Maritime Transportation and Harvesting of Sea Resources
volume 2

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ABSTRACT: The repair of oil tankers presents special and differentiated risks with respect to other ships, due to the characteristics of the products transported, either crude oil (natural product composed of various types of hydrocarbons and varying proportions of other substances, varying its composition according to the origin thereof) or any of its refined products. The entry of these ships to the shipyard has to be made with strict security measures, based on a prior recognition of the situation of their tanks and adjacent spaces and their corresponding certification of the situation in which they are, certification that must be renewed daily. In order to ensure that hazardous situations do not lead to damage to workers and great economic losses for the shipyard and the Shipowner, it is necessary to be fully aware of the special problems of repairing these types of ships and what preventive measures should be put in place to minimize or eliminate such risk situations. The possible cold and hot work in the spaces that contain or have contained combustible products require prior authorization from the risk prevention services of the shipyard, with perfectly defined working procedures.

1 INTRODUCTION

The first reference to the transport of dangerous products appeared in 1894, in the British Merchant Shipping Act, under the title of “Dangerous Goods and the Carriage of Cattle”, and in the first 1914 and 1929 SOLAS Conventions, in which the decision on the goods that should be considered dangerous was left to the discretion of the Contracting Parties and the Administrations. In those years, few dangerous goods were carried.

In 1948, the UN convened a Maritime Conference in which it was decided to create the Inter-Governmental Maritime Consultative Organization (IMCO), later renamed IMO, whose constitutive Convention entered into force in 1958 and whose first meeting was held in 1958. It is responsible for protecting human life at sea, through both its Maritime Safety Committee, body in charge of the coordination and the supervision of technical activities, such as fire prevention, transport of dangerous goods, etc., and its Marine Environment Protection Committee, in charge of the protection of the marine environment.

Since then and whenever it is necessary to solve a global problem, an International Conference is held and a Convention is approved, as well as other fundamental codes and regulations, which are included in the bibliography. All of them are aimed to cover the fields of: the construction of the ship according to International Agreements and National Standards, the protection of human life at sea and the protection of the marine environment.

The conditions for berthing and docking in a shipyard require strict safety measures to ensure the integrity of the ship and the safety of the crew and the shipyard workers.

2 THE MOST IMPORTANT RISKS

Several risk situations can take place in any ship that is being repaired but, in this type of ships, we should focus on two differentiated risks: the risk of flammability and the risk of insalubrity (Fraguela, 2003).

2.1 Risk of flammability

The formation of flammable atmospheres can occur not only inside the cargo tanks but also outside them, despite the ease of dissipation of hydrocarbon vapours, because this dilution is influenced by several parameters, such as: the wind speed and direction; the area, height and shape of the exit orifice; the concentration of vapours; the flow rate; the distance to the superstructure and the distance to other nearby exits, as it has been demonstrated in an aerodynamic tunnel. The risk of flammability affects both the ship and the people.
The formation of flammable atmospheres is basically influenced by the following properties and characteristics of the liquids or wastes present in the tanks and pipes (ICS 2006, NFPA 1993).

Lower explosive limit (LEL). Minimum concentration in percent by volume of fuel in mixture with air, below which the mixture is too poor to burn.

Upper explosive limit (UEL). Maximum concentration in percent by volume of fuel in mixture with air, above which the mixture is too rich to burn.

Flash Point (ti). Minimum temperature in degrees Celsius at 760 mm Hg, at which a combustible substance, in contact with the air, gives off enough amount of vapour so that the inflammation of the vapour-air mixture takes place, with the contribution of an external activation energy.

Autoignition Point (ta). Minimum temperature in degrees Celsius at 760 mm Hg, at which a solid, liquid or gaseous substance, in contact with the air, burns spontaneously without any need of an energetic contribution to the mixture.

In the mixtures of flammable gases or vapours in air, the ignition of the fuel-comburnant mixture will only happen if the fuel-comburnant concentration is between the LEL and the UEL and the activation energy provided by the ignition source or sources is able to reach the autoignition point temperature of the fuel. In order to maintain the combustion, it is necessary for the chain reaction (fourth fire factor) to occur, in other words, the energy given off by the reaction of a certain number of molecules has to be sufficient to activate an equal or greater number of new molecules, in such a way that the reaction progresses within the fuel-comburnant mixture and it is maintained over time and space.

