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# RISK FOCUS: ENGINE ROOM FIRES

*The majority of onboard fires originate in the engine room*

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# Reducing the risk of fire in the engine room

Considering the wide range of both sources of fuel and sources of ignition within the engine room, it should come as little surprise that a large proportion of fires onboard ships originate there.

Research coordinated by IMO<sup>1</sup> has indicated that between 30 and 50% of all fires on merchant ships originate in the engine room and 70% of those fires are caused by oil leaks from pressurised systems. Following a major engine room fire it is relatively rare that a ship is able to proceed under her own power. This leads to expensive costs of salvage, towage, repairs, downtime, cancellation of cruises, etc, which can typically run into millions of dollars.

Special attention should be given towards maintaining a clean and tidy engine room where machinery and emergency control equipment are installed and operated in accordance with SOLAS Regulations and IMO Guidelines and that the equipment is routinely serviced and maintained in good working order, and subject to routine testing. IMO MSC.1/Circ. 1321 dated 11 June 2009 entitled "Guidelines for measures to prevent fires in engine rooms and cargo pump-rooms" is especially relevant. If a failure to carry out proper maintenance or to have proper maintenance systems in place is linked to the cause of a fire, the shipowners or managers could face litigation in which allegations of crew negligence and/or unseaworthiness feature.

Except in certain specialist ships, the engine room is invariably a large enclosed space with limited divisions and compartmentation, with restricted access and with only defined walkways between equipment. It is not surprising, therefore, that engine room fires often present very challenging fire fighting conditions where effective first-hand fire fighting may be limited in time for reasons of safety, and where visiting fire parties may have to fight the fire from above when there is little or no visibility. Frequent and realistic fire drills that are tailored to address foreseeable fire scenarios specific to the particular engine room are essential. Moreover, some ship operators choose to engage specialist fire training companies to provide more advanced training aboard their ships.

## Fire essentials

All seamen should be aware of the Fire Triangle principle in that if the three elements of an oxidiser, (invariably oxygen from air), a source of fuel and a viable source of ignition come together a fire will result. The basic principles of fire fighting are to "break" one or more sides of the Fire Triangle so as to limit or eliminate the source of fuel and/or the oxidiser. It is also important to keep the fire triangle in mind when

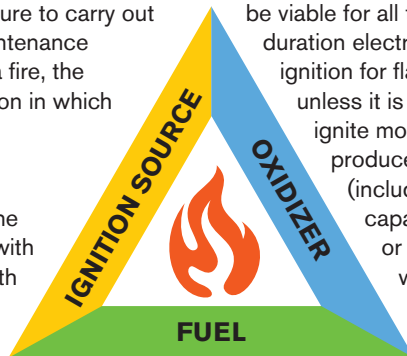
conducting fire risk assessments and implementing fire prevention measures.

In an engine room there is inevitably a plentiful supply of air and very effective ventilation systems. It is helpful, however, to consider in a little more detail the other two elements of the fire triangle; 'sources of ignition' and 'fuels'. An appreciation of the ignition processes will enable engine room personnel to better implement fire risk assessments and fire prevention measures.

## Ignition processes

The process of ignition involves the transfer of a sufficient amount of energy to a fuel to initiate a self-sustained combustion reaction. Not all potential sources of ignition will be viable for all types of fuel. For example, whereas a short duration electrical spark is likely to be a viable source of ignition for flammable gases, it will not ignite a liquid fuel unless it is very hot (above its flash point) nor would it ignite most solids. Similarly, although hot particles produced from welding or cutting operations (including angle grinding and disc cutting) are capable of initiating a smouldering fire in fibrous or finely divided solid fuels such as cotton waste, cotton rags, sawdust and cardboard packaging, such sources of ignition are much less likely to ignite solid materials such as timber and plastics. It should be noted that carelessly discarded smokers' materials (such as cigarettes and matches) provide a potent source of ignition for materials capable of supporting a smouldering fire. Smoking in an engine room should be confined to the control room, where appropriate means of disposing smokers' waste materials should be provided, such as a sand tray or a suitable safety ashtray. On no account should smokers' waste materials be disposed of in a general waste container, such as a waste paper bin.

It will be apparent from these considerations that sources of fuel and potential sources of ignition cannot be considered independently from one another. Possible fuels in an engine room exist in the solid, liquid and gaseous states and their physical and chemical properties will determine the way in which they react to a potential source of ignition and whether that ignition source is viable. The table in Appendix 1 summarises the various types of fuel typically encountered, conditions required to achieve ignition and examples of viable sources of ignition for the fuel. For ease of reference the



<sup>1</sup> Analysis of Fire Hazard and Safety Requirements of a Sea Vessel Engine Rooms, Adam Charchalis & Stefan Czy, *Journal of KONES Powertrain and Transport*, Vol. 18, No. 2 2011

technical terms shown in *italics* in the table are explained in a glossary.

Although the table in Appendix 1 provides a useful and quick source of reference, it is helpful to illustrate how a failure to comply with SOLAS Regulations and to provide for effective maintenance and tidiness in an engine room can lead to a serious fire with the potential for loss of life and injury, major financial consequences and unnecessary litigation.

## Oil fires

Oil fires are invariably the most serious category of engine room fires. Two ships entered with the Club recently suffered significant engine room fires with remarkable similarities. Both fires originated in the region of the generators when leaking oil sprayed onto hot exhaust surfaces and the subsequent efforts to extinguish the fires were hindered because of a failure to maintain the fire smothering systems correctly and/or a lack of understanding by the crew of the correct method of deploying the systems. In one case, two crew members suffered smoke inhalation injuries and in the other, one died while trying to fight the fire. In both cases significant damage to the engine room occurred resulting in towage and expensive repairs.

Fires can result from a failure to attend to small persistent leaks that can, for example, spread across machinery surfaces to reach parts operating at a high temperature, and from larger leaks that develop suddenly. For example those caused by:

- Loose joints
- Fractured pipes and mechanically damaged (perforated) pipes on both high and low pressure fuel lines
- Bleed cocks on generator fuel filters working loose
- Pipe unions that are over or under tightened
- The fracture of flange bolts if over tightened
- The fracture of cyclically stressed bolts or studs that are under-tightened, such as those securing fuel injector pumps
- The use of unsuitable seals or gaskets which deteriorate due to the effects of heat
- The rupture of high pressure oil and hydraulic fluid hoses due to mechanical damage or aging

Correct maintenance procedures should be strictly adhered to. High pressure pipes should be sheathed and flange joints enclosed where they are in proximity to hot surfaces in order to comply with SOLAS Regulations. Any hot surface shielding should also be effectively maintained.

