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Engine rooms fire safety – fire-extinguishing system requirements

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Abstract

This article discusses requirements for the extinguishing systems in the engine room. The sources of fire hazards in engine rooms were characterized. The causes and consequences of selected engine room fires that occurred within the last five years were presented. The basic requirements for the fire-extinguishing systems installed in engine rooms were scrutinized. The most commonly used fire-extinguishing systems in engine rooms are the ones containing a gaseous extinguishing agent. Their main advantages are short response time after agent release and the ability to supply an extinguishing medium to areas that are hard to access. The agent used in such systems does not cause damage and there is no need to remove its residues after fighting the fire, as in the case of other agents such as foams. As an example, a CO_2 system was characterized, as it is the most frequently used in engine rooms.

Introduction

Engine rooms are particularly vulnerable to fire, due to numerous flammable materials and fire sources located in a relatively small area. The occurrence of such a situation in an engine room may disable the ship as the loss of steering ability and stability may result in contact, collision, grounding, capsizing or foundering. Therefore, fire-extinguishing systems are of paramount importance. They should be designed in a way to allow fire-extinguishing within the shortest time possible, limiting damages to a minimum. This article highlights the aspects associated with fire safety in engine rooms. It briefly describes source of fires in machinery space and exemplifies the damage that may be caused through the analysis of selected cases of fire incidents. The main part of the article reports the regulations concerning fire-extinguishing systems in engine rooms. Applicable regulations provide for fitting engine rooms with a fixed gas fire-extinguishing system, a fixed foam fire-extinguishing system, water supply systems, fixed pressure water-spraying and water-mist fire-extinguishing systems as well as placing portable fire-extinguishing appliances. The most common systems used in engine rooms are gaseous fire suppression systems. Their advantages include very short response time after agent release and the ability to supply an extinguishing medium to areas difficult to access. The agent applied in such systems does not cause damage and does not require removal of residues once the fire-fighting action is completed.

Fire in engine room

Most fires on ships start in the engine room (Figure 1).

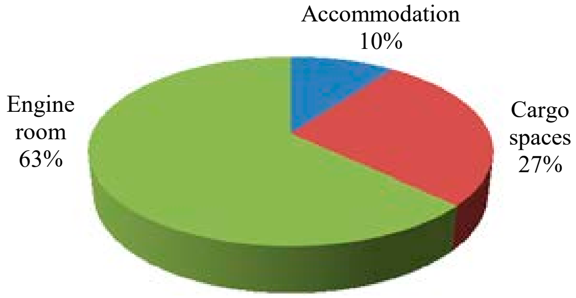

Figure 1. Causes of fire (DNV, 2010)

There are more than 130 types of machines and devices in an engine room (internal-combustion engines, flue gas turbines or steam turbines, fuel purifiers and other) that may constitute a fire hazard. Engine rooms also contain numerous tanks for fuel oil, lubricant oils, diesel, grease and chemicals, since a medium-sized ship uses approximately 40 tons of fuel per day. In addition, the heating temperature of marine residual fuels is high, in the range of 120–150°C. The combination of these fire hazards with heat sources, such as hot surfaces (e.g. exhaust systems), and potential sparking from faulty electrical systems enhances the probability of occurrence of fire. The share of individual sources of fire in the engine room is shown in Figure 2.

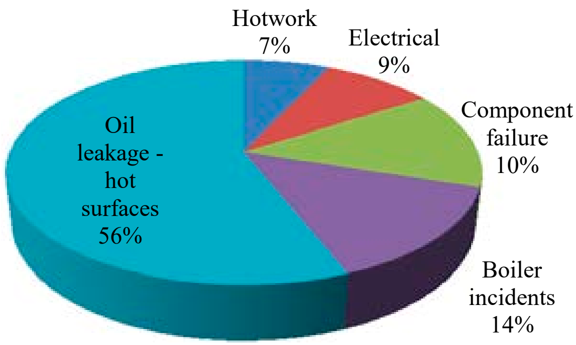

Figure 2. Sources of fire (DNV, 2010)

The most probable fire scenario involving machinery is the contact of leakage oil with a hot surface. Although it is to completely avoid oil leakage in such a particular space, methods to reduce leaks exist and include double piping on high-pressure fuel lines, and valves in fuel oil supply lines fitted with remote controls and operated from a location outside the engine room. To avoid hot surfaces, SOLAS requires maximum surface temperatures to be below 220°C (SOLAS, 2009).