One of the following conditions will always be found (Fraguela, 2003):

- Poor atmosphere, the one whose hydrocarbon vapours content is lower than the LEL and, therefore, not flammable.
- Rich atmosphere, the one whose hydrocarbon vapours content is higher than the UEL, not being flammable in this concentration.
- Flammable atmosphere, the one whose hydrocarbon vapours content is between the LEL and the UEL.

Uncontrolled atmosphere, the one whose concentration of hydrocarbon vapours in air is unknown and which, therefore, from the preventive point of view, should be considered flammable as long as it is not proven otherwise.

Inert atmosphere, the one that complies with the requirements of Chapter 15, Inert Gas Systems, of the International Code of Fire Safety Systems of IMO, which establishes the conditions required for inert gas systems: the oxygen content in any part of the tank should not exceed 8% by volume and the pressure of the inert gas inside the tank should be positive.

2.2 Risk of insalubrity

The absence of oxygen (concentrations below 18%, considered as safe for people) and the presence of toxic atmospheres (in concentrations above ambient toxicity limit values) in cargo tanks, when there is insufficient ventilation, are normal and the consequences derived from ignorance and lack of verification are fatal for the people who enter the tank.

Since the centesimal composition of hydrocarbon values varies according to the different crudes, their toxicity will vary in the same way, but it can be said that this one increases as its molecular weight increases. The effects of these vapours on the human body range from eye (from 1000 ppm), nose and throat irritation to dizziness, intoxication, paralysis, unconsciousness and death (from 20,000 ppm). In particular, the effect of the sulfhydric acid present in sour crudes must be outlined because of its paralyzing effect on the nervous and olfactory systems. Therefore, in concentrations from 200 to 300 ppm in air, it seriously irritates the eyes and the respiratory tracts and, at 1000 ppm, it can cause loss of consciousness and, after a few seconds, respiratory failure.

The tetraethyl lead (TEL) and the tetra methyl lead, which are still added to the petrols used in underdeveloped countries, deserve special mention because of their high dermal, parenteral and respiratory toxicity, which must be taken into account in tank cleanings.

3 RECEPTION OF THE SHIP

This name includes all those operations prior to the berthing or the docking of the ship carried out by the shipyard, which guarantee the control of flammable, asphyxiating and toxic atmospheres during the repair process.

3.1 Operations prior the arrival of the vessel in port

Some weeks before the arrival of the ship, in the communications prior to the signature of the ship repair contract, the shipyard must request the shipping company the detailed list of the works to be carried out, the location of dangerous spaces in terms of ignition and the means that the ship has in order to keep the inerting of cargo tanks (if this condition was necessary) (IMO Resolution MSC.206 2006, IMO Resolution A-473 1981). In these previous communications, it is very
Important that the shipyard indicates in writing the conditions in which the ship arrives, which will allow the captain to have enough days to prepare the dangerous spaces for the conditions demanded by the shipyard, avoiding incorrect interpretations that can lead to delays in the entry of the ship and the corresponding pressures and economic claims.

3.2 Operations at the arrival of the ship, prior to the berthing or the docking at the shipyard

Before the berthing or the docking of the ship, the shipyard security service must embark on board the oil tanker and carry out a preliminary examination which, together with the information provided by the ship's captain, will serve to prepare a report containing:

- Nature and origin of the products transported during the last voyages.
- How, when and with how much intensity the last cleaning and degassing operations were carried out (IMO Resolution MEPC 1979).
- Nature, location and quantity of dangerous products which the ship still contains.
- Oxygen content, toxic vapours and flammable vapours and wastes present in each tank.
- After this first examination of the ship, a certificate of gas detection and combustible wastes will be issued and will be signed by the head of the security service and by the ship's captain.
- It is advisable to clarify that the shipyard must use the concept of gas-free tank, the one that is degassed and salubrious (non-flammable, non-asphyxiant and non-toxic), since it is only allowed to work in a space with these three conditions. Merchant seafarers generally use it as a tank free of flammable atmosphere, a condition that is much easier and faster to obtain, but which would imply a delay in the beginning of the works, with a negative economic impact for the shipyard if this one allows the berthing or the docking.