## Hot surface ignition and preventative measures

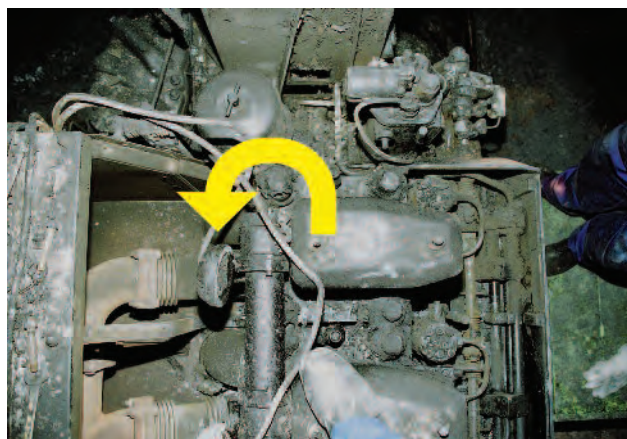
Oil fires usually occur when oil from a large leak or a smaller but persistent leak comes into contact with a nearby hot surface at a temperature that exceeds the 'minimum auto ignition temperature' (MAIT) of the oil. MAITs of diesel and fuel oil are typically about 250°C, but MAITs as low as 225°C have been reported. Lube oils and hydraulic oils have somewhat higher MAITs. High pressure sprays comprising

fine droplets of oil can ignite immediately on contact with the hot surface, and liquid leaks can ignite after a short period of time sufficient to evaporate the oil and generate a flammable concentration of fuel vapour. Under certain circumstances, such as where flammable concentrations of vapour form in confined spaces, the fire may be preceded by an explosion. Clearly, all oils should remain contained within their intended systems. Oil fires often develop and spread quickly compromising the safety of engine room personnel and, in the case of generators, damaging associated main electrical cabling feeding the switchboard which can lead to a loss of electrical power and, as a result, motive power.

Spray shields should be fitted around flanged joints, flanged bonnets and any other threaded connections in fuel oil piping systems under pressure exceeding 0.18 N/mm<sup>2</sup> which are located above or near units of high temperature in accordance with SOLAS II-2 Reg. 4.2.2.5.3 and MSC.1/Circ1321. Furthermore, high pressure fuel delivery pipes should be sheathed within jackets capable of containing leaks from pipe failures, the annular spaces of which must be equipped with suitable drainage arrangements to facilitate the rapid drainage of oil to a safe location, such as a drain tank.

It is essential to employ good maintenance systems and engineering principles in order to reduce the risk of oil leaks. This includes, for example:

- attending to minor leaks without delay
- tightening connections to fuel injectors and fuel injection pumps to the correct torque to prevent leakage and/or fatigue fractures caused by cyclical stresses induced by operation of the pump
- maintaining oil leak detection and alarm equipment that can warn of the presence of oil leaks in concealed areas such as a 'hot box' enclosing fuel pumps on some types of generator



**Potential route for hot oil vapour to spread from the hot box enclosure to the exhaust enclosure (cladding/covers removed for inspection)**

The maintenance of leak detection/alarm equipment is especially important where oil vapour from a leak of hot oil at a temperature above its flashpoint can, for example, migrate from the hot box of a generator, across the engine entablature to exhaust system enclosures where the vapour can auto-ignite



on exhaust components that are otherwise properly shielded from leaks in accordance with the requirements of SOLAS.

Preventing oil leaks is one half of the problem, the other being effective cladding or shielding of hot surfaces so that they do not present a source of ignition if an oil leak occurs. This is possibly the most effective way to prevent Engine Room fires and fairly easy to implement onboard.

It is a SOLAS requirement that surfaces, with temperatures above 220°C that might come into contact with oil as a result of a system failure are properly insulated. Ship's crew should, therefore, appreciate that even a small exposed area of non-insulated hot surface, such as part of a flange joint or an instrument pipe, can be potentially dangerous. The photographs below illustrate examples of defective protection of hot surfaces ranging from a complete failure to clad generator exhausts to the exposure of parts of exhaust systems.



**Exhausts completely uninsulated**



**Exhaust bellows exposed**



**Small portion of exhaust surface exposed (as arrowed)**

While every effort may be made to shield or clad large hot surfaces and their appendages, gaps can exist even in what appears to be well maintained insulation. Turbochargers, in particular, by their complex shape can be particularly challenging to effectively insulate. Therefore, it is sensible practice to carry out routine surface temperature measurements of the critical parts of machinery, especially at bends and flange joints where surface profiles may vary considerably. This can be done effectively by using an Infra-red temperature gun (such as the one illustrated) which is relatively cheap and provides an instantaneous visible reading while being used remotely from the area of interest. It is important to follow the instrument manufacturers' operation instructions otherwise misleading results will be obtained. Some instruments sound an alarm if a measured temperature is outside set limits. It should be noted that higher surfaces temperatures are likely to be reached when there are higher ambient temperatures (such as when the ship is operating in hotter climates) and engines should be under normal or heavy load and up to maximum operating temperature when measurements are made. The instrument can also be used to warn of potential sites of localised electrical overheating on the main electrical switchboard, electrical circuitry and running machinery and for the correct operation of reefer equipment, as will be discussed later.



**Infra-red temperature gun. On some instruments a laser beam pinpoints the target surface of interest, making for precise measurements and accurate temperature profiling. Slightly more expensive instruments provide a heat map image of the area of interest.**



**"Hot spot" due to missing insulation**

Alternatively, surveys can be carried out by using more expensive thermal imaging equipment which provides a clear image of the surface temperature profile as illustrated in the example below, where the thermal image is compared with the visible light image.



IR001153.IS2-NO1 Auxiliary engine



Visible light image

#### Main image markers

Name	Temperature	Emissivity
Hot	318.1°C	0.95

Images courtesy of SVL Singapore Services

As a result of such surveys, it was estimated that around 80% of ships checked had exposed areas in excess of the 220°C SOLAS requirement. Recent checks by the Club's Risk Assessors using an Infra-red temperature gun suggest that this figure may not be exaggerated.

Indicator cocks are another potential source of ignition. IMO MSC.1/Circ. 1321 Para 1.1.5 recommends that "Exposed indicator cocks should be insulated in order to cover the high temperature surface."

Again, an IR temperature gun can be used to assess the fire ignition risk of uncovered indicator cocks.

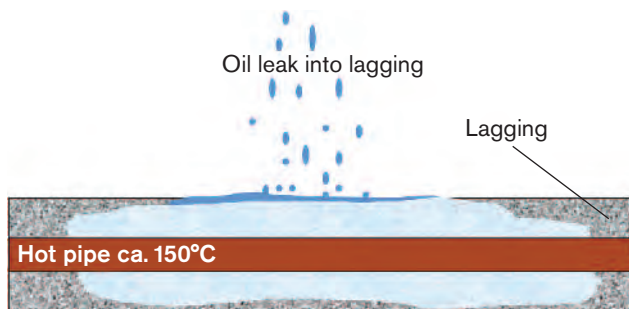


Uncovered indicator cock with exposed temperature above SOLAS limit

### Lagging fires

If mineral oils (fuel oil, diesel oil, lube oil) soak into lagging on pipe work operating at a temperature above about 150°C there is a risk that the oil will oxidise slowly within the matrix of the lagging and eventually ignite spontaneously, causing the lagging to disintegrate and oil from a persistent leak to ignite. This process can take many hours, and there may be little external warning of the imminent danger until smoke appears shortly before the fire becomes visible. It is essential, therefore, that oil leaks are attended to promptly and that permanent repairs, including the replacement of oily lagging, are made correctly rather than resorting to makeshift solutions.

#### Risk of 'spontaneous ignition'



### Tank save-alls

Dirty oil tanks and purifier save-alls present a fire hazard, both from being at a risk of ignition and providing a means of spreading a fire. It is essential to keep drain lines clear and prevent oil accumulation. Oil residues are likely to be at a temperature below their flash points and, therefore, not directly ignitable. However, fibrous solids such as cotton waste and rags partially immersed in the oil can function as a wick. The 'wick' may be ignited by contact with a welding spark or a smouldering source, such as a carelessly discarded cigarette, leading to a smouldering fire that eventually undergoes transition to flame. The oil feeds into the wick to sustain the fire and the surrounding oil layer is raised to a temperature at which flame can spread across the oil surface causing the fire to develop. The failure of tank valves and level gauges directly exposed to the save-all fire becomes possible.



