopted a gas ship code which was directed toward the liquefied gas carriers of at time.

Those carriers subject to the code were expected to survive the normal effects of flooding following certain assumed levels of hull damage externally caused . In addition , in order to protect the ship and the environnment, the cargo tanks were required to be protected from penetration in the event of minor damage to the ship as for example, from handling alongside by tugs. They were also required to have a degree of protection from damage in the event of collisions or stranding. Therefore, the cargo tanks were required to be situated within the hull a certain minimum distance from the shell. For the safe floating of the liquefied gas carrier, the

| Material | Min. temperature degrees Celsius |
| --- | --- |
| Specially treated carbon-manganese steel | - 50 |
| 5 % Ni-steel | - 105 |
| 9 % Ni-steel | - 165 |
| Aluminium | - 196 |
| Austenitic stainless steel (ex. AISI 304 | - 196 |

Table. 1.1. material in relation with temperatures.

| Cargo | design. temp. degrees Celsius | design. densit. t/c |
| --- | --- | --- |
| Methane (LNG) | - 164 | 0.42 |
| Propane | - 42 | 0.58 |
| Butane | - 10 | 0.60 |
| Propylene oxyde | + 33.9 | 0.86 |

Table. 1.2 Design temperatures and densities for some liquefied gases and chemical gas carriers.

Table. 1.3.- Requirements for liquefied gas carriers, Plates, sections for cargo tanks, secondary barriers and process pressure vessels for design temperatures below -55 deg. Cel. and down to -165 deg. Cel.

| Minimum design temperatures deg. Cel. | Chemical composition and heat treatment | impact test temperatures deg. Cel. |
|---|---|---|
| - 60 | 1 1/2 % Nickel steel normalized | - 65 |
| - 65 | 2 1/4 % Nickel steel normalized or normalized and tempered | - 70 |
| - 90 | 3 1/2 % Nickel steel normalized or normalized and tempered | - 95 |
| - 105 | 5% Nickel steel Normalized or normalized and tempered | - 110 |
| - 105 | 9 % Nickel steel -double normalized and tempered | - 196 |
| - 165 | Austenitic steels, such as types 304,304 L,316 316L, 321, 327 and 347 solution treated | - 196 |
| - 165 | Aluminium alloys; such as type 5083 annealed | not requi- red. |
| - 165 | alloy steel 36 % nickel | |

Source: American Bureau Shipping.

free board and initial stability also had to be considered carefully (see Figure 5).

**(ii)- Normal behaviour of a ship at sea:**

We are aware of the consequences of ship motions in waves which involve both hull structures and cargo tanks as well as mechanical effects of cargo motions in tanks (sloshing as defined below).

**Sloshing:** Some conditions of filling tanks associated with the pitching and rolling of the ship and the liquid free surface can create high impact on the tank surface. Therefore it can cause structural damage.

**(iii)- Structural fatigue:**

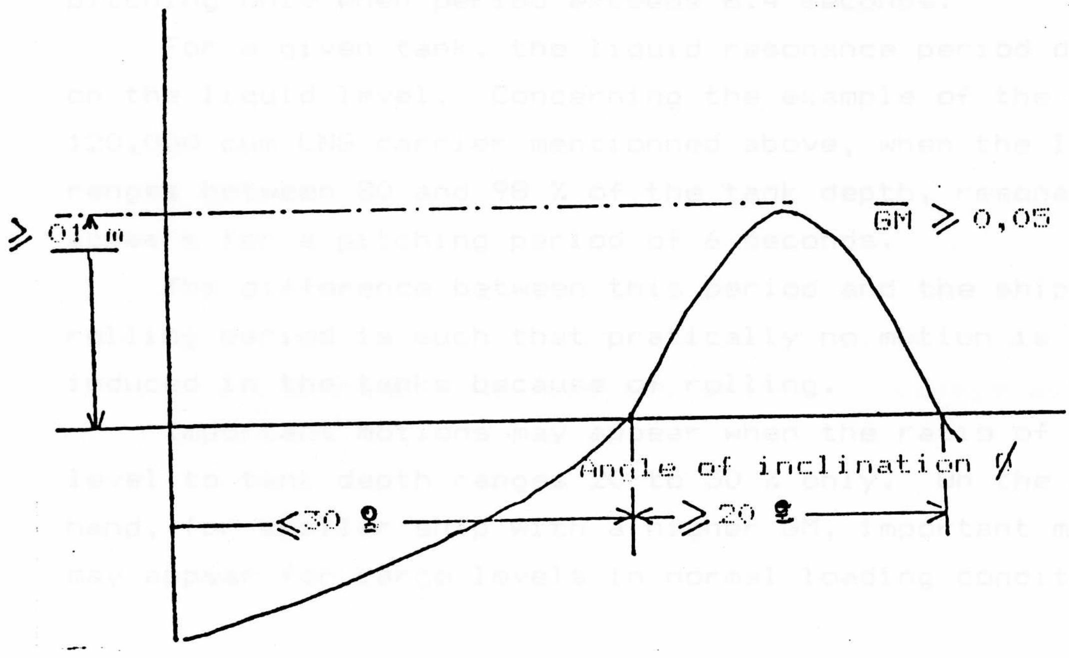
It is known that a small GM in association with a good righting lever curve combined with a good freeboard, which is the height of the deck from the water's surface and is a measure of the reserve buoyaoncy, results in small angular accelerations and thus minimises the dynamic effects of ship motions. Besides, the rolling period of the ship increases when the initial stability decreases.

This means that medium and of course large size ships with small GM will decreases generally by outside rolling resonance conditions. As a consequence, rolling accelerations (and rolling amplitude generally, too) will be small.

**(iv)- Liquid motions:**

The design of gas carriers with a too high initial stability is also very unfavorable as far as liquid

Fig. 5. Requirements for stability. Code on Liquefied Gases in Bulk Liquefied Gas Carriers.




Source: Subdivision and Damage stability by B. Vedeler (hand out of February 1990 to MSA(N)-90).

motions are concerned.

Calculations and experiments have shown that liquid cargo motions in tanks due to ship motions are small when the excitating periods are far from the natural period of the liquid cargo. But when the excitating period reaches the natural period of free surafce cargo in tanks, very amplified motions appear on tanks shells and furthermore on tank fittings (pipes, instrumentations, lattice work, etc...).

For instance, a 120,000 cum methane carrier designed with a GM of 2 meters, has a natural period when rolling ranging from the 20 seconds and gets excitated from pitching only when period exceeds 6.4 seconds.

For a given tank, the liquid resonance period depends on the liquid level. Concerning the example of the 120,000 cum LNG carrier mentionned above, when the level ranges between 80 and 98 % of the tank depth, resonance appears for a pitching period of 6 seconds.

The difference between this period and the ship rolling period is such that pratically no motion is induced in the tanks because of rolling.

Important motions may appear when the ratio of liquid level to tank depth ranges 20 to 30 % only. On the other hand, for smaller ship with a higher GM, important motions may appear for cargo levels in normal loading conditions.

**(v)-Damage satbility:**

LNG carriers have been subject to several studies concerning all kinds of stability tacking in account all heeling forces acting like wind forces (LNG carrier is high free board), manoeuvrability operations moving weight (loading cargo with deballasting or discharging cargo with ballasting).

The survival of a damaged ships is dependent on a number of factors: this subject is very complex for LNG carriers.

With reference to IBC code, the LNG carrier is a gas carrier intented to transport the commodity of methane in liquefied form and classed as type 2G. The carrier, which is more than 150 m. in length, should be assumed to sustain damage anywhere in its length.

IMO has established, in the Gas Carrier Code, requirements for the following items:

- extent of damage,
- damage location,
- permeability factor in flooded spaces,
- damage survival.

**- Extent of damage:**

It is assumed that damage can occur from either collisions or grounding damage, and the damage may consists of the most disabling penetration of sides or bottom of the ship. The assumed extent of damage as required in IMO IBC Code is:

Side damage:

Longitudinal extent: 1/3 or 14.5 m, whichever is less

Transverse extent: B/5 or 11.5 m, whichever is less

measured on board from the ship's side at right angles to the centreline at the level of the summer load line

Vertical extent: upwards without limit from the moulded line of the bottom shell plating at centreline

| | | |
|---|---|---|
| Bottom damage: | for 0.3L from the forward perpendicular | any other part of the ship |
| Longitudinal extent: | 1/3L or 14.5m, whichever is less | 1/3L or 5m, whichever is less |
| Transverse extent : | B/6 or 10 m, whichever is less | B/6 or 5m, Whichever is less |
| Vertical extent: | B/15 or 2m, Whichever is less measured from the moulded line of the bottom shell platting at centreline. | B/15 or 2m, Whichever is less measured from the moulded line of the bottom shell plating at centreline. |

**-Damage location:**

The IBC Code recommended for the type 2G that cargo tanks have to be located from the moulded line of the bottom shell plating at the centreline not less than the vertical extent of damge mentionned before and nowhere less than 750 mm from the shell plating (distances measured inboard).

**-Permeability factors in flooded spaces:**

The permeabilities of spaces assumed to be damaged should be as follows:

| Spaces | Permeabilities |
|---|---|
| Appropriated to stores | 0.60 |
| Occupied by accommodation | 0.95 |
| Occupied by machinery | 0.85 |
| Voids | 0.95 |
| Intended for consumable liquids | 0 to 0.95 |
| Intended for others liquids | 0 to 0.95 |

The buoyancy of any superstructure directly above the side damage should be disregarde. The unflooded parts of superstructures beyond the extent of damage, however , may be taken into consideration provided that:

1. They are separated from the damaged space by watertight divisions and the requirements relative to the final equilibrium after flooding in respect of these intact spaces are complied with; and

2. Openings in such divisions are capable of being closed by remotly operated sliding watertight doors and unproteted openings are not immersed within the minimum range of residual stability required in stage of flooding; however , the immersion of any other openings capable of being closed weathertight may be permitted.

**-Damage survival:**

LNG carriers should be capable of surviving the assumed damage specified in extent damage to the standards provided in standard of damage in IBC Code in a condition of stable equilibrium and should satisfy the following criteria:

a- In any stage of flooding:

(i)- The waterline, taking into account sinkage, heel and trim, should be below the lower edge of any opening through which progressive flooding or downflooding may take place. Such openings should include air pipes and openings which are closed by means of weathertight doors or hatch covers and may exclude those openings closed by means of watertight manhole covers and watertight flush scuttles, small watertight cargo tank hatch covers which maintain the high integrety of the deck, remtely operated watertight sliding doors, and sidescuttles of the non-opening types.

(ii)- The maximum angle of heel due to unsymmetricale flooding should not exceed 30 degrees; and

(iii)- The residual stability during intermediate stages of flooding should be to the satisfaction of the Administration. However, it should never be significantly less than that required by (i) above.

b- At final equilibrium after flooding:

(i)- The righting lever curve should have a minimum range of 20 degrees beyond the position of equilibrium in association with a maximum residual righting lever of at least 0.1 m within the 20 degress range; the area under the curve within this range should not be less than 0.0175 m/rad. Unprotected openings should not be immersed within this range unless the space concerned is assumed to be flooded. Within this range, the immersion of any of the openings listed in any stage of flooding and other openings capable of being closed weathertight may be permitted; and

(ii)- the emmergency source of power should be capable of operating.

**-Conclusion:**

One important and positive aspect of IMO work is the uniformity set for gas carriers. In fact the application of its code willensure a certain reliability of the ship and its equipment.

The naval architect has therefore to carry out calculations required for the subdivision of the actual ship and to calculate the effects of the given damage on trim and heel, and to estimate the residual figures for righting arm GZ range of inclination angle and area under the stability curve.

**3.3 Crew:**

**3.3.1 General :**

Several specialized authors in LNG transport have written in their manuals about safety and training on LNG carriers.

In point of fact, every shipping industry wants safe liquefied gas ships and safe terminals. These considerations lead to the classic question:

**What kind of crew do we require on board LNG carriers?**

R.C Gray- British shipbuilder, UK- in his introduction to a safety and training session (Gas Technique 1981 LNG/LPG Conference. page 287) brings a right note so far as the liquefied gas industry is concerned.

The citation is as follows:

> " In my experience , people follow safe operating procedures when they understand the potentail hazards and the basic science of safe operation after periods of supervised operating experience in all parts of the process; theycan then be made resposible for its safe operation".

I am not surprised by his statement , but I would like to discuss the specific to problem of crew through perspective which is the exemple of my country.

### 3.3.2 Consideration of the potential hazards in LNG ships:

The crew is expected to achieve safety on board by considering the sources of hazards which stem from the specific nature of the cargo.

I stressed indirectly in the beginning of this paper that high technology in gas vessels requires great care in operations. Therefore the primary objectives in LNG safety are to assess and quantify the potential hazards of an accidental release and to develop improved accident prevention and contingency measures.

In today's study on construction standards and setting criteria, there is also identified the need to develop better information on operator error rates, in other words human error.

The relative degree of safety achieved by a human is a function of his ability to understand use the knowledge of handling and conducting the ship. Therefore the major failure risk relative to humans might be categorized as operational risks leading to external risks of groundings and collisions. It might also be that the effects of those mentioned risks will produce internal risks such as sloshing.

However, the potential hazard remains the accidental release of liquefied gas, which upon ignition will result in a fire or possibly an explosion. Events leading to such spills are most probably caused by severe collision or grouding accidents.

### 3.3.3 Qualified crew:

Safety is related to the probability of accidents which relates in turn to injuries and to damage to vital equipment.

The people on board, without the exception of the people working in gas terminals in co-operation with the ship , are wellqualified today.

The first step in understanding behaviour motivation in relation to safety is to realise that safety is made up of certain elements:

**SAFE BEHAVIOUR = KNOWLEDGE + UNDERSTANDING + SKILL + MOTIVATION**

Knowledge is the first rquirement of a crewman on board in order to carry out the job assigned to him. The knowledge comprises cargo handling, navigation, maintenace and repairs, where most of the hazards are hiding.

The understanding is that there may be certain dangers in carrying out the alloted job. As it will be described later in this paper, the job on board an LNG carrier is also complex. Therefore, in order to behave safely, it i necessary to understand the sequence and steps to follow in discharging and loading liquefied natural gas.

Should it become clear that the crew is unable to perform the job, it is necessary to ensure the necessary training for them. Safer and more efficient ships come from proper shipboard planning for training the younger crew members.

The situation on board the ship itself may be considered as quite a different part of the problem. A ship at sea is a relatively independent 24 - hours community that constitutes a socio-technical system. This leads to specific ergonomic problems. Therefore, there are many factors which motivate the crew to perform at the job station inter-alia:

- Particular levels of intelligence, education , background or special physical ability depending on the job assigned.

- Necessary problems to maintain the desired level of performance in normal and abnormal work situations.

- Health problems affecting the crew's ability to carry out physical duties. The adverse effects of medication and drinking (normally more controlled on gas ship).

- Stress from family problems, work pressure, work-mates and even from management.

### 3.3.4 Safety training on LNG carriers:

For many years, the training set down to meet statutory requirements for certificates of competency and similar standards was adequate for all types of ships.

Basic skills and knowledge were the same for all types of ships and all that was required was a change of emphasis and application to meet the operating needs of of specialized ships.

With the increased complexity and numbers of specialized ships carrying what are often potentially hazardous cargoes there arose special training requirements for the crews.

Judge Learred Hand, Keen V. Overseas Tank Ship Corp. 194 F.2d.515 has given the principle in his citation: "An owner is responsible for the seaworthiness of his ship in respect of personnel in the same sense that he is in respect of hull and gear."

The ship's crew has to be competent, efficient and sufficient. The level of the competence and qualification are logical, factors which would have a bearing on the seaworthiness of a ship.

The Convention on Standards of Training,Certification and Watchkeeping for Seaferers 1978, which entered into force on the 28th April 1984, has established in regulation V/3 mandatory minimum requirements for the training and qualification of master, officers and rating of liquefied gas tanker (see appendix no.1.1.1).

#### 3.3.4.1 How is training to be accomplished?

In the past, ship personnel training was accomplished on board. Today, this type of training exposes the owner to risking capital loss which is too great. It also exposes officers to the to the risk of not being able to react effectively to emergencies. Therefore, today the training of tanker personnel in general comprises two steps:

- shore based formal instruction.
- ship board training.

### 3.3.4.1.1 Shore based formal instruction:

This training course complies with regulation V/3 of IMO international convention STCW for Seafarers of 1978. The aim of this course is to provide personnel with an overall understanding of the general principles by which these vessels operate, their construction, the potential hazards associated with the cargo and the necessary precautions to take to ensure safe operations. And the officer responsible for cargo operation must be familiar with:

- duties in connection with the cargo handling system,
- components and instrumentation,
- hazards peculiar to this cargo, such as fire, health and cargo release hazards,
- cargo behaviour under all situations,
- equipment available for trouble shooting and decision-making in realistic emergency situations,
- teamwork situations.

Those requirements can be covered in the form of formal lectures, models, field trips and extensive use of audiovisual teaching aids.

### 3.3.4.1.2 Shipboard training:

This training is a continuation of the first one, and it is usually where the trainee is involved in such activities as:

- long period on board the ship to be familiar with loading, discharging, cargo conditionning and all possibilities of malfunctions that migh occur during the stay on board,
- transfer of knowledge from the instructor (who may be chief engineer or chief officer) to the trainee,
- experience at sea in job effenciency,
- frequent emergency training on board.

**3.3.4.2 Example of training in Algeria:**

The Algerian fleet of "Compagnie Nationale Algerienne de Navigation" (CNAN) started with many gas carriers over a short period of time. Under demand and advice of CNAN, Gazocean Company in France specialized training questions has presented and professionnal method to follow have been introduced on two levels.

The basic level concerns the whole crew and consists of safety training centred on the dangers presented by the cargo, the prevention methods to be adopted and involves practical training similar to that given to sea-going people.

The second level consisting of special training of the personnel having gas-related duties, including:

(i)- the cargo officer in charge of cargo handling (usually the first mate).

(ii)- the gas man (equivalent to pumpman on a crude oil tanker) who assists the first mate in all cargo questions and in the arrangement of the various cargo circuits.

(iii)- The engineer officers who operate the cargo installations and keep them in running order.

