SIGTTO

Society of International Gas Tanker
& Terminal Operators Ltd

FIRE PREVENTION
IN THE CARGO CONTAINMENT SYSTEMS OF
LIQUEFIED GAS CARRIERS
IN SHIPYARDS

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The Society of International Gas Tanker and Terminal Operators is a non-profit making organisation dedicated to protect and promote the mutual interests of its members in matters related to the safe and reliable operation of gas tankers and terminals within a sound environment. The Society was founded in 1979 and was granted consultative status at IMO in November 1983. The Society has over 100 companies in membership who own or operate over 95% of world LNG tankers and terminals and over 55% of world LPG tankers and terminals.

Published in 2001 by

SIGTTO

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INTRODUCTION

In the last 35 years a high number of serious casualties have occurred involving fires in the cargo containment system of liquefied gas carriers, whilst the vessels have been in shipyards. Many of these have resulted in multiple fatalities, environmental damage and serious financial loss to the ship-owner. It should also be borne in mind that it is not unknown for ships to be arrested and owners superintendents, or representatives, to be held in custody for lengthy periods whilst accidents are investigated.

In 1995, the SIGTTO Secretariat undertook research into the subject and published the results at the Balikpapan Panel Meeting in September 1995. At the time this was thought to be sufficient to alert the industry to the problem, but a recent enquiry has shown that since September 1995 there have been 7 reported incidents resulting in 7 fatalities and the constructive total loss of a vessel undergoing repair.

This guide has been prepared by SIGTTO in order to draw attention to the problem and propose risk mitigation measures to those responsible for managing these activities.
Whilst this safety guide was being prepared, in July 2001, a fire occurred on a 3200 m3 semi-pressurised LPGC at a repair yard in Slovenia. The fire, which burned for over 2 hours, damaged the structure and insulation of No.1 cargo tank and was caused by hot work during steel-work renewal in the double bottoms. There were no fatalities or injuries.

The 1995 SIGTTO Report included fires in all parts of the ship; machinery spaces, cargo tanks, accommodation, store-rooms etc.; whilst vessels were in ship-yards. This guide addresses only insulation fires in the cargo containment system of gas carriers and methods that should be adopted to reduce the risk of fire and explosions occurring.

Since 1966 there have been 27 reported incidents resulting in 52 fatalities and 1 vessel being declared a constructive total loss. It is likely that there have been numerous other incidents, albeit of a relatively minor nature, that have never been reported in the public domain.

Although not a shipyard fire, the1973 Staten Island incident deserves mention here as it further illustrates the lethal potential of insulation fires in enclosed spaces. A LNG tank, which had been in service for 3 years, was warmed up, purged of hydrocarbons with nitrogen and then ventilated with air ready to undertake repairs. 10 months after repairs began the Mylar and polyurethane internal insulation was accidentally ignited. The ensuing

fire resulted in the death of *37* workers. The New York City Fire Department Report concluded that the ferocity of the fire caused a rapid rise in pressure within the tank, causing the roof to lift and collapse into the 95,000 m3 tank.

1. PRELIMINARY CONDITIONS

When a gas carrier enters a repair yard, normally all cargo tanks, ballast tanks, pipe-ducts and void spaces will be "safe for entry", in terms of concentrations of oxygen, hydrocarbons and toxic gases. Further guidance on this is given in Chapter 6 of The ICS Tanker Safety Guide (Liquefied Gas) and ISGOTT 11.3. The surfaces of the cargo tanks are unlikely to have oily residues or scale that have the potential to release gas. However, in most cases, depending on the ship type, the tanks will have some form of external thermal insulation. Materials commonly used for this purpose are: mineral wool, perlite, balsa wood, polystyrene and polyurethane.

Mineral wool– This is manufactured by melting volcanic rock and limestone and spinning the molten material into wool. The resultant material is used both as thermal insulation and also for passive fire protection. It is chemically inert and non-combustible, but it does have an open cell structure, which is capable of absorbing hydrocarbon liquids and vapours.

Perlite – Is a finely powdered volcanic rock, is inert it can absorb liquid. A number of fully refrigerated LPG carriers were built in the late 1960s 1970s and 1980s where the hold space was insulated with perlite treated with silicone. At least two of these vessels have suffered serious explosions during repair, resulting in multiple fatalities and one vessel being declared a constructive total loss. It is suspected that butane had leaked into the hold space and was absorbed into the treated perlite, remaining undetected until it was ignited by hot work in an adjacent ballast tank.