Self-closing valves are fitted between the lower end of an oil tank and its gauge glass. The purpose of these valves is to isolate the tank gauge glass from the tank. In normal operation they should be shut and only opened to check the tank contents after which they should be shut automatically under spring pressure or counter balance gravity.

The UK Club's ship inspectors regularly find that various methods are used to keep these valves permanently in the open position. Chocks of wood, pieces of wire and purpose made clamps are often seen to be used to for this purpose. This is dangerous practice. If a gauge glass breaks in a fire the entire contents of the tank will leak into the burning area, escalating the fire.



**Self-closing gauge glass valve gagged with wire**



**Self-closing gauge glass held open with string**

## Solid fuels

As summarised in the Table at Appendix 1, solid fuels typically encountered in an engine room include:

- cellulosic materials, such as constructional timber, cardboard packaging, sawdust, cotton waste and rags, and
- plastic materials, of which there are two main types: thermosetting plastics, which maintain their form and rigidity when exposed to high temperatures, and

thermoplastics, which tend to melt and drip when exposed to high temperatures.

The potential for cellulosic materials to smoulder and to be susceptible to ignition by small ignition sources such as sparks produced by hot work and carelessly discarded smokers' materials is often overlooked. Smouldering fires can develop slowly, sometimes in concealed spaces, and may not be discovered until several hours later after the transition from smouldering to flaming combustion has occurred. Although the presence of constructional timber in an engine room is unusual, it should be noted that timber insulated from its surroundings and in contact with a hot surface at only a moderately elevated temperature (i.e. above about 120°C) can under certain circumstances ignite after many days. Any constructional timber should, therefore, be well separated from or insulated from hot surfaces.

Angle grinding and disc cutting operations should be included in the 'hot work' category because, although the size of incandescent particles produced is generally very much smaller than those produced by welding and flame cutting operations, a stream of grinding or disc cutting sparks landing in the same area of a solid fuel can be sufficient to initiate a smouldering fire. Frictional heating of the work piece may also act as an ignition source, e.g. of oil residues on its surface.



**A stream of sparks from disc cutting**

It is essential that engine room workshops and stores are kept clean and tidy and that smoking is strictly prohibited. In the stores, packaging materials should be kept to a minimum and cardboard cartons should be stored clear of light fittings. In the workshop, floor areas and work surfaces should be clear of all combustible waste, particularly cellulosic materials susceptible to smouldering combustion. This is especially important when hot work is carried out behind welding curtains to prevent the spread of stray sparks. Cotton waste and rags should be kept in a bin fitted with a lid and bales of cotton waste and rags stored in a metal cabinet.

Oil soaked rags have been known to "self heat" and combust spontaneously so, until they can properly be disposed of, should be kept in a steel container with a lid.

Hot work outside the workshop should be the subject of a hot-work permit system. It should be noted that sparks from

welding and flame cutting operations take time to cool to a temperature at which they are no longer incandescing, can be projected considerable distances, e.g. more than 10 metres, can travel horizontally by bouncing and can fall through gaps. Careful consideration must be given to the removal of all combustible materials within range of the hot work and the use of proprietary welding blankets or curtains to cover materials that cannot be moved and to cover any gaps to prevent incandescing particles falling into unprotected areas. If there is a possibility of a flammable atmosphere being present in the area where hot work is planned, gas testing of the atmosphere within range of flying sparks must be carried out before and frequently during the work out by a competent person using an explosimeter that has been calibrated and serviced in accordance with the instrument manufacturers' guidelines. Hot work should only be permitted if the reading on the explosimeter registers 10% LEL or less both before and during the hot work.

Another potential source of ignition is an electrical lead light whose unprotected bulb and its filament are perfectly capable of starting a fire.

## Gaseous fuels

A relatively small number of ships utilise gas as a fuel for propulsion. Gaseous fuels typically encountered in an engine room are acetylene and propane. Oxygen, although not a fuel, will also be present for oxy-gas welding and flame cutting operations. These gases are supplied in colour coded cylinders with gas specific regulators and flashback arrestors. Gas cylinders should not be stored in the engine room. Oxygen and acetylene cylinders should be stored upright in separate ventilated steel compartments above the weather deck, separated from other compartments. From there, the gases at low pressure are distributed via flashback arresters and steel pipes to outlet stations in the engine room fitted with stop valves which should be kept closed when not in use. Alternatively, gases can be distributed at high pressure to outlet stations fitted with flashback arrestors, regulators and stop valves. Where only portable oxy-gas welding or cutting equipment is available this should be secured upright when not in use in designated ventilated compartments on or above the weather deck.

Flexible hoses designated for use with oxy-gas equipment, colour coded blue for oxygen, orange for propane and red for acetylene must be used. When laid out in an engine room the hoses should not be kinked or pass over sharp surfaces that could cause damage. When a cutting or welding torch is not in use the gas supplies must be isolated at the shut off valves. Under no circumstances should hoses be folded over to temporarily isolate a gas supply to the torch. Hoses should be subjected to frequent inspection and damaged hoses should be replaced in accordance with manufacturers' recommendations.

All equipment must be properly maintained and leak tight. The leakage of acetylene into enclosed spaces causes an explosion and fire risk. Acetylene is an extremely reactive gas and, when mixed with air in certain proportions can detonate. In a previous accident a pressurised acetylene flexible hose

was leaking close to the air intake of the starting air compressor, resulting in flammable mixture being created in the air receiver. Subsequently, when the air was used to start a generator, a series of serious explosions occurred, fracturing pipe work and other equipment. Similarly, oxygen leaks must be prevented and special care must be taken to exclude even traces of grease in oxygen handling equipment, such as regulators. Combustible materials that may ordinarily not be easily ignited will ignite readily and burn violently in oxygen enriched atmospheres.

## Electrical fires

Electrical circuits are distributed from the main electrical switchboard to all parts of the ship via sub-distribution boards. Cables are protected against overload by using fuses or circuit breakers. Fuses and circuit breakers are rated specifically for the size of the cable and the load they are protecting and it is dangerous to replace these with protection devices of a higher rating. All circuits should be correctly labelled at the main switchboard and the sub-distribution boards. Where cable routings have been altered it is essential to make permanent changes to circuit labelling at the fuse or circuit breaker board and to updated electrical drawings. Temporary labels marked on adhesive tape or written on adhesive paper to cover over the original label can deteriorate and detach, leading to confusion over which circuit is energised.

Spaces behind switchboards should be clear of packaging materials and the floor area should not be used for storage purposes. Such practices increase the risk of a serious fire developing there. The inside of switchboard casings should also be kept clear of dust, dirt and other flammable materials.

In a normal circuit there should be no added resistance introduced at junction points, such as where cables are screwed to terminal connectors or where plugs are inserted into sockets, or as a result of thinning of conductors in a cable caused by mechanical damage. Unfortunately this is not always the case. A failure to ensure that terminal connections are correctly made and tight can cause a point of local resistance, unwanted heating and a fire hazard ('resistance heating'). Such defects are usually self-worsening as a result of thermal cycling and an accelerated formation of surface oxide which increases the resistance thus further reducing the effectiveness of the terminal contact. It is important, therefore, to not only ensure that terminal connections are correctly made, but also to inspect these whenever the opportunity arises.

Routine inspections of busbar connections on the main electrical switchboard can be made by using an Infra-red temperature gun of the type to which reference was made earlier. However, such inspections will not always be a useful indicator of incipient resistance heating faults at sub-circuit or equipment terminal connections. Whereas the incipient fault may not be apparent at the time of the Infra-red temperature measurement, it could self-worsen exponentially with time. Nevertheless, such measurements are to be encouraged generally, even though the results should be interpreted with caution. There are also companies that specialise in undertaking such surveys.