In this case there are two solutions envisaged for the practical training which forms the main part of the whole teaching:

- Simulating true conditions.

- On board gas carriers.

The solution on board gas carriers is the best but it presents many difficulties which are:

- Necessity to have an operational ship with experienced crew.

- Training will necessarilly be long and incomplete.

As a matter of fact, the trainees can stay on board a methane carrier for a long time without ever attending to the whole process of operation of a ship.

The first solution might be expensive. Therefore , Gazocean presents a half way solution which consists ofthe following :

The first mate does not need to be trained on board the ship as he is already posted. The engineers in charge of gas-related operations and the gasmen will be trained ashore only when training is not feasible on board the ship.

Therefore, the solution is to train the sea going people partly on board ship and partly ashore in a training centre. The training centre comprises mainly:

- a gas chemical physical laboratory.
- an automation room.
- an inert machinery room.
- a training units which comprises:

* two pressure tanks containing butane.

* a reliquefaction unit for cooling the product and simulating an atmospheric pressure installation.
* a cargo control desk similar to the equipment in ships.

To highlight the consistency in the training centre the Appendix 1.1.2 indicates the contents of training for the first mate and duration of training.

**3.3.5 Primary cooperation shore/ship:**

**3.3.5.1 General:**

The concept of safety has been discussed at several points where it was said that carrying liquefied gas requires inter-disciplinary co-operation between the design and the operation of vessels. For this purpose there is a need for an" orchestra" comprising the shipowner, the designer, and the shipbuilder togetyher with regulatory authorities and associated industries sharing responsabilities respectively. The balance between design and operations gives birth to the optimum level of safety see Figure 6.

**3.3.5.2 Ship/shore coordinated control:**

The diagram in Figure 7 shows the various aspects of design safety and operational safety as appli-ed to liquefied gas carriers. Also it shows the position of terminal operators who come into the scene during the period when the ship is connected to a shore terminal and engaged in the transfer of cargo.

The system mentioned above is installed to enable the ship's personnel to safely shut down both the ship and the shore plant in an emergency situation and also provide the

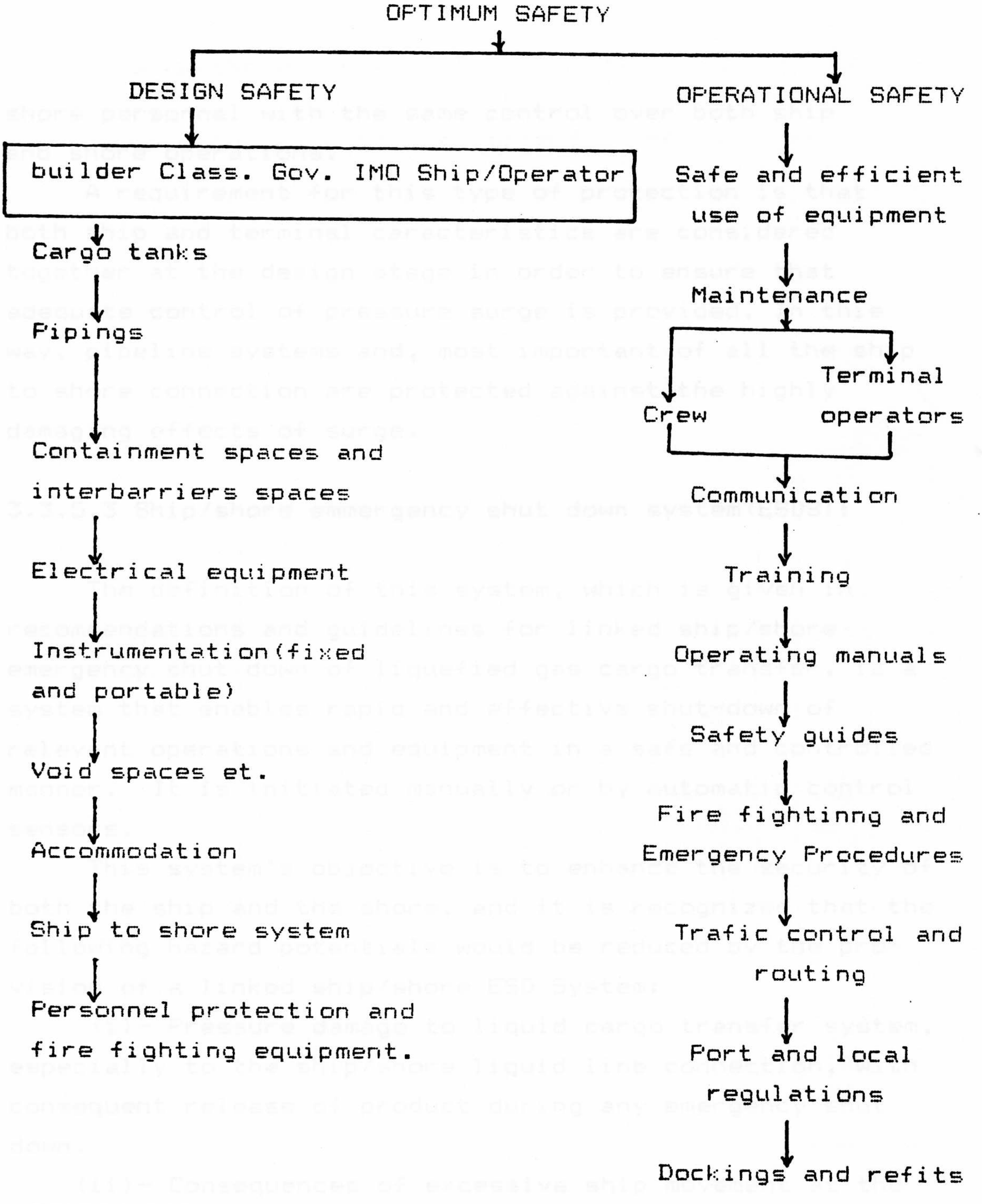



Fig. 6.- Diagram of optimum safety between design and operations.

shore personnel with the same control over both ship and shore operations.

A requirement for this type of protection is that both ship and terminal caracteristics are considered together at the design stage in order to ensure that adequate control of pressure surge is provided. In this way, pipeline systems and, most important of all the ship to shore connection are protected against the highly damaging effects of surge.

### 3.3.5.3 Ship/shore emmergency shut down system(ESDS):

The definition of this system, which is given in recommendations and guidelines for linked ship/shore emergency shut down of liquefied gas cargo transfer, is a system that enables rapid and effective shut-down of relevant operations and equipment in a safe and controlled manner. It is initiated manually or by automatic control sensors.

This system's objective is to enhance the security of both the ship and the shore, and it is recognized that the following hazard potentials would be reduced by the provision of a linked ship/shore ESD System:

(i)- Pressure damage to liquid cargo transfer system, especially to the ship/shore liquid line connection, with consequent release of product during any emergency shut down.

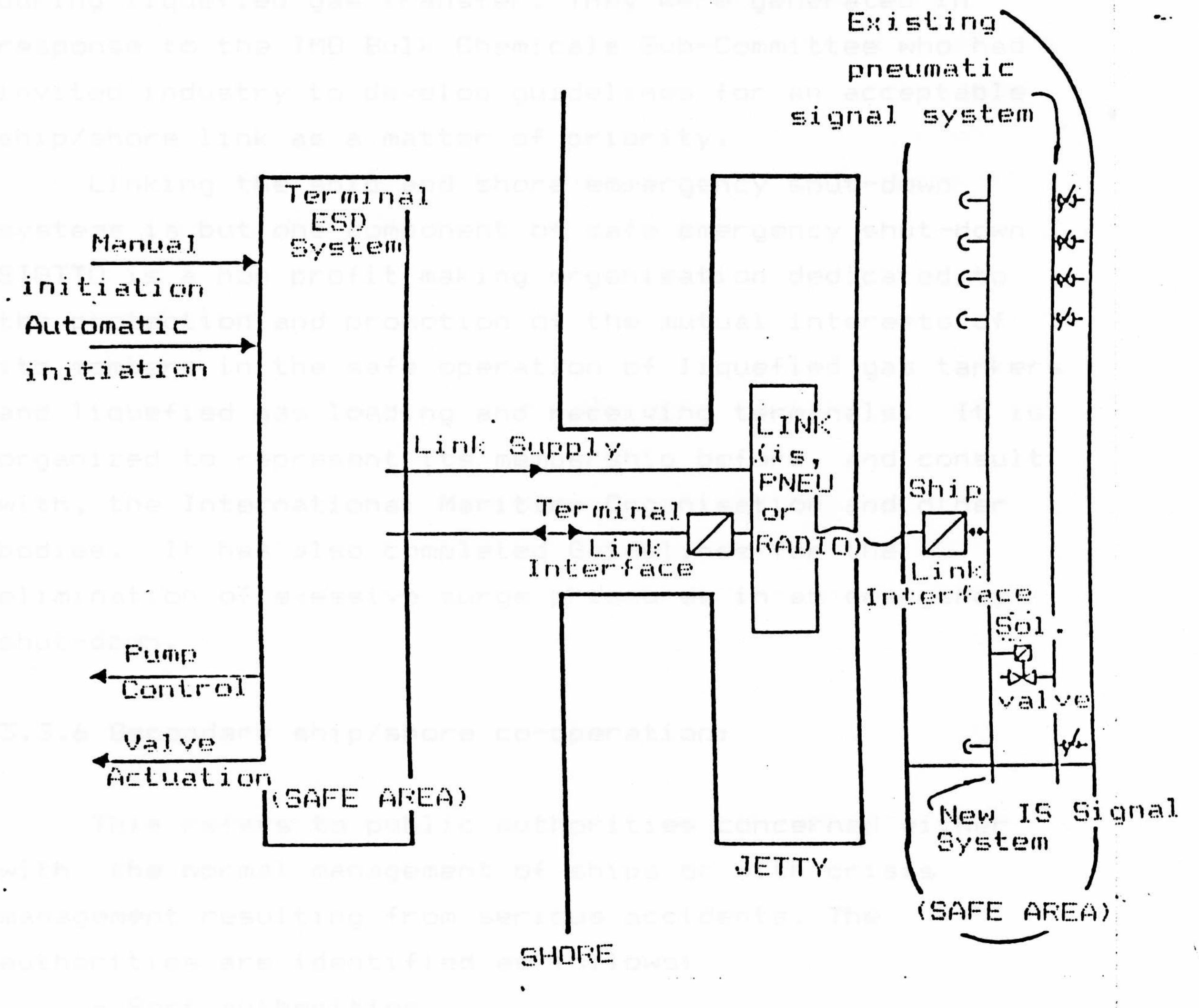
(ii)- Consequences of excessive ship movement at the berth.

(iii)- Overfilling of ship or terminal storage tanks.

The linking is technically powered electrically, pneumatically or by radio. The link system stands alone separate from the ship and terminal system (see Figure 7).

Fig. 7.- Ship/shore linked ESD schematic.

Source: Gas Tanker and Terminal Operators Ltd.
M.P Holdsworth SIGTTO, BERMUDA (GAS TECH.84 p.210).



### 3.3.5.4 Need to estabish ship/shore ESDS:

In 1987 IMO"Recommendations and Guidelines for Linked Ship/Shore Emmergency Shut Down of Liquefied Gas Cargo Transfer" were completed. Those guidelines offered a significant advance in safety at the ship/shore interface during liquefied gas transfer. They were generated in response to the IMO Bulk Chemicals Sub-Committee who had invited industry to develop guidelines for an acceptable ship/shore link as a matter of priority.

Linking the ship and shore emmergency shut-down systems is but one component of safe emergency shut-down . SIGTTO is a non profit making organisation dedicated to the protection and promotion of the mutual interests of its members in the safe operation of liquefied gas tankers and liquefied gas loading and receiving terminals. It is organized to represent its membership before, and consult with, the International Maritime Organisation and other bodies. It has also completed Guidelines for the elimination of exessive surge pressures in an emergency shut-down.

### 3.3.6 Secondary ship/shore co-operation:

This refers to public authorities concerned either with the normal management of ships or with crisis management resulting from serious accidents. The authorities are identified as follows:

- Port authorities.
- Official authorities representing the government, regional and local authorities.
- The navy or coast guard.
- The fire brigade.
- The police department

- The owner.

An example of essential operational disciplines associated with cargo transfer operations - ship/shore is given in Figure 8.

In case of a serious accident, these public authorities are generally available to the ship at any time. They are involved to protect people, property, goods and port operations from any consequences of serious accidents which may occur.

In the following paragraphs, it will be laid down what are considered to be the basic requirements of what kind of crew we have on board gas carriers.

### 3.4 Legislation:

**3.4.1 General problem:** - How to Develope a safe system on gas carriers?

For 30 years now the transport of gas has been a matter of concern with regard to the safety of ships, cargo, personnel and even terminal plants with equipment.

The countries or rather governments involved in the transport of gas had provided safety by establishing appropriate legislation. Therefore it is necessary to set acceptable standards for the safety system. The situation leads to co-operation between governments and industries.

The aim of this chapter is to indentify what legal system is applicable to the gas carrier.

To understand legal system it is necessary to define what legislation is. In the internal law of states,the term legislation designates the process of enacting,

| | Ship's Master | Ship's Agent | Harbour Master | Pilot-tugs | Industrial zone security officer | Customs | Health | Immigration | Security and fire | Berthing dockers | Industrile unit Personnel |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Communication before arrival | X | X | X | | X | | X | X | X | | X |
| Arrival at pilot station | X | | X | X | | | X | | | | |
| Inspection and permission | X | | X | X | X | | | | | | |
| Movement to berth | X | | X | X | | | | | | | |
| Berthing | X | | X | X | | | | | X | X | |
| Civil security procedures | X | | X | X | | X | X | X | X | | |
| Ship/shore connection | X | | X | X | X | | | | X | | X |
| Inspection and approval to load/discharge | X | | X | X | X | | | | X | | X |
| Loading/discharging | X | | X | X | X | | | | X | | X |
| Documentation | X | X | X | X | X | | | | | | X |
| Ship/shore disconnection | X | | X | X | X | | | | X | | X |
| Civil security procedures | X | X | X | X | | X | | X | | | |
| Movement of ship away from berth | X | | X | X | | | | | | X | |

Fig. 9. An example of essential operational disciplines associated with cargo transfer operations ship/shore.
X = Area of involvment and responsability.

amending or repealing laws. Also, international legislation is considered to emerge whenever an original agreement is adopted which authorizes subsequent action by less than unanimity. However, in many countries there may be no domestic regulatory legislation to control gas carriers. In this case, the operator or whoever is responsible may refer to international regulations or guidelines.

This present chapter will identify IMO as the organization which is playing a wide role in the enactement of international legislation.

There have been many types of regulation for gas carriers in domestic and international classification societies and international associated industries up to the present days, but the most significant is the International Maritime Organisation (IMO) that have produced internationaly agreed codes for the construction, equipment and operation of chemical tankers and gas carriers.

### 3.4.2 Instruments of legislation applicable to gas carriers:

There are different aspects that have to be taken into account when we talk about safety in the context of liquefied gas carriers. There is the kind of cargo, and the kind of danger that may evolve in transport or in cargo transfer, there is the danger to the ship that may be caused by the cargo and there are the requirements a ship has to meet to make the transport safe for itself, the crew and the environment.

For the sake of clarification, the identification of the cargo transported on board gas carriers as dangerous substances in the definition of dangerous substances found in IMO recommendations on the Ssfe Transport, Handling and Storage of Dangerous Substances in Port Areas p.9 London, 1983 defined as follows:

Dangerous substances:"Means any substance whether packaged or in bulk,intended for carriage or storage, and having properties coming within the classes listed in the IMO "International Maritime Dangerous Goods Code"(IMDGC) Furthermore it means any substance shipped in bulk not coming within the the IMDGC classes but which is subject to the requirements of the IMO "Code for the Constructiion and Equipment of Ships carrying Dangerous Chemicals in bulk", the IMO Code " Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk".

Within IMO the basic rules for safe transport of bulk dangerous cargoes have been developed and are contained in Chapter VII of Solas Convention, in a form of codes and recommendations.

In 1975 the first "Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk" and the "Code for Existing Ships Carrying Liquefied Gases in Bulk" were adopted by resolution A 328(IX) and A329(IX) respectively. Under the amended Solas Convention, which came into force in 1986 and which had a special part C, in chapter VII, the " New International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk", came into force for ships constructed on or after July 1,1986.

The codes mentioned above, basically prescribe design and construction standards of gas carriers, equipment to be carried, arrangement and control of cargo transfer, tank ventilation systems, electrical installations,fire protection etc...

It is necessary to clarify the definition of a code. A code is just a recommendation to governments, masters and others involved in transport of liquefied gas. To make it mandatory for ships entitled to fly it's flag, the relevant government has to establish the necessary national regulations. This can simply be done in one sentence in the law, but it may be necessary to have the code translated into the national language and relate to that.

As a consequence, the construction and equipment of vessels transporting liquefied gases in bulk is governed by the following codes all details of which it is not possible to study in a paper of this nature .

| **Code** | **Application** |
| --- | --- |
| -Code for Existing Ships Carrying Liquefied Gases in Bulk. | ships built before July 1977. |
| -International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk. | ships built after 1976 but before July 1986. |

| | |
|---|---|
| -International Code for the Construction and Equipment of Ships Carrying Gases in Bulk (the International Gases Carrier Code-IGC Code). | ships built after June 1986. |

### 3.4.3 Role of International Organizations:

During the development of LNG transport, international codification of practices for the design and operation of gas carriers was born in the shape of codes formulated by IMO, which is the most important publisher of nautical legislation and codes of practise.

Beside IMO's work on gas carriers, there are ship classification society requirements which became more "unified" through International Association Classification Societies (IACS) and their contribution to the IMO Code.

However, there are several industry-based international organisations publishing operational guides that are very important. Such guides are more written from the side of industry than from the side of legislation and they are namely:

-International Chamber of Shipping (ICS).
-The Oil Companies International Marine (FORUM).
-The Society of International Gas Tanker and Terminal Operators Ltd (SIGTTO).

Those international organisations are working in co-operation with IMO.

