FIRE PROTECTION & FIRE FIGHTING EQUIPMENT ON BOARD

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ΕΠΙΒΛΕΠΩΝ ΚΑΘΗΓΗΤΗΣ: ΤΣΟΥΛΗΣ ΝΙΚΟΛΑΟΣ

ΘΕΜΑ: **FIRE PROTECTION AND FIRE FIGHTING SYSTEMS ON BOARD**

ΤΟΥ ΣΠΟΥΔΑΣΤΗ: ΤΣΑΛΑΠΟΡΤΑ ΠΑΣΧΑΛΗΣ
Α.Γ.Μ: 3034

Ημερομηνία ανάληψης της εργασίας:
Ημερομηνία παράδοσης της εργασίας:

Α/Α	*Ονοματεπώνυμο*	*Ειδικότης*	*Αξιολόγηση*	*Υπογραφή*
1				
2				
3				
ΤΕΛΙΚΗ ΑΞΙΟΛΟΓΗΣΗ				

Ο ΔΙΕΥΘΥΝΤΗΣ ΣΧΟΛΗΣ :


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SYSTEMS ON BOARD
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HISTORY

Throughout history mariners have gone to sea in all types of watercraft, and, more often than not, with very limited protection against the threat of shipboard fires. In the event of fire, persons ashore often have available the immediate assistance of well-trained firefighting professionals. Mariners are alone aboard ship, and. when fires occur at sea they must remain onboard and cope with these incidents to the best of their own abilities. These efforts, often because of lack of knowledge, training, and experience, have produced less than satisfactory results and at times have resulted in tragedy. Because of the many technological advances in ship design and operation, today's mariner must possess more knowledge than his predecessors in many special areas. Fire prevention, control, and extinguishment are one of these areas.

In 1851 the Steam Navigation Act was enacted, this marking was the beginning of government involvement in the safety and seaworthiness of ships. The monumental Shipping Act of 1894, still on the statute book and known in shipping circles as the Principal Act, was a milestone in maritime legislation and from it all present legislation stems. In 1949 the Safety Convention Act gave the government powers to prepare rules in respect of “inter alia” fire appliances and resulted in the promulgation of the Merchant Shipping (Fire Appliances) Rules 1952. As result of the international conference on Safety of Life at Sea held under the auspices of the Intergovernmental Maritime Consultative Organization in 1960, usually referred to as IMCO, these rules were superseded in due course by the Merchant Shipping (Fire Appliances) Rules 1965. These last named detail the arrangements and equipment necessary for fire detection, prevention and extinction which must, by law, be provided in all ships today.

INTRODUCTION

What is fire?

Fire is the rapid oxidation of a material in the exothermic chemical process of combustion, releasing heat, light, and various reaction products. The *flame* is the visible portion of the fire. If hot enough, the gases may become ionized to produce plasma. Depending on the substances alight, and any impurities outside, the color of the flame and the fire's intensity will be different.

Fire needs three elements to ignite. These three elements are:

Oxygen: When Oxygen in the air combines with flammable vapours given off by Fuels they create a form of heat at a molecular level. Then, a source of ignition (a match or spark, say) can cause it to combust. Without enough Oxygen, ignition cannot happen. In the opposite way, if there is too much Oxygen then the vapours won't be concentrated enough to ignite. The ratio of vapour to Oxygen is known as the 'explosive' or 'flammable' limit and is different for each gas or vapour.

Heat: Combustion occurs when flammable vapours mix with air (Oxygen) and are ignited by a spark or flame. Solids give off flammable vapours by being heated. Certain solids such as paper or flour appear to ignite almost instantly. This is because they give off vapours and reach a flammable temperature almost immediately. In fact, fine dusts dispersed in the air can explode because they give off vapours and ignite so quickly it appear to happen instantly. Other solids like timber take longer to ignite because they are more dense and so don't give off flammable vapours so easily. Liquids are a bit different to solids. They are a lot more runny for a start. But, where solids need to be heated to give off flammable vapours, some liquids give off vapours even in cold weather.

Fuel: Fuels can take almost any form: Solids like wood, fabric, rubber and plastic. Liquids such as petrol, oil, cooking oil or even nail varnish remover. Gases like propane, butane and 'natural' gas. Different fuels burn at different rates and with different intensities.

The above mentioned elements create the "fire triangle". Fire triangle in reality is a simple model for understanding the necessary ingredients for most fires.

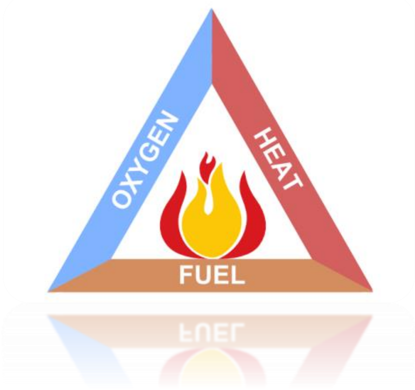


Fig. 1 Fire triangle

The Fire Triangle Theory has been accepted for many years. Today, this theory is modified to explain combustion or fire as a 4-sided figure, called a tetrahedron. A tetrahedron resembles a pyramid and offers a new element when considering combustion. The base of the pyramid represents the chemical chain reaction that occurs when the three other elements heat, fuel and oxygen are present in appropriate proportions. Vapors gases are released during the burning process and are carried into the flame. The heat from the flames drives the chemical reaction. Heat, fuel and oxygen are the three standing sides of the figure and all four elements must be present in order to support combustion.

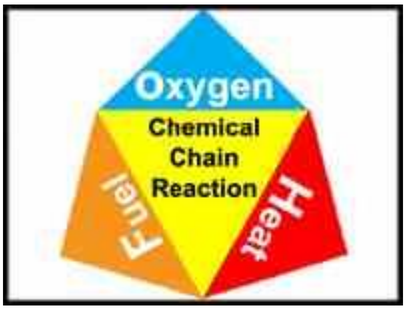


Fig. 2 Fire tetrahedron

CHAPTER 1

Classification of fires

The characteristics of fires and the effectiveness of extinguishing agents differ with the fuels involved. While particular extinguishing agents are very effective on fires involving certain fuels, they may be much less effective or even hazardous for use on other types of fires. Take for example, the use of a portable water extinguisher. Water is a good extinguishing medium and is very effective on deep-seated fires, such as burning wood or rubbish. However, a firefighter would not want to use a portable water extinguisher on a fire involving a "live" electrical panel or switchboard due to the conductivity of the water and the possible shock that could result. Considering the different types of fuels that may be involved in a fire, the different types of extinguishing agents available and the different mechanisms which the various agents use to extinguish a fire, it is important to be able to identify the type of fire on which a particular medium will be effective. The job of selecting the proper extinguishing agent has been made easier by the classification of fires into four types, or classes, lettered "A" through "D", based upon the fuels involved. Within each class are fires involving those materials with similar burning properties and requiring similar extinguishing agents. Thus, knowledge of these classes is essential to efficient fire-fighting operations, as well as familiarity with the burning characteristics of materials that may be found aboard a vessel.

CLASSES OF FIRES	TYPES OF FIRES	PICTURE SYMBOL
A	Wood, paper, cloth, trash & other ordinary materials.	
B	Gasoline, oil, paint and other flammable liquids.	
C	May be used on fires involving live electrical equipment without danger to the operator.	
D	Combustible metals and combustible metal alloys.	
K	Cooking media (Vegetable or Animal Oils and Fats)	

Fig. 3 Classification of fire and their symbols

FIRE PROTECTION

Any crew member may come across a fire in its early stages before the fire alarm system fitted has operated and by prompt and intelligent action using the portable or non-portable extinguishers immediately to hand (depending on where the fire is), he can avert a major conflagration. If the fire is in the machinery spaces and has gained a strong hold the use of the larger and more complicated fixed fire extinguishing system may ultimately be necessary, but in view of the necessity for abandoning and closing down the affected space, these would only be resorted to on authority of the master or chief engineer.

Such an operation would be generally be carried out under the supervision of one of the more senior officers, but this is no excuse whatsoever for the junior or uncertificated members not being familiar with the particular system fitted in their ship .It is also in his best interests to be equally familiar with the fixed fire extinguishing systems fitted in other parts of the ship external to the machinery spaces. Descriptions of the various systems available are given bellow, reference being made to the types of ship and spaces therein for which they are suitable.

CHAPTER 2

PASSIVE PROTECTION

Bulkheads and Fire Doors

In order to restrict the spread of fire the bulkheads and decks of a vessel are constructed to a particular standard. Various standards apply depending on the type of vessel and the nature of the space surrounded. Generally the fire resistance of a bulkhead is expressed as A, B or C followed by a number indicating the time that division will prevent a specified temperature rise.

Class "A" - A division constructed of steel or equivalent material and capable of preventing the passage of smokes or flame four one hour. Class "A" division bulkheads should be insulated with non combustile materials so that on the side opposite to a fire the average temperature will not rise more than 139 °C above the original temperature, nor more than 180 °C at any one point.

- Class "A-60" - must prevent the stated temperature rises for at least 60 minutes.
- Class "A-30" - must prevent the stated temperature rises for at least 30 minutes.
- Class "A-15" - must prevent the stated temperature rises for at least 15 minutes.
- Class "A-0" - must prevent the stated temperature rises for at least 0 minutes.

Class "B" - A division capable of preventing the passage of flame the first half an hour of the standard test. The insulation should be such that on the side opposite to a fire the average temperature will not rise more 139 °C above the original temperature nor more than 225 °C at any one point.

- Class "B-15" - must prevent the stated temperature rises for at least 15 minutes.
- Class "B-0" - must prevent the stated temperature rises for at least 0 minutes.

A Class "B" division must be constructed of approved non combustile materials except that combustile materials may be permitted provided they meet certain other requirements.

Class "C" - These divisions are constructed of approved non combustile materials. They do not need to meet the requirements for limiting the passage of smoke and flame nor limitations relative to temperature rise. Combustile veneers are permitted provided they meet other requirements.

Class "F" - A division primarily permitted on fishing vessels for insulated sub divisions. It is similar to class "B" but may be constructed from combustile materials.

Passenger ships

Passenger ships and ferries are required to be subdivided into main vertical zones bordered by bulkhead and decks constructed to Class A - 60. The bulkheads should extend from the double bottom to the highest deck. Passenger vessel must be divided into at least two vertical zones and in those carrying more than 36 passengers each zone must be not more than 40 meters in length. Where a passenger ship is constructed with a long vehicle deck this is treated as a horizontal zone and separated from the areas below and above by A - 60 de ks and bulkheads. Any vertical zone interrupted by such an horizontal zone should, as far as possible, be maintained in the same vertical line above and below. Fire resistance of doors and doorframes to bulkheads and decks is to be as far as practicable, at least equivalent to the bulkhead or deck in which they are fitted. Watertight doors need not to be insulated.

Cargo ships

The accommodation, services areas and control stations of cargo vessels, except tankers are to be protected by one of following methods:

- Method IC: The construction of internal divisional bulkheads of non combustible “B” or “C” class divisions generally without automatic sprinkler, fire detection and fire alarm systems in the accommodation and service spaces except there is to be a fixed fire detection and alarm system in all corridors, stairways and escape routes within accommodation spaces
- Method IIC: Generally there is no restriction on the type of internal divisional bulkheads, deckheads and linings but there is to be an automatic sprinkler, fire detection and fire alarm system for the protection of accommodation spaces, galleys and other service spaces except spaces which do not present a substantial fire risk (e.g void spaces, sanitary spaces, etc). In addition there is to be a smoke detection and alarm system in all accommodation corridors, stairways and escape routes

Method IIIC: Generally there is no restriction on the type of internal divisional bulkheads, deckheads and linings within a system of “A” and “B” class divisions. No area bounded by “A” or “B” class divisions should exceed 50m^2. However, a flag authority may consider increasing this area for a public space. There is to be a fixed fire detection and alarm system in all accommodation and service spaces, providing smoke

- detection in corridors, stairways and escape routes within accommodation areas, except spaces witch do not present a substantial fire risk (e.g void spaces, sanitary spaces, etc).

