SOLENT
UNIVERSITY
SOUTHAMPTON

Fire Prevention and Fire Fighting

Course Notes

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INTRODUCTION

This Fire Prevention & Fire Fighting course forms part of the mandatory basic training for seafarers.

It deals with the theory of fire and how to prevent it, onboard safety in the event of a fire, use of portable and other fire fighting equipment and being an effective team member in fighting fire.

The course may be integrated into other training such as Personal Survival Techniques, Personal Safety and Social Responsibility or Elementary First Aid in order to form a basic safety training week.

CONTENTS

Aims & Outcomes

Aim

To give seafarers the essential education and training in fire prevention and fire fighting meeting the Knowledge, Understanding and Proficiency (KUP) requirements set out in the following:

Table A-VI/1-2 (STCW 2010)

Function: *Fire prevention and fire fighting*
Competence: *Minimise the risk of fire and maintain a state of readiness to respond to emergency situations involving fire*
Fight and extinguish fires

Outcomes

There are 3 outcomes to the training

Outcome 1: The learner understands and can minimise the risk of fire on board.

Outcome 2: The learner knows the on board equipment, procedures and personal safety requirements in fire situations.

Outcome 3: The learner is able to fight and extinguish fires.

Assessment Plan

Each student will be assessed by a variety of methods including a range of direct observation, oral questioning, simulation and role play. On completion of the course the student will:

- State the elements of fire and explosion (the fire triangle), types and sources of ignition, flammable materials, fire hazards and spread of fire.
- Identify the different classifications of fire and applicable extinguishing agents
- Understand generic shipboard fire-fighting organization & location of fire-fighting equipment and emergency escape routes
- Understand the need for constant vigilance & actions to be taken on board ship in an emergency
- Have awareness of fire and smoke detection and automatic alarm systems
- Safely use various types of portable fire extinguishers on appropriate fires
- Extinguish oil fire with fog applicator and spray nozzles, dry chemical powder or foam applicators
- Safely use self-contained breathing apparatus
- Extinguish small and large fires of different types using an appropriate extinguishing medium
- Fight fire in smoke-filled enclosed spaces wearing self-contained breathing apparatus
- Extinguish fire with water fog or any other suitable fire-fighting agent in an accommodation room or simulated engine-room with fire and heavy smoke
- Effect a rescue in a smoke-filled space wearing breathing apparatus

The above KUP objectives directly relate to Table A-V1/1-2

Where there is a deficiency in the performance of any task following debrief, remedial support/tuition will be provided to the student with opportunity to achieve the required learning objective.

Fire Prevention

Fire On board

Fires aboard ships have to be fought by the crew in the first instance and very often there may be no outside assistance. It leaves the seafarer with little option when at sea, to deal with the situation or risk abandoning ship.

The construction of ships must include many areas that would not normally be located next to each other, engine rooms, cargo spaces, accommodation spaces for example. The different areas on board each have their own fire risk (means for a fire to start) and fire load (amount of fuel for the fire).

Nobody wants to be in a situation where they have to fight fires, but should the situation arise it is important that you are well prepared.

Recognising the different risks in these areas, as well as an understanding of the chemistry of fire, is key to the prevention of fires on board.

Recognising a fire risk and correcting the situation before there is a fire shows that **"prevention is better than cure"**.

Constant vigilance should be maintained at all times when working at sea utilising all the information from this course to enable you to work in a safe environment.

Causes of fire

There are many causes of fire on board ship in the different areas, below are a list of some of the more common examples.

All Areas

- Smoking – Carelessness and improper discarding of cigarettes. Smoking in bed.
- Hot Work – Any job involving heat will introduce a risk into that area and the potential of fire.

Accommodation

- Tumble dryers – Exhaust full of fluff/lint.
- Electrical – Overloaded sockets/Faulty equipment.
- Rubbish – Accumulated rubbish can self-heat and also increases the fire load.

Engine Room

- Oily rags – Through spontaneous combustion.
- Oil leak/spray – Oil spraying onto a hot surface can easily ignite.
- Dirty burner tips – Oil accumulations at the bottom of the furnace may cause an explosion.

The Galley

- Ventilation Hoods – Layers of grease can build up meaning a fire would spread quickly.
- Hot Oil Fire – Overheated oil can auto ignite and cause a fire.
- Inattention – Ovens left on, cloths left on a hot plate are all dangers.

Cargo/Stores

- Cargo – Certain cargos can be dangerous under different conditions. Strict attention must be paid to requirements.
- Packaging – Leaking or damaged packaging can allow cargo to leak or spill with potential to react with other cargoes.
- Paint – Static build up can cause ignition of solvents when pouring.

On Board Safety

There is a clear need on board ship for constant vigilance and awareness. There are distinct ways in which to prevent fire on board.

Good Housekeeping

When an area is kept clean and tidy, the fire risk lowers considerably. A waste paper bin can be a fire preventative measure ensuring it is regularly emptied and not left overflowing with rubbish.
There are many areas where bad housekeeping results in fires:

- Galley extracts full of grease
- Tumble dryers, exhausts full of fluff, lint and dust
- Engine room drip trays and bilges which have collected oil
- Oil soaked lagging etc.

Equipment maintenance

Scheduled maintenance can ensure all equipment remains in good condition and reduce the risk of any defect or failure starting a fire. A program should consist of regular care, testing and inspection, repair or replacement and record keeping detailing checks and routines.

Safe Practice

Procedures can be safely regulated by "Permits to Work" which will ensure that all necessary precautions have been taken before maintenance is carried out. However, as some tasks may not require these procedures personnel must not be allowed to take short cuts. Manufacturer's instructions coupled with the Company's Regulations and Code of Safe Working Practices for Merchant Seamen are supplied to provide guidance on how to operate safely. Issues that arise:

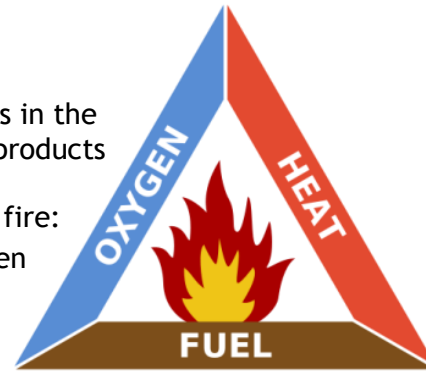
- No fire watch posted during hot work operations.
- Incorrect stowage of materials, dangerous goods etc.
- Poorly loaded or segregated cargoes.

Fire Patrol

On ships with greater than 36 passengers there is a requirement to make regular patrols of the vessel with special regard to fire by personnel familiar with and trained in the use of first aid fire fighting appliances found on board. They should have due regard to all of the above aspects.

Theory of combustion

The Fire Triangle



Fire is a chemical reaction which results in the production of heat, light and other by-products such as smoke and toxic fumes.
Three elements are needed to produce fire:

- Support for combustion - Oxygen
- A source of ignition - Heat
- Something that will burn - Fuel

All three elements must be present for combustion to occur, on many occasions two elements are present and it is important for us to recognise this so that we do not introduce the third.

Sources of ignition

There are various ways to start a fire:

- An open flame, spark or electrical arcing.
- Heating the fuel above its Self or Auto Ignition temperature (SIT or AIT) i.e. a fat pan can catch fire without the application of a naked flame, compression in a diesel engine raises the temperature of the fuel above its SIT/AIT.
- Some materials when damp or soaked with oil, or through a mixture of chemicals are likely to Spontaneously Combust without any external application of heat.