The fire in the engine room may disable the ship, which may lose steering ability and stability, and consequently risk capsizing, foundering or throwing ashore. A fire occurring in the engine room is also hazardous for the adjacent spaces. Fire protection for the location is a difficult task due to the complicated construction of engine room (Kukuła, Getka & Żyłkowski, 1981). Therefore, it is extremely important to select proper fire-extinguishing systems as a means of fire protection. The effectiveness of a system determines damages and losses in the "ship's heart" during the fire.

The examples of occurrences of fires starting in the engine room of ships are presented below:

- On 11th February, 2015 an explosion took place aboard the FPSO *Cidade de São Mateus* due to a gas leak in one of the engine compartments: at least 5 deaths were reported;
- On 25th January, 2015 a fire broke out in the engine room of the luxury cruise ship m/v *Bouddica*; all engines stopped, due to the loss of power and the ship lost steering ability and started to drift;
- On 12th February, 2015 the engine room of the chemical tanker *Amaranth*, docked in Szczecin, burst into flames; the cause of ignition was oil leaking from a broken pipe which eventually flooded the engine collector;
- On 14th June, 2014 there was a fire abroad the LNGRV *Explorer*; the fire was extinguished using portable extinguishing equipment, but the vessel required towing;
- On May 20th, 2013 the fishing vessel *Arctic Storm* experienced an engine room fire; the cause of the fire was damage to the diesel vent valve, located by the main engine, which resulted in diesel spraying on the hot engine surface; the losses were estimated at $ 5mln;
- On March 10th, 2010 the fire spread all over the engine room of the trawler *American Dynasty* (Figure 3); it was suppressed after three hours.

Figure 3. Part of an engine room after a fire (U.S. Coast Guard Newsroom, 2015)

Fire protection requirements

Regulations referring to the fire protection of engine compartments have been included in the International Convention for the Safety of Life at Sea (SOLAS) of 1974. The last consolidated edition of the Convention was issued in 2014 (IMO, 2014). The requirements regarding the fire-extinguishing systems are included in Part C: Suppression of fire, Regulation 10.5 Fire-extinguishing installations in machinery spaces, SOLAS 1974 II-2/10.5.

The provisions concerning fire-extinguishing systems and fire-extinguishing appliances that are on board (to which the Convention provisions refer to) have been incorporated into the International Code for Fire Safety Systems (FSS Code) developed by IMO.

Training

When the fire occurs at sea, initial fire-fighting task will have to be met by the crew. Adequate training for the situation is therefore important. The International Convention on Standards of Training, Certification and Watchkeeping for Seafarers was adopted on 7 July 1978 in London (STCW, 2010). It specifies minimum standards relating to theoretical and practical knowledge and skills and required certification and licenses to perform duties at particular positions. One of such certificates is the "Certificate of Basic Safety Training in Personal Survival Techniques" under Regulation VI/1 of the STCWW Convention (basic level) and the "Certificate of Training in Advanced Fire Fighting" under Regulation VI/3 of the STCW Convention. During the training, participants acquire knowledge on fire protection issues.

Fire-extinguishing systems in engine rooms

Machine compartments require special fire protection. The spaces are subject to high risk of fire due to heat generated by devices and highly flammable liquids. Minor faults or leaks in engine rooms may cause severe fire, as proven by the above-mentioned examples. In order to adjust to the size and power of engines, engine rooms are also becoming larger. Consequently, their protection has become a more difficult task and the time to evacuate crew has extended. All these aspects highlight the importance of fire-extinguishing. Their effective performance affects the crew safety and determines the value of material damage and loss. A proper selection, installation and operation of fire-extinguishing system may significantly limit and minimize the damage.

Machinery spaces, in which oil-fired boilers or oil-fuel units are placed, should be equipped with one of the following fixed fire-extinguishing systems:

- a fixed gas fire-extinguishing system, complying with the provisions of the Fire Safety Systems Code;
- a fixed foam fire-extinguishing system, complying with the provisions of the Fire Safety Systems Code;
- a fixed pressure water-spraying fire-extinguishing system, complying with the provisions of the Fire Safety Systems Code; and
- fixed aerosol fire-extinguishing systems equivalent to fixed gas fire-extinguishing systems required by SOLAS (IMO, 2001a).