The insulation on cable conductors and motor windings can deteriorate over time. A breakdown in cable insulation can lead to stray electrical currents and ultimate short-circuit arcing in a cable. This can be a highly energetic event that can readily melt plastics and may completely evaporate metal contacts and cable conductors resulting in the explosive ejection of molten metal providing a source of ignition. A breakdown in the insulation of motor windings can be a source of localised heating and fire. It is essential, therefore, that a programme of routine insulation resistance testing of cables and other equipment is maintained, and be aware that cable insulation can deteriorate from exposure to UV light.

Arc flash incidents can occur where engine room personnel work carelessly on live equipment and cause a short circuit with a tool. No matter how well a person may be trained, distractions, weariness, pressure to restore power, or over-confidence can cause an electrical worker to bypass safety procedures, work unprotected, drop a tool or make contact between energised conductors. This may not only lead to serious injury or death, but also provide a source of ignition for a fire.



**Arc flash incident**



**PPE to guard against the effects of arc flash**

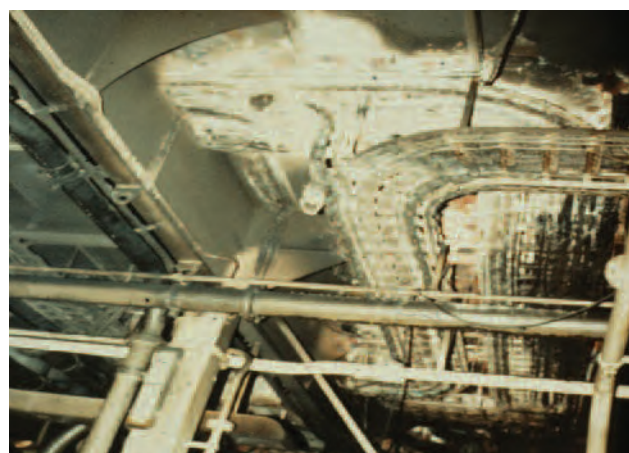
The contacts of switching mechanisms, such as in contactors, can become eroded and this may cause contacts to stick closed or provide a source of resistance heating. Routine inspections of such equipment may not be practicable, especially in respect of small compact devices. However, the equipment should be repaired or replaced if there is evidence that the contacts fail to open and close correctly or if signs of localised heating are discovered.

The confluence of electrical cables in distribution boards necessitates a large number of terminal connections to both cable conductors and overload protection devices such as circuit breakers. Inspections of terminal connections and, ideally temperature measurements of the same made by using an Infra-red temperature gun, should form part of shipboard inspection and maintenance programmes. Where multi-stranded electrical conductors are connected to a terminal care should be taken to ensure that there are no stray strands that could inadvertently make contact with another part of the installation. It should be established that all switchgear is clean and circuit breakers are in good condition. Fire stopping around cable glands should be in good condition to minimise the risk of a fire spreading from the distribution board to surrounding areas.



**Cables entering a distribution board through fire stopped openings in the casing**

Larger electrical cables are often steel braided or steel wire armoured so that combustible insulation is not exposed and the risk of flame spread is minimal. Even though cable insulation is invariably flame retarded to lessen the risk of ignition and flame spread, groups of cables fixed to a cable tray can spread flame, especially when exposed to an external source of fire, such as a fire on an auxiliary generator.



**Damage caused by the spread of fire along cable trays after being exposed to a fire at a lower level of the engine room.**



**Fire spread along cable trays away from an auxiliary generator where the fire originated**

## Scavenge fires

Fires occasionally occur in the scavenge space of two stroke diesel engines. The fuel for such fires is normally a mixture of lubricating oil, unburned fuel and carbon deposits which form an oily sludge. It has been observed that heavy deposits typically accumulate before a fire occurs, normally due to engine deficiencies such as: excessive cylinder liner and/or piston ring wear (sometimes caused by poor quality fuel); broken piston rings; poor combustion; and improper timing. The deposits are normally ignited by the blow-by of hot combustion products between the piston and liners, but mechanical abrasion between components represents an alternative ignition source.

To prevent scavenge fires there should be an adequate maintenance regime for the main engine, and in particular for: the cylinder liner; piston components; piston rod stuffing boxes; fuel system and cylinder lubrication system. Furthermore, scavenge spaces, and the drain pockets therein, should also be regularly inspected and cleaned. If present, the cause of an excessive build-up of oily deposits in the scavenge space should be investigated and rectified. With the engine in operation, scavenge drains should also be regularly checked to ensure that they do not become restricted or blocked.

Crew members should be trained in the actions to be taken in the event of a scavenge fire and in the use of the local scavenge fire extinguishing medium/system provided aboard the ships. In the event of a serious scavenge fire crew members should be aware that: boundary cooling may be necessary; that they should stand clear of scavenge space relief valves in case of explosion; and that the scavenge space should not be opened for inspection until it has adequately cooled.

## Soot fires in exhaust gas boilers/economisers

Diesel engines, particularly those running on heavy fuel oil, inevitably generate soot that will be deposited on exhaust gas boiler tubes. If the soot is dry it is unlikely to ignite when

exposed to exhaust gas temperatures normally encountered in the economiser, which are typically 220-260°C.

The rate of deposition of soot can be greater when diesel engines are operated on light load, i.e. when slow running or manoeuvring for an extended period of time, due to unfavourable combustion conditions and low exhaust gas velocities. When operating on light load, the possibility also exists that there will be a carryover of cylinder lubricating oil and/or unburned fuel with the exhaust gas, which can result in the oil particles mixing with the soot, to form a so-called 'sticky soot' that has a greater propensity to deposit on boiler tubes. It has been reported<sup>2</sup> that oil mixing with the soot can significantly reduce the ignition temperature of the soot deposits and that in the extreme spontaneous ignition can occur below 150°C, i.e. at temperatures below those encountered under normal operating conditions. It is for the reasons explained above that soot fires are more common following manoeuvring or operation on low load. Such fires can be severe and develop to the extent that boiler tubes become damaged, resulting in a loss of integrity. Water escaping from the damaged tubes can break down to release hydrogen that sustains and increases the severity of the fire leading to extensive damage to the boiler.

Soot fires in exhaust gas boilers can be averted by regular soot blowing of the exhaust gas boiler tubes (ideally using automatic soot blowers), particularly after slow running or manoeuvring. In such a scenario it is recommended that soot blowing should be carried out prior to increasing engine power or shutting down the engine. Water washing may also be carried out if permitted by the manufacturer.

The risk of a soot fire can also be reduced by starting the boiler water circulation pump in advance of the main engine and this should not be shut down until after proper cooling of the tubes, for periods of time recommended by the manufacturer. Furthermore, any defects that may lead to excessive engine smoke generation should be promptly addressed.

Crew members should be trained in the actions to be taken in the event of a soot fire in an exhaust gas boiler, taking account of the guidance given by equipment manufacturers and the facilities onboard the ship. In this regard, when discovering a small soot fire the principal objective should be to act promptly to prevent it developing to the extent that there is a loss of integrity of the boiler tubes. It should also be noted that should the fire develop to this stage, then extreme care should be exercised when using water to fight the fire as this may worsen the situation unless copious quantities of water are applied to the heart of the fire.