By Products

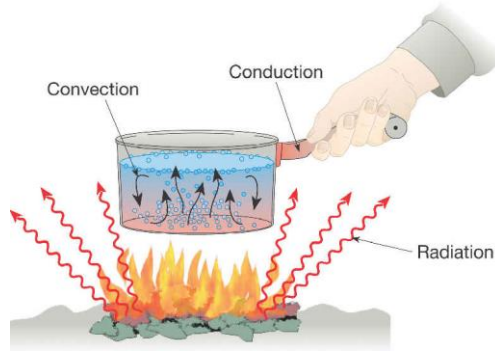
Fires in addition to generating heat and light also produce smoke/toxic products; these are responsible for the majority of deaths in fire cases. Smoke is essentially the incomplete (un-burnt) products of combustion; soot, liquid particles and gasses. It is generally toxic and may contain asphyxiants, irritants, flammable gasses, vapours and toxins. Carbon Monoxide is an example of a by-product of combustion found in smoke which is extremely dangerous to humans. Due to the inherent dangers of smoke any crew members operating in the environment must wear Self Contained Breathing Apparatus (SCBA).

Fire Growth and Spread

The flammability of a material is an indication of how easily something will burn or ignite.

When a material is labelled as flammable it indicates that it is readily combustible or liable to catch fire.

There are other important components in how things combust which will be discussed when we look at the different fuels in more detail.



When a material burns it releases energy in the form of heat. This heat is transferred in one of three ways as shown in the picture.

- **Conduction** - movement of heat through a material. As shown through the pan handle but could be through pipe work to another space. Air is a poor conductor of heat whereas most metals are very good conductors.
- **Convection** - upward movement of hotter less dense gases through the air or in a liquid as shown in the diagram. This can account for up to 75% of fire spread due to the movement of the hot fire gasses and smoke to other areas.
- **Radiation** - heat transfer by electromagnetic waves through the atmosphere. An example of radiation is the sun and how its heat reaches the earth. Radiation will vary as to the size and intensity of the fire, increasing as the fire gets hotter. The fire-fighter should wear fire protective clothing to insulate them against this heat.

Extinguishing Methods

The three primary extinguishing methods are achieved by removing one side of the fire triangle i.e. starvation, smothering, cooling.

Starvation

Removal of fuel which will be a combination of:

- Closing fuel oil or gas valves to stop the fuel supply.
- Boundary Starvation requires the removal of potential fuel from around the six sides of the fire which may be ignited by conductivity through bulkheads, decks or deck heads.

Smothering

Exclusion of oxygen (air):

- It is the flammable vapours given off from the fuel that burn so we can use a fire blanket, container lids, foam or sand which separate the fuel from the air.
- Carbon dioxide (CO^2)or other inert gas which displaces the air.
- Ventilation Control. Any system which is re-circulating air, (this is invariably the case with air conditioning) must be switched off. Selective extraction for short periods may be considered in some circumstances.

Smothering methods must be maintained until all the heat has dissipated otherwise re-ignition may occur.

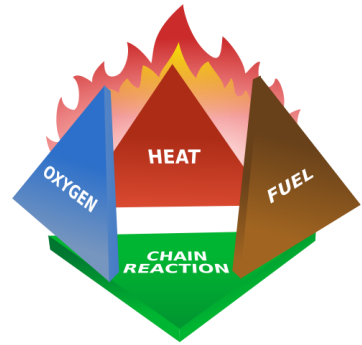
Cooling

Removing the heat energy from the fire:

- Typically achieved with water or foam (because of its high water content), directly into the fire to remove heat energy.
- Water can be applied to the boundaries of a fire as a spray in order to reduce the temperature inside, this is called boundary cooling.
- Isolating any equipment such as a galley hot plate can cool the fire area.

Flame Inhibition

In addition to the fire triangle, another method of extinguishment is flame inhibition – which breaks the chain reaction of fire. The triangle is sometimes expanded to four elements and referred to as the fire tetrahedron. Use of a flame inhibitor (e.g. a dry powder extinguisher) can result in a re-ignition hazard.



Dry powder effectively absorbs the energy in a flame and breaks the chain reaction so the fire goes out. However as no smothering, cooling or starving has occurred (e.g. if a flammable liquid fire is extinguished using dry powder the exposed liquid and hence vapours remain) additional steps must be taken to prevent re-ignition.

Extinguishers

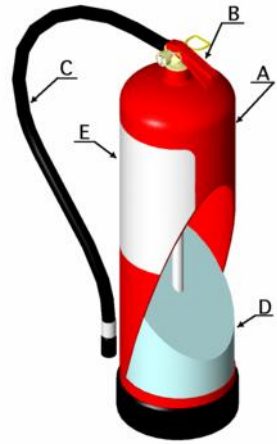
Each method is utilised by the different extinguishers that we have available to us on board and are highlighted below in the table.

Type	Colour Code Refers to British Standard	Method
Water		Cooling
Foam		Cooling/Smothering
CO^2		Smothering
Dry Powder		Flame Inhibition
Wet Chemical		Smothering
Fire Blanket	N/A	Smothering

We will consider why each extinguishing method is the most appropriate under the classification of fuels.

Extinguishers come in two main types:

- **Stored Pressure** – These extinguishers are filled and then pressurised. They will have a gauge on them indicating the pressure and limits above and below.
- **Cartridge Operated** – These extinguishers are not under pressure until the extinguisher lever is operated for the first time. This introduces pressure into the extinguisher to operate as before.



A. Cylinder made from mild steel

B. Activation Lever & Safety Pin/tamper tag

C. PVC reinforced hose

D. Extinguishing Medium with siphon tube.

E. Labelling and colour coding

The fire extinguisher is operated by releasing the pin, breaking the anti-tamper seal and squeezing together the fire extinguisher handles. This will either pierce the co^2 cartridge and pressurise the extinguisher/open the valve or with stored pressure simply open the hose valve. The media is then forced up the syphon tube within the fire extinguisher, through the head cap and hose onto the fire.

Extinguishers (except CO^2) can be recharged on-board if facilities are available. When empty and all pressure released, the units can be washed and dried and then refilled with the appropriate medium. Stored pressure extinguishers are then pressurised to the required pressure by a pump. Cartridge type extinguishers have the spent cartridge replaced for a new fresh cartridge. Extinguishers should be inspected once a year by a competent person and be provided with signed label indicating that it has been examined.

Media Water

Suitability: Wood, paper, textiles.

Technique: Attack from upright position utilising full throw if possible. Keep low if required to avoid heat and steam. Sweep the jet rapidly to break it up into water droplets to enhance the cooling effect and move around the fire. Once the fire is knocked down use the full force of the jet to help the water cool completely and break up the fuel.

Media Foam

Suitability: Liquid spill or contained liquid fires.

Technique: Stay back from the fire and use the full throw of the extinguisher. On a contained fire, spray the foam on the inside edge of the container and let the foam blanket spread undisturbed. On an open spill fire direct the foam jet upwards and sweep side to side to allow the foam to drop gently on to the fire. Fully discharge the foam extinguisher for maximum blanket thickness. Never direct the foam into the oil. If the foam boils away there is a danger of re-ignition. In any fire ensure there are back up extinguishers.

Media CO^2

Suitability: Liquids and inside electrical equipment or under engines where access is difficult. It is electrically non-conductive.

Technique: The gas comes out with some force and may scatter any fuel if the discharge horn is placed too close to loose material or burning liquid. The gas must be directed above the fuel so as to exclude the oxygen from its surface and smother the fire. On an open fire use the same sweeping action as described for dry powder- sweep rapidly from side to side and work from the front to the back. As the CO2 changes state from a liquid to a gas before it leaves the extinguisher, the discharge horn becomes very cold. There is a danger of a frost burn if anything other than the handle or grip is touched by the operator.

Media Dry Powder

Suitability: Ideal for low flashpoint liquids (e.g. petrol) and gases (propane, butane); as was noted before heavier oils such as cooking or lubricating oils may well be already above their auto ignition temperature (AIT) and re-ignite once the dry powder extinguisher is empty.