If the engine and boiler rooms are not entirely separate, or if fuel oil can drain from the boiler room into the engine room, the combined engine and boiler rooms shall be considered as one compartment. Additionally, there shall be in each boiler room, or at an entrance outside of the boiler room, at least one portable foam applicator unit complying with the provisions of the Fire Safety Systems Code. There shall be at least two portable foam extinguishers or equivalent in each firing space, in each boiler room, and in each space in which a part of the oil fuel installation is situated. There shall be no less than one approved foam-type extinguisher of at least 135 l capacity, or equivalent, in each boiler room. These extinguishers shall be provided with hoses on reels, suitable for reaching any part of the boiler room. In the case of domestic boilers of less than 175 kW, an approved foam-type extinguisher of at least 135 l capacity is not required. In each firing space or boiler room there shall be a receptacle containing at least 0.1 m^3 of sand, sawdust impregnated with soda, or other approved dry material, along with a suitable shovel for spreading the material. An approved portable extinguisher may be substituted as an alternative (SOLAS, 2009).

Machinery spaces containing internal combustion engines, oil-fired boilers, or oil-fuel units shall be provided with one of the fixed fire-extinguishing systems. Moreover, there shall be at least one portable foam applicator unit complying with the provisions of the Fire Safety Systems Code. Each one of these spaces shall be equipped with approved foam-type fire-extinguishers (mobile) having at least a 45 l capacity or equivalent each and sufficient in number to enable foam or its equivalent to be directed to any part of the fuel and lubricating oil pressure systems, gearing and other fire hazards. In addition, a sufficient number of portable foam extinguishers or equivalent shall be provided in locations such that the maximum walking distance from any point in the room to the extinguisher is 10 m. In any case, at least two extinguishers must be present in each one of these rooms (SOLAS, 2009).

In machinery spaces containing steam turbines or enclosed steam engines, one of the fire-extinguishing systems specified above shall be provided. Additionally, there shall be approved foam fire-extinguishers (mobile), each of at least 45 l capacity or equivalent, sufficient in number to enable foam or its equivalent to be directed to any part of the pressure lubrication system, on to any part of the casings enclosing pressure lubricated parts of the turbines, engines or associated gearing, and any other fire hazards. Such extinguishers are not required if protection is provided by a fixed fire-extinguishing system. There shall be a sufficient number of portable foam extinguishers or equivalent, which shall be so located that no point in the space is at a walking distance of more than 10 m from an extinguisher. In any case, at least two extinguishers must be present in each one of these rooms (SOLAS, 2009).

Additional requirements have been adopted for engine rooms on passenger ships. In the case of passenger ships carrying more than 36 passengers, each machinery space of category A shall be provided with at least two suitable water fog applicators (a water fog applicator shall consist in an L-shape metal pipe, with the longer section having a length of 2 m, that may be connected to a fire hose, and with a shorter section, 250 mm long, fitted with fixed fog nozzle or other device appropriate for the connection to a water spray nozzle).

The following requirements refer to the fixed fire-extinguishing systems for passenger ships of 500 gross tonnage and above and cargo ships of 2000 gross tonnage and above. In these ships, machinery spaces above 500 m^3 in volume shall be additionally protected by an approved type of fixed water-based, or equivalent, local application fire-fighting system, based on the guidelines developed by the Organization (IMO, 1999; 2003). In the case of periodically unattended machinery spaces, the fire-fighting system shall have both automatic and manual release capabilities. In the case of continuously manned machinery spaces, the fire-fighting system is only required to have a manual release capability. Fixed local application fire-extinguishing systems are to protect areas such as the following without the necessity of engine shutdown, personnel evacuation, or sealing of the spaces:

- the fire hazard portions of internal combustion machinery;
- boiler fronts;
- the fire hazard portions of incinerators;
- purifiers for heated fuel oil.

Activation of any local fire-extinguishing system shall give a visual and distinct audible alarm in the protected space and at continuously manned stations. The alarm shall indicate the specific system that has been activated (SOLAS, 2009).