Tankers are to be constructed using only Method IC.

FIRE DOORS

Passenger Ships

<u>Doors in Class “A” bulkheads</u>

Each door must be capable of being opened and closed from both sides by one person only. The following summaries state the main requirements for fire doors in main vertical zone bulkheads, galley boundaries and stairway enclosures (other than power-operated watertight doors and those which are normally locked).

- Self-closing (up to 3.5° angle of inclination opposing the closure)
- Close in not more than 40 seconds and not less than 10 seconds
- If a sliding door the closing rate shall be between 0.1 and 0.2 m/sec.

- When held be open able to be remotely released from a manned central control position
- Able to be released from its hold back position on both sides of the door
- The release switches must incorporate a system that prevents automatic resetting of the system
- Hold back devices not controllable from the central station are not permitted
- If closed from the central control station it must be possible to re-open the door from both sides locally. After such opening the door must automatically close again
- Have an indication at the central control as to whether it is closed or open
- Automatically close in the event of a power failure power operated doors must be operable at least ten times using local power accumulators
- When released from a remote station a sliding or power operated door must have an alarm that sounds for between 5 and 10 seconds before the door begins to move and continues sounding until the door is completely closed. Doors to certain special category compartments do not require alarms

Doors in Class "B" bulkheads

- Ventilation openings ay be allowed in the lower part of the door
- Cabin doors are to be self closing without any hold back device.

Cargo ships

Doors in Fire-Resisting Divisions

- In "A" class divisions must be constructed of steel and doors in "B" class division must be non-combustible
- In boundaries of category A machinery spaces are to be self- closing and reasonably gas-tight
- Self-closing doors are not to be fitted with any hold back devise, unless is capable of remote release and of the fail safe type
- Ventilation is permitted through the lower part of beneath a door that leads between a corridor and a public space or cabin.
- Water tight doors are not required to be insulated

"SAFE RETURN TO PORT"

Vessels with more than 12 passengers, constructed after July 2010 and over 120m in length or with three or more main vertical zones are to be provided with a 'safe return to port' capability. That is, after a fire casualty that includes loss of the space of the fire's origin up to the nearest "A" class boundaries (this boundary is extended where the fire starts in a space that is not protected by a fixed extinguishing system) the ship must be able to proceed under its own power. If, following a fire any one main vertical zone is unserviceable system such as the fire main, internal and external communications, escape route lighting, and other specified system must remain operational for at least three hours in undamaged zones. For the above, cables and pies within an A-60 trunk are assumed to have remained intact while passing through the damaged vertical zone.

CHAPTER 3

ACTIVE PROTECTION

FIXED INSTALATIONS

Water-mist fire-extinguishing systems

A water mist system is an automatic water-based fire extinguishing system. Water mist is a fine spray with 99 percent of water volume contained in water droplets less than one millimeter (1,000 microns) in diameter. Water mist systems can be designed as a total flooding system protecting a large enclosure with sprinkler heads, spray heads, or nozzles placed at intervals. They can also be used for local streaming applications. This type of system has applicators or nozzles aimed directly onto a specific piece of machinery or equipment to be protected. In 1995, the EPA asked industry to evaluate water mist as a halon alternative. A health panel that was established determined that water mist systems did not present a health hazard to humans when used in occupied spaces. Using this information, the EPA listed water mist as a SNAP substitute**.**

Water divided into very fine droplets creates a greater surface area than standard droplets emitted from sprinkler system heads. Water mist system droplets can be 20 times smaller and have a surface area 400 times greater than sprinkler system water droplets. This enhanced area allows more of the water to absorb the heat from the fire. A greater amount of the water, therefore, will turn to steam, providing what is known as the “latent heat of vaporization.”When water changes from a liquid to a gas, it absorbs approximately 970 British thermal units (Btus) of heat energy per pound. Each gallon of water, which weighs approximately 8.3 pounds, will therefore absorb more than 9,000 Btus (energy required to raise each pound of water to 212°F plus the energy absorbed to change its state of matter). This drastically reduces the combustion rate. The steam will also occupy a much larger volume than if the droplet were in liquid form. The expansion ratio of gas to liquid is in the range of 1,700 to 1. Steam will also create an inert atmosphere as it displaces oxygen from the flame zone, thereby starving the fire of its oxidizing agent, yet another vital element of the fire triangle. Atomized droplets being discharged continue to remove heat from the fuel source even after the fire has been extinguished. This prevents flammable vapors from being emitted and keeps the fire from reigniting. These systems also absorb and scatter radiant heat, reducing the amount of energy projected onto the burning material as well as room contents. Water mist systems have been credited with enhancing visibility inside the fire enclosure. Atomized droplets have a unique smoke “scrubbing” quality that removes the soot from the smoke during the fire. Nozzle spray characteristics, nozzle spacing, ceiling height, smoke layer temperature, and the depth of the smoke are all factors that have to be taken into consideration when quantifying the amount of smoke that will be removed from the atmosphere. Water mist droplets have also been attributed with filtering out corrosive and toxic vapors generated by materials such as wood, plastics, and combustible liquids. Water mist atomized droplets, however, cannot remove insoluble toxic gases, such as carbon monoxide, which is generated in abundance during interior structural fires.

Water mist fire suppression systems have been extinguishing solid and liquid fuel fires since the mid-1950s. They have a wide range of applications against Class A fires (wood, cardboard, paper, cloth, textiles, rubber, and certain plastics Class B fires (liquid, fuel, oil, lubricant, alcohol, ether, grease, and gas) originating in boiler rooms, engine rooms, spray booths, machinery spaces, gas turbine areas Water mist is also effective in extinguishing fires involving energized electrical equipment, known as Class C fires electronics equipment, wiring, cable tunnels, transformers, circuit boards, electrical switchgear modules The shock hazard to firefighting personnel and occupants is negligible. Additionally, the “scrubbing” effect of water mist on carbon smoke particles helps to reduce soot residue damage to sensitive electrical equipment. Both total flooding and local application systems are used. Water mist local streaming application systems are also used on Class K fires, which involve commercial cooking and food-processing equipment that use vegetable oils.

Application

Total Flooding

Total flooding systems are designed with nozzles that discharge water mist throughout an enclosure to provide a uniform extinguishing concentration. Enclosure openings are typically installed with automatic closing devices that activate prior to the discharge of the extinguishing agent.

Local

Nozzles discharge water mist directly onto the equipment or material being protected. This type of application is ideal for outdoor protection, since it does not rely on an enclosure to contain the extinguishing agent during the course of fire suppression.

Zoned

This system segments the area to be safeguarded into spatial zones. Each zone has its own detection and activation components. A zoned system can provide more efficient use of a limited water supply. Zoned systems are used to protect sensitive equipment and valuables found in complex floor layouts and compartments. Applicators apply water directly onto the hazard for dependable fire suppression. A detection system that can determine the exact location of the fire as well as a piping control system capable of opening and closing valves in the water distribution piping is required.

System types

The **wet** system uses automatic nozzles attached to piping that is filled with water under pressure. Water discharges immediately from thermally activated nozzles. This type of system is fast and highly effective.

The **dry** system uses thermally activated automatic nozzles attached to piping that contains air, nitrogen, or inert gas under pressure. On activation of the nozzle, the dry pipe valve opens, allowing water to flow through system piping and out any activated nozzles

In the **preaction** system, the piping contains air that may or may not be under pressure. This system has a supplemental detection system that, when activated, opens a valve, allowing water to flow into the piping and discharge through the open thermally activated nozzles. Preaction systems provide an added safeguard against water accidentally being discharged into an area containing delicate and valuable commodities.

The **deluge** system also has a detection system. When the detector is activated, it supplies water throughout the piping system. In this system, all nozzles are non automatic and of open design. They work, however, by flooding the area to be protected with copious amounts of water from all the nozzles.

SYSTEM PRESSURE

The size of the water mist droplet depends on the nozzle's orifice design and pressure. Pressure allows the droplets to be projected over long distances so that the water reaches the seat of the fire. All three pressure systems—low, intermediate, and high—can be used for fixed (total flooding) and local (streaming) applications.

The water flows through the piping at pressures similar to those of the standard sprinkler type systems (175 psi or less). Low-pressure systems are used in large open-room areas and enclosures for total flooding protection as well as local applications.

Intermediate-Pressure Systems

Intermediate systems use pressure in the 175- to 500-psi range. Total flooding systems using intermediate pressure generate water droplets that provide good circulation and prolonged hang time throughout the protected space. These systems also demonstrate enhanced flame-cooling and oxygen-depletion characteristics

High-Pressure Systems

Their piping can withstand pressures greater than 500 psi. In general, this type of system requires fewer nozzles and less water to achieve successful fire suppression results than low- and intermediate-pressure systems. The high pressure generates substantially smaller water droplets at the nozzle than the other two systems, enhancing the surface area and heat-absorbing capacity of the droplets. As per Fss

Code the requirements about pressure tanks are: A pressure tank having a volume equal to at least twice that of the charge of water specified in this paragraph shall be provided. The tank shall contain a standing charge of fresh water, equivalent to the amount of water which would be discharged in one minute by the pump and the arrangements shall provide for maintaining an air pressure in the tank such as to ensure that where the standing charge of fresh water in the tank has been used the pressure will be not less than the working pressure of the sprinkler, plus the pressure exerted by a head of water measured from the bottom of the tank to the highest sprinkler in the system. Suitable means of replenishing the air under pressure and of replenishing the fresh water charge in the tank shall be provided. A glass gauge shall be provided to indicate the correct level of the water in the tank.

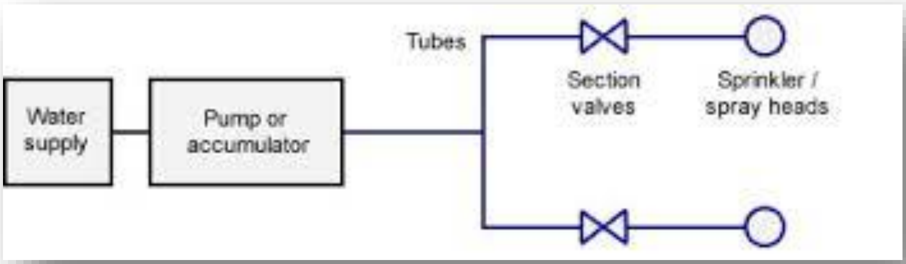


Fig. 4 Water mist system arrangement

SYSTEM COMPONENTS

Water Supply

Water mist systems must have at least one automatic water source. The minimum amount of water should be capable of supplying simultaneously the largest single hazard or group of hazards to be protected. In general, a water supply for a minimum duration of 30 minutes is required. Pre-engineered and specific-hazard systems may warrant a water supply duration of more or less than 30 minutes. Water may be found stored inside pressurized tanks, containers, or cylinders.

Compressed Gas Supply

When an atomizing medium (air, nitrogen) is used as part of a twin-fluid water mist system, it, too, should be automatically supplied from a dedicated source in concurrence with the water being delivered on the fire. Look for a nameplate or placard on or near the gas containers specifying the type of gas, the nominal gas volume, and the container's pressurization level.

Foam Additive Supply

Some water mist systems have an additive injection component to introduce Class A or Class B foam concentrate into the piping. A small amount of foam concentrate added to the water supply can significantly improve the water mist system's performance when suppressing buried ordinary combustibles and liquid fuel spill fires.

NOZZLES

Water mist nozzles are thermally activated, using quick-response glass bulbs that have operating temperature ratings from 135°F to 650°F. They are color coded based on their temperature classification. The nozzles incorporate a high-capacity filter to shield against impurities in the water. Nozzles are designed for use in accommodation and service spaces. Other types of nozzles do not use glass bulbs. They are opened by valves that can be activated manually or automatically by an electrical, hydraulic, or pneumatic signal. They consist of an assortment of nozzles of different sizes, depending on the fire hazard. Nozzles have total flooding and local applications.