Technique: Keep low to avoid flare up when you start extinguishing. Sweep rapidly from side to side and work from the front to the back. Do not walk into the fuel. Although dry powder gives rapid knockdown it has no cooling or smothering effect on oils and vapours may remain to be re-ignited. Beware of a significant reduction in visibility when using.

Media Wet Chemical

Suitability: Designed specifically to fight fires resulting from cooking oils and fats up to 75 litres in size.

Technique: This fire extinguisher contains a specially formulated wet chemical which, when applied to the burning liquid, cools and emulsifies the oil, extinguishing the flame, sealing the surface and preventing re-ignition. It is essential when fighting this class of fire that the extinguisher is used from a minimum of 1 metre (from nozzle to the fire). Ensure entire contents are fully discharged, even after the flames have been extinguished, in order to cool the fat or oil effectively to prevent re-ignition.

They can only be used on animal fats, vegetable oils and solid fires.

Media **Fire Blanket**

Suitability: Fat pan fires, contained liquid fires. Smothering any small fire.

Technique: Fold back the top edge over hands to protect them, hold the hands up with the arms widespread to allow the blanket to hang in front of you to protect your body and face from radiant heat and flames. Advance and drape over the fire stretching towards the back to prevent the blanket dipping in the liquid. Fire blankets are made in different sizes. Have a look at the one on board and practise with it on a simulated fat pan fire.

Stay calm and do not throw the blanket on to the fire; if you do you may force air into the container and cause an eruption of flame. Turn off any heat underneath and leave to cool. If the blanket is removed prematurely the oil may be hot enough to re-ignite.

A person with burning clothing should be laid on the floor as heat rises. Use the blanket to pat out the flames but do not leave him in a rolled up blanket which may trap the hot smouldering clothing next to the skin.

Classification of Fuels

Fires are classified depending on the type of fuel; this allows us to select the most appropriate medium for the fire.

Class A – Solids

Woods, paper, plastics are some example of solids (usually organic in nature) that combust. These are heated to their ignition point where they will break down and release combustible gases. This fire will release heat and this will continue to heat other materials which can lead to the growth of the fire. They will typically leave behind smouldering, glowing embers which can retain a lot of heat. For this reason water, a good coolant, is effective at removing that heat energy. Foam which also contains water is a good coolant as well.

Class B – Liquids & Liquefiable Solids

When a flammable liquid burns it is the vapour that combusts, not the liquid itself. Flammable liquids release these vapours at different temperatures; this is called the flash point. Liquids that have a low flashpoint of below 60°c (so more likely to release flammable vapour) like petrol are termed as volatile.

Smothering will help prevent the vapours, cutting them off at the surface and therefore is a good method of extinguishing liquid fires. Some liquids will ignite when heated without the application of a flame or spark; this is called their auto ignition temperature.

Class C – Gasses

Fires involving flammable gases can be extremely hazardous; these are best extinguished by isolating the fuel. It is important to cool around the area and cylinder (if involved) with water to prevent further hazards such as a BLEVE (Boiling Liquid Expanding Vapour Explosion) from occurring. Gas fires may be extinguished by dry powder.

Class D – Metals

Metal fires such as magnesium, lithium or aluminium typically burn with an intense heat and using a common extinguishing medium can cause an adverse reaction. There is a special Class D dry powder extinguisher designed for metals and works by smothering the fire, sand can also be used to smother small fires.

For larger fires involving metals copious amounts of water can be used from an open ended hose in order to attempt to cool.

Class F – Cooking Oils

Because of the high temperatures that cooking oils can reach they can be difficult to extinguish using ordinary foams. Specially formulated wet chemicals when applied to the burning liquid cools and emulsifies the oil, extinguishes the flame, seals the surface and prevents re-ignition.

Note: Electrical Risks

Electricity, is not a class of fuel, but is considered to be a risk or complication in all types of fire.

To protect the fire fighter and reduce the risk of sparking or heat energy sources whenever possible, the power supply should be isolated in the fire area. In cases where it is unclear if power has been isolated the fire fighter should use only non-conductive media such as dry powder or carbon dioxide.

Safety On Board

Muster Arrangements

There should be clear instructions to be followed in the event of an emergency for everyone on board. These Muster Lists and emergency instructions should be posted throughout the ship including as a minimum the bridge, engine room and crew accommodation. The muster list should also specify the details of the different alarms and in addition the duties of different crew including but not limited to, preparation of life saving appliances, passenger management, manning of fire parties and special duties assigned in respect to the use of fire fighting equipment and installations.

Training & Drill Requirements

Statutory requirements state that a fire or other emergency drill should be held simultaneously with the first stage of an abandon ship drill. Each crew member must participate in at least one abandon ship and one fire drill once a month. These drills must be held within 24 hours of leaving port if more than 25% of the crew have not taken part in drills on board the ship in the previous month. Abandon ship and fire drills must be held weekly on passenger ships.

Drills must be as REALISTIC as possible. It is excellent practice in drills to occasionally take the leader or key personnel out of the emergency structure so that junior ranks may have an opportunity in taking on this difficult task. Use an observer who can also oversee the de-brief.

Once the alarm has sounded the crew muster at their emergency station. Provision must be made for alternative muster points where fire or smoke makes it impossible to assemble. The drill must be followed by a full debrief as there will always be mistakes and misunderstandings. Never surprise your crew with a drill, always give some forewarning even if it is not too precise. Where a public address system is installed, a message must be prefixed by “this is a drill”.

Moving in smoke – Escape Procedures

In the event of an incident it may well be possible that you are in a small group that need to make an escape from smoke. Escape as a group, where this is possible, is generally preferred. This requires some organising, but pools individual skills with a common objective. In the event of you becoming trapped with others, individuals may have greater knowledge of the layout and awareness of the immediate area that you are in. Communication may be difficult but other methods of communication by feel/signal may be possible. Talk/shout if possible. Encourage and assist each other. Basic technique for escape in smoke is the same for an individual as it is for a group.

The following are the procedures that should be followed when moving and making an escape in smoke.

- Working in pairs, or as a group, physical contact should be maintained at all times
- Keep as low as possible – hot gases and smoke rise, visibility and clearer air will improve lower down
- If you have a small bore hose reel or an extinguisher, then take this with you – it may be useful
- Remain in contact with bulkheads/walls – locate one as soon as possible
- Move along the bulkhead always keeping it on the same side to avoid possibility of becoming disorientated
- You will always arrive at an exit or move into another compartment
- Do not change sides unless conditions deteriorate and become so severe that you have to turn back
- Use the back of your hand in a sweeping motion to locate openings, door handles, stairs/ladders or other features. This reduces the possibility of grasping live cables or hot surfaces
- Shuffle along, weight bias to the rear foot, the leading foot testing the integrity of the deck/floor in a probing manner and checking for any obstructions or openings