Fixed gas fire-extinguishing systems

Gas fire-extinguishing systems are most commonly used. Generally, requirements for gaseous fire-fighting systems are included in the ISO 13702 standard. Basic requirements for gaseous fire-fighting systems are as follows:

- gaseous agents not harmful to humans are preferred; if noxious and poisonous gaseous systems (e.g. CO_2) are used, it shall only be used for locked off rooms;
- the room where the gaseous agent is released shall be sufficiently tight to maintain the prescribed concentration for the pre-determined time period of minimum 10 min;
- the extinguishing agent cylinders shall be located outside of the protected room.

Where the quantity of the fire-extinguishing medium is required to protect more than one space, the quantity of medium available need not be more than the largest quantity required for any one space. The volume of starting air receivers, converted to free air volume, shall be added to the gross volume of the machinery space when calculating the necessary quantity of fire-extinguishing medium. Means shall be provided for the crew to safely check the quantity of the fire-extinguishing medium in the containers (SOLAS, 2009). The piping for the distribution of fire-extinguishing medium shall be arranged and discharge nozzles positioned so that a uniform distribution of the medium is obtained. Pressure containers required for the storage of the fire-extinguishing medium, other than steam, shall be located outside the protected spaces, and spare parts for the system shall be stored on board and be to the satisfaction of the Administration. The means of control of any fixed gas fire-extinguishing system shall be simple to operate and shall be grouped together in as few locations as possible at positions not likely to be cut off by a fire in a protected space (IMO, 2001b).

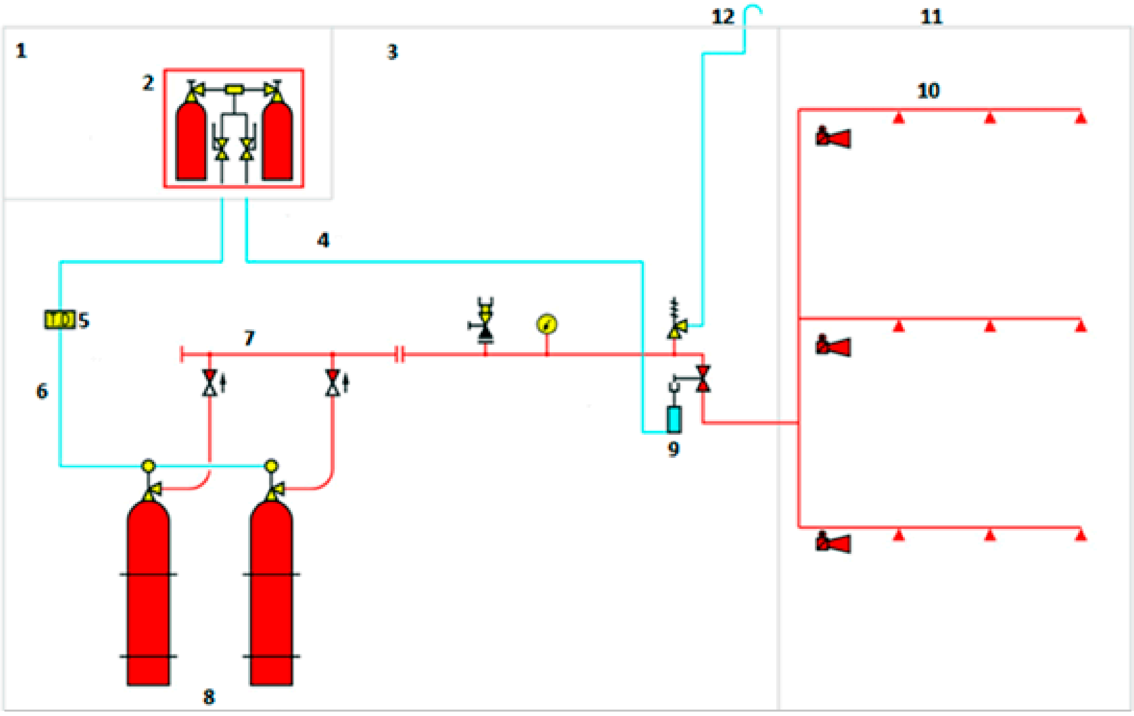

Figure 4. Diagram of gas fire-extinguishing system (CO_2): 1 – control station, 2 –release cabinet, 3 – CO_2 cylinder compartment, 4 – release line – distribution valve, 5 – time delay unit, 6 – release line – cylinders, 7 – manifold, 8 – CO_2 cylinder bank, 9 – distribution valve, 10 – distribution pipelines with nozzles, 11 – protected space, 12 – to free air (Wilhelmsen Technical Solution, 2014)