## Boilers and incinerators

Oil-fired combustion systems installed on boilers and incinerators can be a source of fires and onboard controls and interlocks should be in good working order and never overridden. The risk of fire and explosion incidents occurring can be minimised by implementing effective inspection and maintenance procedures.

<sup>2</sup> Soot deposits and Fires in Exhaust Gas Boilers, MAN Diesel & Turbo, September 2014



## Visual inspections

These should be carried out by a trained and competent engineer on each watch to ensure that:

- The flame picture within the combustion chamber is correct in order to confirm that the oil is atomising properly and combustion characteristics are correct. Incorrect atomisation of the fuel can lead to an accumulation of unburnt fuel in the combustion chamber.
- Pipework both supplying and forming part of the burner equipment is leak-free. Note that fine oil sprays are sometimes less conspicuous than drips and weeps from leaking joints.
- Flexible fuel hoses are in a sound condition, showing no signs of physical damage, corrosion or abrasion.
- There are no unusual noises associated with the operation of combustion air fans and oil pumps.
- Operating pressures and temperatures are correct.
- Drip trays and save-alls are clean and dry.

Routine inspection, testing and maintenance should be carried out in accordance with manufacturers' guidelines and any onboard planned maintenance procedures. This includes control equipment on incinerator waste oil feed tanks. A recent explosion in a waste oil feed tank resulted from a failure to maintain the liquid level sensors and interlocks which allowed the oil level to fall below the thermostat resulting in a loss of temperature control. The heater elements also became partially exposed, which vaporised some of the oil and ignited the vapour.

Large quantities of solid waste for the incinerator should not be allowed to accumulate. Fire detection and automatic fire extinguishing systems for waste storage compartments should be in good working order.

## Fire safety systems

Chapter II-2 of the SOLAS (1974) Regulations and their amendments set out the requirements for the provision and maintenance of fire detection, fire suppression, fire prevention and means of escape in case of fire. For ships, the keels of which were laid on or after 1 July 2002, engineering specifications for these fire safety systems are set out in the International Code for Fire Safety Systems (FSS Code). The lives of crew members and their ability to carry out effective fire fighting to minimise damage is dependent on the operability of these systems and familiarity of crew members with them. Delays in the detection of a fire and in the implementation of fire fighting will inevitably be critical.

### Fire detection

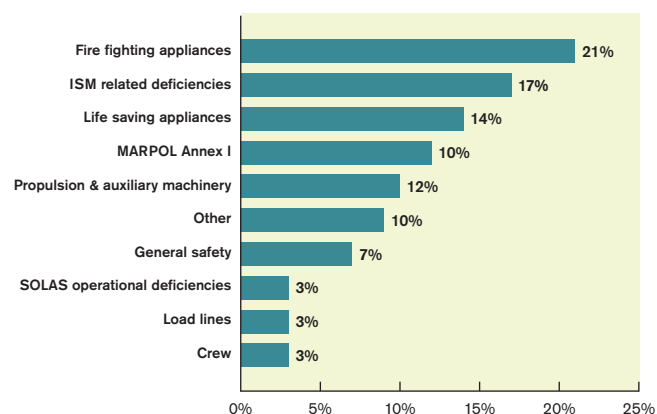
This is normally achieved by smoke or heat detectors. Ideally these should be of the addressable type so that the precise location of the fire can be determined from the fire alarm panel. Under no circumstances should detectors be covered, e.g. whilst conducting hot work in the vicinity. The testing of fire detection and alarm systems should be carried out in

accordance with IMO circular MSC.1/Circ. 1432, May 2012. Weekly tests should be carried out to determine that all fire detection and fire alarm control panel indicators are functioning by operating the lamp indicator/test switch. A sample of detectors and manual call points should be tested on a monthly basis so that all detectors will have been tested within five years, and all detectors should have been visually examined within a one year period to ensure that they are not damaged and that they have not been tampered with. In unmanned or temporarily unmanned machinery spaces additional fire detection equipment will be required in accordance with SOLAS II-1.

## Fire suppression

In their 2015 annual report, the USCG identified that the greatest deficiency onboard ships (21%) was the fire fighting appliances.

### Types of safety deficiencies



The UK Club's Risk Assessors also frequently note defects in this area. Fire hydrant caps are often found to be difficult to remove by hand (requiring the use of a spanner) and hydrant valves are found to be leaking. Leaking hydrants in an engine room may be tightened with a wheel key and this may render them inoperable by hand in the event of a fire. It is recommended that the high risk threat of engine room fires is recognised and that ship's crew pay particular attention to training and the care, maintenance and correct operation of all fire fighting equipment.



Hydrant cap difficult to remove, and valve leaking



**Obstructed FFE**

A possible reason for the substandard condition of fire fighting equipment is that it is infrequently used during fire drills. It is clearly not advisable to rig and discharge fire hoses in the engine room, but hydrant caps and valves, fire hoses and nozzles, and fire dampers can still be checked and tested and the correct positioning and inventory of portable extinguishers can be confirmed. In the case of fire dampers it is not sufficient to test them for correct operation alone. It is important to inspect the condition of each damper to ensure that it is not corroded and that it seals properly with the frame of the opening against which it closes. The exclusion of a ready supply of air to the engine room will be crucial in starving the fire of oxygen and maintaining the effectiveness of total flooding gas fire suppression systems that have been activated.

## Fixed fire suppression systems

In both the recent generator fires discussed earlier, fire fighting attempts were hindered by the ineffectiveness of the fire smothering system because of a lack of understanding of its correct method of deployment and a lack of proper maintenance.

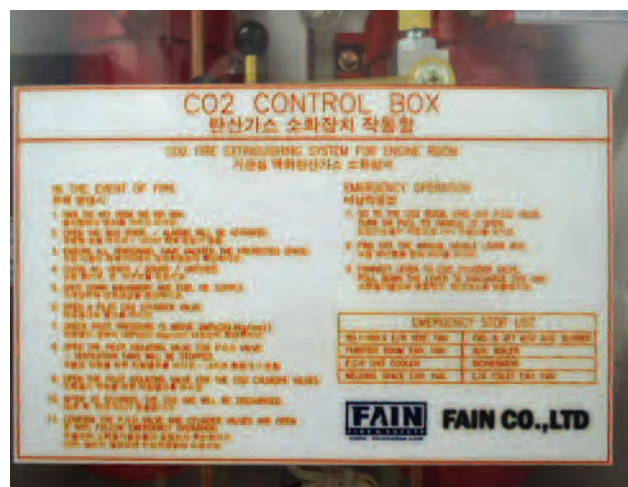
In the first, it is thought that the Chief Engineer did not operate the CO<sub>2</sub> system release mechanism correctly and, as a result, only one cylinder (of 43) was discharged which had a negligible effect on the fire. It is possible that he released a cylinder from the main bank of cylinders instead of a pilot cylinder in the mistaken belief that this would trigger the release of the requisite number of cylinders.

In the other, it was found that of the two banks of halon cylinders, one bank had only been partially released and the other bank had not been released at all. It is noted that halon systems should generally have been decommissioned since December 2003.

During another unrelated engine room fire incident (which started when fuel sprayed onto a hot, unprotected exhaust system) it was thought by the crew that the CO<sub>2</sub> had been released when, in fact, it had not. During a subsequent inspection of the CO<sub>2</sub> system, it was accidentally activated and three crew members in the engine room were fortunate to escape with their lives.