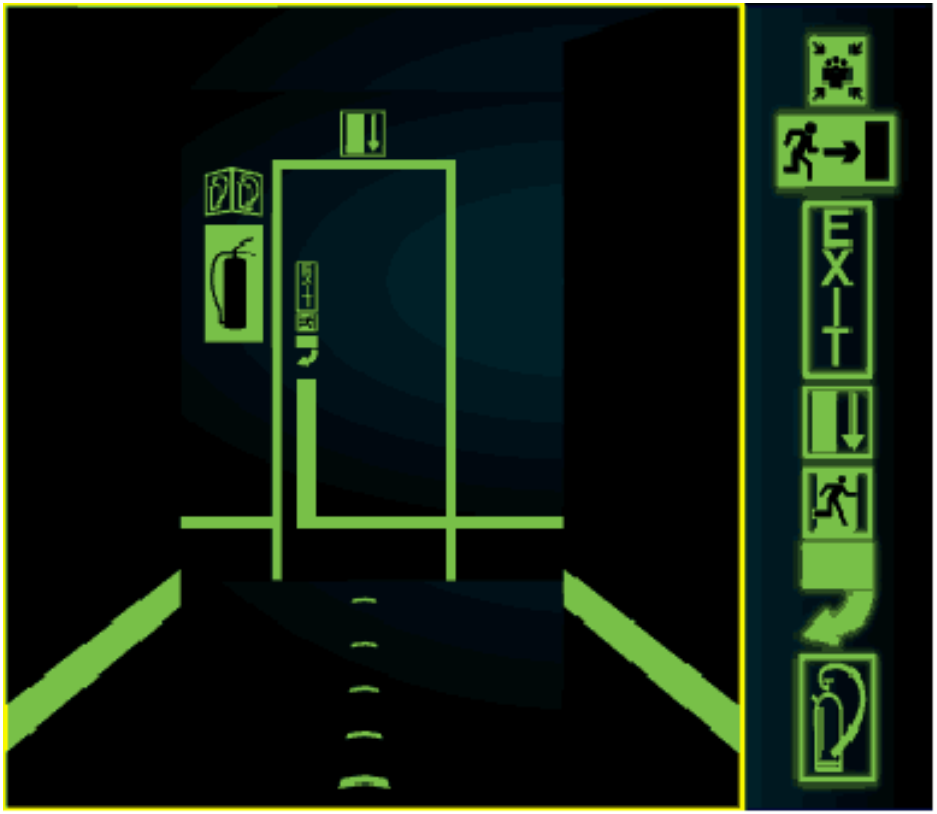


Photo luminescent Low level Escape Route Signage

SOLAS specifies that all muster points, escape routes, exits and essential equipment such as life rafts and fire fighting appliances should be clearly marked with signs meeting specified IMO standards.

This standard is adopted across the industry to avoid confusion and provides guidance when moving in low light or reduced visibility conditions.

Door Opening

Many doors will be designed as fire doors of heavy construction and made of metal. Others may be of lighter construction, but still designed to reduce the passage of fire and or smoke. The principle for negotiating doors is very much the same.

Prior to opening a door the following should be considered:

- Test the temperature of the door by hovering the back of the hand slightly away from the door
- Check the temperature of the door at the top and bottom
    - If it is cooler at the bottom, then the fire is some distance from the door
    - If it is hot at the top and bottom, then assume there is fire in the space

Only open doors if it is safe to do so, however the following precautions should be followed:

- Assess the door, if you can see hinges it will most likely open towards you
- If the door opens away from you, use the bulkhead as a shield.
    - Crouch down against the bulkhead and exposing as little of your arm as possible open the door holding onto the handle.
- If the door opens towards you, use the door as a shield.
    - Crouch down behind it, on the hinge side, using your knee as a wedge adopting a “brace-like” posture
- Open the door slightly, 10 cm for 10 seconds, looking up with caution to allow any hot gases to escape above you
- Stay low, when safe to do so, look into space and assess if safe to enter
- If using an extinguisher, always test the extinguisher before proceeding.

Fire Protection, Detection & Extinction

SOLAS Chapter 2 focuses on the construction of vessels and specifies a range of fire protection arrangements to be employed on-board vessels.

Detection & Alarm

A fixed alarm system must be fitted to the vessel with a central panel usually located on the bridge. This will give an indication when an alarm is activated and if unanswered will sound throughout the ship. This system works in conjunction with a number of detectors and manual call points throughout the vessel. Main detectors are:

Smoke

- Most smoke detectors work either by optical detection (photoelectric) or by physical process (ionization),while others use both detection methods to increase sensitivity to smoke.
- Advantages – Detect a fire early and from some distance away.
- Disadvantage – Subject to various spurious signals, steam, hairspray etc.

Heat

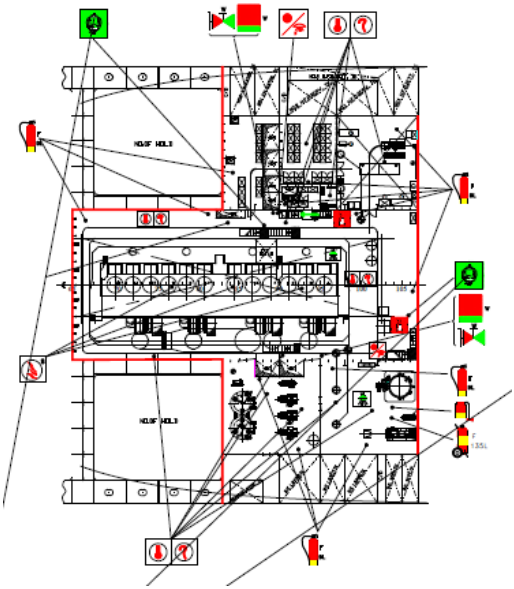
- There are two types of heat detector, fixed temperature and rate of rise. Fixed temperature will alarm when a set temperature is reached, rate of rise will alarm if the temperature increases faster than a set threshold.
- Advantages – Works well in environments such as galleys where smoke detectors are inappropriate.
- Disadvantages – Take time to adjust and must be close to initial fire area to activate early.

Flame

- Flame detectors ‘see’ an area and detect UV or IR or both forms of light to detect a fire. Common in engine rooms where flash fires are possible and in external locations.
- Advantages – Can provide a very rapid alarm for fire over a large area.
- Disadvantage – They can only detect in the area that they can ‘see’.

The information and location of detectors and other fire related equipment are contained on a vessels fire control plan.

Fire control plan



Fire Plan

This sample shows a variety of different pieces of equipment and their locations in an Engine Room compartment. Each item has an internationally recognised symbol from IMO Resolution A.952 (23) which cover most newer vessels.

Some of the more common symbols are shown below.

- Heat Detector

- Smoke Detector

- Flame Detector

- Emergency fire Pump

Fire Hydrant

Manual Call Point

Fire Hose & nozzle

Fire Extinguisher (Foam)

General Emergency Signal

The only alarm specified in SOLAS is the General Emergency Signal.

Seven or more short followed by one long blast.

The vessels fire alarm may be different such as continuous ringing of bells or a two-tone siren, this information will be contained on the muster list and it is essential that all crew are familiar with the different alarms and the appropriate responses to them.

Muster lists will also contain the team make up and muster locations for them respectively.

They must also show the duties to be carried out by each member of the ships complement in an emergency. Such duties include the preparation, swinging out or deploying of survival craft and other life-saving appliances, the closing of watertight and fire doors, and all other openings such as skylights, portholes and side scuttles and any openings in the hull. Duties in connection with fire-fighting, the use of communication equipment and the equipping of survival craft must also be shown.

Where appropriate, communications equipment, channels and reporting chain to be used during abandonment or other emergency situation should be specified.

The means by which the order to abandon ship is to be given must also be included.

Containment

A fire is to be contained within the point of origin as follows:

1. The ship shall be subdivided by thermal and structural boundaries;
2. Thermal insulation of boundaries shall take into account the fire risk of the space and adjacent spaces; and
3. The fire integrity of the divisions shall be maintained at openings and penetrations.

A, B and C class divisions are used to maintain thermal barriers depending on the associated risk. Fire dampers are also provided in ventilation ducting to limit the spread of heat and smoke. The basic definitions of each are as follows.

A Class	Prevent the spread of smoke and flame for 60 minutes.
B Class	Prevent the spread of flame for 30 minutes
C Class	Approved Non-Combustible materials

SOLAS details the given level of protection between different compartments, key control areas and escape routes have higher levels of protection.

Fire divisions within vessels are specifically designed to restrict fire spread. If this integrity is compromised by leaving doors open or tied back, removing insulation, cutting or drilling holes in bulkheads fires will quickly spread between compartments. No such work should be undertaken without class or Company approval. It is essential that you are **FIRE CONSCIOUS** at all times.