CO_2, mixtures of N_2 and Ar, or CO_2 and chemical replacements of halons are used in these systems as extinguishing agents. Still, the most common gas applied in fixed gas fire-extinguishing systems for engine room is carbon dioxide (CO_2). Figure 4 presents a diagram of a gas fire-extinguishing system (CO_2).

Fire-extinguishing, and actually suppression, by carbon dioxide causes oxygen dilution or oxygen displacement in the atmosphere. In order to obtain extinguishing effect, the protected space should theoretically have a CO_2 content of 25%. However, allowing door, skylights or vent ducts leakage, it is assumed that 40% of such a space should be filled with CO_2. According to the FSS Code for machinery spaces, the quantity of CO_2 carried shall be sufficient to give a minimum volume of free gas equal to the larger of the following volumes: (i) 40% of the gross volume of the largest machinery space so protected, the volume excludes the part of the casing lying above the level at which the horizontal area of the casing is 40% or less of the horizontal area of the space concerned, taken midway between the tank top and the lowest part of the casing; (ii) 35% of the gross volume of the largest machinery space protected, including the casing. The fixed piping system shall be such that 85% of the gas can be discharged into the space within 2 min (IMO, 2001b).

Carbon dioxide is a fire-extinguishing agent used for the suppression of fires involving flammable liquids and gases as well as electrical equipment. It is a colorless, odorless, non-toxic, and nonconductive gas. Carbon dioxide is relatively inexpensive and easily available. It does not cause corrosion, but it is an asphyxiator for humans. In extinguishing concentrations, CO_2 is lethal to humans. Therefore, the systems using CO_2 as an extinguishing agent must be equipped with devices signaling and warning the intention of its use by the crew. In spaces where a crew member is present, its concentration shall not exceed 1%, since higher content may be dangerous to human life and health (Table 1) (Kukuła, Getka & Żyłkowski, 1981; Żelichowski & Korzeniewski, 1992).

Table 1. CO_2 impact on humans (Żelichowski & Korzeniewski, 1992)

CO_2 content in the air [% of volume]	Impact to human body
2–4	Minor respiratory problems without harmful consequences
5–7	Harmful to dangerous
10	Major respiratory problems
15	After a short period – loss of consciousness
25–30	Immediate death

The IMO has developed detailed requirements concerning the construction and use of fire-extinguishing CO_2 systems, particularly in terms of protection against accidental operation, including two separate and interlocked controls, pre-discharge alarms and time-delays to protect personnel in the engine room. In any case, between detecting a fire and releasing the gas, time is needed to protect the crew and such a delay in running the fire-extinguishing system may result in an escalation of the fire.

The fixed carbon dioxide fire-extinguishing system must be maintained and controlled in order to ensure its safe and proper functioning. Guidelines developed by the IMO for the maintenance and inspections of fixed carbon dioxide fire-extinguishing systems are presented in document MSC.1/Circ.1318. There are two types of inspection: monthly and annual. Visual inspections should be carried out the overall conditions of the system, identifying obvious signs of damage. Monthly inspections include the verification that:

- all stop valves are in the closed position;
- all releasing controls are in the proper position and readily accessible for immediate use;
- all discharge piping and pneumatic tubing is intact and has not been damaged;
- all high pressure cylinders are in place and properly secured;
- the alarm devices are in place and do not appear damaged.

Additionally, on low pressure systems the inspections should verify that:

- the pressure gauge is indicating a value in the normal range;
- the liquid level indicator is indicating a value within the proper range;
- the manually operated storage tank main service valve is secured in the open position;
- the vapor supply line valve is secured in the open position.