PIPING

Water mist extinguishing systems use small-diameter, stainless-steel or copper/copper alloy piping. Filters and strainers are provided at each water supply connection or system riser.

PUMPS

Centrifugal fire pumps are used in low- and intermediate-pressure water mist systems. High-pressure systems require positive displacement pumps. These pumps will be driven by electricity, diesel fuel, or gas. Fire pumps for water mist extinguishing systems are designed to exceed flow rate and pressure demands by a minimum of 10 percent. Pump installations must have a metal plate that provides the rated capacity and pressure of each pump.

WATER SPRAY SYSTEMS

The accommodation and service spaces of a cargo ship are not required to be fitted with any form of fixed fire extinguishing system although a certain amount of structural fire protection is required under the Merchant Shipping (Cargo Ship Construction) Rules 1965. Improved methods of structural fire protection I cargo ships are presently under consideration at IMCO though.

Passengers ships of certain classes however when built to Method II construction referred to in Part V of the Merchant Shipping Rules 1965,or in fact, to one of the alternatives referred to in Chapter H of the International Convention for the Safety Of Life At Sea 1960, are required to have an automatic sprinkler and fire alarm system fitted for the detection and extinction of fire in all spaces in which a fire may be expected to originate. This incorporates a number of sprinkler heads which are supplied with water under constant pressure, and so arranged that every part of each space requiring protection is adequately covered. Each head has a glass or quartzoid bulb which retains a diaphragm seal in the outlet of the water pipe. This bulb is partially filled with a special fluid so arranged that a rise in temperature in the compartment concerned will cause the liquid to expand. When the liquid haw expanded and entirely filled the space, the bulb, being unable to withstand further pressure, bursts, the water pressure forces the diaphragm out and the water flows from the sprinkler. The usual temperature at which the bulb busts is 155^{o}F but special bulbs are available to burst at 79^{o} C and 93^{o} C for operating in hotter parts of ship. Under the specific pressure 5-5 to 8-3 bars (80 to 120 lb/in^2) maintained in the reserve tank by air pressure the water from the sprinkler is deflected upwards and outwards and broken into a fine spray by the serrated edge of the sprinkler base and will adequately cover a floor area of 12 m^2. As the pressure falls to the lower figure, the salt water pump starts automatically. Each installation is divided into convenient sections, generally containing not more than 200 sprinkler heads and each section has a control valve. When a sprinkler head comes into operation water pressure lifts the non-return valve thereby gaining access to the annular ports normally covered by the valve face. This allows pressure to build up in the alarm system and operate the trip switch, causing the alarm to sound on the bridge and indicate the section concerned.

For testing purposes a small valve is incorporated, and when this is opened it allows the same flow through the valve as a sprinkler head and confirms that the alarm system is in good order. This method may also be used to give the alarm if a small fire is discovered before the sprinkler heads into operation. The control valve must be open at all times except when sprinkler heads are being replaced so it is either locked open or has an electric alarm to show if it is inadvertently shut. The system is charged initially with fresh water to prevent corrosion, but the pump naturally supplies sea water so that when the system has been operated it must be drained, flushed though and refilled with fresh water. The system should be tested each week and to avoid contaminating the standing fresh water charge with sea water each time, a drain valve is fitted in the pump discharge line. By opening this valve and shutting the cock at the pressure operated switch and the pump discharge valve, the pump can be allowed to cut in automatically as required and discharge to the bilges.

Maximum Ceiling Temperature	**Temperature Rating**	**Temperature Classification**	**Color Code (with Fusible Link)**	**Liquid Alcohol in Glass Bulb Color**
100°F / 38°C	135-170°F / 57-77°C	Ordinary	Uncolored or Black	Orange (135°F / 57°C) or Red (155°F / 68°C)
150°F / 66°C	175-225°F / 79-107°C	Intermediate	White	Yellow (175°F / 79°C) or Green (200°F / 93°C)
225°F / 107°C	250-300°F / 121-149°C	High	Blue	Blue
300°F / 149°C	325-375°F / 163-191°C	Extra High	Red	Purple
375°F / 191°C	400-475°F / 204-246°C	Very Extra High	Green	Black
475°F / 246°C	500-575°F / 260-302°C	Ultra High	Orange	Black
625°F / 329°C	650°F / 343°C	Ultra High	Orange	Black

***Indicates the maximum ceiling temperature, nominal operating temperature of the sprinkler, color of the bulb or link and the temperature classification**.

FOAM SMOTHERING SYSTEMS

Foam

Foam is produced by the combination of three materials:

• Water

•Air

• Foam making agent

Foam Room

Foam is formed by first mixing the foam-making agent (foam concentrate) with water to create a foam solution. The actual foam bubbles are created by introducing air into the foam solution through an appropriate aerating device. The correctly chosen foam concentrate, when properly proportioned with water and expanded with air through an application device, will form a finished foam. The foam concentrate is required to be thoroughly mixed with water at a particular concentration to produce the foam solution needed to create the desired foam. Two of the most common concentrations are 3% and6% foams. These values are the percentages of the concentrate to be used in making the foam solution. Thus, if 3% concentrate is used, three (3)parts of concentrate must be mixed with 97 parts of water to make 100 parts of foam solution. If 6% concentrate is used, six (6)parts of concentrate must be mixed with 94 parts of water.

General principals of foam extinguishing system

Firefighting foam is used to form a blanket on the surface of flaming liquids. The blanket prevents flammable vapors from leaving the surface and prevents oxygen from reaching the fuel. A fire cannot exist when the fuel and oxygen are separated and therefore a properly placed foam blanket will smother the fire. In addition, the water in the foam also has a cooling effect, which gives foam the ability to cool surrounding structure to help prevent flash back. The ideal foam should flow freely enough to cover a surface rapidly, yet have adequate cohesive properties to stick together sufficiently to establish and maintain a vapor tight blanket. In addition, the solution must retain enough water to provide a long-lasting seal. Rapid loss of water would cause the foam to dry out and break down (wither) from the high temperatures associated with fire. The foam should also be light enough to float on flammable liquids, yet heavy enough to resist winds.

Foam must contain the right blend of physical characteristics to be effective:

•Knockdown Speed and Flow. The ability of the foam blanket to spread across a fuel surface or around obstacles and wreckage in order to achieve complete extinguishment is very important. The foam must have good cohesion properties to maintain the blanket affect yet at the same time not be so viscous to hinder the ability of the foam to flow over the area and form a self-supporting blanket.

•Heat Resistance. The foam must be able to resist the destructive effects of heat radiated from any remaining fire from the liquid's flammable vapor and any hot metal wreckage or other objects in the area.

•Fuel Resistance. An effective foam minimizes fuel pick-up so that the foam does not become saturated and burn.

•Vapor Suppression. The vapor-tight blanket is a critical function of a foam's ability to extinguish a fire. The foam produced must be capable of suppressing the flammable vapors to break the fuel-oxygen-heat fire triangle and to minimize the risk of re-ignition.

•Alcohol Resistance. Due to alcohol's affinity to water and because a foam blanket is more than 90% water, foam blankets that are not alcohol-resistant will be destroyed if used on alcohol-based cargoes

Types of foam

There are two basic types of foam, chemical and mechanical.

Chemical type: Chemical foam is formed by mixing together a solution of an alkali (usually sodium bicarbonate), an acid (usually aluminum sulfate), water and a stabilizer. The stabilizer is added to make the foam tenacious and long-lived. When these chemicals react, they form a foam or froth of bubbles filled with carbon dioxide gas. The carbon dioxide in the bubbles has little or no extinguishing value. Its only purpose is to inflate the bubbles. From 7 to 16 volumes of foam are produced for each volume of water. Premixed foam powders may also be stored in cans and introduced into the water during fire-fighting operations. For this, a device called a foam hopper is used. Or, the two chemicals may be premixed with water to form an aluminum sulfate solution and a sodium bicarbonate solution. The solutions are then stored in separate tanks until the foam is needed. At that time, the solutions are mixed to form the foam. Few chemical foam systems are still in use aboard vessels.

Mechanical type: Mechanical foam is produced by mixing a foam concentrate with water to produce a foam solution. The bubbles are formed by the turbulent mixing of air and the foam solution. As the name air foam implies that the bubbles are filled with air. Aside from the workmanship and efficiency of the equipment, the degree of mixing determines the quality of the foam. The design of the equipment determines the quantity of foam produced. There are several types of mechanical foams, similar in nature, but each has its own special fire-fighting capabilities. Types of mechanical foams include the following:

Protein Foam: Protein foams were the first types of mechanical foam to be marketed extensively and have been used since World War I. These foams are usually produced by the hydrolysis of waste protein material, such as protein-rich animal waste (i.e., hoofs and horns) and vegetable waste that is hydrolyzed (subjected to a chemical reaction with water that produces a weak acid). In addition, stabilizing additives and inhibitors, such as mineral salts, are added to prevent corrosion, resist bacterial decomposition, to control viscosity and increase their resistance to withering from the heat of a fire .At the time of a fire, the protein foam concentrates are mixed with fresh or seawater in 3% or 6% solutions. The foam concentrate can produce foam with all types of water, except water that is contaminated with oil. When antifreeze is added, foam can be produced in subfreezing temperatures down to -23.3°C (-10°F).

Fluoroprotein Foam (FP): Fluoroprotein foams are formed by the addition of special fluorochemical surfactants with protein foam (fluorinated compound bonded to the protein). This enhances the properties of protein foam by increasing foam fluidity (ease to flow) and improves the properties of regular protein foam by providing faster knockdown and excellent fuel tolerance. Fluoroprotein foam works well with dry chemical agents, and when the water is mixed with antifreeze, it produces foam in sub-freezing temperatures.

Film Forming Fluoroprotein Foam (FFFP): FFFPs are a combination of fluorochemical surfactants with protein foam. They are designed to combine the burnback resistance of a fluoroprotein foam with an increased knockdown power. These foams also release a film on the surface of the hydrocarbon.

Aqueous Film Forming Foam (AFFF): AFFFs are a combination of fluorochemical surfactants and synthetic foaming agents that create a unique characteristic –an aqueous film. This film is a thin layer of foam solution with unique surface energy characteristics that spreads rapidly across the surface of a hydrocarbon fuel causing dramatic fire knockdown. The aqueous film is produced by the action of the fluorochemical surfactant reducing the surface tension of the foam solution to a point where the solution can actually be supported on the surface of the hydrocarbon. AFFFs are more effective on hydrocarbons (fuels) with higher surface tensions, such as kerosene, diesel oil and jet fuels, and less effective on fuels with lower surface tensions, such as hexane and high octane gasoline's. AFFF's may drain foam solution (the water and foam concentrate mixture) rapidly from the foam bubble to produce optimum film formation for rapid fire extinguishment. To achieve these qualities, long term seal ability and burnback resistance are sacrificed.

Alcohol Resistant-Aqueous Film Forming Foam (AR-AFFF): Alcohol resistant foams are produced from a combination of synthetic stabilizers, foaming agents, fluorochemicals and alcohol resistant membrane forming additives .Polar solvents and water miscible fuels, such as alcohols, are destructive to non-alcohol resistant type foams. Alcohol aggressively mixes with the water in the foam and destroys the foam blanket and its fire-fighting properties .Alcohol resistant foams act as a conventional AFFF on hydrocarbon fuels, forming an aqueous film on the surface of the hydrocarbon fuel. When used on alcohol type fuels, the membrane forming additives form a tough polymeric (sometimes called mucoloid) membrane which separates the foam from the alcohol and prevents the destruction of the foam blanket. While some concentrates are designed for use on alcohol-type fuels at 6% and hydrocarbon fuels at 3%, today's newer formulations are designed to be used at 3% on both fuel groups. These newer formulations provide more cost effective protection of alcohol-type fuels, using half the amount of concentrate as a 3% 6% agent. The use of a 3 ×3 AR-AFFF also simplifies setting the proportioning percentage at an incident, since it is always 3%.Overall, AR-AFFF's are the most versatile type of foam available today, offering good burnback resistance, knockdown and high fuel tolerance on both hydrocarbon and alcohol fuel fires.