The simple act of closing a door could prevent the fire and smoke spreading for one hour.

Fire Fighting Systems

Fire Main

The fire main is the primary means of moving water around the vessel for fire fighting. SOLAS states that,

"The number and position of hydrants shall be such that at least two jets of water not emanating from the same hydrant, one of which shall be from a single length of hose, may reach any part of the ship normally accessible to the passengers or crew."

The deck fire main must have a **main isolation valve** outside the machinery space from the fire main within the machinery space. This is because an explosion inside the engine room which ruptured the fire main could lead to loss of water for fire fighting throughout the ship. The **emergency fire pump**, which must be sited outside the machinery space, must be able to supply the accommodation and deck with water through a fire main which does not pass through the machinery space. The isolation valve must be able to allow water to flow from the deck to the engine room hydrants.

Emergency Generator

Ships are required to have an emergency generator on board in order to provide power to essential services.

These include, but are not limited to,

- Emergency lighting in;
    - Control stations
    - Fire lockers
    - Muster and embarkation points
    - Stairways, accommodation alleyways & exits
- External communication equipment
- Internal emergency communication equipment
- Fire detection and alarm panel
- Fire pump (if it requires electrical power).

Fixed Systems

Ships can be fitted with a variety of fixed fire systems and this can depend on the size, type or nature of operations of a vessel. Generally speaking fixed installations must only be operated on the orders of a senior officer. Fires can occur on ships when the senior officers are ashore therefore all duty personnel must be aware of the operating procedures for any fixed installations on board. The systems work utilising methods that have been discussed but on a larger scale, examples that will be found on board are:

Inert Gas System

CO2 and other gases rely on keeping the fire smothered until all the heat has dissipated. If anyone remains inside the space they will soon be asphyxiated. Before the system is operated every opening has to be closed and fuel isolated. This is reported to the bridge and a muster is held to ensure there is no one left inside. All of this has to be done quickly and must be practised regularly. These systems are commonly found in engine rooms but may be found in other places such as cargo spaces or incinerator spaces for example. They may also be utilised on a smaller scale for ducting in a galley space.

Hi Expansion Foam

Where a 9 litre portable foam extinguisher will expand the foam concentrate up to twelve times i.e. 108 litres of finished foam, Hi-ex expands up to 1000 times. The water content is low, the bubbles produced rapidly cool the fire and surrounding surfaces fill the space and extinguish the fire. Being trapped in Hi-ex also has dangers, it can be very claustrophobic and disorienting, cause problems hearing and locating casualties and make moving in complicated areas (ER) dangerous. Foam systems are an alternative to a gas system in an engine room they can also be used to protect cargo spaces as well such as car carriers and tankers for example.

Sprinkler System

A sprinkler system is a fire detection system with the added advantage that it immediately sprays water on to the fire. A charged system of pipes kept pressurised with fresh water has outlets which are sealed by a glass bulb containing a liquid of a known coefficient of expansion. At a certain temperature this liquid will have expanded and bursts the bulb; the water hits the diffuser and sprays on the fire. Sprinkler systems are a requirement on all passenger vessels in accommodation areas.

Deluge System

Similar to a sprinkler system only there are no bulbs and the system is in zones. When the system is operated, usually by a manual valve, it fills the line with water and all heads in that zone operate. These types are often seen on enclosed mooring decks, balcony areas, car decks and LNG tank protection on tankers.

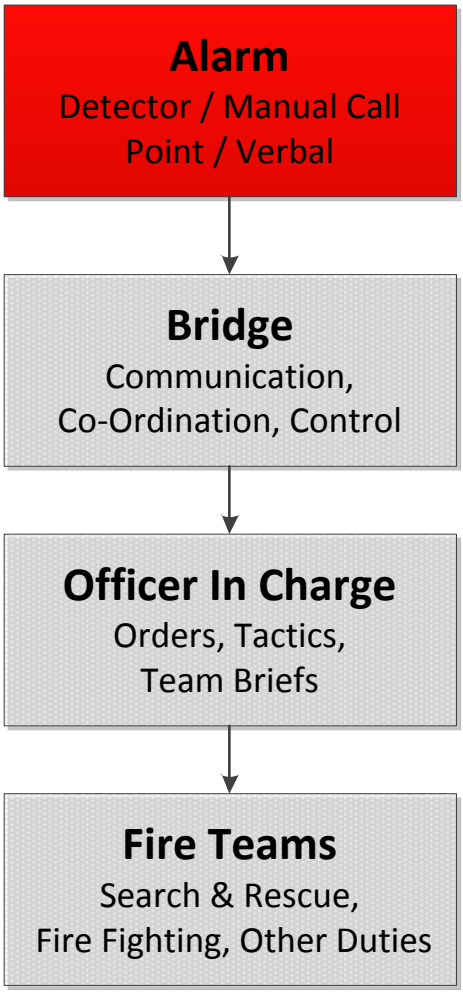
Water Mist System

Water mist systems can work in similar set ups to sprinkler or deluge systems; however the water introduced is in a fine mist form. This allows for greater cooling and some steam suppression locally around the fire. Water mist is required on certain passenger ships and larger cargo ships in the engine room. These systems can be operated locally or automatically when detectors are activated. The advantages are that the space is not required to be evacuated or shut down before activation allowing for early or immediate release in the event of a fire. This early and immediate suppression of fire can make a big difference on the outcome and it is essential that the crew are aware and familiar with the system.

All systems must be operated by trained personnel and regular drills and training must accompany each system.

Team Organisation and Equipment

The command structure of all vessels will vary but the following is an outline of how most incident command structures fit together.



The initial alarm is raised and this will either be investigated by the crew or they will go straight to their muster stations as per procedures on board.

The bridge team will include the Master who has overall responsibility for the vessel. This is the control for the incident and the hub of external communications on board. Lots of information will pass through the bridge.

Typical set up on board will consist of two teams, one deck and one engine. The officer with the most experience/knowledge of the fire area will normally take charge. The OIC will then brief the teams as to what he wants them to accomplish.

The fire team's priorities are saving life and fighting the fire. They will be directed by the officer and utilise standard operating procedures to safely achieve set objectives. The resources and teams available will depend on the type of vessel and number of crew.

Equipment

Each team member will be equipped with a firefighters's outfit which will consist of the following as a minimum:

- Protective clothing (Fire suit) to protect from heat and steam, must also be water resistant.
- Non-conducting boots (usually rubber).
- Rigid helmet.
- Electric lamp.
- Axe with insulated handle.
- Safety Line
- Two portable radios for each fire party

Each fire fighter will also be provided with a self-contained breathing apparatus capable of functioning for at least 30 minutes.

As a minimum all SOLAS applicable ships should carry two fire fighters outfits (typically ships will have more) and there are further requirements for ships carrying passengers or dangerous cargo.

All kit should be stored in the lockers ready to go in the event of an emergency. This includes trousers and boots together, tunics hanging up, all other equipment, lamps, SCBA sets etc. tested regularly so they are ready to use.

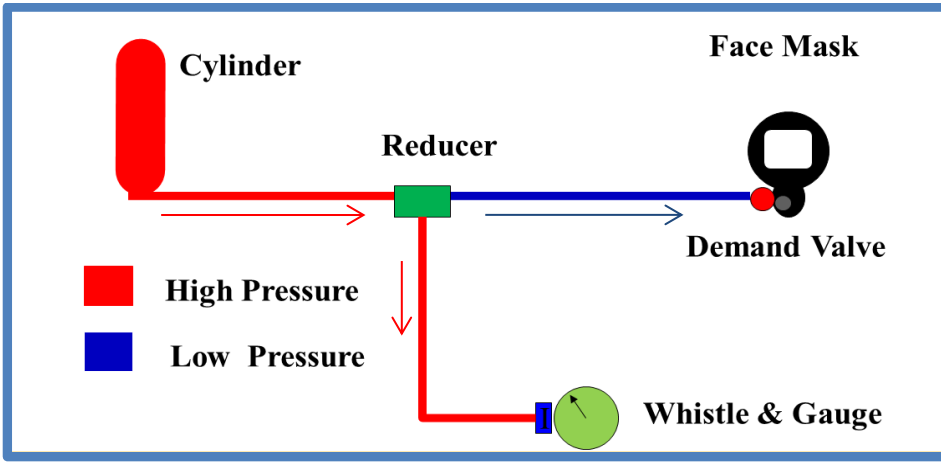
Fully dressed fire fighter wearing SCBA.