Balsa wood - Because of its open grain structure, has very good thermal insulation properties compared with other timbers and was much used in one of the early membrane systems. Unfortunately, should the timber ignite, this open grain structure results in both a comparatively high charring rate and a rapid rate of surface flame spread. Balsa also has the capability to absorb several times its own weight of water and therefore has the ability to absorb large quantities of petroleum liquids or vapour.

Polystyrene and polyurethane – These are not only highly inflammable, but, when ignited, rapidly release large quantities of extremely toxic, dense black smoke. Therefore, should a fire start in a hold space containing a cargo tank insulated with these materials any personnel present will be quickly disorientated and overcome by the fumes, standing little or no chance of escaping. This is born out by the number of incidents where there have been multiple deaths and also the fact that almost a third of all fires results in a fatality.

2. GENERAL PRECAUTIONS

The OCIMF www.ocimf.com publication "Shipyard Safety" is a comprehensive guide on the general subject of accident prevention in ship repair yards and its advice should be strictly adhered to. Safety advice on dry-docking and repair periods for gas carriers is also given in Appendix 4 of the "ICS www.marisec.org Tanker Safety Guide (Liquefied Gases)". The Shipbuilders & Shiprepairers Association www.ssa.org.uk also publish general health and safety information papers and bulletins. The recommendations of this SIGTTO guide are concerned only with matters specific to the cargo containment systems of gas carriers and therefore should be read in conjunction with the above publications.

- Most shipyards that build or repair gas carriers have previous experience of this type of work. However, it is of paramount importance that the appropriate supervisory staff are thoroughly briefed, by senior management, to ensure that they are aware of the potential hazards of undertaking work within the cargo containment system and that they understand the necessity of passing this information on to their workforce. Daily briefing sessions, or "toolbox talks should be encouraged.

- The ship yard should have a dedicated Safety Manager responsible for the implementation of policies and procedures.

- The yard should be required to provide a written method statement, explaining how the work is to be carried out and what risk mitigation and incident response methods they intend to employ.

- A "Permit to Work" system should be in operation, in conjunction with a safety checklist.

- In ship repair yards it should never be assumed that the yard personnel are familiar with the construction of a particular ship type.

- In all cases where hot-work is to be carried out in the cargo containment system, no work shall be permitted before the holds are confirmed, *by a qualified chemist*, as being under breathable air and gas free and an appropriate certificate issued to that effect. The atmosphere of these spaces should be re-checked at least once per shift and the gas free certificate re-validated. Tests for gas should be carried out using portable gas detectors. The vessels fixed system should not be relied up on, as it may not detect pockets of gas in stagnant areas.

- When hot-work is to be carried out at or near the tank insulation, a suitable area shall be checked for gas in the insulation. If working on the tank surface, a sufficient area of insulation should be removed to ensure that ignition of possible entrapped gas pockets or the insulation material cannot occur.

- All exposed insulation in the vicinity of hot work should be covered with non-flammable material.

- Flammable materials should be identified and be kept in a “no hot work area” and these areas should be monitored. The minimum amount of flammable materials should be kept in the working area.

- Many of the adhesives used for gluing insulation panels and protective foil are solvent based and give off heavier than air flammable vapours. Solvent free adhesives should be used wherever possible.

- Phenolic and polyurethane foams have been developed for use that are “self extinguishing”, whereby the charred surface effectively seals the material from the atmosphere and prevents further combustion. It is strongly recommended that these materials are specified whenever possible. It should be noted that small off-cuts have a large surface area compared to mass and can produce smoke before they char and extinguish.

- Good housekeeping is essential to prevent the accumulation of flammable materials in the work area.

  Off-cuts of foam insulation materials should be collected and stored in steel drums with lids and NOT polythene bags; as the bags may be ignited by sparks and it has been shown that burning polythene reacts with the foam to intensify the combustion. See appendix 2

- Whenever repairs are to be carried out in cofferdams or ballast tanks adjacent to cargo tanks it is *imperative to ascertain if there is any flammable material on the other side of the bulkhead*. It should also be borne in mind that shipyard workers may weld staging brackets to bulkheads some distance from where work is to take place.

- A trained fireman should be present when any welding or hot work is being undertaken.

- A 24 hour fire watch should be maintained and the watchmen should be made aware that fires can break out many hours after hot work has stopped.