3.3 Conditions of the arrival of the ship

There are several situations in which the cargo and slop tanks of an oil tanker can be found at the arrival at the shipyard (ICS 2006).

The first problem that arises is to know the safety margins that must be taken, in order to avoid uncontrolled situations and, therefore, to allow or prohibit the berthing or the docking of the ship. In brief, they are the following:

- For atmospheres with a significant concentration of hydrocarbon vapours in air, which in turn will be an unhealthy atmosphere, 20% of the LEL will be set as the maximum permissible concentration, above which no berthing or docking will be allowed.
- For non-degassed or unhealthy atmospheres, there is no problem with the berthing or the docking, although the time required to ventilate the tanks and turn them into the situation of gas-free tank (degassed and salubrious) is an economic factor which leads to a delay in the start of the repair works to be done inside the tank.
- For inerted atmospheres, there are also no berthing or docking problems if the oxygen content in any part of the tank does not exceed 8% by volume and the inert gas pressure inside the tank is positive. These conditions must be maintained with the ship's or shipyard's own means during the repair processes.
- The reason for these preventive measures, regarding the flammability of the atmosphere, is that a poor atmosphere can evolve into a flammable atmosphere, either naturally or by the works inside the tank, in addition to the possible hydrocarbon vapour locks present in certain areas of the tank, which may not be detected in the measuring process. In the case of a rich atmosphere, it can easily become flammable when there is an air intake into the tank.

3.4 Works in cargo tanks

Works in cargo tanks cannot begin without the authorization of the security service technicians, who will determine:

- The type and layout of the required ventilation, in order to maintain permanently the atmosphere of the tank in the gas-free situation (degassed and salubrious). Fans must be axial (low static pressure and high flow), tire or water ones. If they are electric, they must be intrinsically safe with anti-explosive protection.
- The cleaning and removal of sludge, sediment and accumulated waste in the work area, to another area of the tank or to outside it, depending on the size and type of the works to be carried out.
- The advisability of covering the bottom of the tank, or part of it, with a layer of high, medium or low expansion firefighting foam or aqueous film forming foam (AFFF), in order to separate the fuel (hydrocarbon vapours) from the oxygen in the air.
- The means of fire protection, which are necessary to stop any incipient fire (a 45 mm diameter and 20 m length hose with a triple effect and permanently pressurized lance, as well as 12 kg BC powder extinguishers), supervised by a firefighter or staff trained in fire fighting.
- Before the beginning of the works inside a tank, and as a result of the examination made, a label
must be stuck at the tank entry in order to know its situation. The label will be daily updated and it will indicate that the tank is in one of the following conditions:

**Degassed tank.** It is the one which contains a concentration of flammable gases or vapours below 0% of the L.E.L. for hot works or 15% of the L.E.L. for cold works.

- **Salubrious tank.** It is the one whose oxygen content is greater than 18% (non-asphyxiant) and simultaneously does not exceed the environmental limit values for any of the chemical substances present in its atmosphere or waste (non-toxic).
- **Gas-free tank.** It is the one which is degassed and salubrious (non-flammable, non-asphyxiant and non-toxic).

### 3.4.1 Control of the risk of unhealthiness
In order to be able to work inside the cargo tanks, their atmosphere must be healthiness, which is a condition that guarantees the existence of more than 18% of oxygen and non-toxicity. When work has to be carried out, for whatever reason, in an insalubrious environment, personal protective equipment must be used, which will be determined by the security service on the basis of the results of the oxygen and toxicity measurements carried out prior to the authorization of the works in these conditions.

### 3.4.2 Control of the risk of flammability
In this respect, the situation of cargo tanks determines the possibility of carrying out cold or hot works in tanks and in dangerous areas (the space that surrounds dangerous places and is less than 15 metres away from any orifice or opening of those places). The possible work conditions, depending on the condition of the tanks, are the following:

- **Condition “A”.** Inerted cargo tanks.
- **Cold and hot works** can be carried out outside the loading area (engine room, propeller, rudder, aft peak, etc.).
- **Blasting and painting works** can be done anywhere on the hull.
- For work or manipulation related to valves and pipes, the authorization of the security service must be obtained.
- **Condition “B”.** Open cargo tanks, with non-flammable atmosphere, but with wastes susceptible to generate flammable atmospheres.
- The conditions of salubrity and non-flammability of the atmosphere of the tank must be maintained by means of ventilation during the works.