Synthetic Foam: Synthetic detergent-base foam is made up of alkyl sulfonates. This form has less burnback resistance than protein formulas, but may be used with all dry chemicals. It foams more readily than the proteins and requires less water. This is important where the water supply is limited.

Depending on his expansion foam dividing at three categories:

Low expansion foam: Low expansion foams are considered to be those foams with an expansion ratio of 12:1 when mixed with air. That is one volume if foam concentrate will create 12 volumes of foam. Low expansion foams are effective in controlling and extinguishing most flammable liquid (Class "B") fires. Foams typically used on tanker deck foam systems are of the low expansion foam type.

Mid low expansion foam: Mid expansion foams refer to those foams with an expansion ratio of between about 20:1 to 100:1. Few applications of mid expansion foams are found in shipboard applications.

High expansion foam: High-expansion foams are those that expand in ratios of over 100:1. Most systems produce expansion ratios of from 400:1 to 1000:1. Unlike conventional foam, which provides a blanket a few inches over the burning surface, high-expansion foam is truly three dimensional; it is measured in length, width, height, and cubic feet. High-expansion foam is designed for fires in confined spaces. Heavier than air but lighter than oil or water, it will flow down openings and fill compartments, spaces and crevices, replacing air in these spaces. In this manner, it deprives the fire of oxygen. Because of its water content, it absorbs heat from the fire and cools the burning material. When the high expansion foam has absorbed sufficient heat to turn its water content to steam at 100°C (212°F), it has absorbed as much heat as possible, and then the steam continues to replace oxygen and thus combat the fire.

FOAM FIRE FIGHTING APPLICATION TECHNIQUES

Bounce-off technique: When foam nozzles are used, particular care should be taken to apply the foam as gently as possible. For straight stream use, the foam should be bounced or banked off of a wall or other obstruction when available.

Bank-in technique: Foam can also be rolled onto the fuel surface by hitting the ground in front of the spill, and allowing the foam to "pile up" in front of the spill. The velocity of the stream will roll the foam onto the fuel.

Rain-down technique: The foam nozzle is directed almost straight up and the foam stream is allowed to reach its maximum

height and break into small droplets. The nozzle operator must adjust the altitude of the nozzle so the fallout pattern matches that of the spill area. This technique can provide a very fast and effective knockdown. However, if the fuel has had a significant preburn and a thermal column has developed, or if the weather is severe (high winds), the Rain down method may not be practical or effective.

LIMITATIONS ON THE USE OF FOAM

i) Because they are aqueous (water) solutions, foams are electrically conductive and should not be used on live electrical equipment.

ii) Like water, foams should not be used on combustible-metal fires.

iii) Many types of foam must not be used with dry chemical extinguishing agents. AFFF is an exception to this rule and may be used in a joint attack with dry chemical.

iv) Foams are not suitable for fires involving gases and cryogenic (extremely low temperature) liquids.

v) If foam is placed on burning liquids (like asphalts) whose temperatures exceed 100°C (212°F), the water content of the foam may cause frothing, spattering or slop over. Slop over is different from boil over, although the terms are frequently confused. Boil over occurs when the heat from a fire in a tank travels down to the bottom of the tank and causes water that is already there to boil and push part of the tank's contents over the side. Certain oils with a high water content, such as crude oil, have a notorious reputation for boil over. Slop-over occurs when foam, introduced into a tank of hot oil [surface temperature over 100°C (212°F)] sheds its water content due to the high heat. The water forms an emulsion of steam, air and the foam itself. The forming of the emulsion is accompanied by a corresponding increase in volume. Since tanks are three dimensional, the only place for the emulsion to go is over the sides of open tanks or into the vents of enclosed tanks.

vi) Sufficient foam must be on hand to ensure that the entire surface of burning material can be covered. In addition, there should be enough foam to replace foam that is burned off and to seal breaks in the foam surface.

ADVANTAGES OF FOAM

In spite of its limitations, foam is quite effective in combating Class

"

B" and some Class "A" fires and has

the following advantages:

i) Foam is a very effective smothering agent, and it provides cooling as a secondary effect.

ii) Foam sets up a vapor barrier that prevents flammable vapors from rising. The surface of an exposed tank can be covered with foam to protect it from a fire in a neighboring tank.

iii) Foam is of some use on Class "A"fires because of its water content. AFFF is especially effective, as are certain types of wet-water foam. Wet-water foam is made from detergents, and its water content quickly runs out and seeps into the burning material. It is not usually found aboard vessels; a more likely use is in protecting bulk storage in piers or warehouses.

iv) Foam is effective in blanketing oil spills. However, if the oil is running, an attempt should be made to shut down a valve if such action would stop the flow. If that is impossible, the flow should be dammed. Foam should be applied on the upstream side of the dam (to extinguish the fire) and on the downstream side (to place a protective cover over any oil that has seeped through).

v) Foam is the most effective extinguishing agent for fires involving large tanks of flammable liquids.

vi) Foam can be made with fresh water or seawater, and hard or soft water.

vii) Foam does not break down readily, and it extinguishes fire progressively when applied at an adequate rate.

viii) Foam stays in place, covers and absorbs heat from materials that could cause re-ignition.

x) Foam uses water economically.

x) Foam concentrates are not heavy, and foam systems do not take up much space.

FOAM SYSTEM EQUIPMENT

Proportioning Devices: All foam proportioners are designed to introduce the proper percentage of foam concentrate into the water stream. There are several varieties of proportioning systems available to the fire service today. The choices range from the more commonly-used and economical in-line eductors to Around-the-Pump systems to the sophisticated and more expensive Balanced Pressure systems.

Foam Nozzles: For the most effective and economical use, the foam solution must be properly expanded. Standard fog nozzles generally do not provide optimum expansion, and therefore, do not provide for the best, most cost effective application of the foam supply. In the case of Polar Solvent fuels, these standard fog nozzles may not deliver a foam quality that is able to extinguish the fire. Foam nozzles are specifically designed to air aspirate (expand) the foam solution and form finished foam. There are three main types of foam nozzles.

Low Expansion. Low expansion nozzles expand foam solution up to 12:1, i.e., for every 3.8 liters (1 gallon) of foam solution that enters the base of the nozzle, approximately 45.6 liters (12 gallons) of finished foam is produced. These nozzles draw air at the base of the nozzle, the air and the solution mix travel up the foam tube (this is called residence time) and the properly-expanded foam exits the nozzle.

Medium Expansion. Medium expansion nozzles can have expansion characteristics as high as 100:1, although expansions of 50:1 are more common. They operate in much the same way as low expansion nozzles. However, the diameter of the nozzle is much larger. High expansion foam nozzles can expand foam in excess of 100:1, when high expansion foam concentrates are used.

Foam Monitors: The foam monitors or turrets are permanently-installed foam discharge units capable of being aimed and projecting large quantities of foam substantial distances. They normally are mounted on a rotating base that allows the projection of foam in a 360-degree circle around the monitor platform. The angle of throw from the horizon can also be adjusted to facilitate flexibility in directing the foam to the fire. The foam solution is supplied to the monitor through a hard-piped foam main system that incorporates an expansion nozzle to aspirate the foam.

Applicators: Foam applicators are portable foam discharge devices supplied with foam solution through a hose from the hard-piped foam main. The applicators provide the flexibility to apply foam directly to specific locations or in a manner that the monitors may not be effective.

Valves and Piping: The foam solution is distributed from the proportioning device to the monitors or applicators through a system of pipes and valves. The piping system must be adequately designed to match the flow rates of the equipment, and a thorough understanding of the system control valves is critical for quick and effective operation of the system. A diagram of the piping system and control valves is typically posted in the foam supply room and identifies which valves are to be opened in the event the system must be activated. The diagram normally explains thoroughly and clearly all the steps necessary to put the system into operation. Color coding of the valves is also frequently used and aids in identification (e.g., all valves that are to be opened when a fire alarm is received might be painted some distinctive color). Each valve is also normally labeled as to its function, which helps in operating, restoring and maintaining the system.

Foam Concentrate Storage: The foam-concentrate is stored in tanks ready to supply the proportioning system. The concentrate tank should be kept filled with liquid halfway into the expansion dome to ensure prolonged storage life of the concentrate. The tank should be kept closed to the atmosphere, except for the pressure-vacuum vent. When a tank is partially empty, there is a larger liquid surface area to interact with air. This allows excessive evaporation and condensation, which degrade the foam concentrate and permit corrosion of the tank shell.

DECK FOAM SYSTEMS FOR TANKERS

Tankers over 4000 dwt must be provided with a fixed, low expansion deck foam system capable of delivering foam to the entire cargo tank deck and into any cargo tank the deck of which has been raptured. The foam is to be applied at a specified rate per square meter of deck but no less than 1250 ltrs per minute. Tankers over 20,000 dwt must also have an inert gas system protecting the cargo tanks. On oil tanker there is to be sufficient foam concentrate to ensure at least 20 minutes of foam generation, and should there still be any vessels without an inert gas system then thirty minutes foam generation is required. On chemical tankers there is to be sufficient foam for 30 minutes.

Foam from the fixed system is to be supplied by monitors and foam applicators. At least 50% of the foam supply is to be delivered by each monitor. In determining the number of monitors required to protect a tank deck the farthest point of coverage from each monitor is to be not more than 75% of the monitor throw in stillair. In practice a cross wind if only 10 knots may greatly affect the throw of a monitor, and a cross of 30 knots may reduce the effective monitor range to 1/3 of that achieved in still conditions.

The system will include hand held foam applicators and hoses and foam hydrants. The number and position of these must allow for at least two applicators to direct at any part oft he cargo tank cargo area but there must be atl east four applicators and hoses and each applicator must deliver not less than 400 ltr/min and have a range of not less than 15m in still conditions.

Oil tankers under 4,000 dwt may not require monitors but only applicators, each of which must have a capacity of at least 25% ofthe calculated foam solution rate. For chemical tanker under 4,000 dwt the minimum capacity of monitors must be to the satisfaction of the Administration.

Normally low expansion foam with a ratio not exceeding 12:1 is used, but medium expansion foam with a ratio of between 50:1 and 150:1 may be used if acceptable to the administration. The type of foam is to be effective against the risk presented by the cargo, and various main types.

The main components if the system include a water supply, foam concentrate storage, a water foam proportioning mechanism, a network of fixed distribution pipes and a method of delivery. The foam concentrate is stored in a tank fitted with vents, contents gauge, isolating valves and inspection access. Normally the foam is delivered by a foam pump and mixed with water via a balance pressure proportioner to form a foam solution although other systems such as bladder tanks and around the pump proportioning may also used. The foam solution delivered to the deck monitors and applicators by a network of fixed pipes. There are to be foam monitors and foam hose connections both port and starboard at the forward end of the poop or accommodation spaces facing the cargo tank decks. The rest of the cargo tank deck is normally provided with monitors situated along the centreline.

Oil Tankers	**Chemical Tankers**
The rate of supply of foam to the cargo tank deck should not be less than the greatest of the following	
0.6 ltr/min per sq. m. of cargo tanks deck area	2.0 ltr/min per sq. m. of cargo tanks deck area
6 ltr/min per sq. m. of the horizontal sectional area of the tank having the largest such area	20 ltr/min per sq. m. of the horizontal sectional area of the tank having the largest such area
3 ltr/min per sq. m. of the area protected by the largest monitor such area being forward of monitor	10 ltr/min per sq. m. of the area protected by the largest monitor such area being forward of monitor
1250 ltr/min	1250 ltr/min
Duration not less than 20 min. or not less than 30 min. if no I.G system	Duration not less than 30 min

Fixed Gas Fire-extinguishing Systems

Fixed gas fire-extinguishing systems typically suppress fires by reducing the available oxygen in the atmosphere to a point where combustion can no longer take place or by interrupting the chemical reaction necessary for the progression of the fire.