#### 3.4.3.1 Classification societies:

Historically a classification society is an organisation whose function was to evaluate ships by classifying them in several grades, thus giving insurance a common standard for evaluating these ships to enable them to see if a specific ship is strong enough to carry its cargoes. In the past, classification societies were involved in free board assignment. Later they set up new requirements for issuing a class certificate of construction for ships.

Today the role of classification societies is to execute the classification surveys according to their own technical rules and regulations for the benefit of underwriters and, at the same time, to execute statutory surveys on behalf of the admnistrations according to the various international regulations and codes relative to ship safety and prevention of pollution of the marine environment.

### 3.4.3.2 Activities of classification societies :

The services offered by classification societies are in general divided into three groups as follows:

(i)-Classification services: They develop and administer the technical standards for the design, construction, and periodical survey of ships and other structures (i.e mobil offshore). Through their staff, classification societies certify that the ships comply with their rules.

(ii)-Statutory services: Many administrations authorize classification societies to act on their behalf ( i.e: entrust surveys, and issue of statutory certificates ), for example, the articles of regulation of the load line convention 1966. Regulation 1 annexe 1;

Solas 1974, Ammendment and the Protocol of 1978 Marpol 1973.

Classification societies play a role in admnistration of major international conventions, among them the International Gas Carrier Code (IGC) , and the Code for the Construction and Equipment of Ship Carrying Liquefied Gases in Bulk.

(iii)-Technical advisory services: Utilising their expertise in the marine industry, safety at sea and international maritime legislation, classification societies are continuously performing their services to the benefit of the industry.

The example given in this paper of Det norsk Veritas was given because of the shortage of information on other classification societies which, without doubt, have worked under the same objectives as Det norske Veritas.

**3.4.3.3 Det norske Veritas work on gas carriers:**

It is stated that DnV was the first of the classification societies to publish comprehensive rules for gas tankers. Therefore the first (tentative) DnV rules for tankers carrying liquefied gas originated about 1960 and have later been amended on a more or less continuous basis refflecting developments in technology and in the trade.

By the entry into force of IMO'S gas carrier codes in 1976, the design, equipment and operations of gas carriers became subject to international regulations.

The DnV's rules for gas carriers are considered also to include the International Gas Carrier Code which now is mandatory under the Solas convention. Det Norske Veritas has established rules in the classification of a steel ship of January 1990 by Division Ship and Offshore, Part 5

Chap. 5 cover Liquefied Gas Carriers. These rules are into the contents as follows:

1.General requirements.

2.Materials.

3.Damage stability and ship arrangements.

4.Arrangemants and environmental control in hold spaces.

5.Scantlings and testing of cargo tanks.

6.Piping systems in cargo area.

7.Cargo pressure/temperature control, cargo heating, arrangements, insulation.

8.Marking of tanks, pipes and valves.

9.Gas-freeing and venting of cargo tanks and piping systems.

10.Mechanical ventilation in cargo area.

11.Fire protection and extinction.

12.Electrical installation.

13.Instrumentation.

14.Tests after installation.

15.Additionnal requirements for certain cargoes.

16.Gas operated propulsion machinery.

17.Filling limits for cargo tanks.

18.Inert gas plants.

### 3.4.3.4 The International Association of Classification (IACS):

IACS is composed of eleven classification societies as follows:

-American Bureau of Shipping.

-Bureau Veritas.

-Det norsk Veritas.

-Germanical Loyd's

-LLoyd's Register of Shipping.

-Nippon Kaiji Kyokai.

-Registro Italiano Navale.

-USSR Register of Shipping.

- Poliski Rejest Statkow.

- Korean Registry of Shipping.

- Z. China.

They are working together in order to harmonize their own rules. IACS,which was established in 1968 and has been granted consultative status with IMO since 1968, has the objectives inter alia:

-To promote improvement of standards of safety at sea and prevention of pollution of the marine environmemt.

-To consult and cooperate with relevant international and maritime organizations.

-To maintain close cooperation with the world's maritime industries.

The close work of IACS relative to gas carriers is moulded in resolutions which take the form of requirements on cargo containment on gas tanker and unified "interpretations" in the IGC Code.

**3.4.3.5 The International Chamber of Shipping (ICS):**

The Chamber was first formed in 1921. The membership is mainly from the long established maritime nations, and represents about half of the world's merchant tonnage.

The ICS has an important role in maintaining and improving the operational standards of shipping, and its publication reflects that role. Among others things, ICS has published the "Tanker Safety Guide".

### 3.4.3.6 The Oil Companies International Marine Forum (OCIMF):

The interesting point of this organization is the transmission of the opinion and views of oil companies to bodies such as IMO. It has an important role in safety and pollution prevention. Their guides in the application of emergency procedures in case of fire in marine terminals are interesting.

The publications of this organisation are found on board gas carrier for the purpose of guidelines. In association with ICS and the International Association of Ports and Harbours (IAPH) OCIMF have published the "International Safety Guide for Oil Tankers and Terminals".

### 3.4.3.7 The Society of International Gas Tanker and Terminal Operators Ltd (SIGTTO):

The society was founded in 1979 and the members are involved in the operation of gas terminals and/or the operation of gas tankers. One of the main reasons for its existence is therefore the safe and efficient operation o tankers and terminals. Although a relatively new body, it has consultant status with IMO and has produced two major reference works which are "Liquefied Gas Handling Principles on Ships and in Terminals" and "Recommendations and Guidelines for Linked Ship/Shore Emergency Shut Down of Liquefied Gas Cargo Transfer".

The society is continuing its work on the "Guides to Contingency Planning" as follows:

-Volume one on"Contingency Planning for the Gas Carrier at Sea and in Port Approach".

-Volume two on "Contingency Planning for the Gas Carriers Alongside and Within Port Limits".

-Volume three on "Contingency Planning for Marine Terminals Handling Liquefied Gases in Bulk".

**3.4.3.8 National safety legislation:**

The statutory instrument is the means by which national regulations are formulated. The definition of a statutory instrument as " a rule, order, or admnistrative regulation having the form of law " is found in the dictionnary. Therefore a motion of legislation adopted on the safety of gas carriers falls in the general category of regulations monitoring other ships (i.e:Passenger ships, Roll-on/Roll-off, Tankers, etc...), but there is more attention given to gas carriers because of caracteristics presented by the dangerous cargo transported.

The administrations involved in the gas industry adopted into national regulations IMO codes which are internationaly documents necessarily containing some very broad and general language. Therefore, those administrations have the responsibility to interpret a comprehensive content in issuing regulations.

Those national regulations are the methods by which safety should be brought to the attention of seaferers and management, or to the gas industries. Because an LNG transport system must always be regarded as an element within a total system comprising terminals, ship procedures, and gas industries.

Therefore, it should be necessary that what we call national regulations drawn up in the Merchant shipping gas carrier regulations (specifically the IGC code) become mandatory for national ships throughout the world and even foreign ships in national waters. Also national regulations draw attention to the survey rquirements for national gas carriers and and note that,in addition to an initial survey for the issuance of the "certificate of Fitness" and a periodical survey for the renewal of the certificate, annual surveys and at least one intermediate survey are also required during the validity of the certificate.

## 3.5 Cargo handling:

### 3.5.1 General:

The cargo handling equipment is similar to that of oil tankers: shore cargo arms are connected to the ship's deck piping system at the manifolds located close to the midships, deck mains run fore and aft from the manifolds and branch pipes lead from the deck mains to the individual tanks.

However, the basic concepts which govern the design of LNG carrier cargo handling arrangements are that:

(i)- No entry of air permitted in the cargo tanks and piping, excluding when the tanks are prepared for inspection or dry docking.

(ii)- Cargo vapour must never be permitted to be vented to the atmosphere either at sea or alongside in port.

(iii)- All proper arrangements must be made for the low temperatures involved (refrigeratyed ships) both as regards selection of materials and allowances for expansion and contraction.

(iv)- Separate piping and reliquefaction equipment will be required where two or more grades are a gas carriers are quite different from those of an oil tanker. This applies in particular to cargo loading and cleaning of cargo tanks.

This chapter describes in broad outlines the cargo, the cargo handling equipment and the operations relative to the carriage of gas.

### 3.5.2 Properties and hazards of liquefied gas:

#### 3.5.2.1 Description:

Generally liquefied gases which are categorized as LPG, LNG, and liquefied chemical gases are mixtures of low-mollecular weight hydrocabons transported as bulk liquid by special ships usually referred to as gas carriers.

#### 3.5.2.2 Composition of LNG:

LNG is the product of liquefaction of a natural mixture of hydrocarbons obtained in petroleum bearing regions. Its composition varies from field to field: 65% to 100% can be methane, 0% to 16% ethane, any balance being propane, butane, pentane, nitrogen and carbon dioxyde.

#### 3.5.2.3 Properties:

Substances, which under ambiant conditions are gaseous, are transported as bulk liquids of the gas (LNG or LPG), which this reduces the volume by a factor of approximately 600. When transported at low temperature, the inleak of heat will cause the liquid to evaporate. The vapour is sent to the engine and used as fuel (see

Fig. 10 - Vapour pressure and boiling point of some liquefied gases.

| Cargo | Boiling Point at Atmospheric Pressure | Vapour Pressure at 45 %C Kg/cm2 abs | Practical carriage |
|---|---|---|---|
| N-Butane | - 0.5 | 5.2 | |
| Propane | - 42.1 | 15.0 | |
| Propylene | - 47.7 | 18.5 | |
| Ethylene | - 104.0 | Above critical Temperature | Semi-refrig. Fully-refri. |
| Methane | - 161.0 | Above critical Temperature | Fully refrigerated |

| PRODUCT | UN NUMBER | CHEMICAL FORMULA | MOL WEIGHT | TEMPERATURE OC | | | FLAMM. RANGE % VOL IN AIR | ABSOLUTE VAPOUR PRESSURE AT 15 OC (Bars) | TLV ppm |
|---|---|---|---|---|---|---|---|---|---|
| | | | | BOILING (A) | CRITICAL | IGNITION | | | |
| METHANE | 2043 | $CH_4$ | 16 | - 161 | - 82.5 | + 595 | 5 - 15 | Gas | 1000 |
| PROPANE | 1978 | $C_3H_8$ | 44 | - 42.1 | + 97 | + 460 | 2 - 9.5 | 7.3 | 1000 |
| N-BUTANE | 1011 | $C_4H_{10}$ | 58 | - 0.5 | + 152 | + 410 | 1.8 - 8.5 | 1.8 | 600 |
| ETHYLENE | 1038 | $C_2H_4$ | 28 | - 104 | + 9 | + 425 | 2.7 - 32 | Gas | 1000 |
| PROPYLENE | 1077 | $C_3H_6$ | 42 | - 47.7 | + 91 | + 497 | 2 - 11 | 8.9 | 1000 |

Fig. 11 - Flammability range of some liquefied gases.

Figure 9).

**3.5.2.4 Hazards:**

The major hazards of liquefied gases derive from their flamability and their low temperatures. Some hazards are identified under the following list below and the complete list is shown in appendix 1.1.3.

(i)-Flammability:

In a liquefied gas fire only the vapour burns. Thus the major danger is the ignition of the vapour cloud. The flammable vapour can ignite only when mixed with air in certain proportions as shown in Figure 10.

(ii)-Explosivity:

In confined spaces an ignition of vapours of liquefied gases can develop into a violent explosion, creating forces sufficient to destroy structures.

(iii)-Cold temperature hazards:

Human contact with liquefied gases or materials chilled to low temperatures can produce deep and severe freezing of body tissues. Most steels lose their ductibility when their temperature falls below OC. this means that they become brittle and lose much of their resistance to impact.

(iv)-Toxicity, asphyxia, and anasthesia:

LNG cargo is toxic because of its chemical properties can present temporary health hazards causing symptoms such as irritation, tissue damage or impairment of faculties.

In general, for every gas considered, a maximum exposure limit is given. The limit, called Threshold Limit value (TLV), refers to the maximum concentration of gases in the air to which it is believed that persons handling the gases may be exposed, day after day, without adverse effects assuming an 8 hours per day, 40 hours per week exposure. Exposure to higher concentrations than the TLV. may be permitted for short periods (designated by short term exposure limit :STEL) but for prolonged working above the TLV respirators should be worn. Figure 10 gives values for some gases.

### 3.5.3 Cargo handling systems for gas carriers:

#### 3.5.3.1 General:

A complete system of piping, pumps, compressors etc.. is provided on board ship for handling the cargo.The system is a closed one and it is used exclusively for this purpose.

In the scope of safety, all connections to the cargo tanks are required to be situated above the weather deck and it is therefore necessary to arrange for the cargo tanks,or domes on the cargo tanks, to protrude above this deck. The necessary connections for liquid and gas lines, relief valves, liquid level gauging devices, pressure gauges and thermometers should be located on this portion of the cargo deck.

Prior to first loading a cargo of liquefied flammable gas the system of tanks and piping should be purged of air in order to prevent any explosive mixture forming in the system with the consequent risks, especially if vapour compressors are being used for handling the cargo gas. When we talk about purging it is usually carried out by means of an inert gas which may be produced or stored on board ship or obtained from shore.

**3.5.3.2 Cargo pumping and piping arrangements:**

The main cargo pumps are located inside the cargo tanks at the tank bottom and they are of two basic types (a) deep well and (b) submerged.

(a)-Deep well:

In this type of pump the driving motor is located on deck and it is driven by a shaft which passes through a cargo sight gland at the tank top down to the pump. The pump is usually suspended from the cargo tank top by a pipe through which the cargo is discharged to deck and which also encloses the pump driving shaft and bearings.

(b)-Submerged:

This type is situated at the bottom of the tank and is a fully submerged, electrically driven centrifugal pump. The pump sucks the liquid through its centre and the liquid is sent up to the deck via the pump discharge pipe. Strict precautions are taken to ensure that the pumps never operate in an explosive atmosphere.

**3.5.3.3 Vapour blowers, or compressors:**

They are provided on board for handling cargo vapour and for pressurising the cargo tanks. These compressors are also used for handling the inert gases and atmospheric air when inerting, gas freeing and purging the cargo tanks and containment spaces, etc...

### 3.5.3.4 Spray rails:

These are pipes located within the cargo tanks and used for cooling the tank before loading and also for returning the condensate during passage. The spray rails used for the returning condensate have larger holes which permit the returning liquid to mix with the cargo before evaporation takes place.

### 3.5.3.5 Purge lines:

These are used to change the tank atmosphere. Purge lines lead to both the top and the bottom of a tank as the replacing element may be lighter or heavier than the previous atmosphere.

### 3.5.3.6 Relief valves:

Relief valves are fitted to cargo tanks so that if tank pressure exceeds the pre-set limits the vapour is vented to the atmosphere. This venting is undesirable as the gas is flammable and toxic, and because the cargo loss is costly.

### 3.5.3.7 Cargo valves:

These are operated hydraulically or pneumatically. An automatic quick closing system can close all cargo related valves in an emergency.

### 3.5.3.8 Refrigeration and reliquefaction plant:

The cargo conditioning plant may consist of two or more units. A unit is a complete mechanical system with compressors, pumps. heat exchangers. etc.. that is capable of converting the boil off cargo vapor back to liquid.

During the loaded passage gas will evaporate from the cargo, the process being known as "boil off". On LNG carriers the boil off is vented to the atmosphere or, alternatively, is used as propulsion fuel in the boilers. The units of a cargo conditioning plant may be reliquefaction, refrigeration or a combination of the two.

**3.5.3.9 Ballast tanks:**

The cargo tanks are never used for ballast and thus the ballasting arrangements are completely separate from the cargo system.

**3.5.3.10 Inert gas plant and gas freeing:**

This system is used for purging to avoid conditions that may cause an explosion. And it is a closed one and normally always be full of gas with no explosive mixture.

**3.5.3.11 Tank dome:**

This provide the entry point into the tank for cargo lines, sensors, control and monitoring equipment.

**3.5.3.12 Tank monitors and controls:**

There are three basic monitoring parameters:

- Cargo and tank temperatures: within levels and measuring the column of the tank.

- Cargo liquid: measured by a variety of devices (i.e: gauges, pressure gauges, ultrasonic gauges).

- Tank pressure: gauges measure high and low pressure within the tanks.

In addition to the monitoring function, tank instruments also activate alarms and in some cases automatically control equipment such as cargo valves.

**3.5.3.13 Gas detection sensors:**

These monitor spaces other than the cargo tank such as accommodation, duct keels, void spaces, control room,reliquefaction plant, and peak tanks. They are connected with gas detection alarms in the bridge and in the cargo control room.

**3.5.4 Operational procedure:**

**3.5.4.1 Safety procedures:**

Safety procedures are linked to the hazards that the cargo itself presents. Gas vapour can be flammable, explosive, toxic, asphyxiating, poisonous, corrosive, and can inflict frostbite or other injuries on personnel. The maintenance and operability of the ship in a satisfactory state are essential to the ability to handle the cargo satisfactorily between the ship and its shore reception facilities, this being verified by certification, inspection and check lists.

However, ashore and within the port area, the same method of safety is applied in order to handle cargo safely. In the preceding chapters the design of the ship has been discussed in association with IMO regulations, classification societies and national authorities. Therefore, it may appear that safety procedures for handling LNG cargo safely are complex which are commented below and shown through the Figure 11 representing overview of ship/ shore cargo operations.

a- Advance information prior to arrival of the vessel with cargo at the port and terminal.

b- Procedures for verification of valid certificates of the ship.