- Adequate fire extinguishers and at least one set of compressed air breathing apparatus should be available in the vicinity of hot work. Insulation fires spread rapidly out of control and must be extinguished in the initial stages if major casualties and damage are to be avoided.

- Due to limited access and dense smoke an insulation fire can be extremely difficult to fight. Therefore it is recommended that a contingency plan is formulated to outline the action to be taken in the event of a fire occurring.

- Exits and evacuation routes from enclosed spaces should be clearly marked and evacuation should be practised. Spaces should be adequately lit at all times and the use of guide wires, reflective tape, or the flashing light strings now commonly fitted in passenger aircraft should be considered. Each space should have at least two escape routes.

- The provision of emergency escape smoke hoods should be considered when undertaking hot work in areas with limited egress.

- Regular inspections should take place to ensure safe working conditions are being maintained.

- Regular inspections should be made of all gas burning and welding equipment used in enclosed spaces. This is particularly important with oxygen hoses. Hoses should be removed to the open deck when work stops for the day.

- Adequate ventilation should be provided to prevent the build up of flammable vapours and dust.

3. PRECAUTIONS FOR LNG CARRIERS.

- **Moss type vessels**

The spherical tanks are insulated with phenolic, polyurethane or polystyrene panels and extrusions, bonded with flammable solvent-based adhesive. Therefore it is imperative that when working with these materials adequate ventilation is provided and that no hot work is allowed in the hold space, and that suitable precautions are taken to prevent sparks entering the hold via access hatches or ventilation openings. The polystyrene insulation is covered by a protective layer of aluminium foil and at any time that sparks, molten metal or tools might fall on this layer protection from mechanical damage and sparks should be provided, such that the inflammable insulation is not exposed and possibly ignited.

A problem that is occasionally encountered for the first two or three occasions that Moss type tanks are warmed up after being put into service, is that the gas detection system for the space between tank surface and insulation shows an abnormally high reading. This is normally due to the solvent being released from the adhesive as it warms up and not due to a defect in the containment system. However, attention should be paid to the fact that the solvents used in adhesives may well be flammable.

- **Membrane type vessels**.

Membrane tanks are insulated with 2 layers of insulation separated by a secondary barrier. The insulation is either rigid polyurethane foam separated by a triplex barrier, with balsa load bearing insulation, or perlite filled plywood boxes separated by an invar barrier. The membranes may have some permeability, and it is imperative that these spaces are sufficiently purged before any hot-work is permitted. The manufacturer provides detailed procedures in order to achieve proper ventilation, without damaging the containment system by over-pressurisation or ingress of moisture. These consist of applying a vacuum to the interbarrier space followed by a dry nitrogen purge and repeating this process until a hydrocarbon content of less than 0.25 % v/v (5% LFL) is

achieved at a number of temporary sampling points around the tank.

Unless the owner's superintendent and shipyard has considerable experience in the repair of membrane tanks it is strongly suggested that a representative of the manufacturer is present when undertaking repairs to the membrane or renewing steelwork on the inner hull.

During welding operations on the membrane or inner hull the insulation space needs to be at atmospheric pressure to prevent the weld pool being sucked into the insulation or interbarrier space and fire spread by the airflow.

During welding on the membrane the manufacturers recommend thermal protection is placed over the insulation behind the weld seam to prevent burning.

During steel replacement on the inner hull a pre-defined procedure must be carried out. This consists of placing a "thermal shield" between the double hull and the insulation, injecting nitrogen into the insulation space adjacent to the area where welding is being undertaken and welding in short runs to limit the maximum temperature that the steel reaches.

A serious concern with membrane systems is that the insulation may be ignited by hot work in an adjacent space.

The manufacturers now select low flammability materials, but considerable care still needs to be taken when undertaking hot work on these vessels. (see Appendix 2)

Should a fire occur in the interbarrier or insulation space the manufacturers recommend punching a hole in the membrane or inner hull and injecting Carbon Dioxide. The hole should be covered when not injecting the extinguishing agent. Also the rate of purge nitrogen injected into the space should be increased to keep the pressure at atmospheric and prevent air being drawn in and supporting the fire.

- **IHI SPB and "ESSO" vessels.**

Similar precautions should be taken to those mentioned under fully refrigerated LPG carriers.