Advantages of fixed gas systems over water-based systems are that:

•Damage to sensitive equipment can be avoided, especially in the case of electronic equipment.

•Clean up time and equipment down time is substantially reduced.

Disadvantages are that:

•Some gaseous agents are hazardous to personnel.

•Cooling effect of gas systems is significantly less than water-based systems.

•Unlike the unlimited supply of water for fire-fighting systems, the quantity of gas available is limited to that carried in the cylinders protecting the space. Due to the above disadvantages, it is essential that fixed gas fire-fighting systems be deployed as quickly as possible to minimize heat buildup. Also, care should be taken to avoid the possibility of a fire being restarted due to dissipation of the fire-extinguishing gas and the introduction of fresh air from protected compartments being prematurely opened after a fire. In new installations, the most common fixed gas extinguishing systems encountered are either high/low pressure CO2 systems or those utilizing Halon "alternatives".

CARBON DIOXIDE EXTINGUISHING SYSTEMS

The advantages of carbon dioxide gas for fire extinguishing purposes have been long known. As early as 1914, the Bell Telephone Company of Pennsylvania installed a number of seven pound capacity portable CO2 extinguishers for use on electrical wiring and equipment. By the 1920's, automatic systems utilizing carbon dioxide were available. In 1928, work on the NFPA

Co2 Extinguishing System

Standard for carbon dioxide extinguishing systems was begun. The mechanisms by which carbon dioxide extinguishes fire are rather well known. If we go back to the familiar fire triangle, we realize that an interaction between fuel, oxygen and heat is necessary to produce a fire condition. When these three elements are present in a proper relationship, fire will result. Carbon dioxide extinguishes fire by physically attacking all three points of the fire triangle. The primary attack is on the oxygen content of the atmosphere. The introduction of CO2 into the fire zone displaces sufficient oxygen in the atmosphere to extinguish the open burning. At the same time, the extinguishing process is aided by a reduction in the concentration of gasified fuel in the fire area. And finally, CO2 does provide some cooling in the fire zone to complete the extinguishing process.
With a surface-type fire, that is, a fire which has not heated the fuel to its auto-ignition temperature much beyond the very surface of that fuel, extinguishment is rapid. Such surface fires are usually the case when liquid fuels are involved. Unfortunately, there is no guarantee that all hazards will produce surface fires.
In fact, a great many hazards are more likely to produce fires which will penetrate for some depth into the fuel. Such fires are commonly referred to as deep-seated. When dealing with a so-called deep-seated potential, it is necessary not only to remove the oxygen and decrease the gaseous phase of the fuel in the area, but it is equally important to permit the heat which is built up in the fuel itself to dissipate. If the heat is not dissipated and the inert atmosphere is removed, the fire may very easily reflash. For such hazards, it is necessary to reduce the concentration of oxygen and gaseous fuel to a point where not only is the open flaming stopped, but also any smoldering is eliminated. To accomplish this, the concentration of agent must be held for a sufficiently long time to permit adequate dissipation of built-up heat. The NFPA Standard 12 on carbon dioxide systems has long been a leader in prescribing thorough and conservative fire protection. The standard requires a mandatory 20-minute holding time, or soaking time, for any potentially deep-seated fire hazard. What this means is that the inerting concentration of carbon dioxide shall be maintained in a deep-seated hazard for a minimum of 20 minutes in order to permit cooling and complete extinguishment.

CO2 gas is an effective agent for class “A” (wood, paper, etc.), class “B” (flammable liquids and gases) and class “C” (electrical equipment) hazards as it displaces the oxygen necessary for combustion. The CO2 concentration must be maintained for a sufficient period to allow the maximum temperature to be reduced below the auto-ignition temperature of the burning material. Reduction of oxygen content to 15% is sufficient to extinguish most fires. Developing a CO2 concentration of 28.5% in the atmosphere will reduce the oxygen content to about 15%. However, the concentrations required normally exceed this amount in order to allow for possible escape of gas or infiltration of air, as well as to provide an adequate margin of safety. Carbon dioxide cannot be used on Class “D” (reactive metals, metal hydrides and chemicals containing their own oxygen supply) hazards, such as magnesium, potassium, sodium and cellulose nitrate. These Class “D” fires can only be controlled by special extinguishing agents and procedures.

AEROSOL SYSTEMS

Fixed aerosol fire extinguishing systems usually comprise a fine potassium powder held in a container or ‘generator’ until activation causes the powder to be dispersed as an aerosol around the protected space. In context, the term aerosol refers to a suspension of fine solid particles in a gas. the primary extinguishing mechanism is trough chemical interference which inhibits the chemical chain reaction within the fire. The potassium based extinguishant exhibits characteristics similar to gas extinguishants but remains in suspension for up to an hour.

There are two types of aerosol systems:

- *Condensed aerosols*: created in pyrotechnical generators through combustion. These systems require no pipe work or nozzles and the aerosol extinguishing units are placed directly on or in the risk being protected.
- *Dispersed aerosols*: not pyrotechnically generated, but stored in containers with carrier gases (such as inert gases or halocarbon agents) with the aerosol released in the space through valves, pipes and nozzles.

Advantages

- Small extinguishant quantity required an low weight
- No pressure vessels or pipe work required for condensed systems
- Does not generate toxic or corrosive products of decomposition
- Zero ozone depletion and zero global warming potential

- Simple installation
- Fast flame knockdown
- Good space penetration
- No oxygen displacement
- Safe for personnel
- Minimal machinery downtime and simple system replacement after release

Disadvantages

- Not proven for the protection of large spaces
- Visibility significantly obscured on release
- Not suitable for deep seated fires

Although the International Maritime Organization has issued SOLAS guidelines for the approval of fixed aerosol fire extinguishing systems there are no such systems approved for

the protection of large spaces. There is due in part to the difficulties with height and area limitation of these systems. However, some Administrations accept fixed aerosol extinguishing systems for the protection of small spaces.

POWDER SYTEMS

Vessels of any size, including ships of less than 500 ton gross, carrying flammable liquefied gases and certain chemicals in bulk must be provided with a dry chemical powder system for the fire protection of the cargo deck. The system must deliver powder from at least two hand held hose lines and/or monitors to any part of the deck including above deck product piping. The system must be activated by an inert gas (e.g nitrogen) designated exclusively for the purpose.

There are to be a least two independent self contained powder units, each with their own controls, pressurizing gas, piping, monitors and hand hoses/pistols. Vessels of under 1000 m^3 cargo capacity may require only one unit, subject to the approval of the flag authority. Ships with bow or stern loading areas arrangements will have that area protected by an additional powder unit and at least one monitor and one hand hose line.

A monitor must protect the cargo loading and discharge manifolds areas. The system must be capable of being operated locally (at the powder storage location and remotely at each hose and monitor position) although remote aiming is not necessary if the required area of protection is covered from its fixed position. At least one handheld hose line and pistol or monitor should be situated at the after end of the cargo area. Monitor capacity is to be less than 10 kg/s with a maximum distance of coverage as the table below. Handheld hose lines may be up to 33m in length, discharge at a rate on not less than 3.5 kg/s and must be operable by one person. Each powder unit is to contain sufficient extinguishant to provide not less than 45 seconds of continuous discharge from all monitors and handheld hoses fed by it.

Fixed monitor capacity each	**10 kg/s**	**25 kg/s**	**45 kg/s**
Maximum distance of coverage	10 m	30 m	40 m
The reach of dry chemical from a hose line is considered equal to the length of hose as it has no effective jet			

FIRE WATER MAIN AND PUMPS

The fire water system which must be able to deliver an immediate supply of water to all areas of the ship, comprises fixed dedicated pumps, distribution pipes control valves and portable hoses and nozzles. Design considerations include avoiding the possibility of freezing, suitable drainage, isolation valves and accessibility and protection of hydrants even when deck cargoes are carried.

Availability of water supply

Passenger ships

- Ships of 1000 grt and over must have at least one jet of water immediately available from any hydrant in an interior location. To ensure the continuation of the supply one of the required fire pumps is to start automatically.
- Ships of less than 1000 grt must have at least one fire pump start automatically or by remote operation from the bridge
- The size of the fire main is to permit effective distribution of the maximum required discharge from two fire pumps operating simultaneously

<u>Cargo ships</u>

- The availability of water supply must be to the satisfaction of the Administration
- In ships with periodically unattended machinery spaces or when only one person is on watch there is to be immediate water delivery either by remote starting of one of the main fire pumps from the bridge and fire control station or permanent pressurization of the fire main by one of the main fire pumps.
- In vessels of less than 1600 grt the Administration may accept fire pump starting arrangements in the machinery space if the space is easily accessible
- The size of the fire main is to be sufficient for a discharge of 140 m^3/h
- The required fire pump capacity and fire main size and pressure are not to be limited to the basic requirements when they are used as part of a water spray system but increased as required by the prevailing regulation.

Hydrants

Hydrants are to be located so that at least two jets of water (not from the same hydrant) one of which is a single length of hose can be directed to any part of the ship normally accessible to passenger or crew and any part of a cargo space when empty. In passenger ship in accommodation and service spaces the requirements for two jets of water is to be met when all watertight doors and all doors in main vertical zone bulkheads are closed. Also for passenger ships there are additional requirements relating to the provision of hydrants at the accesses to category A machinery spaces.

Vessels carrying dangerous goods must be capable of supplying four jets of water to any part of the cargo space when empty. This amount of water may be applied by equivalent means if agreed by the administration. The number and position of the hydrants must be such that at least two of the required of the four jets when supplied from single lengths of hose may reach any part of the cargo space when empty and all four jets each supplied by single lengths of hose may reach any part of ro-ro cargo spaces. SOLAS specifies maximum hose lengths for vessel constructed after July 2002 but older vessels may have hoses of different maximum lengths.

With two pumps running and delivering the quantity of water as stated above a minimum water pressure is to be maintained at all hydrants. But the pressure must not be so high that fire fighters have difficulty in controlling a fire hose. Each hydrant must me fitted with a valve so that fire hoses may be disconnected while the fire main is pressurized.

Fire pumps

In addition to independent fire pumps sanitary, ballast, bilge or general purpose pumps may be used as fire pumps provided they are not normally used for pumping oil. However if they are occasionally used in this manner (e.g bunker transfer) suitable change over arrangements must be fitted.

Independently driven fire pumps must be provided as follows:

Passenger ships

- Ships of 4000 grt and over – at least 3 independently driven pumps
- Ships of less than 4000 grt - at least 2 independently driven pumps
- Ships of 1000 grt and over – fire in any one compartment must not be able put all the pumps out of action
- In ships of less than 1000grt – if fire in any one compartment could put all pumps out of action there must be an alternative emergency fire pump with its power source and sea connection outside of the space where the main fire pumps or their power sources are located.

Cargo ships

- Ships of 1000 grt and over – at least 2 independently driven pumps
- Ships of less than 1000 grt - at least 2 power-driven pumps one of which must be independently driven
- All cargo ships – if fire in any one compartment could put all pumps out of action there must be an alternative emergency fire pump with its power source and sea connection outside of the space where the main fire pumps or their power sources are located.

Emergency Fire Pump

An Emergency Fire Pump

Emergency fire pumps are not required on passenger ships of 1000 grt and over as they are required to locate one of their dedicated fire pumps in a separate compartment from the other(s). However, smaller passenger ships and all cargo vessels must be provided with a fixed independently driven, power-operated emergency fire pump. The emergency fire pump must have a capability of at least 40% of the total capacity of the fire pumps required for the fire main supply but in any case not less than:

- For passenger ships of less than 1000 grt – 25 m^3/h
- For cargo ships of 2000 grt and over – 25 m^3/h
- For cargo ships of less than 2000 grt – 15 m^3/h

When delivering these quantities of water the pressure required at the hydrants is not to be less than that required by the regulations.