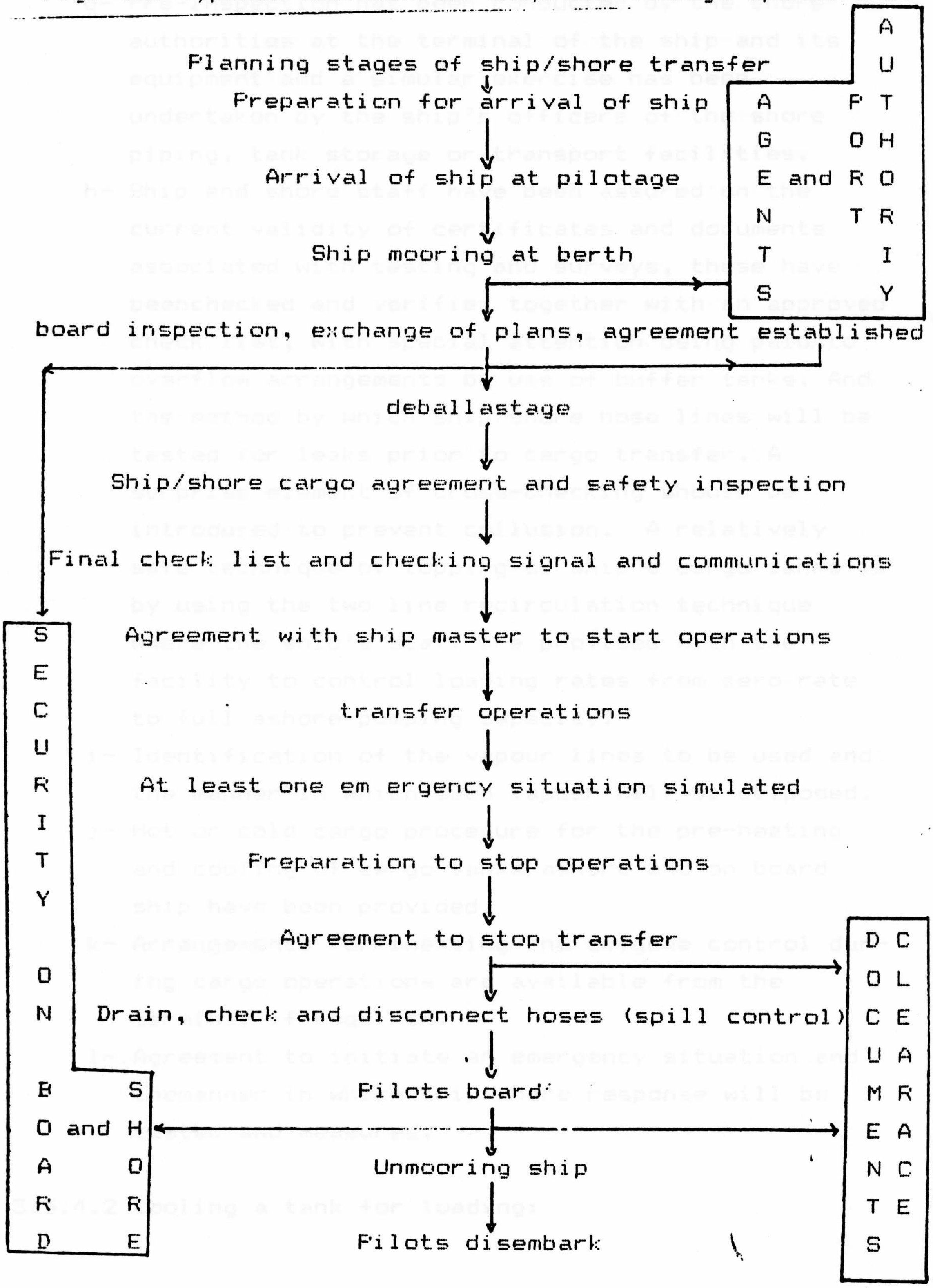
c- All equipment for cargo conditioning, monitoring and transfer is in proper working condition.

d- Emergency shut down devices have been tested and communication and signaling devices have been understood, including emergency procedures and the areas of responsibility of key personnel ashore and on board.

e- Tracing and checking of pipelines on board ship from cargo tank to fixed storage tanks or secondary transport system ashore has been done and the necessary fixed and portable isolation devices have been fitted to non-compatible cargo tanks.

f- Security has been arranged ashore and warning notices have been placed in the right position, and all fire fighting appliances and fixtures in relation to the preposed cargo transfer operations have been agreed on. Emergency fire water supply and connections have been tested.

Fig. 12. Typical overview of ship/shore cargo operations.



g- Pre-inspection has been conducted by the shore authorities at the terminal of the ship and its equipment and a simular exercise has been undertaken by the ship's officers of the shore piping, tank storage or transport facilities.

h- Ship and shore staff have been assured on the current validity of certificates and documents associated with testing and surveys, these have beenchecked and verified together with an approved check list, with special attention being paid to overflow arrangements by use of buffer tanks. And the method by which ship/shore hose lines will be tested for leaks prior to cargo transfer. A surprise element of cross-checking should be introduced to prevent collusion. A relatively safe technique of topping up ship's cargo tanks is by using the two line recirculation technique where the ship's staff are provided with the facility to control loading rates from zero rate to full ashore pumping capacity.

i- Identification of the vapour lines to be used and the manner in which such vapour will be disposed.

j- Hot or cold cargo procedure for the pre-heating and cooling of cargo tanks ashore and on board ship have been provided.

k- Arrangements for inerting and oxygene control during cargo operations are available from the terminal if required.

l- Agreement to initiate an emergency situation and themanner in which ship/shore response will be tested and measured.

**3.5.4.2 Cooling a tank for loading:**

Before cooling takes place, the tank must first be inerted and then purged with vapour compatible with the methane. Some vessels are equipped with deck storage tanks containing liquefied natural gas which can be used for the purging and cooling operations. On other vessels the purging vapour and cooling liquid natural gas must be taken from the shore.

The methane is introduced into a tank via the cooling spray rails. When the liquid droplets are sprayed into the tank, vaporization of the droplets will occur. The heat required for the vaporization process is obtained from the tank atmosphere and structure and thus the tank is cooled. The rate of cooling must be controled. The time taken for cooling depends on the tank size and the construction materials. The temperature of the tank structure must be carrefully monitored to ensure that the temperature differential between various parts of the tank does not become excessive.

Pressure within a tank will increase due to the vaporization of the liquid droplets. This pressure is relieved by the reliquefaction process or by returning the vapour to the shore by a pipe which connects to a shore line at the manifolds and which is known as the vapour return line.

### 3.5.4.3 Loading on LNG carrier:

Before loading starts, the tanks must be dry and free of oxygen. The tanks will therefore have been dried with air which has been passed through a dehumidifier. The dewpoint of the air must be low enough to prevent condensation of water vapour onto the cold tank structure. The tanks will then have been inerted with nitrogen to prevent the formation of an explosive atmospheric mixture. Methane vapour is introduced from the shore until the inert gas is vented, usually to the atmosphere, and a suitable positive loading pressure is attained. A vessel may also arrive alongside gas-free and under an 80% vacuum which is broken by the introduction of the shore methane vapour and the atmosphere inside the tank is raised to a slight positive pressure. When methane is detected in the vented exit gas, cooling commences via the spray rails. Once a suitable level of liquid is formed in the bottom of the tank. loading is carried out as previously described.

During loading the cargo, vapour must be returned to shore tankks via the ship's piping and the shore vapour return hire. The rate of loading is determined by the rate at which vapour is generated within the tank and the ability of the vapour return line to remove the vapour to shore.

### 3.5.4.4 Loaded passage:

On LNG ships cargo vapour is withdrawn from the vapour space, passed through the reliquefaction plant, and the condensate returned to the tank. On LNG vessels the boil off is either vented to the atmosphere or used as propulsion fuel.

### 3.5.4.5 Discharging:

Before commencing the discharge on an LNG ship, the liquid lines on deck must be cooled. The discharge may be aided by the use of ship's booster pumps which assist the individual tank pumps. Discharging usually commences with one tank only and once the system is observed to be functionning satisfactorily all the tanks are discharged simultaneously. Pressure must be maintained within the tank during all stages of the operation.

### 3.5.4.6 Ballast voyage:

In order to maintain pressure in the cargo tanks, and to use a cooling pilot, some quantity of cargo is retained in the cargo tanks after discharging.

### 3.5.4.7 Preparing a tank for entry after cargo discharging:

The following procedure should be adopted:

a- The puddle heaters should be used to boil off any remaining liquid is boiled off by the introduction of heated vapour.

b- Isolate the tank from any reliquefaction plant and secure any cargo inlet or outlet valves in the closed position.

c- Carefully raise the tank temperature to the ambiant (or surrounding) temperature.

d- Purge with inert gas to prevent any remaining cargo vapour forming a flammable mixture with air.

e- Ventilate with fresh air using fixed or portable foams of approved fire-proof construction.

f- Institute entry to enclosed spaces procedures.

### 3.5.4.8 Comments on operationnal procedures:

After delivery, shipyards provide ships carrying liquefied gases with technical manuals giving details regarding cargo handling equipment and instructions for ship operators. Therefore, the different operations described above are only summarized in order to show the complexity of safety involved in the sequence of LNG ship operations.

Several industry-based international organizations which have already been mentioned in earlier chapters, publish operational guides that are very useful and important and which may not be ignored by ship and shore management. one of Those manuals is namely:

-"Tanker safety guide liquefied gas" is published by the ICS and its purpose is to provide those serving on gas carriers with information or recognized good operationnal practises and safe procedures.

This guide covers all aspects of the operation of vessels carrying gases such as liquefied petroleum gas(LPG), liquefied natural gas (LNG),and ammonia.It contains the following items:

- Information on the general properties of liquefied gas, the hazards of such, and how to transport them in safety.
- General precautions for the safety of the ship, specially the avoidance of fire.
- Cargo operational guidance, including loading,discarging, reliquefaction, purging and sampling.
- Information on cargo equipment , instrument operation and maintenance.
- Correct procedures for entry into enclosed spaces, fire fighting, emmergency actions, and personnel protection.

The guide is written in pratical terms, the physical properties of gases are explained at some lenth and explanations are given as to why special precautions are necessary.

There is another guide drafted by Graham Mc Guire and Barry White of the Hazardous Cargo Tank Unit, Leith

Nautical College (now center for Advanced Maritime studies), entitled "Liquefied Gas Handling Principles on Ships and in Terminals". This edition is similar in contentsthan the ICS manual.

# CHAPTER FOUR

# CASUALTIES

## 4.1 Casualty types :

In this chapter the types of casualties are classified, with their definition as per "Lloyd's Register casualty" given below:

**Collision:**

Striking another ship, regardless of whether under-way, anchored or moored. this category does not include striking underwater wrecks.

**Grounding:**

Vessel touching sea bottom, underwater wrecks etc...

**Fire/explosion:**

Where the fire and/or explosion is the first incident reported.

**note:** It therefore follows that casualties involving fires and/or explosions after collisions, or stranding etc...would be categorised under "collision" . Scavenger fires will be included in fire and explosion.

**Foundered:**

Includes ships which sank as a result of heavy weather, springing of leaks, breaking in two, capsizing etc... and not as consequence of collision and grounding.

**Machinery damage:**

Ships lost or damaged a result of machinery, shaft, rudder or propeller failure.

**Contact:**

Striking an external object but not another ship or sea bottom. This includes striking a pier or off-shore structure.

**Missing:**

After a resonable period of time, no news having been received of a ship and its fate being therefore undertermined, the ship is reported as missing at Lloyd's and is included in the missing category.

**4.2 Casualty categories:**

Casualties can be divided in 3 categories as follows:

(i)-all casualties (non serious and serious),
(ii)-serious,
(iii)-total loss.

**Non serious:**

Any incident occuring to a propelled seagoing merchant ship of 100 tons gross and above in which the condition of the ship suffers adversely.

**Serious:**

Is a casualty to a ship which results in:

a)- structural damage which renders the ship unseaworthy, such as penetration of hull underwater, immobilisation of main engine, extensive damage etc....

b)- breakdown necessiting towage or shore assistance.

c)- actual total loss.

**Total loss:**

Refers to a merchant ship which as a direct result of being a marine casualty, has ceased to exist, either by virtue of the fact that the ship is irrecoverable or has subsequently been broken up.

Ships which have been declared constructive total losses but which are undergoing or have undergone repairs during the year are not included.

## 4.3 Casualty statistics:

### 4.3.1 Introduction:

In the absence of updated statistics specific to LNG ships in comparison with LPG and even with ships other than LNG/LPG ships. The following Section is based on the limited informations available from the following sources:

a)- Analysis of the record 1964 to 1981 on Liquefied

Gas Ship Safety by POTENS & PARTNER'S NewYork.

b)- Safety Review of Ships for Liquefied Gases and Features Legislative Needs by D.S Aldwinckle and D.S Mc Lean-Lloyd's Register of Shipping London- page 120 (Gas Tech.84, LNG/LPG -Conference Amsterdam .November 6-9,1984).

### 4.3.2 Gas ships casualty and damage statistics:

#### 4.3.2.1 Ship casualty statistics:

LNG and LPG are both inflammable when evaporated and mixed with air. Casualties which are judged "serious" are those where there was some actual or potential threat to the cargo containment system. The accidents which result in a cargo spill or leakage, or in a cargo fire, are potentially the most dangerous. Any spill or leakage of cargo creates a possibility of fire which could endanger nearby persons or property. A survey of serious incidents on LNG ships has been undertaken by POTTEN & Partners Inc. and they are summarised in Table 1.5 below:

Table 1.4 - Summary of serious incidents (LNG ships):

| Type of incident | Number of incidents 1981 | 1964-1980 | Cargo leakage | Cargo fire |
|---|---|---|---|---|
| Collision while underway | 1 | 2 | 0 | 0 |
| Struck while moored | 0 | 1 | 0 | 0 |

| | | | | |
|---|---|---|---|---|
| Contact with stationary object | 0 | 1 | 0 | 0 |
| Grounding | 0 | 2 | 0 | 0 |
| Explosion/fire on board | 1 | 4 | 0 | 0 |
| Spillage of cargo | 0 | 1 | 1 | 0 |
| T o t a l | 2 | 11 | 1 | 0 |

Another approach to studying casualties and total losses is to compare both LNG and LPG with dry cargo ships as shown in Table 1.5 .The source is drawn from page 122 (of reference (b) presented) in the introduction of this Section.

**4.3.2.2 Reports on casualties:**

The following records, which are not definitive, indicate that in no instance was a tank damaged so that cargo escaped and no case of serious cargo fire is to be found.

The range of the following accidents and incidents is limited to those which affected the cargo containment system or cargo handling system and they include liquid spill and lightning strike, grounding and stranding. Therefore the data related to consequences of accidents that are less serious as shown the following reports.

**Grounding:**

Table.1.5 Casualty and total loss statistics LNG & LPG ships:

| Types of casualty | | LNG | LPG | Total | Dry cargo ships |
|---|---|---|---|---|---|
| Collision | A | 0.00 | 0.36 | 0.32 | 0.82 |
| | B | 0.00 | 1.08 | 0.95 | 5.82 |
| | C | 0.00 | 1.43 | 1.27 | 6.64 |
| | D | 0.00 | 0.00 | 0.00 | 2.97 |
| Contact | A | 0.00 | 0.00 | 0.00 | 0.21 |
| | B | 0.00 | 0.36 | 0.32 | 1.88 |
| | C | 0.00 | 0.36 | 0.32 | 2.08 |
| | D | 0.00 | 0.00 | 0.00 | 0.23 |
| Fire / Explosion | A | 0.00 | 0.72 | 0.63 | 1.82 |
| | B | 0.00 | 3.58 | 3.16 | 3.37 |
| | C | 0.00 | 4.30 | 3.79 | 5.20 |
| | D | 0.00 | 2.87 | 2.53 | 4.98 |
| Foundered | A | 0.00 | 1.43 | 1.26 | 2.61 |
| | B | 0.00 | 0.36 | 0.32 | 0.33 |
| | C | 0.00 | 1.79 | 1.58 | 2.94 |
| | D | 0.00 | 0.00 | 0.00 | 8.35 |
| Hull / Machinery damage | A | 0.00 | 0.00 | 0.00 | 0.29 |
| | B | 2.65 | 9.32 | 8.52 | 8.08 |
| | C | 2.65 | 9.32 | 8.52 | 8.36 |
| | D | 0.00 | 0.00 | 0.00 | 0.27 |
| Miscellaneous | A | 0.00 | 0.00 | 0.00 | 0.02 |
| | B | 0.00 | 0.00 | 0.00 | 0.22 |
| | C | 0.00 | 0.00 | 0.00 | 0.25 |
| | D | 0.00 | 0.00 | 0.00 | 0.00 |

| | | | | | |
|---|---|---|---|---|---|
| Missing | A | 0.00 | 0.00 | 0.00 | 0.15 |
| | B | 0.00 | 0.00 | 0.00 | 0.01 |
| | C | 0.00 | 0.00 | 0.00 | 0.16 |
| | D | 0.00 | 0.00 | 0.00 | 0.00 |
| War loss / Hostility | A | 0.00 | 0.00 | 0.00 | 0.25 |
| | B | 0.00 | 0.00 | 0.00 | 0.62 |
| | C | 0.00 | 0.00 | 0.00 | 0.88 |
| | D | 0.00 | 0.00 | 0.00 | 1.03 |
| Wrecked / Stranded | A | 0.00 | 1.79 | 1.58 | 2.81 |
| | B | 10.59 | 2.51 | 3.47 | 7.38 |
| | C | 10.59 | 4.30 | 5.05 | 10.19 |
| | D | 0.00 | 0.00 | 0.00 | 1.20 |
| Total | A | 0.00 | 4.30 | 3.79 | 8.98 |
| | B | 13.24 | 17.20 | 16.73 | 27.71 |
| | C | 13.24 | 21.50 | 20.52 | 36.69 |
| | D | 0.00 | 2.87 | 2.53 | 22.76 |

A = number of reported total losses ) Per 1000 Ship
B = number of reported serious casualties ) Years
C = total of A plus B ) (rounded to
D = number of people killed or missing ) two decimal places)

Sources : Safety Review of Ships for Liquefied Gases and Features Legislative Needs by D.S Aldwinckle and D.S Mc Lean- Lloyd's Register of Shipping London- page 121. (Gas tech. 84, LNG/LPG . Conference Amsterdam November 6-9, 1984).

Ship: El Paso Paul Kayser
Date: 29 June 1979
Category: Grounding
Type: LNG
Capacity: 125,000 m3

The grounding hapenned in Gibraltar. The ship, fitted with a Gaz Transport membrane tank system, was severely damaged as reported after the survey in drydock.

The bottom plating on the starboard side was ripped open and set up a maximum of about 2.5 m from the bow thruster room aft to the aftermost cargo tank. The greatest damage appeared to be in way of cargo tanks Nos. 2 and 3. On the port side, damage was confined primarily to the double bottom in way of cargo Tanks Nos. 2 and 3, the bottom plating being ripped open and set up about 1.5 m.