Fixed fire suppression systems should not be considered as a "last resort" as they are possibly the most effective and least dangerous method of fire fighting. Indeed, it should be appreciated that these systems are most effective if used promptly. As such, the crew must be familiar with their operation. Clearly, CO<sub>2</sub>, high expansion foam, high-pressure water mist and water sprinkler systems should not be activated during fire drills. Ship's staff must, however, be trained on and be familiar with their operation so that they can be correctly deployed and with minimum delay. Fire mains can, however, be tested by pressurising with designated fire pumps, including the emergency fire pump, and connecting fire hoses on deck to ensure that the correct water jets are provided. Crew members should be trained in the use of all fire pumps, as it is possible that the crew members most familiar with the fire pumps could be incapacitated or unavailable when a fire occurs.

Instructions to operate CO<sub>2</sub> systems can be complicated and valuable time will be wasted if it is necessary to read these for the first time in order to activate the system. Fire drills should include rehearsing the sequence in which the necessary operations should be carried out to activate the systems, including the importance of stopping fans and closing engine room ventilation dampers. In one instance, an electrician was instructed to activate the CO<sub>2</sub> system but, with no previous knowledge or training, did so incorrectly.



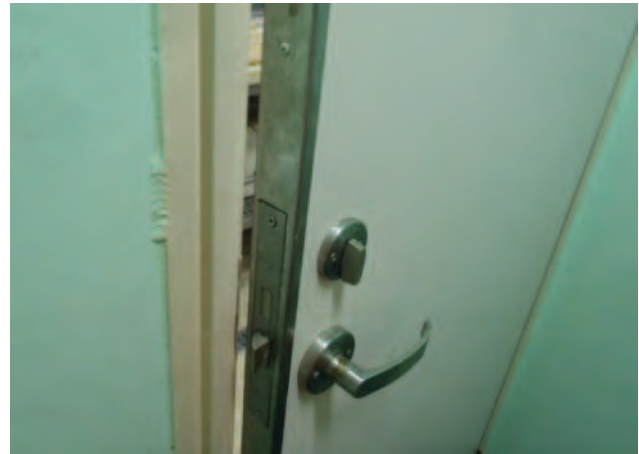




After a CO<sub>2</sub> system has been activated in accordance with operating instructions, it is prudent to check that the pilot bottles have operated and the requisite number of cylinders has discharged. This can be done by visually inspecting the cylinder release mechanisms to determine that they are in the activated position. It is important to bear in mind, however, that leaks from the activated system can occur which may reduce the oxygen concentration in the cylinder storage room. For this reason crew members should be ready to perform enclosed space entry procedures with self-contained breathing apparatus sets when undertaking such checks. Automatic fire suppression systems, such as local application high pressure water mist systems, can be used in the auto or manual modes. However, in order for such systems to be most effective they should be left in the auto-mode and the smoke and flame detection systems that trigger their operation should be active and fully operational. Valves in pipework feeding these systems should be kept open.

## Limiting fire spread

Engine rooms are separated from other parts of the ship, such as the accommodation, by fire resisting divisions constructed in accordance with SOLAS II-2 to contain the fire and limit the risk of fire spread. Openings in these divisions, such as engine room access doors, are fitted with self-closing devices. Similar arrangements are found within the engine room for the purpose of subdividing it into compartments. Fire doors are, however, regularly found to not fully close automatically or are tied / wedged in the open position.



Fire door failing to close



Fire door tied open

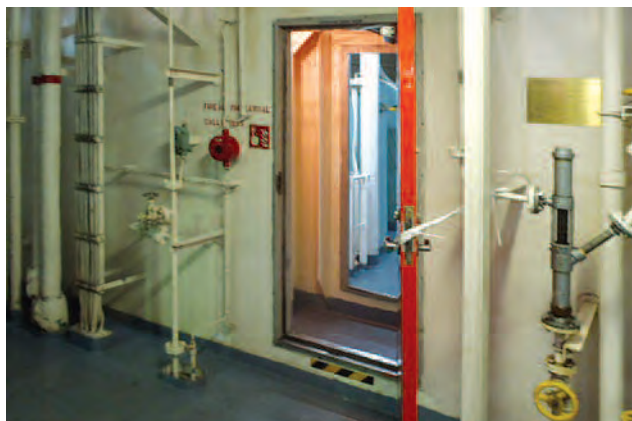
This creates an unnecessary hazard because it provides a route by means of which smoke and fire can spread to adjacent compartments and accommodation areas can quickly fill with smoke preventing safe egress, resulting in fatalities. Moreover, this may also prevent fire parties from preparing and taking up the most favourable strategic positions or accessing fire lockers etc. It may be necessary to evacuate an engine room before there is sufficient time to close engine room access doors that are held open. This is likely to render the CO<sub>2</sub> system as ineffective.



Fire door tied open

All fire doors on a ship are important, but when the high risk of Engine Room fires is considered, Engine Room fire doors should receive special attention.

The particular importance of the fire doors between the Engine Room and Steering Gear Compartment should also be emphasised. These are very frequently found to be tied in the open position.



**Steering gear fire doors tied open**

Not only do these doors prevent fire spread from the engine room into the steering gear compartment, they would prevent wastage of CO<sub>2</sub> in the event that the total flooding system has been released. The calculated volume of the CO<sub>2</sub> required to flood the engine room does not include the volume of the steering gear compartment which means that the concentration of CO<sub>2</sub> in the engine room would be less than required in the event that the door was left open.

Combustion products and/or CO<sub>2</sub> escaping into the steering gear compartment would make it difficult to access, leading to delays in priming and/or starting the emergency fire pump if it is located there, as is often the case. Open fire doors would also hinder any fire-fighting / rescue attempts from the steering gear compartment which, typically being at a lower level than other engine room access doors, is an obvious place from which to tackle engine room fires, which was the case in one of the aforementioned incidents. The dead crew member was later recovered from here. During the other incident, the steering gear compartment was used as the principal escape route.

The UK P&I Club has already issued a Technical Bulletin No. 25/2007 (Steering Gear Compartment Fire Doors) on this topic, and it should be added that the door from the steering gear compartment onto deck should be able to be unlocked from both sides.

## Escape routes and escape doors

In the UK Club Technical Bulletin No. 39/2012 (Escape from Engine Rooms) it is suggested that arrows are painted on the deck plates pointing to the nearest escape route. This good practice is commonly seen on UK P&I Club ships, but sometimes the arrows could be laid out more clearly. The photographs show excellent arrows leading to the escape trunk, but none to the steering gear compartment which is an alternative escape route.



**Well marked escape route arrows**



**Poorly marked escape route and door**



**Well marked door**



Technical Bulletin No. 39/2007 also recommends that the exit doors are clearly highlighted. In both the above photographs, it can be seen that white painted doors do not stand out well against white painted bulkheads. Doors painted with “tiger stripes” or marked with retro reflective tape are far more obvious.

The best escape route from an engine room fire will depend on the location of the fire and its severity and so it is, therefore, difficult to generalise. However, careful thought should be given when marking emergency escape routes and these should not be confused with normal exit routes. In a fire situation, the safest escape route may not be via the internal ladders leading up to the accommodation exits, but sideways (or even downwards) via the escape trunk, the steering gear room or other “safe” areas such as shaft tunnels and side passageways.



**Arrows leading away from exit door**

Technical Bulletin No. 39/2007 also points out that even though engine room staff might believe that they know their way around blindfold, others (for example visitors and newly-joined crew) may not. Furthermore, smoke is very disorientating. A crew member who suffered smoke inhalation injuries during a recent fire became disorientated in the thick smoke was an Oiler who would be expected to have been very familiar with the engine room layout. He was fortunate to survive whereas an AB who was wearing a breathing apparatus in order to fight the fire died in the process. The air bottles of his breathing apparatus were found to be empty and it was assumed that he became disorientated and was unable to find his way out of the smoke filled engine room, the layout of which was less familiar to him than engine room personnel. For this reason, the composition of fire fighting parties should be considered carefully.