4. PRECAUTIONS FOR LPG CARRIERS

- **Fully pressurised vessels**

These ships are generally less than 2000 m3 and carry their cargo at ambient temperature in spherical or more usually cylindrical pressure vessels and therefore do

not require the thermal insulation that other gas carriers need. They may have the surface of the tank above the main deck insulated as a protection against thermal radiation to supplement the water spray in the event of a fire, but this material, by definition, will be non flammable. Also, being on the tank dome LPG and heavier than air vapours are unlikely to congregate there. On these vessels it is generally easier to determine if the hold spaces are safe for hot work than on other types of LPC carrier. It is no coincidence that none of the casualties mentioned in the appendix are fully pressurised vessels.

- **Semi-pressurised vessels**

These ships are generally up to a size of about 20,000 cubic metres capacity although larger vessels do exist. These vessels often have independent IMO Type-C tanks that can either be built as individual cylindrical tanks or as bi-lobe tanks. The tanks are insulated with polyurethane foam, which is glued to the tank surface and usually covered by a galvanised steel cladding or aluminium foil. The hold spaces may or may not be inerted depending on the cargo carried. In all events the cargo holds are to be ventilated and confirmed gas-free before hot-work is permitted. If hot-work is required on or near to the tanks, special precautions must be taken to ensure against ignition of the insulation material or trapped pockets of gas that may have leaked into the insulation.

- **Fully refrigerated vessels**

The tanks are usually prismatic IMO Type A or Type B tanks, Type A being the most common. The tanks are insulated with polyurethane foam panels that are glued to the tank surface and covered with galvanised steel or aluminium foil cladding. On occasions the insulation for Type A tanks can be applied to the Inner hull.

The hold spaces must be inerted when carrying flammable cargoes. Prior to entry the holds will have to be ventilated and confirmed gas-free. If hot-work is required on or near to the tanks, special precautions must be taken to ensure against ignition of the insulation material or trapped pockets of gas that may have leaked into the insulation.

- **Hold Spaces Filled with powdered Perlite.**

A number of fully refrigerated LPG carriers built between 1969 and 1986 have their hold spaces insulated with powdered perlite and these require special precautions to be taken before hot work is undertaken.

Hold spaces other than those containing type “C” tanks are required under the “Gas Codes” to have a fixed gas detection system. However, if this space if filled with perlite the effectiveness of any detection system, fixed or portable must be called into question and the ship’s staff could be unaware of cargo leaking into the insulation. For this reason if hot work is to be carried out in spaces adjacent to perlite insulated holds, or on the steelwork of these spaces it is imperative that the perlite be removed from the

hold and the hold atmosphere tested, before hot work commences. It is also recommended that a specialist contractor is used to perform this task.

Because the perlite may contain flammable liquids and gas, checks should be carried out during its removal to prevent the inadvertent introduction of a fire hazard to the area of the shipyard where the insulation is to be stored during the repair period*. It should also be noted that perlite can absorb odourant from stenched LPG that may have leaked into the insulation.*

5. PRECAUTIONS IN VESSELS UNDER CONSTRUCTION

It is strongly suggested that safety policies and procedures are thoroughly discussed during the contract negotiations. If these matters are left to a latter stage it may be difficult to achieve a level of safety that is satisfactory to both parties. Safety issues should be continuously reviewed and amended in the light of experience.

In new building yards the construction path should be planned, wherever possible, such that all welding and hot work is complete before the insulation materials are placed in the hold space.

Stocks of insulating panels should be stored in a safe, well-ventilated area. Away from all possible sources of ignition.

Panels should NOT be protected with self-adhesive plastic sheet, as this would encourage the spread of any fire.

Due to the volatility of certain solvents particular care should be taken when injecting “two-pack” insulation into the inter-panel joints,

Strict control should be kept on persons entering areas where insulation work is taking place.

In new building yards, safety will be the responsibility of the shipyard until the vessel is accepted by the ship-owner, but it is the duty of the owner’s representatives to support the shipyard in a constructive manner.

6. SUMMARY

That the undertaking of hot work on the cargo containment system of gas carriers and adjacent spaces has the potential to cause serious and fatal fires is without question. Appendix 1 gives a list of all reported incidents in the last 35 years, which is a slight on an industry that otherwise claims an exemplary safety record.

Therefore, before undertaking any hot work in the cargo containment system it is imperative that the operation is researched and planned by yard management and owner’s

superintendent etc. and that all staff are thoroughly briefed. It is essential that the location of all combustible materials is ascertained and that precautions are taken to ensure that it does not come in contact with sources of ignition. This is particularly true of bulkheads that have insulation on the reverse side, where hot work could endanger workers in a space ADJACENT to that in which hot work is taking place. Due consideration should also be given to the fact that normally benign materials can become saturated with flammable liquids and vapours and thus become hazardous.