The space in which an emergency fire pump is located should not have a common boundary with any A class machinery space or other space containing main fire pumps. But where this is not practicable the common bulkhead is to be insulated to the standard required for a control room. There is not to be any direct access between the machinery space and the space containing the emergency fire pump and its power source. However, if this is not practicable access may be permitted via an airlock or watertight door subject to other stringent consideration. In such cases a second access to the space containing the emergency fire pump is required

Any diesel driven emergency fire pump must be capable of being capable of being readily started by manual cranking fro cold even if the temperature is 0°C. If lower temperatures are likely suitable heating arrangement should be provided. If hand starting is not practicable alternative means are permitted provided the engine can be started at least six times within a period of 30 minutes and at least twice within the first ten minutes. The service fuel tank of any emergency fire pump must be enable the pump to run on full load for at least three hours. These must also be sufficient fuel available outside of category A machinery spaces to enable the pump to run on full load for at least another 15 hours.

HOSES, COUPLINGS AND NOZZLES

Hoses

Standard fire hoses are constructed from non-perishable material. Typically this may be woven polyester internally lined with a synthetic rubber to give a smooth low friction bore. The hose may be externally coated to provide additional abrasion resistance. Other higher quality hoses comprise an all synthetic woven textile reinforcement encased in a PVC/Nitrile rubber which forms a unified lining and outer cover. Fire hoses must be a sufficient length to project a jet of water to any of the spaces in which they may be required to be used and each hose must be provided for each hydrant there is to be complete interchangeability.

SOLAS Requirements

In passenger ships there should be at least one hose for each hydrant and these hoses shall be used only for fire fighting or fire fighting training. In interior locations on passenger ships carrying more than 36 passengers' fire hoses shall be connected to the hydrants at all times. Cargo ships over 1000 GT must have one hose for each 30m length of the vessel plus one spare but no less than five hoses and in some cases Administration may increase the number of hoses required. The number of hoses required in vessels of less than 1000 GT will be calculated in a similar way but should not be less than three. For vessels constructed after July 2002 the permitted minimum length of hose is 10 m and the maximum is

- Not more than 15m for machinery spaces
- Not more than 20m for other spaces & open deck
- Not more than 25m for open decks of ships with a maximum breadth in excess of 30m

Hoses, which are to be kept ready for use in conspicuous positions near to water service hydrants or connections, may be stowed rolled, Dutch rolled or flaked.

Couplings

Firefighting hoses are joined together and connected to the hydrants by couplings. There are many different types of coupling all of which are incompatible unless a suitable adapter is available. Most commonly on British vessels are found 2 ½ (65mm) inch *Instantaneous* couplings which also available in 50, 70 and 100 mm.

On other European vessels *Storz* couplings are mainly used, Storz 'C' is the size that we met usually.

Other types of couplings that frequently we found is Russian ROTT, Russian GOST, British Nunan and Stove, Swedish SMS, Japanese Nakajima and Norwegian Nor couplings.

Nozzles

When in use the discharge end of the hose will be fitted with a nozzle so that the operator may control the manner in which water is projected at a fire. In jet mode they must be capable of producing a plain jet without spread and have a throw of at least 12m. the spray must produce a reasonably fine spray which can form a curtain from behind which it is possible to approach a fire. The spray pattern would have a diameter of 5m at a distance of 2m from the nozzle.

SOLAS Requirements

Standard nozzle sizes are 12mm 16mm and 19mm although larger sizes may be permitted. For accommodation and service spaces and exterior locations the nozzle size shall be as to obtain the maximum discharge possible from two jets at the required pressure from the smallest pump but nozzles of greater than 19mm need not to be used. They must be of the adjustable spray/jet type and include a shut-off facility.

HOSE REEL UNITS

Hose reel units are not specifically mentioned in SOLAS or the FSS Code but may be found in accommodation alleyways and in some service spaces. Where they are provided the Administration may specify that they must be in addition to the hydrants and hoses required by the regulation as the latter would still be required when fighting a larger fire. However some Administration may consider the use of those reels for statutory purposes on the basis that two hose reel together with one hose and nozzle of regulation size would provide the equivalent throughput of two jets of water required by the regulations. The Administration may also require that such concession be subject to the hose reels having appropriate throughput pressure and throw and that they are at all times connected to the ship's fire main and under pressure at least as great as that required by the regulations.

Hose reel units may be fixed or hinged. Often they are recessed into alleyway bulkhead and may be concealed behind a solid or glass fronted door. In any event their locations should be clearly identified by the appropriate signs. Hoses are non-collapsible and usually of 19mm or 25mm bore.

Being on a reel they are easily run out and brought into use and usually have a bending radius much smaller than other types of fire hose. They will be permanently connected to the water supply and may be automatic or manual. In the automatic version the water supply valve is opened as the hose is withdrawn from the reel and the delivery controlled by use of the nozzle. This allows one person to attack any small fire without delay.

FIRE DETECTION & ALARMS SYSTEMS

FIXED FIRE DETECTION AND ALARMS SYSTEMS

A fire detection system is designated to detect rapidly the onset of fire and give early warning of the situation, so as to provide the crew with the best possible chance of controlling and extinguishing a fire, before it can destroy property, the ship and even lives. The system comprises a central control and monitoring panel, possibly with repeater panels, a combination of heat, smoke and flame detectors, manually operated alarm call points and alarm sounders and warning lights. In passenger ships the system must be capable of remotely and individually indentifying each detector and manually operated call point. The system may be fairly simple or more complex with addressable detectors, and computerized control, and it may not be used for any other purpose, except that closing fire doors and similar functions may be permitted at the control panel

There are to be at least two separate power sources, one of witch is taken from the emergency supply, which must be engage automatically in the event of a main failure. The system is to be operable at all times , with the power supplies and electric circuits continuously monitored for failure or fault. The control panel is located either on the bridge or at the main fire control station. Detectors and manually operated call-points are grouped in sections, and activation of any unit initiates an audible and visual alarm at the control panel and indicating units. If alarm is not acknowledged within two minutes then audible alarms are activated through the crew accommodation, control stations and main machinery spaces.

Conventional Systems

In a typical Conventional Fire Alarm System the ‘intelligence’ is within the control panel. The detectors are arranged in ‘zones’ and each detector will be in one of two states: either normal or alarm. When the control panel receives an alarm from a convectional detector or calls point it initiates the audio and visual alarms and indicates in which zone the detector is located.

Addressable Systems

An analogue Addressable Fire Alarm System is more versatile than a conventional system, and differs in a number of ways. An addressable system is more ‘intelligence’ is able to speedily identify the detector or call point in alarm and it has wider control possibilities, making it more suitable for larger more complex systems. Each detector has its own unique identification. The control panel communicates with each detector and call point individually, constantly monitoring its status. As each detector and call point is individually identifiable its status can be displayed at the control panel and the precise location of an alarm immediately known. Arranging the detectors in zones is not technically necessary but is done for convenience. Addressable detectors are themselves intelligent and be to communicate more than just fire or fault. Most are able to indicate if dust contamination within the device has reached a pre-set level, provide pre-alarm warnings when smoke or heat levels reach a pre-set threshold, so enabling investigation of a possible fire prior to initiating a full evacuation alarm.

Linear heat detectors

Types of line heat detectors include pressurize tubing, cables that contain dielectring materials, fiber optic cables and other systems. Linear heat detection may be found on cable trays, supply tunnels, deck head voids, areas of difficult or impossible access, and environments where smoke detection would not be suitable. Linear heat detection detects heat conditions anywhere along its length and are available in a range of alarm temperatures to suit various fire detection applications.

Intrinsically safe systems

Areas where an explosive mixture of air and gas vapour may be present either continuously or occasionally are liable to ignite or explode so all electrical equipment inclunding fire detection systems and detectors, must be designated and installed so as not to ignite any explosive mixture, not only in normal operation but also in fault conditions. Such hazardous areas are common on oil, chemical and gas carriers and in stores where solvent or volatile substances are kept. Most commonly electrical safety is achieved by use of intrinsic safety. Intrinsically safe equipment and systems operate at electrical and thermal energy levels incapable of causing ignition.

Machinery Spaces

Fire detection and alarm systems must be fitted in:

- Periodically unattended machinery spaces
- Machinery spaces where:
  - Automatic and remote control systems have been installed in lieu of manning the space continuously and
  - The main propulsion, associated machinery and sources of electrical power are provided with various degrees of automatic or remote control and are under continuous manned supervision from a control room

Accommodation, service spaces and control stations

Accommodation spaces: Smoke detectors are to be installed in all stairways, corridors and escape routes within accommodation spaces. Consideration must be given to installing special purpose smoke detectors within ventilation ducting.

Ships carrying more than 36 passengers: Smoke detection and alarm is required in service spaces, control stations and accommodation, including stairways, corridors and escape routes within accommodation spaces. Smoke detection need not to be fitted in private bathrooms and galleys or spaces having little or no fire risk, such as public toilets, CO_2 cylinder rooms and similar spaces.

Ships carrying not more than 36 passengers: There is to be throughout each separate fire zone, in all accommodation and service spaces and in control stations, but excepting those spaces which afford no substantial fire risk either: A fixed fire detection and alarm system, including smoke detection in corridors stairways and escape routes within accommodation spaces or an automatic sprinkler, fire detection and alarm system and a smoke detection system in corridors, stairways and escape routes within accommodation spaces.

Ships carrying more than 12 passengers built from January 2010

These vessels must have a fire detection and alarm system capable of remotely and individually identifying each detector and manually operated call-point. Detectors in cabins must also initiate an audible alarm within the space where they located.

Cargo ships

Accommodation, service and control rooms are to be protected by a fixed fire detection and alarm system and/or an automatic sprinkler, fire detection and alarm system as follows, depending on the protection method adopted

- Method IC: A fixed fire detection and alarm system in all corridors, stairways and escape routes within accommodation spaces.
- Method IIC: An automatic sprinkler, fire detection and fire alarm system for the protection of accommodation spaces, galleys and other service spaces except spaces which do not present a substantial fire risk (e.g void spaces, sanitary spaces, etc). In addition there is to be a fixed detection and alarm system in all accommodation corridors, stairways and escape routes.
- Method IIIC: There is to be a fixed detection and alarm system in all accommodation and service spaces, providing smoke detection in corridors, stairways and escape routes within accommodation areas, except spaces witch do not present a substantial fire risk (e.g void spaces, sanitary spaces, etc).

Cargo spaces in passenger ships

A fixed fire detection and alarm system or a sample extraction smoke detection system is to be provided in any cargo space which is not accessible, except there may be exemptions for vessel on short voyages.

TYPE OF DETECTORS

Heat Detectors

Top temperature / rate of rise detectors give an alarm when the detected temperature exceeds a fixed limit. Normally this will be between 54 and 58 ^{o}C . However detectors with a higher temperature rating may be used in areas of ambient temperature such as drying rooms (Max. 130 ^{o}C) and saunas (Max. 140 ^{o}C). The detectors will alarm at lower temperature if the rate of increase in temperature is more than 1 ^{o}C per minute.

Ionization smoke detectors

An ionization smoke detector uses a low activity radioactive foil to detect fires by irradiating the air in the smoke chamber and causing a current flow. If smoke enters the chamber the current flow is reduced leading to an alarm.

Optical smoke detectors

These use a light source to determine obscuration or light scatter caused by smoke particles entering the chamber. More advanced units use laser technology. They are capable of detecting the visible smoke produced by materials which smoulder or burn slowly, i.e. soft furnishings, plastic foam etc. or smoke produced by overheated but unburnt PVC.

Photo thermal detectors

In this type of detector the status of the optical chamber is monitored and compared with the heat sensing element. The alarm signal is sent when the comparison indicates a fire situation. The system is able to discriminate between smoke from fires and smoke from other sources such as cigarettes or steam and reduces the incidents of false alarms.