## Emergency shut-down equipment

In the event of a fire in the engine room it may be necessary to activate emergency shut-down equipment, often from remote stations, with the principal objective of isolating fuel and air – two sides of the fire triangle. This includes stopping ventilation fans, closing ventilation dampers, stopping fuel pumps and tripping oil tank quick closing valves.

## Quick closing valves

The UK Club Technical Bulletin No. 36 deals with Quick Closing Valves. These are fitted to the outlets of lubricating and fuel oil storage, settling and service tanks within the machinery space, boiler room and the emergency generator room. These spring loaded valves may be operated locally or remotely by pull wires, hydraulic systems or compressed air.

The majority of serious engine room fires are fuelled by oil. In the event of fire it is essential that sources of fuel from storage and service tanks are rapidly isolated to prevent a continuous flow to a point of leakage, extending the fire both in severity and time. This can be achieved by the operation of quick closing valves, either locally or remotely, leaving only residual oil in pipelines as the feed for a source of leakage.

It is suggested that regular operation of these valves not only familiarises staff with the process, but helps ensure that the valves do not become seized or stuck. Just because the valve appears to be shut does not necessarily mean that it is properly seated and oil tight and this should be checked whenever practicable.

Quick closing valves will not shut if, as sometimes noted, they are tied or wedged in the open position. This is an unnecessary and highly dangerous practice.



**Quick closing valve held open with a steel wedge**



**Quick closing valve held open with a strop**

## SUMMARY

Engine room fires are one of the most common fires on ships owing to the presence of a wide range of sources of fuel, sources of ignition and running machinery. An extended period of time onboard a ship without a fire incident can lead to complacency and a failure to prioritise fire prevention measures and simulated fire incident practices.

The risk of a fire can be substantially reduced by:

- Maintaining a clean and tidy engine room.
- Ensuring that machinery and emergency control equipment are installed and operating in accordance with SOLAS Regulations and IMO Guidelines and they are routinely serviced and maintained in good working order, and subject to routine testing.
- Ensuring that hot surfaces are shielded and clad in accordance with SOLAS requirements.
- Ensuring that emergency equipment such as oil tank quick closing valves, fire pumps, remote stop systems and fire fighting apparatus are generally armed and immediately ready for use.
- Ensure that automatic closing mechanisms on all fire doors within and at the boundaries of the engine room are working correctly.
- Ensure that ventilation closures are operable, are visually free of corrosion and provide a reasonable seal.
- Carry out routine inspections of electrical equipment to include (i) the insulation resistance of cables and equipment where appropriate (such as motor windings) and (ii) visual inspections of terminal connections and Infra-red temperature gun measurements.
- Ensure that portable fire fighting appliances are correctly positioned and serviced.
- Ensure that all hydrant outlets are accessible, and operable.
- Ensure that fixed fire fighting installations are properly maintained and armed.
- Carry out routine fire drills to address different simulated fire incidents in various parts of the engine room.
- Ensure that responsible persons are fully familiar with the correct operating sequences for the CO<sub>2</sub> and foam fire fighting systems so that valuable time is not wasted.
- Ensure that oxygen, acetylene and propane cylinders are safely stowed in a ventilated compartment above deck and provided with correct regulators, flash back arrestors and shut-off valves. Ensure that cylinder valves are isolated when systems are not in use.
- Ensure that escape routes are clearly marked by using deck plate arrows and that exit doors are readily visible.

## DO

- Ensure that oil leaks are attended to promptly by effecting permanent repairs.
- Ensure that where required by SOLAS II-2, oil pipes are sleeved and pipe joints are shielded, and that all oil pipework is adequately supported in correct fitting pipe clamps.
- Carry out routine temperature measurements of shielded or clad hot surfaces to ensure that even small parts are not exposed. This can be achieved by using an Infra-red temperature gun.
- Ensure that oil leak alarms on generators are in good operating order.
- Ensure that engine room stores are tidy and that packaging material is not close to light fittings.
- Ensure that engine room workshops are kept tidy, the floor area is clear of combustible materials and that cotton waste or rags are stored in a metal bin fitted with a lid or in metal cupboards.
- Ensure that drain lines in oil tank save-alls are clear and the save-alls are kept clean and free of solid materials such as cotton waste or rags.
- Ensure that oil tank gauge glass self-closing cocks are unrestricted and operating correctly.
- Ensure that oil tank quick closing valves are properly armed and that they are tested regularly.
- Ensure that fire detection equipment is properly maintained and operable.

## DO NOT

- Allow smoking in the engine room other than in the control room where suitable arrangements are provided for the disposal of waste smokers' material.
- Make temporary repairs to oil containing pipe work.
- Work on pressurised fuel systems.
- Secure open self-closing oil tank gauge glasses.
- Secure open by external means oil tank quick closing valves.
- Secure open fire doors within and at the boundaries of the engine room.
- Carry out hot-work in the engine room without a correctly completed, properly considered permit to work and until all necessary hot work precautions are in place.



## APPENDIX 1

Sources of fuel typically encountered in an engine room, the conditions necessary for ignition, and viable sources of ignition

Fuel	Conditions for ignition	Viable sources of ignition
<b>Cellulosic material</b> , e.g. cardboard; waste paper; cotton waste; cotton rags; sawdust. NB this type of fuel can be set smouldering leading to a small fire that may be inconspicuous (e.g. in a concealed space) that later undergoes transition to flame.	Contact with a flame or hot surface for a sufficient length of time or exposure to radiated heat of sufficient intensity to reach its <i>firepoint temperature</i> , or exposure to a small hot surface (e.g. a spark or contact with an unguarded light bulb) for a sufficient length of time to initiate smouldering combustion.	Naked flames; flame cutting; disc cutting; hot surfaces such as parts of exhausts, hot flues, economisers etc; live residues from smokers' materials e.g. cigarette ends; contact with the unguarded bulb of an inspection lamp; exposure to radiant heat from a halogen lamp.
<b>Solid timber</b> . Timber structures, timber cladding etc can also be set smouldering in inconspicuous spaces leading to a fire that later undergoes transition to flame.	Contact with a flame or hot surface for a sufficient length of time or exposure to radiated heat of sufficient intensity to reach its <i>firepoint temperature</i> .	Naked flames; hot surfaces such as parts of exhausts, hot flues, economisers etc; sparks produced by hot work such as welding, flame cutting; close contact with localised electrical overheating due to a poor electrical connection or defective component; exposure to radiant heat from a halogen lamp.
<b>Thermosetting plastics</b> Such as are used for electrical fittings and mouldings and for thermal/acoustic insulation e.g. rigid polyurethane foam. Can form a char when exposed to high temperatures which can smoulder before later undergoing transition to flame or ignite other combustible materials with which it is in contact.	Contact with a flame or hot surface for a sufficient length of time or exposure to radiated heat of sufficient intensity to reach its <i>firepoint temperature</i> .	Naked flames; hot surfaces such as parts of exhausts, hot flues, economisers etc; close contact with localised electrical overheating due to a poor electrical connection or defective component; exposure to radiant heat from a halogen lamp.
<b>Thermoplastic materials</b> , such as polystyrene foam used as packaging material or thermal insulation on refrigeration pipework. These materials tend to melt and shrink away from a heat source.	Contact with a flame or hot surface for a sufficient length of time or exposure to radiated heat of sufficient intensity to reach its <i>firepoint temperature</i> .	Naked flames; hot surfaces such as parts of exhausts, hot flues, economisers etc; exposure to radiant heat from a halogen lamp. Because thermoplastics tend to shrink away from heat sources this makes them more resistant to ignition.
<b>Liquids stored and used at temperatures below their flashpoint</b> , such as gasoil, diesel oil, lubricating oil and hydraulic oil.	<ol style="list-style-type: none"> <li>1. Contact with a source of heat that raises the liquid to at least its flashpoint temperature so that the vapour derived from the liquid becomes ignitable by an external ignition source such as a spark or naked flame.</li> <li>2. Contact with a source of heat that evaporates the liquid and which is at a temperature that exceeds the <i>minimum autoignition temperature (MAIT)</i> of the vapour causing the vapour to ignite spontaneously, i.e ignition results from exposure of the vapour to the hot surface alone, without the need for an external ignition source such as a spark.</li> <li>3. Leakage of the liquid fuel into lagging insulating a hot surface at a temperature above about 150°C where the liquid can catch fire by <i>spontaneous ignition</i>. There can be many hours delay between the accumulation of sufficient oil in the lagging and ignition.</li> </ol>	<ol style="list-style-type: none"> <li>1. Exposed parts of engine exhausts, turbochargers, economisers, steam pipes, hot flues and thermal fluid pipes at a temperature exceeding the <i>flashpoint temperature</i> of the liquid in the presence of an adjacent external source of ignition such as a spark or naked flame.</li> <li>2. Exposed engine exhausts, boiler combustion chambers and thermal fluid pipes at a temperature exceeding the <i>minimum autoignition temperature (MAIT)</i> of the vapour derived from the liquid.</li> <li>3. Exhausts, turbochargers, boiler casings, steam pipes etc lagged with Rockwool or glass fibre insulation.</li> </ol>