The damage on the starboard side extended to a portion of the inner bottom plating forward, where the plating and the containment system components above were set up, it was alleged, about 15 cm. The containment system, including both the primary and secondary barriers, remained liquid tight despite the deformation to which it was exposed.

Ship: LNG Taurus
Date: 12 Decembre 1980
Category: Grounding
Type: LNG
Capacity: 125,000 m3

The grounding of LNG Taurus happened at Mutsure Anchorage in Japan. The damage is likely similar to the damage that occured to El Paso Paul Kayser but on LNG Taurus the damage extended over much of the cargo area of the ship. In this case the author does not give more information.

Ship: El Paso Columbia
Date: 16 December 1981
Category: Grounding
Type: LNG
Capacity: 125,000 m3

The grounding of El Paso Columbia happened on the Coast of Nova Scotia near Cape Sable Island. The ship was being moved, in an incomplete state, from Boston to Halifax for lay-up.

The damage as stated by the author was worse than the damage in the preceding cases.

The damage caused flooding of the engine room and, apparently, one cargo hold. The cargo tank in the hold is stated to have floated, releasing the deck plating and pushing it upwards.

**LNG Spill:**

Ship: Methane Princess
Date: Early 1965
Category: Liquid Spill
Type: LNG
Capacity: 27,400 m3

The site of casualty was not stated by the author. The damage consisted of the fracture of deck plating which occured on Methane Princess after discharging on an earlier voyage. The discharging arms were disconnected before the liquid lines had been completely drained, and a sliver of PTFE lodged next to the wedge of a shipside gate valve, causing LNG to pass through the imperfectly closed valve and into a stainless steel drip pan underneath. The sliver of PTFE had been sheared from the face of the wedge by prior valve openings and closings.

Ship: Jules Verne
Date: May 1965
Category: Liquid spill
Type: LNG
Capacity: 25,500 m3

The casualty hapened during loading in Arzew, Algeria. It was caused by overfilling Cargo Tank No.1, which resulted in the fracture of tank cover plating and the adjacent deck plating.

Ship: Mostefa Ben Boulaid
Date: 8 April 1979
Category: Liquid spill
Type: LNG/LPG
Capacity: 125,000 m3

During a discharge of Mostefa Ben Boulaid at Cove Point Maryland, an LNG spill occured, resulting in the fracture of a certain amount of deck plating.

The spill was caused by the escape of LNG from a swing-check valve in the liquid line. In this valve, the hinge pin is retained by a hex head bolt which penetrates the wall of the valve body. In the course of operating the ship and/or cargo pumping system, it appears that vibra-tion caused the bolt to back out, releasing a shower of LNG to the deck. The vessel was taken out of service after the incident and the structural work renewed.

Ship: Pollenger

Date: 25 April 1979

Category: Liquid Spill

Type: LNG

Capacity: 87,600 m3

The damage hapened during the discharging of LNG at the Distrigas terminal at Everett, Massachussets. The LNG leaked from a valve gland and apparently fractured the tank cover plating at Cargo Tank No. 1. The quantity of LNG that spilled was probably, as stated by the author, only a few liters. The fractures in the cover plating covered an area of about two square metres.

**Lightning Strike:**

Ship: Methane Progress

Date: 25 december 1964

Category: Lightning Strike

Type: LNG

Capacity: 27,400 m3

During loading at Arzew, lightning struck the forward vent riser of Methane Progress and ignited vapour venting routinely from the ship's vent system. Loading had been terminated when a thunderstorm broke upon the terminal area, but vapour generated by the loading process was being released to the atmosphere through the ship's venting system, the shore return piping not yet being in operation. The fire was extinguished in a short time by the use of the nitrogen purging connection to the riser.

Ship: Jules Verne

Date: Undetermined

Category: Lightning Strike
Type: LNG
Capacity: 25,500 m3

As in previous case, a lightning strike occured on board Jules Verne, and the ensuing vapour fire was extingui-shed using the nitrogen purge connection.

In the same manner, a lightning strike happened to LNG ship "LNG Aquarius" while discharging LNG at Tobata, Japan. This ship experienced a simultaneous lightning strike on two vent masts and the fire was extinguished in a short time.

**4.3.2.3 Damage cause analyses:**

These various casualty statistics were presented in this Section with minimum interpretation by the authors in the stastics tables together with short written reports. In further developing an explanation concerning the causes of such marine casualties, I found it particulary helpful to consider the study case by case.

**(i)-Analysis of Table 1.4:**

In this table it is shown that the total of eleven ser-ious accidents over eighteen years, as per Poten & Partners Inc., does not tell us a lot about critical elements to decide which factors to pay attention to and which to ignore. Furthermore, we can accept what is causal may well be dependant on the possibilities of these LNG ships have always set high standards of safety and there is no evidence from the data given in Table 1.4 that standards of safety are declining.

**(ii)-Analysis of Table 1.5:**

In this table the causes of casualties are presented as follows:

-Collision (between mooring vessels)
-Contact with a stationnary object
-Fires and explosion
-Wrecked/stranded
-War loss/hostility
-Hull/machinery damage
-Foundered
-Missing
-Miscelleanous.

As in any classification system of casualties, there are problems with this categorisation. One difficulty is that a casualty may fall into more than one category ( for instance, a fire in the steering gear room causing the gear to fail, which in turn causes a collision or grounding in shallow water).

For the purpose of analysing the causes of damage in this, table it may be essential to make a connection between one type of casualty and another figuring in the same table.

The casualty frequency of LNG ships regarding the various types of casualties contained in Table 1.6 will clearly differ from that of LPG and dry cargo ships but it can be clearly seen that only in the latter two areas are there comparable numbers.

Let us consider the numbers of reported serious casualties and total losses in LNG, LPG and dry cargo ships. It is shown that:

a)- In hull/machinery damage:

| LNG | Dry cargo | LPG |
|---|---|---|
| 2.65 | 8.36 | 9.32 |

b)- In wrecked/stranded:

| LPG | Dry cargo | LNG |
|---|---|---|
| 4.30 | 10.19 | 10.59 |

The high number for LNG in (b), may not be accurate and I feel that it should have been examined at the time of writing this statistics table ( November 84 ).

Let us consider the two areas presented in the above stastics and analyse them.

Generally, hull/machinery damage tends to be a consequence of a distinct chains of events such as collision, contact with a stationary object, stranding or ground-ing, fire/explosion etc...

The causes are difficult to discuss in detail. Nevertheless, the particular casualty of stranding, which is mentionned above in Table 1.6, will serve as an example of investigating the cause of damage.

The first idea brought to mind, is why stranding or grounding happens ?.

Stranding or grounding tends to occur near the coast an near approach to the land. Therefore, in general, a warning of shallow water should have been obtained from the echo sounder, is the primary navigational equipment. Therefore, the cause of stranding or grounding is due the non-use of the echo sounder by navigators.

Some groundings on approach to land might be attributable to fatigue or stress of the officer as a consequence of experiences during the voyage.

Frequently, they may be attributed to some errors in position fixing, in the equipment or in identifying buoys.

As a consequence of this brief analysis, there is no doubt that the human element in stranding or grounding may be greatly involved. And hull/machinery damage may come as the consequence of the grounding and the stranding.

**(iii)- Analyse in the reports:**

The causes of damage are not adequately stated or even omited by the author in the reports cited above. Therefore, the desirable way to study the causes of damage is to conduct an identification of the actors involved in casualties such as grounding, LNG spills and lightning strike.

**Grounding:**

These points were discussed briefely in analysing the Table 1.5 relative to grounding and the position was taken that to the human element is a cause for such casualties.

This conclusion was suported earlier by the source quoted by Reen Admiral W.M Benkert U.S.C.G in his manual "Reasons for Collision and Groundings" (Oil Companies International Marine Forum. 17th - 18th January 1978), and where he stated the following: << Aproximately 85 % of all marine casualties have been the result of the human factor >>.

Looking now at some specific details relative to groundings in the reports, it seems, at the first approa-ch, that deficiencies might exixt in the standard of na-vigational equipment provided on board but in the great majority of cases in this category of accidents, the cause remains humans on board.

The man in charge of marine operations on board the ship has all means and facilities to accomplish a safe navigation. He has modern aids to navigation of all types such as:

- Radar
- Decca
- Gyro-compass
- Log speed system
- Omega
- A-C Loran
- Satellite System ( Transit )
- Doppler Sonar
- Echo sounder
- Conventionnal marine radio- equipment.

He has the responsability of collecting a large amount of data such as restrictions or limitations on navigation in certains areas with high density of traffic and making a choice of the route according to the weather.

The vessel is fitted with efficient handling and with maneuvrability capabilities.

So far as equipment and design are concerned, to be identified as contributing causes of damage, it stated that their requirements are satisfied and a very high safety record is achieved. if the human on board have observed the general state of the vessel by making vigilant checks /controls of the vessel's performances by, keeping equipment in good working and condition through maintenance and repairs.

Because, regarding at this last point, it may be, that the reader has accepted that the causes of damage may come from the failure of a vital equipment causing the grounding. Therefore, part of the answer is that, the equipment is always under the control and maintenance of the human on board.

In addition, the causes of grounding are attributable to human error under the following two major sources:

- failure to navigate safely despite properly trained and competent personnel and an adequately equipped ship.
- Insufficient knowledge or inability to use available equipment correctly to navigate the ship safely.

**LNG Spills:**

LNG spills accidents and damage have been discussed in the reports in so far as they are due to normal events considered as known and expected to occur over the ship's life time, or to abnormal events if they are beyond the control of humans (builder or operator).

An LNG spills is the most likely event leading to, under small LNG streams, potentially cracking of the weather deck or other exposed plating. They have occured mostly at load stations in the vicinity of vent masts, and manifold shore connections.

They also happen during loading / unloading while the hu-man on board is operating. The LNG spill might be human on board is operating. The LNG spill might be the result of overfilling, of disconnecting the loading arms before draining the LNG line of deficiencies in thigteness of the shore connection.

Although the report, presented here are not explicit on this case of damage, it must be assumed that in general the causes might be attributable to the human element.

Rare is the external factor such as a heavy swell during bad weather or a natural catastroph causing to the ship a rupture and disconnection of loading arms. In other parts experiment and experience have verified that this case in the general dynamics of ship are insensitive to such external factors.

The occurence of LNG spill damage is shown in the reports to be minimised by a short duration of contact between LNG and exposed steel when the human on board is trained for emergency cases, and he responses immediately.

It should be noted that recorded incidents of LNG spill damage to ships have not been accompanied by a serious threat to ship safety, but have only led to periods of ship lay-up during repairs.

**Lightning Strike:**

Lightning strikes have generally occured on venting masts. In this case the spill is limited only to vapour escaping from the mast and the extent and duration of the resulting fire is function of the maximum credible spill.

The causes are attributable to external factors as a thunderstorm. The ability and fast response of the operator on board may extinguish the fire very fast by using nitrogen.

**4.3.2.4 Conclusion:**

It has been shown that the safety record of LNG ship is of high standard compared with other ships. There is no high number of casualties. The statistics tables and reports have indicated there are possible safety deficiencies. Nevertheless they are not all serious, and if they are, generally the extent of damage wherever observed was limited by the immediate response of a human on board or by the high level of confidence in the levels of safety provided earlier by existing requirements such as the design and construction codes or other IMO recomendations.

For the purpose of comparison, the crude oil carriers of present day design may have more severe damage consequences after grounding than LNG ships.

Finally, we must conclude that up to now designers, industry and legislators have solved technical safety of LNG carriers. However, an exception exists regarding the human element which plays an important role in maintaining the whole safety level onboard LNG ships.

The human on board should be selected and trained to comply with national and international requirements, to be familiar with the cargo handling operations, and to conduct the vessel in a safe way. Because the requirements for classroom training as requested are not and never have been, designed to substitute for long experience on board operational training is a must on gas carriers before the personnel should be given responsible positions.

# CHAPTER FIVE

## THE SAFETY OF LNG CARRIERS WITH PARTICULAR REFERENCE TO THE ALGERIAN FLEET

### 5.1 General:

In Algeria the most important trade goes by sea. Among the objectives assigned by the national charter to the seatrade is " to fit the country with a maritime fleet which constitutes a logistic support necessary for the expansion and independance of the international trade".

Therefore the Algerian governmemt developed over a period of time:

- the maritime fleet,
- the construction of new ports, and
- the training of humans.

The companies of maritime navigation were born as CNAN (Compagnie Nationale Algerienne de Navigation) and SNTM -Hyproc (Societe Nationale des Transports Maritime des hydro-carbures et produits chimiques).

Joint venture companies are associated with the Algerian fleet such as AMPTC, COMAUNAM, CALTRAM, COBENAM.

In 1972, Algeria started with one LNG ship - Hassi R'mel, LNG carrier of 40,000 m3 - to export gas from Skikda (east coast of Algeria) to Fos (South coast of France) in the first phase of the first contract with "Gaz de France".

Four other LNG carriers named Ben Boulaid, Larbi Ben M'hidi, Abane Ramdane, and Bachir Chihani were received and ready to ship the LNG but they were delayed due to the extension of negociations of Sonatrach with its partners.

Algeria is the main supplier of natural gas to France, and also exports it to Belgium, the US, and Spain.

The LNG fleet is spreading with contracts in its respective scheduled lines. However during the period of 1983 to 1988 the Algerian LNG ships were not in operation. They were lying idle in Algerian ports for lack of employment. This was due to the consequence of the conflict with the USA raised from gas price wich was tied to crude oil price by algerian government.

The above reason lead to ceasing the services of some LNG carriers in their lines. Therefore, the long standing of these ships in the ports brought shortages and difficulties in the maintenance. This was due to the reduction of personnel on board and also to the creation of indesirable costs for the maintenance itself.

### 5.1.1 LNG carriers in the fleet:

Algeria had always aspired to build up a shipping fleet as shown below in the Table 1.6.

Table 1.6 - Algerian fleet

| Ships types | Nber of ships | 1000 DWT | 1000 grr/gt | 1000 ntr |
|---|---|---|---|---|

| | | | | |
|---|---|---|---|---|
| Oil Tankers | 17 | 191.3 | | |
| Chemical carriers | 01 | 3.0 | | |
| Liquid gas carriers | 08 | 403.4 | | |
| Bulk and ore carriers | 05 | 126.0 | | |
| General cargo ships: | | | | |
| Single deck | 10 | 99.0 | | |
| Multi deck | 30 | 197.1 | | |
| Ferries | 06 | 14.8 | | |
| Total | 75 | 946.4 | 825.5 | 493.3 |
| World fleet | 33130 | 615332.5 | 376663.1 | 234044.0 |
| % share of total | | 0.2 | | |
| Rank out of 152 | | 54 | | |

Source ISL Merchant fleet data bases - February 1989.

Algerian LNG production, which represents 25 % of the world's LNG was not expected to be on full stream until 1977. Since that year Algeria has constructed five new LNG carriers as shown in table 1.7 - each having approximatively a total capacity of 125,000 m3 . Those new LNG carriers were built by French shipbuilders.

These ships owned by SNTM Hyproc, are built and operated to the highest degrees of safety and reliability. This fleet regulary services the Algerian- USA/ France/ Belgium/ Spain LNG routes for the full 20-year life of the normal contract. They are fitted with advanced safety equipment and modern, integrated control systems for cargo and propulsion machinery. They are propelled by steam turbines designed to provide flexible and economic operation, using "boil-off" gas from their LNG cargos as a primary fuel. These ships also have tanks of the membrane design type, each equipped with five giant LNG tanks which give the vessel its distinctive outline.

Table 1.7 - Report of algerian gas fleet.

| Name of ship | Capacity of tanks(m3) | Tank design | Year | Builder |
|---|---|---|---|---|
| Hassi R'mel | 40,109 | G.T | 1971 | CNIM |
| Larbi Ben M'hidi | 129,500 | G.T | 1977 | CNIM |
| Bachir Chihani | 129,500 | G.T | 1979 | CNIM |
| Mostefa Ben Boulaid | 125,260 | T.M | 1979 | CIOTAT |
| Mourad Didouche | 126,000 | G.T | 1980 | Atlan-tique |
| Ramdane Abane | 126,000 | G.T | 1981 | Atlan-tique. |

G.T = Gaz Transport membrane type
T.M = Technigaz membrane type.
Source: Research by JAMIR.

**5.1.2 Ports:**

Delimited in the north by the Mediteranean Sea with a length of 1200 km, Algeria has good climatic conditions. This situation promotes the littoral which is navigable by sea at any seasons (see annexe 1.1.4)

The Algerian littoral has a specific reputation for a good nautical safety ( depth, shelter, easy access ).The choice of ports would constantly make reference to the safety aspects of shore terminals in the interests of the lives of personnel on board, onshore in the area, and also the need for some form of traffic control to minimise the risk of collisions in the approach to the terminal.

For the purpose of LNG projects, Algeria has constructed two great ports for exporting this gas, namely:

- port of Arzew and
- port of Skikda.

The gas terminal in the port of Arzew is called Bethioua, which is a liqified gas terminal East of Arzew. It was almost completed when extensively damaged during a storm in 1980. Vessels await a pilot anchor between 1 and 1.5 n. miles North of the breakwater. Two pilots are compulsory during the entry and one for the departure. The towage is compulsory and six tugs are required on entry and four on departure. THe maximum draft is 26.4 meters. There are four LNG berths called M1, M2, M3, and M4; their maximum lentgh is 480 meters , their depth is 13,5 meters; and finally their maximum tonnage is 125,000 cubic meters.

The gas terminal in the port of Skikda is situated 400 km east of Algiers, the port formed by a breakwater 1,615m in lentgh with an entrance 100m wide. The depth in the entrance channel is 15.0m. The pilotage is compulsory and there is one tug available. A pier provides two berths for loading LNG with maximum draft of 14.0 meters.

## 5.2 Background:

The purpose of this paper is to identify the actual programme of safety applied with regard to liquefied gas carriers in Algeria.

Generally this category of ships falls as a matter of routine into the group of other ships in the whole Algerian fleet such as tankers other than for liquefied gas carriers, cargo ships other than tankers and passenger vessels.