Flame detectors

The infrared (IR) and ultraviolet (UV) bands of the electromagnetic spectrum may be used for flame detection, but more commonly it is infrared flame detectors that are found on board. A UV flame detector has a single sensor with a narrow spectrum response, which helps to discriminate between flames and other causes of radiation. IR flame detectors in order to discriminate between flames and other causes of radiation operate on more than one wavelength. They respond to electromagnetic radiation resulting from the burning of carbon and hydrocarbon materials and to the flame flicker frequencies. The units should be immune to false alarms caused by solar rays. If hydrogen is a particular risk a particular type of flame detector will be required.

Beam detectors

Beam detectors are used to protect large open spaces such as auditoriums. An infra red light beam is projected 30-60 cm below and parallel to the deckhead and directed to a receiver on the other side of space to a reflector which returns the beam to a receiver located in the same unit as the transmitter. They can protect spaces up to 100m long. If it is not possible to mount the receiver opposite to the transmitter they may both be fitted to the same bulkhead and a reflector provided at the opposite end of the space. In clear air the receiver registers all the light sent by the transmitter. Smoke from a fire would rise and obscure a portion of the light. This decrease in the amount of light registered causes the beam detector to initiate an alarm.

POSITIONING OF DETECTORS

Detectors must be positioned to give the best performance. Positions near beams, ventilation ducts and other positions where patterns of air flow could adversably affect performance and positions where damage is likely must be avoided. Detectors mounted overhead must be a minimum of 0.5m from bulkheads except in corridors lockers and stairways. The maximum spacing of detectors is to be as shown below unless different spacing is permitted or required by the Administration.

Type of detector	Maximum deck area as per detector	Maximum distance between centers	Maximum distance from bulkheads
Heat	37 m^2	9 m	4.5 m
Smoke	74 m^2	11 m	5.5 m

Smoke detectors are to be found in accommodation stairways, corridors and escape routes. Flame detectors may be used in addition to smoke and heat detectors but not in lieu of them. The sections of a fire detection system which include accommodation and/or service spaces may not include category A machinery spaces. There are additional requirements regarding the installation of fixed fire detection systems in unattended machinery spaces, cargo holds, special category spaces and ro-ro decks.

Detectors must be tested periodically by hot air or smoke simulation.

Manual call points

In addition to the detectors manually operated call points are installed through the accommodation, service spaces and control stations. There is to be one call point at each exit and in the corridors of each deck so that no part of the corridor is more than 20 m far from a call point.

CHAPTER 4

FIRE EXTINGUISHERS

A portable fire extinguisher is a hand held, pressurized vessel designed to attack a fire in the early stage. The fire fighting medium stored within an extinguisher will be water, foam, dry powder, wet chemical or carbon dioxide (CO_2) which when in use is expelled under pressure to either smoother, cool or chemically interfere with the fire or extinguish it by combining two or more of these effects.

Extinguishers colour coding

The main body of an extinguisher will normally be red and it may also colour coded to indicate the type of extinguishant contained within. If there is a colour code it may be by a block of colour on the body of the extinguisher or a colour coded handle. Some older extinguishers may have the entire body appropriately coloured and some vessels may have extinguishers that are red without any colour coding in this case it is necessary to read the instructions to determine the extinguisher contents.

RED=WATER	**CREAM=FOAM**	**BLACK=CO_2**
BLUE= DRY POWDER	**YELLOW=WET CHEMICAL**	

Other markings

The symbol for electrical hazard will be shown on those extinguishers whose contents are safe to use on fires involving all types of electrical equipment.

All extinguishers capable of extinguishing classes A,B and F fires carry a fire rating which is indicated by a number and letter (e.g 13A, 55B). These numbers denotes the size of fire it can extinguish under test conditions, the larger number the larger the fire it can extinguish. Two extinguishers that looks the same may have different ratings because an additive to the extinguishant can significantly increase its effectiveness. The letter indicates the fire classification. Some extinguishers like Dry Powder carry both a class A and B rating because of the properties of the extinguishing medium. There are no specific performance tests for fires C an D.

Extinguisher design

Extinguishers containing water, foam, dry powder or wet chemical may be similar in appearance, except that they will be clearly labeled and may be colour coded so that the content may be easily identified and they all operate on the same principal. In each case the medium is stored in a welded container. When the valve is opened CO_2 or nitrogen gas exerts a downward pressure on the extinguishing medium forcing it up a siphon tube and out through the delivery hose or applicator. The discharge will be controlled by either squeezing and releasing the operating head valve or by a control lever at the end of the discharge hose.

Choosing the correct extinguisher

The most appropriate extinguisher should be found near any risk but this may not always be the case, especially where is more than one risk in the same area. For instance, in a Control Room there may be hydraulics, computers and other electrical equipment, papers and books. If the wrong type of extinguisher is used on a fire the already serious situation may be made considerably worse. It is important that every crew member is familiar with the advantages and limitations of each fire extinguisher and its method of use.

WATER

Suitable for use on Class A fires

Extinguish effect: water extinguishes by absorbing the heat and so cooling the fire. It has a greater cooling effect when applied as a fine spray or mist. There is also some smothering effect from the steam generated by the application of a fine spray or mist. Sprays may have surfactants added (these reduce surface tension and assist in forming a uniform distribution) to aid the penetration.

Limitations: do not use on fires involving liquid (oils, paints, cleaning fluids, etc.) or on fires where there is live electricity in the vicinity.

FOAM

Standard foams are suitable for use on liquids spills and contained liquid fires of oils, paints, cleaning fluids, etc. and fires involving liquefiable solids such as fats and waxes (Class B) but standard foams are not suitable for use in cooking oil fires (Class F) where high temperature achieved.

Extinguish effect: a foam blanket is formed over the burning material which suppresses hazardous vapours and excludes the air. The water in the foam provides a cooling effect.

Limitations: do not use on fires where there is live electricity in the vicinity, unless the extinguishers specifically states that is safe to do so.

Foam Extinquisher at stowage position

DRY POWDER

The type of powder known as BC Powder is suitable for use on liquids and liquefiable solids (Class B). BC Powder may also with the correct technique be used to extinguish a high pressure gas flame (Class C). Additionally ABC Powder or Multi-Purpose Powder may be used against carbonaceous fires (Class A). Dry Powder gives a fast flame knockdown and may be used on fires involving live electrical equipment.

Extinguish effect: Dry Powders extinguish by interference (interruption of the chemical chain reaction which sustains the fire) and it is this which gives the fast flame knockdown. There is some heat absorption by the decomposing powder.

Limitations: May not penetrate deep into electrical equipment and not effective against a deep-seated smouldering fire. ABC powders should not be used on electrical equipment as the residue may damage contacts and components parts. Do not use on deep fat fryers. No sealing effect and minimal cooling effect. Poor inspection and maintenance may result in the powder compacting within the extinguisher and impair or negate its effectiveness in use. Avoid inhalation of powder.

WET CHEMICAL

Suitable for use on cooking oil fires (Class F) and also on carbonaceous fires (Class A).

Extinguish effect: The spray from the extinguisher has a cooling effect and by interaction with the burning fat forms soap like layer over the surface to exclude the oxygen.

Limitations: The conversion into soap works only with animals fats and vegetable oils so the Class F extinguisher is not suitable for tackling Class B flammable liquids. Do not use on fires where there is live electricity in the vicinity, unless the extinguishers specifically states that is safe to do so.

CARBON DIOXIDE (CO_2)

Suitable for use on Class A & B fires when in liquid state (e.g liquid gas leak such as methane, propane, butane, acetylene or hydrogen). Safe for use on fires involving electricity.

CO2 Fire Extinguisher

Extinguish effect: Carbon dioxide excludes the air from the fuel to extinguish the fire.

Limitations: Do not use without a horn as the discharge will the entrain air and cause an increase in the intensity of the fire. Hold only the insulated parts of the discharge hose and horn as with the expansion an evaporation of the CO_2 there are cooling processes and a larger of frost burn if the extinguisher is not correctly held. If using a CO_2 extinguisher in an explosive atmosphere stand it on the ground to ensure any electrostatic change is dissipated without arcing. Do not remain in the area after the discharge as CO_2 is asphyxiating. CO_2 may not be effective when used outside especially in a breeze and has no cooling effect.

SOLAS Requirements

- A powder or CO_2 extinguisher is to have a capacity of at least 5 kg and a foam extinguisher a capacity of at least 9 litres. The mass of any portable extinguisher must not exceed 23 kg.
- Accommodation spaces, service spaces and control stations are to be provided with portable fire extinguishers of appropriate types and in sufficient number. Vessels of 1000 grt and over are to have at least fine portable fire extinguishers.
- One of the portable fire extinguishers intended for use in a space must be stowed near the entrance to that space and it is recommended that the remaining portable extinguishers in the public spaces and workshops be located at or near the main entrances and exits.
- If a space is locked when unmanned portable fire extinguishers required for that space may be kept inside or outside the space
- CO_2 extinguishers must not be placed in accommodation spaces.
- In control stations and other places containing electrical equipment necessary for the safety of the ship, fire extinguisher media shall be neither electrically conductive nor harmful to the equipment
- Fire extinguishers are to be situated ready for use at easily visible places, which can be reached quickly and easily at any time in the event of fire. Their serviceability must not impaired by the weather, vibration and other external factors.
- Fire extinguishers are to be provided with devices which visually indicate whether they have been used.
- For each type of extinguisher able to be recharged on board, spare charges must be carried as follows: 100% for the first ten extinguishers and 50% for the remaining extinguishers but no more than sixty spares charges are required. For extinguishers which cannot be recharged on board additional extinguishers of the same type and capacity and in the same quantities as the spare charges listed above are to be carried.

- Each extinguisher is to be clearly marked with the manufacturer's name, type of fire and rating for which the extinguisher is suitable, type and quantity of extinguishant, approval details, instruction for use and recharge operating temperature range and test pressure.
- The FSS Code also details various inspection routines for extinguishers
- At least one extinguisher of each type manufactured in the same year and kept on board should be test discharged at five-yearly intervals (as part of fire drill). All extinguishers together with their propellant cartridges should be hydraulically tested at intervals not exceeding ten years.

FIXED AND WHEELED FIRE EXTINGUISHERS

Machinery spaces may be provided with larger foam, dry powder or CO2 fire extinguishers that may be either fixed or wheeled. The principal differences between these extinguishers and fully portable units is that they contain much more of the extinguishing medium but they are either fixed at one location or with a limited portability and so intended for first aid fire fighting near to the position at which they are located. On the foam and powder units the pressuring CO2 used to expel the extinguishant is contained in a cylinder mounted on the outside. The capacity of the foam units is normally 45 or 135 litters, the dry powder units 50,70 or 165 kg and the CO2 units 9,18,22 or 45 kg.

SOLAS Requirements

FIXED & WHEELED EXTINGUISHER typical data				
TYPE	Use on Class	Capacity	Discharge duration	Range
AFFF FOAM	B	45 ltr 135 ltr	65 sec 212 sec	15m
BC POWDER	BC	50 kg 70 kg 100 kg 100 kg	44 sec 50 sec 70 sec 93 sec	14m
CO2	B	9 kg 18 kg 22 kg 45 kg	24 sec 32 sec 41 sec 75 sec	4m

- In category A machinery with oil-field boilers or oil fuel units there must be at least one 135 litters foam extinguisher in each boiler room. But this is not required in areas with domestic boilers of less than 175 kW.
- In category A machinery with internal combustion machinery 45 ltr foam extinguishers are required sufficient to enable foam directed to any part of the fuel and lube oil pressure systems, gearing and other fire hazards


A Wheeled Foam Extinguisher (135 ltr)

The requirements for spaces with steam turbines or enclosed steam engines with total output of 375 kW or more are similar to those for spaces with internal combustion machinery, except that such extinguishers may not be required if equivalent protection is provided by a fixed fire extinguishing system.