Provision for adequate egress should be made for any enclosed space containing flammable materials, in which hot work is to take place. Adequate fire-fighting equipment should be provided with trained firemen and consideration should be given to the provision of emergency escape smoke hoods and light strings if there is likely to be any difficulty, whatsoever, in evacuating the space. Good housekeeping is essential.

Because of the rapidity with which insulation fires can escalate and gain hold it is essential that first aid fire-fighting equipment is on hand whenever hot work is undertaken. However*, it cannot be over-emphasised that prevention is better than cure and that time spent in planning and implementing safety procedures is not wasted.*

Finally, of course, it is imperative that the atmosphere is gas free and breathable before hot work commences and is re-checked on a regular basis.

Appendix 1

Casualties to Gas Carriers during refit or building - involving fires and explosions in cargo containment systems

Date	***Ship type & capacity***	***Details***
2/66	LPGC 46700 m3	Insulation fire No.3 tank during construction. **15 fatalities.**
10/70	LPGC 31200 m3	Minor fire in No.1 tank
8/71	LPGC 50700 m3	Fire in No.4 tank. **5 fatalities**.
10/71	LPGC 29800 m3	Fire in insulation. 8 hours to quell.
7/74	LNGC 77700 m3	Fire in No.5 tank whilst under construction
10/77	LPGC 1600 m3	Fire in insulation
3/78	LNGC 125000 m3	Insulation fire during construction
7/79	LNGC 27400 m3	Fire in insulation No.3 tank
9/79	LPGC 4100 m3	Fire during construction. **1 fatality**.
1/80	LPGC 820 m3	Fire in hold. **1 fatality**.
3/82	LPGC 59700 m3	Insulation fire during construction
3/84	LNGC 125000 m3	Fire in No.3 tank insulation
7/84	LPGC 12000 m3	Fire in insulation
11/88	LPGC 80000 m3	Fire in No.1 tank insulation. **3 injured**.
3/87	LPGC 3750 m3	Fire in cargo tank insulation. **14 fatalities**.
6/91	LPGC 14000 m3	Fire in insulation caused by hot work
11/93	LPGC 66300 m3	Explosion during repairs. **6 fatalities**. Repair bill >$10 mill
11/94	LPGC 2770 m3	Fire on board. No details.
12/94	LPGC 3880 m3	Fire and explosion. **4 fatalities**.
7/95	LPGC 52500 m3	Fire in No.4 tank insulation
3/96	LPGC 54250 m3	Fire in No.2 tank – not insulation
5/96	LPGC 2750 m3	Explosion during repair work
10/99	LPGC 22240 m3	Explosion fire in cargo tank. **5 fatalities**. Vessel scrapped
6/00	LNGC 135000 m3	Insulation fire in No.3 tank
2/00	LPGC 8600 m3	Tank fire during construction
12/00	LNGC 87600 m3	Fire in cargo tank (hold?) **1 fatality**
7/01	LPGC 3200 m3	Fire in No.1 cargo tank. Vessel out of service 10 weeks.

Appendix 2

At the request of a ship-owner, a far east ship-yard was recently asked to carry out a series of simple experiments to demonstrate the flammability or otherwise of the various foams used for the cargo tank insulation. The following is the report of the owner's representative who witnessed the tests on off cuts of self- extinguishing phenolic and polyurethane foams.

"The first photograph shows a section of foam that we ignited with an oxy- acetylene torch. As per the material specification there was very little smoke or flame and the foam rapidly self extinguished.

The second photo shows a drum containing off cuts of foam wrapped in polythene bags. This is the way the foam scraps are collected on board and transferred to the skips on the jetty. A burner was used on a piece of steel plate on the platform above the drum. The cutting sparks quickly ignited the polythene bag, and the bag and foam burnt rapidly with large flames and a lot of dense black smoke. As you can see from the photos, the difference is quite remarkable.

We then tried it with a small polythene bag on top of the first piece of foam. The bag ignited quickly and the flame seemed to spread in a pool in the foam with a lot of smoke being generated. The fire was extinguished by inverting the foam and letting the liquid (polythene?) pool drop out. The foam then charred and quickly self extinguished.

The foam by itself is very safe, but the addition of the polythene bags makes it potentially lethal.

Based on our results I think it is important to realise that what is a perfectly safe material can be changed into something very dangerous by the addition of few readily available polythene bags. "