The Algerian Maritime Safety Administration, under the auspices of the Ministry of Transport, is responsible for the ownership, registration, management, operation, maritime training, maritime industries ( design, construction, alterations, rapairs ) of merchant vessels under the CMA ( Code Maritime Algerien ).

Integrated in one complex structure which is the Maritime Safety Administration, the whole programme of safety, relative to the LNG ships, is developed in the flow of international and national legislation and enhanced by the national laws issued for this purpose.

A large part is therefore devoted to the Maritime Safety Administration and its relations with other international maritime affairs, which are both necessary for understanding the issue of safety in Algerian LNG carriers.

## 5.3 Existing system of Maritime Safety Administration:

### 5.3.1 Algerian system of government:

Algeria, which is a socialist country, had the constitution of 1975 revised in 1985 based on the principle of division of power between the executive power, the legislative power and the judicial power.

Since 1962, the year of independence, maritime affairs have been in the hands of Ministry of Transport, which shares related functions with several ministries as shown in Table 1.8.

Table 1.8- Ministries concerned with maritime affairs.

| Ministries | degree of work | functions |
|---|---|---|
| Finance | full | taxation matters |
| Justice | full | Commercial law aspects of maritime legislation. |
| Labour of local gvt. | partly | Safety matter |
| Environment | partly | Oil pollution |
| Defence (Coast Guard) | Full | Safety inspection |
| Foreign affairs (Consulates). | Partly | Delegation of maritime affairs in broad. |

### 5.3.2 The Algerian maritime law:

The most important act on which martime affairs are based is the CMA. It was adopted in October 1975 and consists of 887 articles written in two books divided into parts, chapters and paragraphs.

### 5.3.3 The algerian maritime admnistrations:

Maritime affairs mainly come under the Merchant Marine Directorate and the Port Directorate which are under the responsability of Ministery of Transport.

Making constant reference to safety regarding LNG carriers, I will deal only with this matter taking in account that the subject of maritime affairs in Algeria is very large.

### 5.3.4 The Merchant Shipping Directorate:

The principal objectives of the Merchant Shipping Directorate are to:

- ensure the safety of navigation,
- deal with contingency plan to combat marine pollution.
- regulate the organisations of the maritime administration.
- adopt the minimum standards as regards safety at sea within the framework of the national maritime legislation.

To avoid work overload, the directorate is divided into two sub-directorates which are as follows:

- The Sub-Directorate of Maritime Transport.
- The Sub-Directorate of Maritime Navigation.

#### 5.3.4.1 The Sub-Directorate of Maritime Transport:

Briefly this Sub-Directorate has a role to play connected to office activities:

- the trade and fleet office,
- the economics analysis office,
- the development and international relations office.

Their respective main activities are as follows:

- considering and proposing developments relating to maritime transport regulations and other activities dealing with shipping,
- studying and proposing projects to set up and to put into operation programmes of modernisation, maintenance, equipment and development of the national merchant fleet,
- participating in the evolution of international conventions and agreements as far as maritime transport is concerned.

**5.3.4.2 The Sub-Directorate of Maritime Navigation:**

It is in charge inter-alia of:

- preparing regulations dealing with the national maritime legislation and the managing of the competing applications of the national legislation and regulations, which are in force;
- proposing all measures relating to the safety of maritime navigation and defining standards of safety of ships and rules for ships routing;
- Setting up and putting into operation contingency plans in response to eventual marine pollution; organising and co-ordinating interventions at sea in connection with concerned organisations.
- defining conditions for access to the maritime profession.

The Maritime Navigation Sub-Directorate is divided into three offices as follows:

- the Maritime Navigation Office,
- the Maritime Safety office,and
- the Seamen office.

**-The Maritime Navigation Office**

It is in charge of preparing or proposing of:

- rule of ship routings ( controling maritime navigation and the quality of navigation);
- rules of ship status proceeding with the required inspections;
- regulation for the management of the sea-board status and plans/ programms for the development of the maritime navigation sector;
- contributions to the preparation and negotiation of international conventions and agreements regarding maritime navigation;

**-The Maritime Safety Office:**

It is in charge inter-alia of

- preparing standards of the safety of ships and the safety of maritime labour;
- preparing, proposing and co-ordinating the setting up of all kinds of measures to ensure the safety of maritime navigation;
- preparing rules and standards of safety of life at sea and controlling their applications;

**-The Seamen's Office:**

It is in charge inter-alia of:

- defining criteria affecting the manning of ships;
- preparing and proposing the professional status of seamen;
- contributing to the preparation of training programmes for sea-going personnel.
- preparing and proposing all measures to ensure the welfare of marine personnel within the framework of the national regulations and rules which are in force.

**5.3.5 The Port Directorate:**

The Port Directorate is responsible for preparing projects and orientations to fulfill the objectives of the national policy as regards ports activities. It is in charge of co-ordinating national port activities.

**5.4 Basic principles of Algerian gas fleet operations:**

The LNG ships and other ships of the Algerian merchant fleet were built under the inspection and according to the rules of classification societies and international rules. Construction and drawings were reviewed under the responsibility of the Ministry of Transport- to ascertain compliance with those regulations for LNG carriers. Upon the satisfactory completion of its first delivery to Algeria, each vessel was issued a permanent classification certificate by a recognised classification society and an approval of compliance by the Ministry of Transport. In order to keep those documents in force, it is necessary to undergo periodic inspections and surveys by the representives of the classification societies and the Maritime Administration. The purpose is to ensure that the owner is maintening the vessel- its machinery, cargo equipment, all safety devices, and alarm system- in a safe and satisfactory operating condition.

To make vessels available for such surveys, scheduled dry-docking is normally part of every vessel's shipping schedule. After a discharge of cargo, the vessel goes to sea for gas freeing, and then returns to a ship yard designated in the schedule by the owner.

Depending on its size, the vessel will normally spend a period of time in drydock for hull work (scrapping, painting and plate work). Tail shaft and propeller surveys are conducted at the same time.

The vessel will spend a long time afloat for machinery repairs, cargo tank inspection, safety relief valve checking, plus any other work which requires gas free conditions.

### 5.4.1 Actual model of LNG ship construction:

#### 5.4.1.1 General idea:

Gas carriers have been subjected to special attention from national authorities, shipyards, owners and classification societies.

National authorities have to deal with security problems, because the governments require rules which ensure a minimum resistance of the ship structure and security in case of casualties.

IMO has considered this problem and a set of rules has been written in IBC. These rules have been based on the experience and studies of classification societies .

New sophisticated methods have been used, and are accepted by shipyards and owners in spite of their complexity and cost, because a gas carrier is an intricate and expensive ship. Both security and cost lead to more precise methods of calculation and building. Direct calculation methods using large computer facilities are used.

This section covers the whole purpose and functions of safety on Algerian LNG carriers and the way in which it is carried out in terms of the duties of shipowners, in the contruction within the shipyard, inspections and surveys by the national authorities or classification societies, and the role of IMO rules and other provisions of International organisations.

**5.4.1.2 Shipowner:**

A part of the economic need to build the vessel, the owner has to decide that his ship must carry a certain kind of cargo (which is liquefied natural gas) and that the vessel must be able to do a designated speed to respect the engagment of contracts in the project of transportation of gas.

He may require that the vessel will be propelled by a specific type of engine and that the ship does not float too deeply in the water when loaded so that she will be able to enter a certain port when the depth of water is limited.

The shipowner may be so specific in his requirements, that he will issue the ship builders with a lengthy document in the form of a book called "new-building specifications".

On the other hand, there may be investigation of certain details with a view to the use of low and less costly materials, more efficient design and improved methods of construction.

A complete analysis of the potential costs of operating and maintaining a fleet of ships is an extremely demanding task.

The shipowner, who represents the state of Algeria, is in a position to discuss the matter with a naval architect once he has decided on the main service requirements for his new LNG carrier.

The shipowner or state usually employs his own ship design staff and the board of directors will ask its naval architect to submit a preliminary proposal based on certain requirements.

In pratice in Algeria, the task is not done in this way because there is a lack of people with either high technical training or general education in design and construction of LNG carriers. For example, I have seen in the yard a young engineer taking decisions in matters of ship building, and he was not capable of judging design, because he was too fresh for yard work and not qualified.

Taking into consideration this lack of manpower, the owner calls in the services of a firm of consulting naval architects who will do the same job.

The shipowner forwards his plans and specifications to several shibuilders, inviting them to tender for the construction of the vessel with a price and a delivery date. The main shipbuilders for Algerian gas fleet are in France as shown in Table 1.9.

Table 1.9 - List of Algerian LNG carriers with their shipbuilders.

| Ship's name | Shipyard | Volume | Nb of | Type | Propul- |
|---|---|---|---|---|---|

| (registration) | (Y/Delivery) | (m3) | Tank | | sion. |
|---|---|---|---|---|---|
| Bachir Chihani (32Y705) | CNIM La Seyne (1979) | 129,500 | 5 | G.T | B |
| Hassi R'mel (29P913) | CNIM La Seyne (1971) | 40,850 | 6 | G.T | B |
| Larbi Ben Mhidi (32X704) | " | 129,500 | 5 | G.T | B |
| Mostefa Ben Mhidi (30R835) | Chantiers Naval de la Ciotat (1976) | 125,234 | 6 | TGZ Mark 1 | B |
| Mourad Didouche (326873) | Chantier de l'Atlantique (1980) | 126,131 | 5 | GT | B |
| Ramdane Abane (32H874) | " (1981) | 126,131 | 5 | GT | B |

B = Dual fuel boiler.

Note: Mourad Didouche and Ramdane Abane are fitted with partial LNG liquefied plant.

Source: Bureau Veritas ( August 1985).

In addition to everytthing else the designer has to observe the requirements of classification societies authorized by Algeria ( see the chapter relative to authorized classification societies). The regulations to which the ship must conform in matters of safety are most stringent and are governed by international agreement ( Solas 74 ).

**5.4.1.3 Recognized classification societies in Algeria:**

Under the orders of 2 February 1973 and 10 April 1973, Algeria has recognized the following classification societies:

(i)-Bureau Veritas (B.V)

(ii)-Lloyd's Register of Shipping (LRS)

(iii)-Det Norsk Veritas (DnV)

(iv)-Germanisher Lloyd (GL)

(v)-American Bureau of Shipping (A,B,S) and,

(vi)-Nipon Kaiji Kyokai (NKK).

All the above mentionned societies are members of the International Association of Classification societies and the Algerian Administration has delegated to them the duties of:

(i)- assigning load line marks and issuing the corresponding certificates in accordance with the LL Convention.

(ii)- following up constructions and issuing the corresponding safety certificates in accordance with Solas and,

(iii)- ensuring the classification of Algerian ships.

For the purpose of information the Algerian LNG fleet is classified in Bureau Veritas as shown in Table 1.10 below.

Table 1.10- Recognitions and authorizations.

| Certificate | Ref. | Auth. Cert. issue | Type of Cert. | Informations |
|---|---|---|---|---|
| Tonnage | Decree No80.077 | B.V | Oslo 1947<br>London 1969 | |

| | | | |
|---|---|---|---|
| Load Line | Decree dated 10.04.73 | B:V | ILLC 66 |
| Marpol | Telex 152 N of 28.11.83 | B.V for ships CNAN&SNTM | "IOPP Certificate of compliance" (Annexes IandII) |

Bureau Veritas

Ref VTX : S01ML1 Guidance Note NI 190 A - R. 10.08.87

**5.4.1.4 Algerian gas fleet under Bureau Veritas:**

Bureau Veritas has been associated with the development of gas tankers since the beginning of the new technology. The classification by B.V of a gas carrier is not basically different from the classification of other ships. For LNG carriers B.V has the following tasks to carry out:

- set up the concept approval procedure after reviewing detailed drawings and supervising relevant tests or trials on LNG containment and hull design.
- Set up surveys and certificates of approval on major components to be fitted on board gas carriers.

Gas carriers are subjected to various International Maritime Organisation instruments depending on the date on which their buliding contract was placed. Among those, they are to comply with the code for existing ships carrying liquefied gas in bulk, resolution A.328. Besides classification, Bureau Veritas checks compliance with the applicable IMO regulation.

The other possible function of B.V, is to provide technical assistance to either shipyard engineers or ship-owners. Therefore, it is possible to work out computer programms which perform calculations required by rules viz:

(i)- Hull structure temperature calculation,

(ii)- Safety relief valves flow calculation,

(iii)- Filling curves drawing,

(iv)- Different points on calculation and statistical analyses to determine ship behaviour at sea,

(v)- Hydrodynamics efforts,

(vi)- Safety factors on calculation of dynamic stresses associated with fatigue analyses and estimation of lifetime or acceptable stress concentration for a given lifetime of the ship.

**Approval, certification and survey:**

Algeria granted a delegation to B.V which delivered a formal document called attestation or certificate of compliance.

In respect of the aim of classification or certification as defined in the rules of B.V classification society, there is an approval to be issued by B.V at different steps of performance in a building ( e.g: basic approval, design approval and final approval).

In order to maintain the classification, Bureau Veritas carry out sufficient surveys to assure that the ship's degree of compliance with requirements warrants the continued possession of the certificates and that the ship can continue to be operated with safety. The surveys contained in regulations of Bureau Veritas are the following:

(i)- special survey,

(ii)- annual survey,

(iii)- periodic survey other than annual survey,

(iv)- other surveys.

**Special survey:**

The special survey contains , in addition to the surveys of the hull which must be examined at least twice during the whole period of 5 years, one general survey of the hull, engines, fire fighting equipment and other installations.

The conditions of survey must be detailed and strict. Before carrying out the inspection outside and inside of hull and accessories, the ship must be prepared for this purpose. The tanks, holds and the thickness of structural elements might be checked and measured respectively. Special precautions might be taken for the inspection of cargo handling equipment, to eliminate all kinds of danger for the surveyor. All cargo tanks must be examined from inside. The inert gas installation must be surveyed during this special survey as well the engines, electric equipment, automatic installations, and prevention installation of oil pollution.

**Annual survey:**

At each annual visit, the ship must be available to the general survey afloat, which consists of:

- sufficient visual survey of the ship and its equipment and some tests to show their working maintenance.
- visual survey to check that only approved modifications have been made to the ship and its

- equipment.

The annual visit consists therefore of the following items:

- the hull,
- engine and electrical equipment,
- fire-fighting equipment,
- inert gas installations, isolation protection, drying,
- weather deck for different cargo handling installations,
- pumproom and handling cargo room,
- automatic installations, and
- oil pollution prevention installations .

**Periodic survey other than annual survey:**

The survey is carried out outside in the dry-dock to check the state of the hull for corrosions or deterioration or other deformation. The anchors must be examined as well as the rudder , propeller and shafttail. This visit may be done by diving.

**Intermediate visit:**

This visit consists of the following operations:

- to check arrangments for drain release circuit,
- to be sure cargo tanks and cargo line are to earth connection,
- to check in detail that that the electrical equipment in hazardous areas is in good order .
- to make a general inspection and test of ballast tanks,

- to make a general inspection of cargo tanks,
- to conduct a test on leakage detection in the isolation of barriers in the cargo tanks,
- to check cargo lines for detection of gas and if they are corroded, different gas instrumentation analyse are used here, and
- to check inert gas installations.

Bureau Veritas makes other visits such as occasional visits in case of grounding or other damage caused to the ship, in case of alteration in the ship classes, or when the ship is laid up.

**5.4.1.5 Identification of surveying body in Algeria:**

The surveying bodies which are responsible for the implementation of the provisions of the Algerian Maritime Code and the international conventions pertaining to the safety of life at sea, working conditions and welfare of seafarers ( conventions IMO and ILO) are called Committees under article 235 of the Code Maritime Algerien. And they are as follows:

(i)- Central Committee of Safety located at central level and

(ii)- Local Inspection Committee at local level.

The power of those committees is limited to the implementation of safety legislation in the port areas, while the national Coast Guard has the responsibility for enforcement of laws outside the port areas.

Under the Ministry of Transport, the Central Committee of Safety is composed of representatives of the Ministry of Transport, the National Coast Guard

Service, the Ministry of Telecommunications, the Ministry of Health and shipowner.

**Local Inspection Committee:**

Under the head of the Maritime Affairs Bureau , the local inspection committee is composed of representative members of the national Coast Guard Service: nautical surveyors, and engineer surveyor, a radio communications surveyor, and a medical doctor for seamen and shipowner.

**Overview of responsibilities of the two committees:**

The responsibilities of the committees are summarised as follows:

(i)- Rewiew and approve drawings and documents of new buildings .
(ii)- Review and approve reconstruction drawings of existing ships.
(iii)- Reiew and approve life saving appliances and other safety equipment,
(iv)- Carry out initial surveys on ships,
(v)- Examine appeals to the decisions of the local inspection committee.
(vi)- Investigate shipping casualties relating to ships,
(vii)- Carry out different surveys on board ships.

**Coast Guard National Service:**

The CGNS (Coast Guard National Service) was created by ordinance no 73-12 under the authorities of the Ministry of Defence in 1973 and their responsabilities are inter-alia:

(i)- enforce laws relating to maritime naviagtion, immigration and customs,

(ii)- participate in search and rescue operations,

(iii)- contribute to enforcement of laws pertaining to the prevention and combat of oil pollution, and

(iv)- ensure policing of the territorial waters and the protection of the public maritime domain,

**LNG carriers under the survey of MSA:**

The Maritime Safety Administration guarantees the efficiency of the surveys. The severity of the survey should depend upon the conditions of the ship and its equipment. However, the LNG gas fleet has been, as a matter of routine, subject to the mandatory annual survey and additional surveys arising from special events involving the ship.

The mandatory annual survey consist of:

(i)- an examination of the ship's certificate and,

(ii)- a visual examination of sufficient extent together with certain tests of ship's equipment to confirm that its condition is properly maintained.

(iii)- a visual examination to confirm that no unauthorised modifications have been made to the ship and its equipment.

**Surveys on LNG carriers:**

Under aricles 228, 232 and 261 of CMA mentioned that "every ship " is subject to:

(i)- initial survey before the gas carrier is put into service,

(ii)- periodical survey to renew the certificates,

(iii)- additional surveys as occasions arise,

(iv)- unscheduled survey, and

(v)- departure survey at the initiative of the head of Maritime Bureau Affairs, shipowner, master, or crew member.