Note trousers outside boots to prevent water run-off into boots.

Breathing Apparatus

During the course of any fire, toxic products and poisonous gases are produced as a result of combustion. In order to protect fire-fighters, breathing apparatus (BA) is required. The self-contained breathing apparatus (SCBA) set, which is carried like a rucksack and provides the wearer with fresh air, is most common. In addition, atmospheric BA, which requires the wearer to drag hose line from an outside bellows set, can be found in use but only until July 2019.

There are a variety of sets available but most are of a positive pressure type which will be described here.



This schematic diagram represents the component parts of a SCBA.

Cylinder

All cylinders are grey in colour, with black and white quartered shoulders denoting the contents as medical air (i.e. dried and filtered air). It must have a minimum content of 30 minutes of air, which for an average person is a charged capacity of 1200 litres. (This is based on the assumption that an average person breathes 40 litres of air per minute.)

Reducer

Passes un-restricted air from the cylinder to the Pressure Gauge and Low Air Warning Whistle, and supplies low pressure air, to the Demand Valve.

Pressure gauge & Whistle

A gauge gives the wearer a constant indication of the cylinder pressure. The gauge face is calibrated in 10 bar intervals and may be numbered every 30 or 50 bar. The whistle is designed to operate automatically when the cylinder pressure falls to 40-45 bar, allowing a safety margin for emergency purposes. The team should plan ahead and aim to be clear of the danger area before the whistle sounds.

WARNING - Hard work may reduce duration.

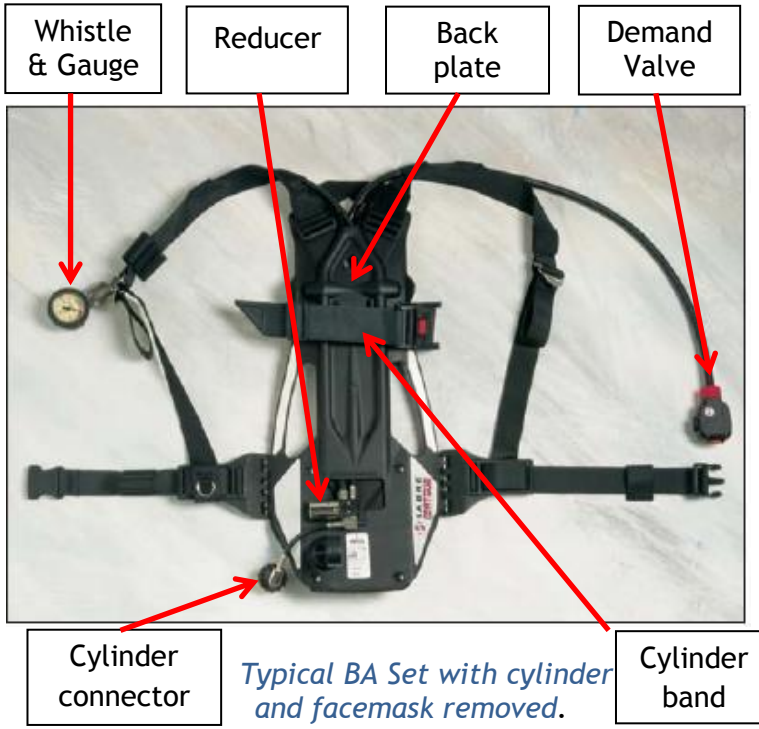
Demand valve

The air delivered by the demand valve depends upon the requirements of the wearer. Demand valves are capable of delivering up to 5 times the average volume of air. The demand valve is attached to the facemask.

Face Mask

The mask is constructed of non-dermatitic rubber and has a high-density polycarbonate shatterproof visor, providing maximum vision to the wearer. The mask is fitted with the following:

a) Speech Diaphragm – This is a thin mica disc situated opposite the mouth, allowing the wearer to converse normally.
b) Ori-Nasal Mask – This inner mask avoids the build-up of exhaled carbon dioxide (CO^2) within the face mask by the use of one-way mushroom valves. These valves open on inhalation and allow air into the ori-nasal mask. On exhalation these valves close which means that the air is directed out through the one-way exhalation valve to atmosphere.



Typical BA Set with cylinder and facemask removed.

Cylinder with black And white collar

The cylinder air is joined with the cylinder connector valve. The cylinder is attached to the back plate and secured with the cylinder band. The mask attached to the demand valve. There are various designs of mask available.

BA Mask, Internal view showing oral nasal mask

Donning (*putting on*)

- Press demand valve reset button and check bypass valve is in the off position.
- Open main cylinder valve fully – check that the warning whistle momentarily operates.
- Check gauge reading – ensuring sufficient cylinder contents. A minimum of 80% of the cylinders maximum capacity is required (e.g. for a cylinder with a maximum charging capacity of 200 bar, the minimum pressure reading before entry will be 160 bar i.e. 80% of 200 bar).
- Stand BA set upright, making sure the back plate is facing you and the facemask is released from the top of the cylinder.
- Grasp the right hand shoulder strap and face mask harness in the left hand and swing the set onto the right shoulder. Next slip the left arm through the left shoulder strap.
- Place the face mask neck strap over the head.
- Adjust the shoulder straps so that the set is comfortable and tighten the waist strap. (Do not over tighten as this can restrict deep breathing)
- Inspect the face mask ensuring that the head harness straps are fully extended.
- Check that the gauge is in a readable position.

Starting Up/Pre Entry Checks

- This must be carried out in “safe” air (an environment where the air is breathable and will not be harmful without the use of respiratory equipment).
- Don the facemask, adjust to ensure good fit and tighten the straps (bottom to top, two at a time)
- Breathe in sharply to operate the first breath mechanism, and then breathe in and out 2 or 3 times to ensure the air is flowing in through the demand valve and out through the exhalation valve.
- Carry out the following safety checks:
  - Check that positive pressure is functioning by inserting a finger between the face mask and the face, this should cause an audible flow of air.

- Operate the bypass valve – This will cause a free flow of air into the mask (bypassing the demand valve) so proving air can be supplied to the wearer in event of a demand valve failure.
- Take a breath and hold it, move your head vigorously from side to side, stop and listen for leaks. If there are any leaks, adjust the head harness.
- N.B. Facial hair may affect the ability of the wearer to get a face seal so causing an air leak.

Doffing (*taking off*)

- Remove helmet, gloves, pull back flash hood. Helmet must be removed with gloves on to prevent any burn injuries to the hands.
- Take a deep breath, press the reset button, loosen straps and remove mask.
- Switch off cylinder.
- Drain BA set and ensure whistle activates.
- Ensure all straps are fully extended (loosened off)
- Hang mask from neck.

It is recommended that the manufacturer's guidelines are followed in all instances as SCBA sets will vary from vessel to vessel. Ensure that you are familiar with your sets onboard, that they fit correctly and all the associated procedures for use.

Fire Fighting

Equipment

Fire teams will have a variety of equipment available to them and this will partly depend on the type of vessel and area of operations.

Hose

Fire hose enables us to move water to where it is required for fire fighting efforts. Modern hoses are made out of synthetic materials and are not prone to rot however they may be damaged by shock or abrasion.