During the annual inspection:

- the boundaries of the protected space should be visually inspected to confirm that no modifications have been made to the enclosure that not opening that would render the system ineffective have been created;
- all storage containers should be visually inspected for any signs of damage, rust or loose mounting hardware. Cylinders that are leaking, corroded, dented or bulging should be hydrostatically retested or replaced;
- system piping should be visually inspected to check for damage, loose supports and corrosion. Nozzles should be inspected to ensure they have not been obstructed by the storage of spare parts or a new installation of structure or machinery;
- the manifold should be inspected to verify that all flexible discharge hoses and fittings are properly tightened;
- all entrance doors to the protected space should close properly and should have warning signs, which indicate that the space is protected by a fixed carbon dioxide system and that personnel should evacuate immediately if the alarms sound. All remote releasing controls should be checked for clear operating instructions and indication as to the space served (IMO, 2009).

As mentioned, the equivalent fixed gas fire-extinguishing systems for machinery spaces can be used. The requirements for these systems were included in MSC/Circ. 848 – “Revised Guidelines for the Approval of Equivalent Fixed Gas Fire-Extinguishing Systems, as referred to in SOLAS 74, for Machinery Spaces and Cargo Pump-Rooms”, MSC/Circ. 1267, MSC/Circ. 1316 and MSC/Circ. 1317. The agents used are clean halocarbon agents (halon replacements) and inert gases other than CO_2. Clean halocarbon agents break down the chemical reaction in the fire. Some of these agents are: FM 200 (CF_3CHFCF_3), NOVEC 1230 ($CF_3CF_2C(O)CF(CF_3)_2$), Halotron IIB – HFC 3-4-9 C2, FE 13 – CHF_3 and only need to be used in concentrations ranging between 5 and 12%. Inert gases work by reducing oxygen levels and typically require concentrations of 35–50% to work. They include: Argonite [Nitrogen (50%) + Argon (50%)] and Inergen [Nitrogen (52%) + Argon (40%) + Carbon dioxide (8%)] (IMO, 1998).

Other fire-extinguishing systems

Fixed foam fire-extinguishing systems shall be capable of generating foam suitable for extinguishing oil fires. Any required fixed high-expansion foam system in machinery spaces shall be capable of rapidly discharging a quantity of foam sufficient to fill the greatest space to be protected at a rate of at least 1 m in depth per minute. The quantity of foam-forming liquid available shall be sufficient to produce a volume of foam equal to five times the volume of the largest space to be protected. The expansion ratio of the foam shall not exceed 1,000 to 1 (SOLAS, 2009).

Fixed pressure water-spraying fire-extinguishing in machinery spaces shall be provided with approved spraying nozzles. The number and arrangement of the nozzles shall be to the satisfaction of the Administration and shall be such as to ensure an effective average distribution of water of at least 5 $l/m^2/min$ in the spaces to be protected. The system may be divided into sections, the distribution valves of which shall be operated from easily accessible positions outside the spaces to be protected so as to not be rapidly cut off by a fire in the protected space. The pump and its controls shall be installed outside the space, or spaces, to be protected (SOLAS, 2009).

Fixed aerosol fire-extinguishing systems for machinery spaces should have the same reliability that has been identified as significant for the performance of fixed gas fire-extinguishing systems approved under the requirements of the FSS Code. Aerosol fire-extinguishing systems involve the release of a chemical agent to extinguish a fire by interruption of the process of the fire. The system discharge time should not exceed 120 s. The quantity of extinguishing agent for the protected space should be calculated at the minimum expected ambient temperature using the design density based on the net volume of the protected space, including the casing (IMO, 2001a).

Conclusions

Fire is one of the basic hazards to a ship. According to DNV, nearly 2/3 of the fires on ships have their source in the engine room. Due to the characteristics of a space such as an engine room, the risk of fire is always high. Therefore, it is worth paying attention to fire prevention. Every seafarer is trained in fire prevention. The ability to identify a potential fire hazard is significant as well as being aware of the risk entailed by fire at sea. Contrarily to situations onshore, the crew have to fight the fire on their own. Therefore, fire-extinguishing systems on board are one of the most important elements of any ship. In case of fire, they are the main mean to fight it. Due to the fact that the engine room contains the most important operating systems and devices, it is extremely important to provide its protection. In case of failure of any of these components, the operation of the entire ship is compromised.

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