The above surveys are to be carried out by the Maritime Safety Administration ( article 234 of CMA ) which shall issue the following certificates:

- cargo ship safety certificate,
- cargo ship equipment certificat,
- cargo ship radiotelegraphy certificate,
- other additional certificates in the responsibility of the MSA and proper for the policy of the country.
- tonnage measurement certificate and class certificate.

Other certificates such as International Certificate of Fitness for the Carriage of Liquefied Gases in Bulk (mandatory VII of Solas 74 for gas carrier constructed on or after July 1986)

**Survey procedure:**

The inspector is carries out the required annual inspection on board Algerian LNG carriers. He looks at safety and anti-pollution standards so far as these are operational and not equipment related.

The inspector is empowered to require boat and fire drills and to generally ensure that the ship's officers and crew are competent to deal with any routine or emergency situations that they may be faced with. in the event of serious operational deficiencies being detected, the inspector will normally report to his control office.

In general, the inspectors are comprise a number of mariner officers, who are salaried staff, and they are stationed at certain selected ports.

**Problems faced LNG surveys:**

Among matters which demand constant attention is the problem that the LNG ship inspection function is not as well carried out as it is supposed to be because of:

- the shortage of surveyors, and
- the large volume of work which has to be dealt with by a Marine Directorate.

The problems of shortage of surveyors arises from inadequate recruitment, a shortage of qualification and unacceptable working conditions.

**Recruitment:**

The recruitment of surveyors by the Maritime Safety of Algeria is inadequate. This is due to the fact that the career of the surveyor is less attractive in terms of conditions of employment relating to renumeration, hours of work, employee benefits and general working conditions Applicants may have to accept less pay compared to their previous job on board a ship.

**Qualification:**

Actually, the surveyors are recruited as " ship nautical or engineer surveyor ", the titles commonly used in the Algerian Maritime Safety Administration to indicate the division of work contained in the given survey.

Traditionally, the marine surveyor is nominated on the basis of his background in the maritime fields (respectively engineer or nautical) disregarding the volume of his experience in the field. Nowadays with the high level of technology in the Algerian gas fleet the surveyors are expected to have at least five years of sea-going experience as marine master or marine chief engineer. This is because a surveyor of LNG ships needs at least a good knowledge of ships in practical service accompanied by the ability to grasp the technical significance of any requirement being dealt with.

**Working conditions:**

The surveyor is, as said before, a qualified master or chief engineer who has had practical experience in the day to day managment of a ship. Work on board ship often follows a pattern which does not require too much organisational effort; tradition and customs of the trade form many aspects of life.

Now if we compare this to the office, the work is completely different. There are several small tasks at the same time. The task, for instance, of a surveyor in gathering information may put him in very dificult position. The information needed to do his job may be available only through the recollection by people who have observed past events. The informants are numerous or far away or simply the information has not been or cannot be collected easily.

This example is only one on the list of elements which make the appointment of surveyors difficult as many candidatures refuse the job of surveyor.

## 5.5 Inquiries/investigations into casualties:

**5.5.1 General information:**

In principle, the investigations conducted in Algeria conducted of LNG carriers are the same as those of others ships in the fleet.

The MSA undertakes to conduct an investigation of any casualty under the following regulations:

**At the national level:**

Article 604 of the Code Maritime Algerien states the obligation to report a casualty as follows: " If during a voyage, any casualty happens with serious damage to the ship and/or cargo or injury to the crew on board, the master must within 24 hours on arrival at the first port, establish a sea protest which must be deposited with the competent authority".

In addition, Article 605 stipulates that the master must follow the procedure of verification required by the competent authority receiving the sea protest. The authority receiving the sea protest is:

(i)- the Maritime Bureau Affairs in Algeria,

(ii)- the Consulate representation outside Algeria,

(iii)- where there is no Consulate representative, the master must follow the procedure prescribed by the local law.

**At the international level:**

Solas 74: In accordance with regulation 21 of chapter I of solas 74, each admnistration undertakes to conduct an investigation of any casualty occuring. Conducting an investigation may assist in determining what changes in the present regulations of Solas might be desirable.

Marpol 73/78: Article 12 obliges the administration to conduct investigations into casualties causing major harm to the marine environment.

ILO Convention: Article 29 requires states to hold an official inquiry into any serious marine casualty, particulary those involving injury and/or loss of life.

UNCLOS: In accordance with the new law of the sea convention, article 94(7) it is required that each state shall hold an inquiry into marine casualties involving a ship flying its flag.

**5.5.2 Identification of maritime casualties:**

Maritime casualties are not identified in the Code Maritime Algerien, therefore the appreciation and identification of those casualties are the responsbility of the writer of the sea protest. However, the casualties may be categorised in general as per the following list:

(i)- Violation of: -safety regulation, and
- marine pollution regulations.

(ii)- Accidents such as:
- collision,
- grounding,
- fire or explosion,
- human failure,
- leakage,
- hull/engine damage,
- injury to death.

(iii)- Incidents which could have caused a casualty.

**5.5.3 Accidents and investigations on Algerian gas ships:**

#### 5.5.3.1 Accidents and incidents:

The following accidents were recorded in the Ministery of Transport and the list is not definitive.

Ship: Larbi Ben M'Hidi
Date: 18 June 1981
Category: Collision at anchorage in Arzew (Algeria)
Type: LNG
Capacity: 125,000 m3

While at anchorage in Arzew, a collision happened between LNG Larbi Ben M'Hidi and the Greek ship "Ioannis Commander" , caused by a drift due to a current . The LNG Larbi Ben M'Hidi was stranded by portside (hull). She stayed in good sailing condition and the damage was estimated at 100,000 US dollars.

Ship: Mostefa Ben Boulaid
Date: 8 April 1979
Category: LNG spill
Type: LNG/LPG
Capacity: 125,000 m3.

During a discharge of Mostefa Ben Boulaid at Cove Point, Maryland, an LNG spill occured, resulting in the fracture of a certain amount of deck plating. The spill was caused by the escape of LNG from a swing check valve in the liquid line. The vessel was taken out of service after the incident and the structural work renewed.

Ship: Mostefa Ben Boulaid
Date: July 89 and March 88
Category: Defectuosity in steering gear and regular technic visit not done.

Type: LNG/LPG
Capacity: 125,000 m3.

The first deficiency was only mentioned in the report and the repair was carried out later.

The second defectuosity, which is more administrative was found by port state control in France, and at that time the ship was detained and released after the intervention of the consulate of Algeria.

**5.5.3.2 Investigation procedures:**

The main purpose of investigation as analysed in Algeria is to:

- ascertain the causes of accidents,
- evaluate present international or national regulations,
- propose amendmemts to regulations, and
- consider criminal or other liability on the part of owner, master or crew.

**Algerian statutory requirement in investigation:**

The existing instruments of law in the system of inquiry in Algeria are:

- Articles 604 and 605 in the CMA relative to the obligations of MSA and master of ship in case of accidents,and
- The order promulgated in 1988 relative to the procedure of verification of sea protest and investigation.

Algeria does not yet have a Merchant act in the investigation into maritime casualties.

**The accidents happen:**

Accidents may befall ships or people on board and an reference to accidents brings to mind a question: What kind of accidents are we facing?

Actually the normal practice on board is that the master or the writer of the first sea report shall mention in his report the accident,the causes,the damages and the conclusions, as obliged by law.

**Information to the authority:**

The sea protest is deposited with the appropriate competent authority which is in this case the Maritime Bureau Affairs.

**First stage of inquiry:**

The procedure of verification and investigation is carried out by the surveyor.

Pratically the surveyor is the person appointed by MSA to carry out an inquiry. The surveyor is a sea-going master/chief engineer versed in shore jobs; he deals with the normal tasks of a surveyor such as surveys and different visits on board ships. He is probably not suitable in particular circumstances for the investigation into casualties. In the case of caualty, he may fallback on his own experience to make the best possible assessment of what happened.

**The task of surveyor in the inquiry:**

The first task of the surveyor is to collect and to verify the gathered information regarding the casualty:

(i)- verification of information given by the master to the shipowner concerning any related defect that arose before the casualty.

(ii)- examination and comparison of information contained both in the log book and the sea protest.

(iii)- investigation into the :
- circumstances, causes and damage to the ship.

(iv)- identification and assessment of the responsibility degree of the persons involved in the casualty.

(v)- organisation of the hearing with witnesses and persons involved in the casualty.

This paper is not leading to suggestions for the surveyor, but I will express my own views in this important task. I would say that the reports written by the surveyors are weak, because some investigations in the reports have never been completed due to the incapacity of the surveyor to explore all aspects of the casualty to the ultimate.

**Final report:**

The surveyor submits his report to the competent authority with his conclusions.

**Impact of weak investigation:**

The reports on investigation into LNG carrier casualties shown in this chapter show that there is litle help to understand what has happened. The range of information given obviously reflects the extent of the preliminary investigation done by the apointed surveyor. The statments about casualties in the mentionned reports demonstrate how easy it is to misinterpret official statistics if the study may require it. However, it is probably just as important to notice what data are not in the casualty reports and to ask qestions to get further background information.

## CHAPTER SIX

## GENERAL CONCLUSION

I have discussed, in the background of my paper, the objectives and the general situation of safety on board LNG carriers, namely: construction, training of the crew, the handling of the cargo, and finally the rules monitoring the whole structure of safety.

Now, the planned safety concept for LNG carriers is a reliable solution in the areas of technical design and construction and in the application of International Maritime Organisation regulations, resolutions and codes as well as the rules of classification societies and national regulations.

But, in point of fact, the problem lies in the conversion of this planned safety concept into quantifiable safety objectives and safety criteria.

As a matter of fact, the selected examples of the accidents illustrated in my paper show a failure of safety from which I conclude that the consequences of incidents could be severe in these reports. Therefore those consequences could be a threat to the ship itself, to the life at sea and to the reliability of the working environment.

The risks of such incidents are somehow created by humans through poor operating procedures and poor training.

Now to encourage safety, it is recommended that national regulations should be enacted.

By the way an important recommendation for the safety on LNG carriers is the necessity of training humans in all aspects of new technology.

Because there are no major changes with regard to technical development; I recognize efficiency and reliability in the quality of safety on board LNG carriers which is due to the development of a high degree of technichnology and which will not reach this level without the support of IMO.

APPERNDIX 1.1.1

## Regulation V/3

### Mandatory Minimum Requirements for the Training and Qualifications of Masters, Officers and Ratings of Liquefied Gas Tankers

1. Officers and ratings who are to have specific duties, and responsabilities related to those duties, in connexion with cargo and cargo equipment on liquefied gas tankers and who have not served on board a liquefied gas tanker as part of the regular complement, before carrying out such duties shall have completed an appropriate shore-based fire-fighting course; and

(a) an appropriate period of supervised shipboard service in order to acquire adequate knowledge of safe opertional practises; or

(b) an approved liquefied gas tanker familiarization course which includes basic safety and pollution prevention precautions and procedures, layouts of different types of cargo, their hazards and their handling equipment, general operational sequence and liquefied gas tanker terminology.

2. Masters, chief engineer officers, chief mates, second engineer officers and, if other than the foregoing, any person with the immediate responsibility for loading, discharging and care in transit or handling of cargo, in addition to the provisions of paragraph 1, shall have:

(a) relevant experience appropriate to their duties on liquefied gas tankers; and

(b) completed a specialized training program appropiate to their duties including liquefied gas tanker safety, fire safety measures and systems, pollution prevention and control, operational practice and obligations under applicable laws and regulations.

3. Within two years after the entry into force of the Convention for a Party, a seafarer may be considered to have met the requirements of paragraph 2(b) if he has served in a relevant capacity on board liquefied gas tankers for a period of not less than one year within the preceding five years.

## APPENDIX 1.1.2

**Trainning of the first mate (responsible for the cargo)**

| Professional situation object | Field | Means |
| --- | --- | --- |
| (i)-Having a good perception of the behaviour of the gas transported in different phases and being capable of foreseeing this behaviour and its consequences on the installation<br>Duration:3 weeks | Chemistry: being capable of using the operation handbook | Chemical laboratory |
| | Physics and thermodynamics: acquiring a good perception of the and thermodynamical behaviour of gases | Laboratory of gas physics |
| | safety:adoptingof positive behaviour in relation to the dangers presented by gases | case studies |
| | Construction regulations. Understanding the why and the wherefore of gas carriers and the regulations applying to these ships. | Ship model |

| | | |
|---|---|---|
| (ii)-Being capable of reconstituting the typical diagrams of cargo installations and of figuring out correct locations from piping diagrams and drawings | The means necessary for loading and unloading<br>- gas and liquid lines<br>- cross overs<br>- valves<br>- pumps<br>- ballast tanks | Reconstitution of circuits from representative cases<br><br>Comparison with actual installation diagrams |
| Duration: 2 weeks | Seatransportation loaded ship<br>- boilers gas-firing<br>- reliquefaction<br>- Gas-freeing mast<br>- Safety valves<br>Keeping in cold state light ship<br>- Spray nozzles<br>-Recovery pumps<br>-Gas freeing/filling with air<br>- Nitrogen circuit pumps<br>- Inert gas generator<br>- Air line. | Application to models and and marking on actual circuits |
| (iii)-Being capable of shaping the circuits in view of the main operations<br>- filling with gas | - cargo installation<br>- control room | - True diagrams and model<br>- Control room simulator |

| | | |
|---|---|---|
| - Keeping in cold state, light ship<br>- vaporizing of unpumpable liquids<br>- heating of the tanks<br>- inerting of the tanks<br>- inerting<br>- filling with air<br>- cargo changing<br>- simultaneous transportation of 2 different cargoes<br>duration : 2 weeks | | - training period on board ship for a short voyage |
| (iv) being capable:<br>-of starting up the installations<br>-of operating them<br>-of acting in appropriate manner when facing potential incidents at sea and under various conditions related to land-ship situation.<br>Duration : 3 weeks | Cargo operations and any related incidents | Training unit/examination of the different cases |
| (v) Knowing how to use the measuring apparatus of the cargo installations<br>-reading<br>-setting<br>-current maintenance<br>-current emergency | Gas detectors/oxygen detectors/gauges<br>Level indicators<br>Temperature recorders<br>Pressure recorder<br>Ammeter<br>Any apparatus used | Laboratory and training rooms<br>Training organized by manufactu- |

| | | |
|---|---|---|
| repairs<br>Duration : 2 weeks | by the first mate | rers |
| (vi) Being capable of finding out the reasons of a technical break-down :<br>- with the automatic units<br>- with the regulating circuits which allow the correct utilization of this apparatus, making it possible to know what can be expected from them.<br>Duration : 1 week. | Automatic units<br>Pneunatics devices<br>Electropneumatic units<br>Control lines | Training unit<br>Training rooms |
| (vii) Being capable of keeping in good order and repairing the cargo installations<br>Diagnosis<br>Interpretation of anomalies<br>Examination of possible repair or substitution<br><br>Determination of repairing conditions<br>Duration : 3 weeks | Cargo pumps/ blowers,reli-quefaction unit<br>Vaporizer and heaters<br><br>Pipes and flanges<br>Safety valves/ nitrogen tank<br>Expansion compensators<br>Droplet separator | Training unit<br>Inert machi-nery room<br>Plans of equipment |
| (viii) Knowing how to | Useful calorific | Statement/ |

| | | |
|---|---|---|
| calculate the cargo weight and the losses during transportation<br>Knowing and applying port authorities regulations and other current regulations<br>Duration : 1 week | Energy due to evaporations/ losses due to evaporation excess (released) to the atmosphere delivered to the condenser). | Discussions Exercises a few examples |
| (iX) Being capable of preparing, organizing and controlling dry dockings | Cargo installation automatic devices, safety installations | Training period during dry dockings. |
| (X) Showing initiative in case of danger resulting from a cargo incident<br>Knowing how to apply the safety or pevention means available.<br>Being capable of directing a group intervention<br>Organizing and preparing on board safety exercices.<br>Duration : 2 weeks. | Any safety and prevention means | Specialized training |

Duration of training periods retained.

First mate ................5 months
Engineer officer...........6 months
Gasman.....................4 months
The whole crew.............2 weeks

## APPENDIX 1.1.3

a- Flammability:

- Controlled combustion (flame or flare)
- Explosion - violent ignition
- Detonation- restricted ignition causing extremely powerful explosion-
- Blow- back, caused by low velocity vapour flow after ignition-

b- Toxicity and other health hazards:

They may be temporary or permanent health hazard

- Tissue damage.
- Irritation.
- Impairment of faculties.

Toxic effects by:

- Tissue contact
- Inhalation
- Inspection
- Absorption.

c- Pressure:

- Pressure surge
- Locked in pressure.
- Differential pressure + membrane systems
  + heat exchangers
- Relief valve malfunction.
- Vaccuum causing damage to tanks and equipment.
- Sampling
- Pressure testing
- Sloshing.

d- High temperature:

- Ignition in its various forms.
- Exothermic reactions.

e- Low temperature:

- Physical contact.
- Brittle fracture from spillage.
- Venting- vapour buoyancy affected.
- Ice and hydrate formation.