CHAPTER 4

FIRE FIGHTER'S OUTFITS

A SOLAS "fire fighter's outfit" consists of a set of personal equipment and a breathing apparatus which include a lifeline. Each vessel must carry fire fighter's outfits the number in depending on the type and the size of the vessel


Fire Fighter's Outfit

Personal equipment

A set of Personal Equipment includes the following items:

- Protective clothing to protect from the heat radiating from fire and from burns and scalding by stem. The outer surface must be flameproof, water resistant and easy to clean. Usually the suit will be a two piece (jacket and trouser) but some times is possible to find one piece garments. The clothes should be comfortable so they can allow to the person who use the outfit to have freedom of movement. Most usually the set of the outfit consists of the following:

- Trousers (with braces) – worn outside of the boots
- Jacket – elasticated at the wrists and worn over the trousers
- Gloves (heat resisting) – worn outside of the jacket sleeves. As well as heat and burns these protect the hand from wounds and punctures but they must allow dexterity and tactile feel. Some Administrations may also require the provision of electrically non-conducting gloves.
- Boots – constructed by rubber or other electrically non-conducting material
- Rigid helmet – giving protection against impact. This will normally be provided with chin strap and full face visor and neck curtain.

The clothing that describes above is designed to protect the wearer from high temperatures, steam, hot materials and common fire hazards. They are not a “fire entry” suit.

- Electric safety lamp. These are battery operated and must have a duration of at least three hours. If they are of the hand-held type they must have a belt clip or other suitable hands free carrying method. The batteries should be of the rechargeable type. The lamps are usually Class I but also we can found Class II in some older vessels. Safety lamps must be suitable for use in atmospheres where may exist mixture of air and flammable gases. The differences between Class I & II lamps are described on the above table.

SAFETY LAMPS	
Class I	For use in any vessel including those where flammable gases may exist. Suitable for oil tanker but may be not suitable foe all flammable cargoes.
Class II	For use in vessel where there is no risk of flammable gas.

- Fireman axe. An axe with a high voltage insulation handle also provided. One side of the axe has a cutting edge and the other one side a spike. With the also need to provide a belt that the fireman can hang the axe so he can be hands free.
- Breathing apparatus (BA). Breathing apparatus shall be a self-contained compressed air breathing apparatus for which the volume of air contained in the cylinders shall be at least 1.200 L or other self-contained breathing apparatus which shall be capable of functioning for at least 30 min. all air cylinders for breathing apparatus shall be interchangeable. Also BA shall be fitted with an audible alarm and a visual or other device which will alert the user before the volume of air inside the cylinder has been reduced to no less than 200 L.

Lifeline. For each BA a fireproof lifeline of at least 30 m in length shall be provided. The line shall be capable of being attached by means of a snap-hook to the harness of the apparatus or a separate belt in order to prevent the BA becoming detached when the lifeline is operated.

SOLAS Requirements

Type of vessel	Minimum number of Fire Fighter's Outfits
Cargo vessel	2 sets
Passenger vessel	2 (as cargo vessels) + 2 for every 80m of the aggregate length of all passenger spaces and service spaces on the deck which carries such spaces or if there is more than one deck
Passenger vessel with more than 36 passengers	As passenger vessels above + 2 fire fighter outfits for each vertical zone.
Tankers	2 (as cargo vessels) + 2

SOLAS also requires that the fire fighters outfits must be kept ready for use in an accessible location that is permanently and clearly marked

CHAPTER 5

INTERNATIONAL SHORE CONNECTION

The International Shore Connection enables water to be pumped from another vessel or from the shore to the ship's main fire.

SOLAS Requirements

SOLAS requires that all vessels of over than 500 GRT carry at least one International Shore Connection and that it must be possible to use the connection on either side of the vessel. One side of the connection has a flat face and on the other a coupling that will fit the ship's hydrant and hose. It must be designed for $1N/mm^2$ services. The dimensions and detail required are given at the table below.

An International Shore Connection Box

Outside diameter	178 mm
Inside diameter	64 mm
Bolt circle diameter	132 mm
Slots in flange	Four holes 19 mm diameter, spaced equidistantly on a bolt circle of the above diameter slotted to the flange periphery
Flange thickness	14.5 mm minimum
Bolts and nuts	Four. Each of 16 mm diameter, 50 mm in length with washers and suitable gasket

The International Shore Connection must be kept in a clearly defined and accessible place. This may be in the ship’s fire control station together with the fire control plan or some other suitable location. Some vessels ay choose to carry more than one unit.

FIRE BLANKETS

Fire blankets are made from thick wool treated with a flameproof coating, fiberglass or flameproof synthetic materials such as Nomex or Kevlar. They are distinguished by their temperature resistance, flexibility and draping characteristics, electrically conductivity and ability to prevent the escape of vapours and flame gases. Typically a blanket would be 1.8 x 1.2m or 1.8 x 1.8m. Traditionally associated with small fat fryer fires they are also useful in a pantry protecting against weld splatter, combating waste bines fires, enfolding a person with burning clothes and as a wrap to held escape from flames. The effect of a correctly used fire blanket is to form an airtight seal over the fire and so exclude the supply of oxygen

CHAPTER 6

INERT GAS SYSTEMS

With the term “Inert Gas” means a gas or a mixture of gases such as flue gas containing insufficient oxygen to support the combustion of hydrocarbons. An “Inert Gas System” is an inert gas plant and inert gas distribution system together with means for preventing backflow of cargo gases to the machinery spaces, fixed and portable measuring instruments and control devices.

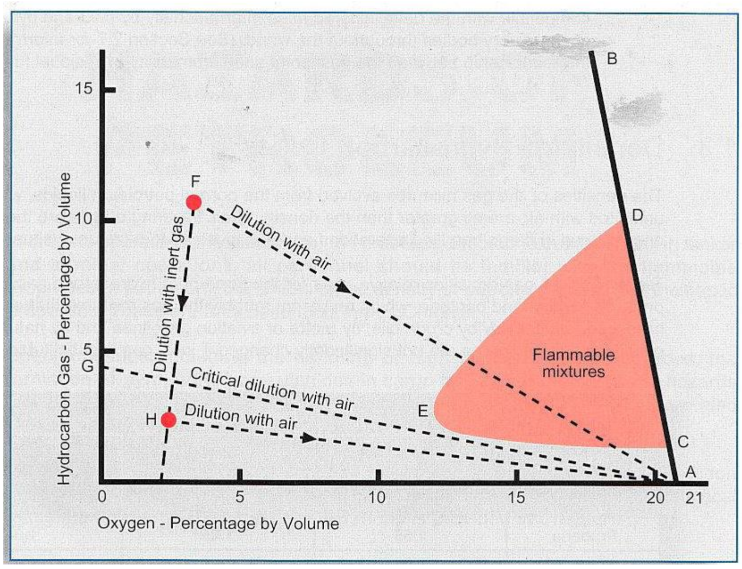
With an inert gas system the protection against a tank explosion is achieved by introducing inert gas into the tank to keep oxygen content low and reduce to safe proportions the hydrocarbon gas concentration of the tank atmosphere.

Flammable limits

A mixture of hydrocarbon gas and air cannot ignite unless its composition lies within a range of gas in air known as the “flammable range”. The lower limit of this range known as “lower flammable limit” is any hydrocarbon concentration below which there is insufficient hydrocarbon gas to support combustion. The upper limit of the range known as the “upper flammable limit” is any hydrocarbon concentration above which there is insufficient air to support combustion. The flammable limits vary somewhat for different pure hydrocarbon gases and for the gas mixtures derived from different petroleum liquids. In practice however the lower and upper flammable limits of oil cargoes carried in tankers can be taken for general purposes to be 1% and 10% hydrocarbon by volume respectively.

Effect of inert gas on flammability

When an inert gas is added to a hydrocarbon gas/air mixture the result is to increase the LEL concentration and to decrease the UFL concentration. These effects are shown on the figure below.



Any point on the diagram represents a hydrocarbon gas/air/inert gas mixture. Hydrocarbon/air mixtures without inert gas lie on the line AB the slope of which shows the reduction in oxygen content as the hydrocarbon content increase. Points which are they left of line AB represent mixtures with their oxygen content. As we see from the figure when an inert gas is added the flammable range progressively decreases until the oxygen reaches a level of about 11% by volume at which no mixture can be burn.

The LEL and UFL mixtures represent by the points C and D. as the inert gas content increases the flammable limit mixtures change. We can see this by the lines CE and DE which finally converge at the point E. Only mixtures inside the shaded area CED are capable of burning.

When an inert gas mixture is diluted by air its composition moves along the line FA and therefore enters in the shaded area of flammable mixtures. This means that all inert mixtures in the region above the line GA pass through a flammable condition as they are mixed with air. Those that are below of GA such as point H they don’t become flammable on dilution.

Sources of Inert Gas

Possible sources of inert gas on tankers including combination carriers are

- The uptake from the ship’s main or auxiliary boilers
- An independent inert gas generator or
- A gas turbine plant when equipped with an afterburner

Good combustion control in the ship’s boiler is necessary to achieve an oxygen content of 5% by volume. In order to obtain this quality it may be necessary to use automatic combustion control.

General policy of cargo tanks atmosphere control

Tankers fitted with an inert gas system should have their tanks in non flammable conditions always.

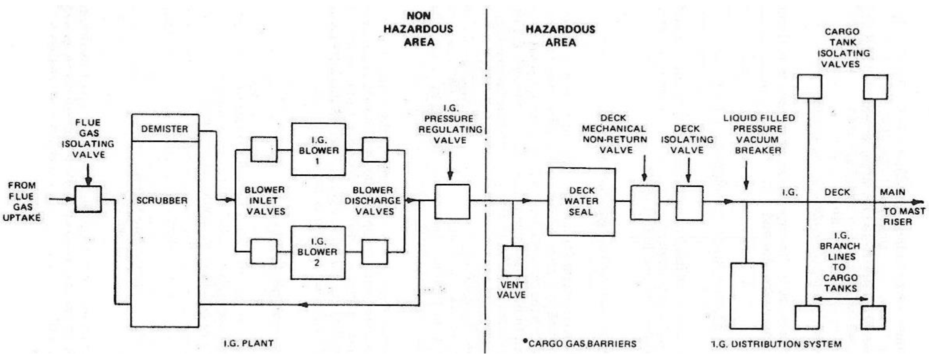
- Tanks should be kept in the inert condition whenever they contain cargo residues or ballast. The oxygen level should be kept 8% or less with a positive gas pressure.
- The atmosphere within the tank should make the transition from the inert condition to the gas free condition without passing trough the flammable condition. This means that before any gas free operation the tanks should be purged with inert gas until the condition of hydrocarbons is below than the critical line.
- When a ship is in a gas free condition before arrival at a loading port tanks should be inerted prior loading.

In order to maintain cargo tanks in non flammable condition the inert gas plant will be required to:

1. Inert empty cargo tanks
2. Be operated during cargo discharge, deballasting and necessary in-tank operations
3. Purge tanks prior gas-freeing
4. Top up pressure in the cargo tanks when necessary during other stages of the voyage

Description of an inert gas flue system

A typical arrangement for an inert gas system it consists of flue gas isolating valves located at the boiler uptake points through which pass hot, dirty gases to the scrubber and demister. Here the gas is cooled and cleaned before being piped to blowers which deliver the gas through the deck water seal, non-return valve and the deck isolating valve to the cargo tanks. A gas pressure regulating valve is fitted downstream of the blowers to regulate the flow of gases to the cargo tank. A liquid-filled pressure/vacuum breaker is fitted to prevent excessive pressure or vacuum from causing structural damage to cargo tanks. A vent is fitted between the deck isolating/non-return valve and the gas pressure regulating valve to vent any leakage when the plant is shut down. For delivering inert gas to the tanks during cargo discharge, de-ballasting, tank cleaning and for toping up the pressure of gas in the tank during other phases of the voyage, an inert gas deck main runs forward from the deck isolating valve for the length of the cargo deck. From this inert gas main inert gas branch lines lead to the top of each cargo tank.



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