Fuel	Conditions for ignition	Viable sources of ignition
<b>Liquids stored and used at temperatures above their flashpoint</b> , such as heavy and intermediate fuel oils.	<ol style="list-style-type: none"> <li>1. Exposure of the fuel vapour to a spark or naked flame.</li> <li>2. Contact with a surface at a temperature that exceeds the <i>minimum autoignition temperature (MAIT)</i> of the vapour causing the vapour to ignite spontaneously, i.e ignition results from exposure of the vapour to the hot surface alone, without the need for an external ignition source such as a spark.</li> <li>3. Leakage of the liquid fuel into lagging insulating a hot surface at a temperature above about 150°C where the liquid can catch fire by <i>spontaneous ignition</i>. There can be many hours delay between the accumulation of sufficient oil in the lagging and ignition.</li> </ol>	<ol style="list-style-type: none"> <li>1. Naked flames; electrical discharges, sparks from hot work.</li> <li>2. Exposed parts of engine exhausts, turbochargers, boiler combustion chambers and thermal fluid pipes at a temperature exceeding the <i>minimum autoignition temperature (MAIT)</i> of the vapour.</li> <li>3. Exhausts, turbochargers, economisers, boiler casings, steam pipes etc lagged with Rockwool or glass fibre insulation.</li> </ol>
<b>Gases</b> , such as lpg and acetylene	<ol style="list-style-type: none"> <li>1. Exposure of the gas to an electrical spark or naked flame.</li> <li>2. Contact with a surface at a temperature that exceeds the <i>minimum autoignition temperature (MAIT)</i> of the gas causing the gas to ignite spontaneously, i.e ignition results from exposure of the vapour to the hot surface alone, without the need for an external ignition source such as a spark.</li> </ol>	<ol style="list-style-type: none"> <li>1. Electrical discharges, sparks from hot work.</li> <li>2. Exposed parts of engine exhausts, turbochargers, boiler combustion chambers and thermal fluid pipes at a temperature exceeding the <i>minimum autoignition temperature (MAIT)</i> of the gas.</li> </ol>

## GLOSSARY OF TERMS

### Flashpoint

Combustible liquids are classified according to their flashpoint. This is the lowest temperature at which the concentration of the vapour in air above the liquid surface becomes flammable and capable of being ignited by an external source such as a naked flame or an electric spark. Flashpoints are normally determined according to the 'closed cup' method by using an apparatus where the test liquid is contained in a small cup with a lid to minimise loss of vapour. The liquid is heated slowly and a small flame is introduced to the vapour space at frequent intervals until the vapour ignites in a flash. In practical situations involving an open pool of liquid, however, sustained burning at the surface of a liquid at its flashpoint is unlikely to occur until its temperature is raised further (typically by 5-20°C for hydrocarbon fuels) to the 'firepoint' temperature. This is because the rate of evaporation of the liquid at the flashpoint is not fast enough to support sustained flaming.

### Firepoint

Visible flame at the surface of a burning liquid or solid fuel involves the combustion of vapour generated from the fuel. The vapour concentration in air at the surface of the fuel must exceed a minimum concentration before it is ignitable and can burn freely. The *firepoint* of a liquid is the temperature at which the rate of evaporation is sufficient to sustain this minimum concentration. In the case of solids, the *firepoint* is the temperature at which the surface of the solid breaks down to release a stream of volatiles (vapours) at a concentration sufficient to support a flame. The volatiles can be ignited by contact with a flame or some other source of ignition such as a spark. If the rate of heating of the solid surface is high enough, such as can happen when it is exposed to the radiant heat from a nearby halogen lamp, the volatiles can '*autoignite*', i.e. the vapour/air mixture bursts into flame without the need for an external source of ignition such as a spark.

### Minimum autoignition temperature, MAIT

When a flammable gas or vapour/air mixture is raised to a sufficiently high temperature it can ignite spontaneously, i.e. without an external source of ignition such as a spark or naked flame. This is known as the *autoignition* temperature. The *autoignition* temperature is, however, very sensitive to the geometry of the surface that is providing the heating. For reasons of safety we are interested in knowing the *minimum autoignition temperature (MAIT)* of a fuel. As spherical flasks provide the most favourable conditions for ignition, these are invariably used to determine the *MAIT*. Such favourable geometries are not commonly found in an engine room. However, for reasons of safety, it is prudent assume that if the temperature of any surface (irrespective of its geometry or size) exceeds the reported *MAIT* of a fuel, a fire will occur. The *MAIT* for diesel has been reported to be as low as about 220°C, whereas the *MAIT* for fuel oils, lube oils and hydraulic oils is somewhat higher (above about 250°C). It is understandable, therefore, that SOLAS requires all high temperature surfaces to be reduced by insulation to below 220°C.

### Spontaneous ignition

When certain bulk solids and solids contaminated with certain liquids are exposed to moderately elevated temperatures, they react with oxygen to liberate heat. This causes the temperature of the material to rise further by a process of self-heating and can eventually lead to ignition. Examples of spontaneous ignition are fires caused by the leak of mineral oils (e.g. diesel oil and lube oil) into lagging on pipes operating at a temperature in excess of about 150°C, the ignition of oil and soot residues in an economiser and the self heating of a pile of waste rags contaminated with oxidisable oils.



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consulting scientists and engineers

Burgoynes is an international Partnership specialising in the forensic investigation of fires, explosions and other major incidents. The Partnership was founded in 1968 by the late Emeritus Professor Jack Burgoyne. Being the first organisation of its type in the UK, the eight offices around the country provide a comprehensive national service, with a worldwide presence provided by its offices in Singapore, Hong Kong and Dubai.

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