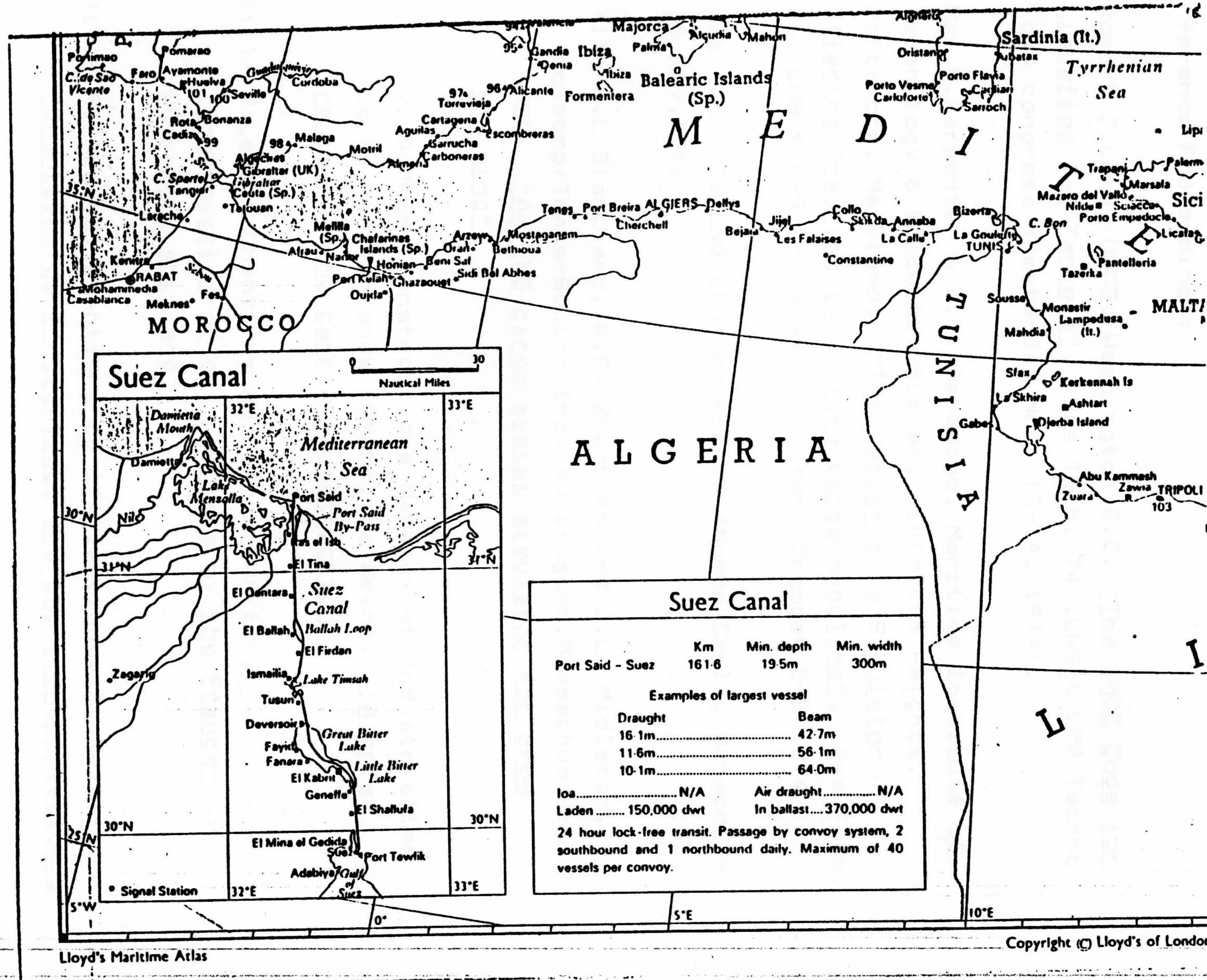
f- Reactivity and chemical stability:

- Interaction - cargo/ cargo/ other matter.
- Peroxide and polymer formation.
- Pyrophoric components.

g- Static electricity:

- Steaming operations.
- $CO_2$
- Lightning.

Map of coast of Algeria.




APPENDIX 1.1.4

## REFERENCES

**Conference Proceedings:**


- Robert J.Lakey USCG. Washington D.C. "The IMCO Code for Liquefied Gas Tankers". Gas Tech. 74 .LNG & LPG Technology congress (Amsterdam Nov. 13-14, 1974).

- Max H.Carpenter & L.P. Aanestad, Maritime Institute of Technology & Graduate Studies, Linthicum Heights, Baltimore, Maryland. "The Design of a Simulator Offering Training in LNG/LPG Cargo Handling". Gas Tech. 76. LNG & LPG Comferences (N.York October 5-8 1976).

- Gas Tech. 78 LNG/LPG Conference (Monte Carlo, Monaco 7-10 Nov.78):

  (i)- R.L Blanchard, A.E. Sherburn and J.L. Midleton, Foxboro/Trans-Sonics Inc.,Burlington,Massachussetts, USA. "An LNG cargo system simulator for crew training".

  (ii)- V. Andren, Constructions Navales et Industrielles de la Mediterranee (CNIM), La Seyne. "A brief review of LNG carrier construction".

  (iii)- J.Lefol, Chantiers de France-Dunkirk. "Construction of gas carriers by the France-Dunkergue shipyard".

  (iv)- R. Regard, chantiers de l'Atlantique, St Nazaire. "Chantiers de l'Atlantique and LNG transportation".

  (v)- E.A.Destremps, European Regional distrubution, EssoChem Belgium, Brussels, Belgium. "A gas shipping safety program".

(vi)- S.E Handman, Pullman Kellog Division of Pullman Inc.,Houston, Texas, USA. "LNG safety: facts and fiction".

(vii)- E.T. Hillberg, Fairchild Stratos Division, Manhattan Beach, California, USA. "Evaluation on LNG Terminals".

- Gas Tech.79. LNG/LPG Conference (Houston, Texas 13-16 Nov.,1979):

(i)- Dr.R.Glasfeld, General Dynamics Corp.,Quincy,Mass. "Some aspects of LNG safety and reliability".

(ii)- F.S. Harris, F.S.Harris (Oban)Ltd.,Scotland. "The pratical application of the IMCO Gas Carrier Code for Existing Ships".

(iii)- Dr.D.H. Slater, R.A.Cox, P.J. Cower and M.Pyman, Cremer & Warner, London. "Safety issues in the siting of modern LNG terminals".

(iv)- H.H. West, D.B. Pfenning and L.E.Brown, Energy Analysts, Norman, Oklahoma. "A systems approach to LNG fire safety".

(v)- Dr. G.B.Kaiser, UK Atomic Energy Commission,Safety and Reliability Directorate, Culcheth, Warrington,UK. "The modelling of large scale accidental releases of dense cold vapours and some exemples".

(vi)- M.Bockenhauer, Germanicher Lloyd, Hamburg, Germany. "Some considerations on gas carrier safety".

(vii)- M.I. Rudnicki and E.M. Vander Wall, Aerojet Energy Conversion, Sacremento, California. "Gelled LNG- a safer approach".

(viii)- G.Mc Guire, Leith Nautical College, Leith, Scotland. "Improved safety through training".

- Gas Tech. 81 LNG/LPG Conference (Hamburg, Germany 20-23 October, 1981):

(i)- Dr.R. Nagamato, M.Ushijima, D.Sakai, K.Hagiwara, T.Takahashi, Y. Kuranto, Mitsubishi Heavy Industries Ltd.,Nagasaki, Japan. "On the study of the tank system of 125 000 cum. MRV type LNG carrier (loads and stress analysis).

(ii)- M. Bockenhauer, Germanischer Lloyd, Hamburg. "Some notes on the pratical application of the IMCO Gas Carrier Code to Pressure vessel type cargo tanks".

(iii)- Dr. J.C.Peck, P.Jean, Gaz-Transport. "Prediction of sloshing loads in LNG ships".

(iv)- P.R.Lyon.-M.A.F. Pyman and D.H.Slater. "Port planning and management aspects of the safe shipment of LNG and LPG".

(v)- Dr.S.Mankabady, University of Liverpool, UK. "The control of the movements of gas carriers in ports".

(vi)- D.M. Solberg and E.Skramstad, Det norsk Veritas. "Assesement of consequences from accidental release of liquefied gases".

(v)- S.Attalah."LNG safety overview".

(vi)- G.Angas."Simulation and its role in liquefied gas carrier personnel training".

(vii)- P.R.Mitchell. "Gas tanker operations: crews and qualifications, safety and training".

- Gas Tech. 86 LNG/LPG Conference (Hamburg, Germany 25-28 Nov.,1986):

(i)- J.B.Whitemore and R.C.Gray. "The SIGTTO Recommendations and Guidelines for Linked Ship/ Shore Emergency Shut Down".

(ii)- M.Z.Navaz,Lloyd's Register of Shipping,London. "An approach towards establishing a safety survey of a liquefied gas Terminal".

(iii)- E.C.Blogg. "A safety training programme on board LNG carriers".

(iv)- M.Huther, P. Anstot and M.Zehri, Bureau Veritas , Paris. "Reliability and safety verification of membrane containments".

- Gas Tech.84 LNG/LPG Conference (Amsterdam 6-9 Nov.1984):

(i)- D.S.Aldwnickle and D.McLean. "A safety review of ships for liquefied gases and future legislative needs".

(ii)- G.B.Angas. "On board operations and safety training for liquefied gas tanker personnel".

(iii)- A.Valk, R.Sylvester-Evang Cremer and Warner. "Safety in the design of gas terminals".

(iv)- P.Jean and M.Bourgeois, Gaz transport, France. "A new generation of LNG carriers based on a proven cargo containment system".

(v)- P.J, Latreille, Bureau Veritas, Paris. "On the structural details of gas tankers".

- Gas Tech. 75 LNG & LPG - Technology congress- Paris Sept.30- Oct.3, 1975.

(i)- J.M. Chauvin, Technigaz S.A.,Paris. "Developments of the technigaz integrated tank system for methane carriers".

(ii)- R.J. Lakey. "The IMCO Code for Gas Tankers- a review of the finalised Code"

(iii)- J.M.S. Smith, R.C.Mathew and J.A.F.Crook. "The safety of gas carriers with particular reference to the I.C.S. Tanker Safety Guide (liquefied gas), movement control and personnel training".

(iv)- Lcdr.A.E. Henn and Lcdr. T.R.Dickey. "New regulations for liquefied gas carriers".

(v)- M.LeFloch. "The importance of the human element in the transportation of liquid gas"

- Gas Tech. 85 LNG & LPG Conference. Nice, France Nov. 12-15,1985.

(i)- R.C. gray- "Introduction to safety and training".

(ii)- D.Mc Lean and R.M.Cripps,-"Design, construction and periodical surveys of ships for liquefied gas- A classification society's view point".

(iii)- N.Itoyama, S.Fukushima, S.Hata, Y.Kobayashi and K.Kawabata. "Design and actual service of cargo handling equipment on an LNG carrier".

- Gas tech. 82 Proceeding LNG/LPG conference. Paris 5-8, October 1982.

(i)- Dr. R. Nagamoto, Dr. M. Matoba, Y.Kuramoto, M. Ushijima and D.Sakai. "On the study of the tank system of a 125,000 Cum MRV type LNG carrier (thermal leak before failure and buckling analysis)".

(ii)- G.W Van Tassel. "Training of LNG carrier personnel".

(iii)- B.White. "Training for gas handling operations at terminals".

(iv)- M.Valckenaers. "Risk assessment of LNG installations".

- A.Allieveli. "Training for the safe operation of gas carriers". Conference on ship operations and safety. Southampton April 7-9, 1981.

- G.B.F Angas and M.Harries. "The training of Liquefied gas tanker personnel through simulation".

- Fitness for sea. An International conference on seaworthiness. Sept. 9-10,1980-NewCastle University:

(i)- R.C. Gray. "Safety aboard gas carrier".

(ii)- L.A.Holder. "Automation and safety".

(iii)- A.Wepster. "The ship Manager's responsibilities for seaworthiness".

(iv)- F.J.J. Cadwallader. "Unseaworthiness-manning, competence and carriage by sea".

- International conference on ship safety and marine survey - Malmoe Sweden. 8-9 may, 1986:

(i)- I.B. Mathiessen. "The role of the Government Nautical Surveyor".

(ii)- "International safety standards and classification societies surveys".

(iii)- J.de Coverly. "Marine accident investigation; a government surveyor's perspective".

(iv)- "Maritime law and ship safety".

- The Institute of Marine Engineers. The Nautical Institut.
"Marine Inquiries and casualties investigation". Seminar . London 23 Nov. 1982.

- Bureau Veritas-LNG tanker 1985.- "Improved rational appraisal of membrane LNG tanker by B.V.".

- Bureau Veritas."International Register de Classification de Navires et d'Aeronefs. Partie II. Updated as per Nov. 1986".

- J.Benoit.Chief Surveyor/Bureau Veritas. "International regulations applicable to liquefied gas carriers & chemical tankers". Technical paper - 86/3 October 1986.

- Larbi Ahmed Yahia. " Promotion ship of safety in Algeria".
File copy paper to World Maritime University in 1986.
- International Chamber of Shipping. Conference in Bergen Norway. Oct. 1975.

(i)- Mr. W.O.Gray. "Vessel operating casualty records (inc. grounding, collisions, fires, explosions, etc...)".

(ii)- Captain I.E. Le Cocq. "Ship shore liaison".

(iii)- M.P.G.Bonnafous and Mme H. Kutmiak. "Gas carriers (design)".

(iv)- Mr. B.B.Leland. "Recent developments in the field of safety training".

(v)- Mr. L. Pascual & Mr. A. Michel. "Gas carrier training".

- Jens B. Riksheim- Principal surveyor. "Gas cariers- Aspects of design and construction and operation in relation to rules and regulations". Paper series No. 88 P003 Feb.,1988.

- Symposium. Luxembourg, du 18 au 20 Avril 1979. Vol.II (C.C.E). "Les techniques nouvelles pour l'exploration et l'exploitation des ressources de petrole et de gas". Editions technip. ISBN 2-7108-0359-3.

- **Periodicals/Seminars:**

- Capt. J.G.Benyo. "Tank entry procedures for LNG carriers". Safety at Sea, July 1981 no. 148 page 12.

- "Tanker safety- A look at how Esso maintains a high standard in its fleet". Safety at Sea, October 1984. No. 1986 page 20.

- "Why gas carriers are not floating bombs". Safety at Sea, August 1983 no. 173. page 14 to 18.

- Capt.Ernst G. Spender. harbour Master. "Bulk transport of dangerous cargoes in maritime transport operation". Bremen port authorities . August 1989 seminar at WMU. in Malmoe.

- Mitsuo Abe- Managing Director and Chief Surveyor Nippon Kaiji Kyokai Chairman of the IACS council . "Classification societies and International Association of classification societies (IACS)". Lecture held in Technical Museet in Malmoe to WMU students in 1989.

- "The Medideterranean, Africa and the Middle East". Fair play world Ports directory 1990. Volume III.

- Bjorn Vedeler. "Subdivision and damage stability". Lecturer BVedeler/nnp Feb.1990 to MSA(N) 90 students.

- **Books:**

- Andrew S. Nicholson, John E. Ridd. "Health Safety and Ergonomics". Butterworth & Co Ltd 1989.

- D. Rutherford. "Ship Safety Personnel Role and Duties". British library. ISBN 0-85264-269-5.

- H.I.Lavery. "Ship Board Operations". Second edition. ISBN 0-434-91091-0.

- Robert Taggart. "Ship Design and Construction". by the Society of Naval Architects and Marine Engineers One World Trade Center, N.York 10048.

- S.Shields, K.J. Sparshott, E.A.Cameron. "Ship Maintenance and Quantitative Approach". 1975, Marine Media Management Ltd.

- R.G.Wooler. "Marine Transportation of LNG (Liquefied Natural Gas) and Related Products". Cornell Maritime

Press, Inc. Cambridge, Maryland 1975.

- Institute of Petroleum. London Wimsar England. "International Oil Tanker and Terminal Safety Guide". Adland & son Ltd, Bartholomew press, borking, survey.

- Oil Companies International Marine Forum. "Safety Guide for Terminal Handling Ships Carrying Liquefied Gases in Bulk ". Sept. 1975.

- Oil Companies International Marine Forum. "Marine and Terminal Operations. Surveys Guidelines". Sept. 1983.

- International Chamber of Shipping. "Tanker Safety Guide (Liquefied Gas)". Witherby & Co.,Ltd, London.

- SIGTTO. July 1987." Recommendations and Guidelines for Linked Ship/Shore Emmergency Shut-down of Liquefied Gas Cargo Transfer". Witherby and Co. Ltd, London, EC1.

- Oil Companies International Marine Forum. "Ship to Ship Transfer Guide (liquefied gases)".

- Capt. T.W.V.Woolcott. "Liquefied Petroleum Gas Tanker Practices". 1987 Brown & Ferguson Ltd. Glasgow.

- Oil Companies International Marine Forum. "Safety Inspection Guidelines and Terminal Safety Check List for Gas Carriers". May, 1989.

- SIGTTO July 1987. "Guidelines for the Alleviation of Excessive Surge Pressure on ESD".

- Gabriel Salvendy. "Handbook of Human Factors". 1987 by

John Willeyd sons, Inc.

- P.M. Alderton. "Sea Transport Operation and Economics". Third edition 1984. Thomas Reed Publications Ltd.

- Japan Maritime Research Institute. "World's LNG Situation and LNG Carriers". ISSN 0913-5480 No.28 June 1988.

- Raymon Kuhlman. "Professional Accident Investigation". Institut Press 1977.

- Trevor kletz. "Learning from Accidents Industries". Butterworths & Co; (Publishers) Ltd, 1988.

- "Lloyd's World of Shipping". Honk-Kong Oct. 12-16 1981.

- Mc Guire Graham. "Liquefied Gas Handling Principles on Ships and in Terminals". ISBN 0-900886-93-5.

- Prof. P.S.Vanchisvar. "Maritime Administration/Maritime Safety Admoinstration (revised 1987/1989)". Volume I. Lecture at WMU (Malmoe) in 1989.

-**International Instruments:**

- International Maritime Organisation. "International Code for the Construction and Equipment of Ship Carrying Liquefied Gases in Bulk (IGCode)". (1983 edition) Vol.III .

- "Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk". (1983 edition).

- "Code for Existing Ships Carrying Liquefied Gases in Bulk ". (1976 edition).

- "Supplement 1980 to the Code for Existing Ships Carrying Liquefied Gases in Bulk".

- "International Conference on Training and Certification of Seaferes 1978".

- Resolution A.328(IX). Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk. Adopted on 12 Nov. 1975.

- Resolution A.329(IX). Recommendations Concerning Ships not Covered by the Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (Resolution A.328(IX)). Adopted on 12 Nov.1975.

- Intenational Conference on Safety of Life at Sea. 1974.

- Protocol of 1988 relating to the 1974 SOLAS Convention.

- International Conference on Tanker Safety and Pollution Prevention, 1978 (TSPP).