Cold works will be permitted on any part of the ship, including the tanks, provided that the fuel-combustant concentration in air does not exceed 15% of the LEL. Hot works will be permitted on any part of the ship, except inside the cargo tanks containing wastes and in the areas adjacent to their openings. In order to carry out these works inside the cargo tanks, it is necessary to clean combustible wastes from an area around the working point, whose extension must be fixed by the security service, as well as to verify that the fuel-combustant concentration in air does not exceed 0% of the LEL. In addition, it can be necessary to take other complementary measures, such as: partially flooding the bottom of the tank with water; covering the bottom of the tank with high, medium or low expansion firefighting foam or AFF; maintaining the necessary fire protection means (a 45 mm diameter and 20 m length hose with a triple effect and permanently pressurized lance, as well as 12 kg BC powder extinguishers) handled by a fireman or, if this service does not exist in the shipyard, by staff trained in fire fighting; other measures that the security service considers appropriate according to the particularity of the work.

Condition “C”. Open cargo tanks with no flammable atmosphere and no waste.

To fulfil this condition, the atmosphere of the tank must be maintained at 0% of the LEL, six hours after the first measurement. Cold works will be permitted in any part of the ship, including the interior of the tanks. Hot works will be permitted on any part of the ship, including the interior of the cargo tanks, will be permitted, despite the possible presence of combustible waste in any part of the tank, in which case the security service will provide the necessary prevention measures.

### 3.5 Works on slop tanks

The situation of these tanks can be similar to that of cargo tanks, so we can apply to these tanks what has been said in section 3.4. In the event that the slop tanks have not been unloaded, they must remain closed and inerted, as well as insulated (keeping the valves of the pipes which flow into these tanks closed). Even in this situation, no hot works will be allowed in the areas around these tanks.

### 3.6 Works in the pump room

For ships in condition “A” of section 3.4.2, as they are inerted tanks, there must be no handling with the valves of the pipes, a fact which may lead to a loss of that inertization. In condition “B” of section 3.4.2, elements must not be removed without first checking that the insulation of the cargo tanks is not damaged. Normally, load and stripping pipes, filters, pumps and other elements in the pump room contain combustible or flammable
liquids and/or flammable vapours, so no work must be carried out without having previously checked the absence of these products, as well as taking a series of additional safety measures (maintaining forced ventilation, installing mobile fire-extinguishing means, etc.).

3.7 Works on pipes, devices or accessories

Cold works can be carried out on a pipe, device or accessory containing or having contained flammable or combustible liquids.

For hot works, prior notice to the security service is required, reporting which tanks it connects with and in what situation they are:

- Knowing the type of fuel that has flowed inside.
- Checking the flammability of its atmosphere.
- Determining if prior cleaning is required.
- Giving instructions about the most appropriate procedure to isolate the operating area from the rest of the circuit (using blind flanges, flooding the bottom of the circuit, injecting a strong air or inert gas flow). If blind flanges are used, they will be signalled to avoid wrong operations.

Periodically checking that, due to these operations, the situation of the tanks that it connects has not changed.

4 CONCLUSIONS

The repair works of oil tankers must be considered of high risk and its prevention must begin in the communications previous to the works contract.

These risks affect the safety of the ship, the crew and the shipyard workers. They need perfect coordination between the ship and the shipyard.

The crew of the ship must only carry out maintenance works, outside the areas classified as dangerous in terms of flammability and salubrity of the atmospheres. They will always be cold works.

The works in cargo tanks, pump rooms or pipes containing or having contained combustible liquids must only be carried out with special permits issued by the security service, which will be renewed daily.

A fire in a cargo tank is very difficult to control; that is why the extinguishing means mentioned must be maintained in the vicinity of the hot works, in order to prevent any start of fire. Large fires in cargo tanks will only be put out by professional firefighters from the shipyard and with many difficulties.

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