- Where a hose leads over sharp edges protect it with a mat.
- Where a hose is led through a doorway make sure the door is held ajar with wooden blocks or wedges.
- Open and close nozzles or hydrants gently.

The diameter of hoses is not specified but is often 45 mm in accommodations and engine rooms and 64 mm elsewhere. They should be long enough to project a jet of water into any space they are required to be used. They shall be at least 10 m long but not more than 15 m in machinery spaces, 20 m in other spaces and open decks and 25 m for open decks on ships with a maximum breadth in excess of 30 m.

Hoses are stored typically either in a “Dutch roll” on a bight or a “conventional” roll. Either method can be used but the same one should be used throughout the ship.

The “Dutch roll” has the advantage that both coupling remain in hand when the hose is rolled out.

After use the hose should be drained out by walking along it and lifting it to shoulder level any contaminates washed off and the couplings rinsed in fresh water.

Couplings

Whichever type of coupling is found on board will be uniform throughout the whole vessel.

Some of the more common are:

Instantaneous Couplings

These couplings push together and two spring loaded lugs hold the two together. To release the lugs are pulled outward simultaneously. Each hose has a male and female coupling.

Storz type coupling

These couplings twist together locking into place, they will often come with a 'C' type spanner in order to facilitate this. Both ends of the hose are the same enabling more adaptability

International Shore Connection

Because of the non-standardisation of couplings every vessel over 500 gross tonnes must be fitted with an International Shore Connection.

It permits connection of the shipboard fire main with another ship or shore facility when the hose couplings are different to allow the damaged ship's fire main to be pressurized.

Nozzles

Nozzles on board must have the ability to offer a jet, a spray and shut off option. These may be facilitated in a number of ways but this must be a minimum.

Common types include:

Unifire V-12 Nozzle

Akron Turbo jet Nozzle

The fact that all nozzles can be shut off means that the amount of water used can be reduced to:

- Limit the amount of water damage.
- Limit the effect that excess water may have on the ship's stability.
- Preserve water pressure in the fire main for use elsewhere in the ship.
- Control the humidity in the space by turning the nozzle off for a moment to allow the steam will dissipate.

The nozzle can be adjusted to a jet so that:

- Water can be thrown a long way if necessary
- The force of the jet can be used to assist water penetration when damping down after a fire.

It can be adjusted to a spray so that:

- The nozzle is being used in the most effective way provided the water is sprayed on the fuel and not just on hot smoke. The cooling effect of water will be most effective if it is applied in the form of a spray rather than a jet. If water is turned to steam the maximum amount of heat is taken out of a fire. When fighting an internal Class A fire, control the amount of water applied by using short (2 – 4 second) bursts to limit the steam production.
- The hollow cone of water spray will protect the fire fighter from radiant heat and flame.
- A 60° arc of spray is the ideal fire fighting mode.
- It can be adjusted to a 'water wall' so that it allows close approach to a fire e.g. to close a valve or to use another hose through the wall. Foam or dry powder can be directed through the water curtain.

Waterwall in use to protect fire fighters

Precautions

Most adjustable jet/spray nozzles operate from shut-off through jet to spray. The hose should always be pointed down to the deck when it is opened or closed otherwise a jet may be inadvertently put into the fire. Possible hazards are:

- If the jet hits a red-hot steel bulkhead it may splash back as boiling water, or may cause local cooling. Unequal thermal expansion could crack open the bulkhead.
- If the jet strikes another person unseen in the smoke, it could injure them, or knock their breathing apparatus mask off.
- If the jet strikes live electrics, it could provide the shortest path to earth. Water as a jet or spray must never be used near high voltage switch-boards.
- If the jet enters a hot liquid, it may flash to steam and expand about 1700 times, atomise to produce a boilover. A jet directed into a dusty cargo may throw the dust in the air and cause a dust explosion.

Remember water can easily spread fire because oil fuels will float on water.

Fog Lance

A fog applicator or fog lance can be inserted into the end of the nozzle or be standalone kit. It can be used in places which are difficult to access e.g. under vehicles, engine compartments, but steam production will be considerably higher than that produced by a normal spray. The fog lance is found on all types of car carrier and ro-ro ships where it can be particularly useful in extinguishing fires underneath lorries or cars where the drencher system cannot reach. They can also be found in the engine rooms of passenger vessels.

Foam Making Equipment

Additional foam making equipment is carried on board vessels in the engine room and may be required for other areas including helidecks or cargo areas. There are a number of different foam types available.

Foam Types

- Protein Foam
  This is based on hoof and horn meal from a slaughterhouse and has a good resistance to higher oil temperatures. It is mainly used in the fixed foam systems on tankers. Manufacturers will recommend in which temperature range it must be stored because it may deteriorate and lose its properties in very hot or cold conditions. Tankers require a sample of their foam compound used for pump rooms and deck fires to be tested annually.
- Aqueous Film Forming Foam (AFFF)
  This foam is detergent based. Because of its film forming properties it is particularly good on low flash point liquids as it resists re-ignition. On hotter fires (high flash point) there may be a tendency for the thin aqueous (water) film to boil away. It is very commonly used in extinguishers and can be found in some tanker fixed systems.
- Film Forming Fluoro Protein Foam (FFFP)
  This foam has the film forming properties of AFFF and the heat resistance of protein foam.

Low expansion foam (LX) is the usual type found aboard ship.
Foam is normally supplied as a 6% or 3% concentrate, this means that:

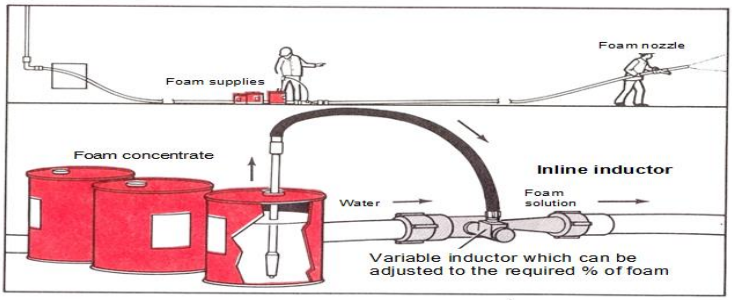
- 6% foam concentrate + 94% water and air = Finished Foam
- 3% foam concentrate + 97% water and air = Finished Foam

The percentage will be written on the side of the drum.

Foam Making Equipment

The Inline Inductor

This allows the foam to be induced into the fire hose two lengths back from the fire front, in a safe area where foam supplies can be maintained by deck crew.



A foam nozzle will be required to aspirate the foam liquid.

Ensure that your equipment is compatible or adjusted to the foam percentage carried

Foam Nozzle

These come in a variety of types and will aspirate (add air) to the foam as it goes through the nozzle. The nozzle can be used with an inline inductor as shown above or often in a standalone mode where the pickup tube comes from the nozzle and is put in to the foam concentrate.

A foam nozzle with a pickup tube.

This can be operated with or without an inline inductor, with the pickup tube being removable.

Typically these can throw foam up to 20 metres.

Larger wheeled units

Larger foam, dry powder and carbon dioxide wheeled units are usually found in engine rooms and often placed near manifolds during tanker loading or discharge. They are operated on the same principle as hand held extinguishers.

Because of their larger capacity and higher application rates they are able to control larger fires. Do not place them too close to high fire risk areas where a fire may limit access.

CO^2 Unit

Dry Powder

Foam

Initial Response

Providing the following actions are taken in order most emergencies are dealt with effectively. It is invariably the failure to inform that allows the incident to get out of control.

F Find - detect - using all senses, sight, smell, hearing.

I Inform - raise the alarm - by all available means

R Restrict - close doors, isolate electrics, switch off fuel, stop ventilation etc.

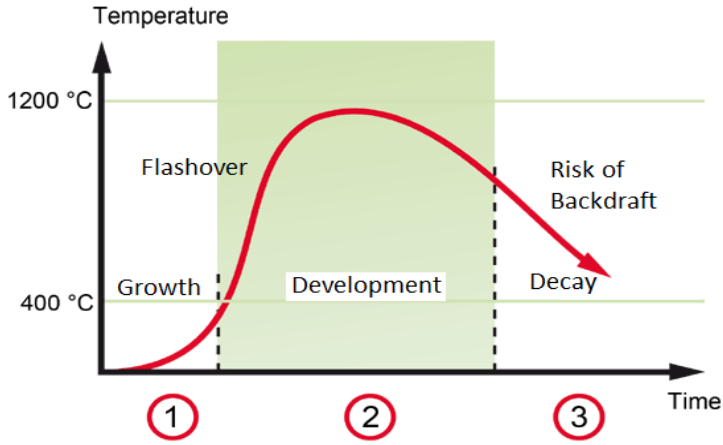
E Extinguish if it safe to do so or Escape and/or Evacuate.

Fires can start small and quickly grow in intensity. For this reason a rapid response can be an effective tool in combat against fire.

Growth is due to the process of combustion in which the heat given off will spread (through conduction, convection and radiation) and heat other items nearby. These will then start to release flammable vapour and ignite further items causing a **Chain Reaction** and increase in intensity.

There are a number of factors that will have an influence on fires such as the amount of fuel, air, location of fire and combustibility of the fuels involved.

Typically fires involved in a compartment such as a cabin will follow the same curve of development as shown in the diagram.



1. Ignition is the start of the fire and we see a steady increase in temperature as it grows incorporating more materials. Smoke and hot gasses start to be produced, rising in the compartment, forming a hot layer at the top of the space. In addition to the heat from the fire this layer of smoke also radiates heat downwards.
2. The heat levels inside the space increase to the extent where, along with a possible re combustion of hot gasses, all the items begin to break down and release combustible gasses. This sees a rapid conflagration known as ‘Flashover’ in which the temperature very rapidly increases and all the items in the space ignite. The temperature now reaches its maximum as now all the items are on fire.
3. We now see a reduction in the heat as the fuel is used up inside the space. The other reason for a possible reduction in intensity is a lack of oxygen, this can be dangerous to fire fighters if when entering the space oxygen is re-introduced causing a re-ignition which can often be violent. This is known as a backdraft. In order to prevent this care should be taken utilising the correct door opening procedures.

Techniques Door Opening

When opening doors inside a structure involved in fire, the temperature of the surface of the door and its fitting should be tested. Look around the edges of the door for signs of heat and smoke. Apply water on door to ascertain its temperature. If a fire or potential backdraught condition is suspected then certain precautions must be taken to prevent injury:

- Ensure that suitable fire fighting equipment is available and in position.
- Determine the type and the direction of opening of the door. Which side are the hinges? Are the door stops on your side?

If the door opens towards the team:

- The team should be positioned on the hinge side of the door.
- Use door as shield.
- Brace leg against door.
- Keep low.
- Pass nozzle to second in team.
- Warn the team and others in the area.
- Open no more than 10cm for 10 seconds.
- Look into the compartment at low level to assess the conditions.
- If it is safe, proceed through the door.

If the door opens away from the team:

- The team should be positioned on the handle side of the door.
- Use the wall on the opposite side to the door's hinges as protection. This may not always be practicable.
- Keep low.
- Keep hold of the handle, maintain control of the door.
- Pass nozzle to second in team.
- Warn the team.
- Open no more than 10cm for 10 seconds.
- Look into the compartment at low level to assess conditions.
- If it is safe, proceed through the door.

In any event doors should be left in the closed position after exiting to stop the spread of fire.

Techniques Search Procedures

BA wearers must balance the need for making progress and taking safety measures to avoid the numerous potential hazards found at all incidents. The following safety measures must always be adopted to reduce the possibility of accidents:

- A fire fighter should always shuffle not walk.
- The weight of the body should be placed on the rear foot until the advancing foot has tested that it is safe to move forwards.
- The feet should not be lifted from the ground; the foot should slide forward to detect obstructions or openings and other dangers such as a buckling deck.
- As you move forward, you should raise the free hand in front of you, lightly clenched with the back outermost to feel for obstructions. If the back of the hand touches a live electrical wire the shock will throw you clear and will not cause the hand to grasp the wire.

Searches should be carried out methodically to a pre-planned route detailed by the OSC/Team Leader before the search has begun. There are two directions in which a search can be carried out:

- Left hand search (maintaining contact with a bulkhead using the left hand on the way into the incident).
- Right hand search (maintaining contact with a bulkhead using the right hand on the way into the incident).

These searches can be carried out using two different methods of search pattern depending on the circumstances of the task.

Indirect Search

When teams are briefed to search and locate a casualty or the seat of a fire, then team members must spread out to cover the maximum area possible whilst maintaining physical contact. The team leader is responsible for maintaining the designated search pattern and wherever possible, the team must remain at right angles to the bulkhead. Any hatches or doors that are found on the opposite side to the search should be briefly assessed and if they cannot be searched without leaving the designated search pattern, the team should make note of it and inform the team leader/ OSC.

Direct Search

When teams are briefed to go to a specific area of a structure on either a left or right hand search pattern to carry out a search for casualties, locate a fire, or relieve a team then there is no requirement to search the areas of the structure prior to the arrival at the designated area. Therefore teams will proceed one behind the other with the team leader as the pathfinder, remaining team members must still carry out personal search procedures. Also direct search patterns can be used by teams withdrawing from an incident.

Techniques Heat / Condition Monitoring

Burns through heat transmission can cause serious injury. In a fire situation heat will be transferred to the BA wearers by:

- Conduction through direct contact with hot surfaces.
- Convection through high atmospheric temperatures caused by the fire.
- Radiated heat.
- Excessive steam production.

When working in BA regular sampling of the temperature to prevent contact burns can be achieved by rolling back the cuff of the glove and testing the air temperature at or above head level. This technique is designed to prevent BA wearers, who by the nature of their protective clothing are isolated from the environment, entering into potentially hazardous conditions of high radiant heat and atmospheric temperatures. A count of 5 seconds should be able to be sustained before rising from a low position or when entering a compartment.

When fighting Class A fires in the accommodation, always do so in the standing position and use water in short sharp bursts. Monitor the steam/heat barrier, stop applying water and crouch down into the cooler conditions when necessary. When the steam/heat barrier rises and it is safe to do so, stand and continue to fire fight, repeating this process as necessary until the fire is extinguished.

If a BA wearer starts to experience burns through their fire kit they should withdraw immediately and remove it ASAP. Usually the first signs of heat transmission through the PPE are felt at the shoulder straps and other places where the material of the PPE is in contact with the body. Note: Radiant heat is directional and unless the wrist is exposed in line with the direction of transmission BA wearers will not detect its presence.

Techniques Communications

Radio communications in all its forms are vital to the efficiency and safety within operations; this is particularly true during fire incidents. Even the best radio system can suffer from interference, because of this it is possible that others cannot hear anything or everything that is said. Therefore it is of utmost importance that proper procedures and simple clear language are used to save time.

All teams are to follow the following procedures when communicating on the radio,

- Radio messages and traffic should be kept short.
- Do not interrupt other users – except for priority messages prefix with “Urgent Urgent Urgent”.
- Always yield to more important messages.
- Speak slowly and clearly.
- Use easily understood words.
- Avoid ambiguity.

Radio discipline is the responsibility of every operator, and all users should adhere to the following:

- Listen before you speak.
- Use correct procedure (call station to, station from).
- Maintain constant radio watch.
- Answer all calls promptly.
- Keep the airways free of unnecessary talk.
- Be brief and to the point.

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