Scientific Journals
of the Maritime University of Szczecin

Zeszyty Naukowe
Akademii Morskiej w Szczecinie

2016, 47 (119), 29–35
ISSN 1733-8670 (Printed)
ISSN 2392-0378 (Online)
DOI: 10.17402/145

Received: 29.04.2016
Accepted: 08.08.2016
Published: 20.09.2016

Engine room fire safety

Agata Krystosik-Gromadzińska

West Pomeranian University of Technology, Faculty of Maritime Technology and Transport
Department of Safety and Engineering
41 Piastów Ave., 71-065 Szczecin, Poland, e-mail: agata.krystosik@zut.edu.pl

Key words: fire safety, engine room, recommendation for fire safety, rules and regulations, factors, prevention

Abstract

The paper characterizes an engine room as a place of a fire's origin and its spread. It presents potential sources of fire and fire protection onboard. Examples of international rules and regulations are described as well. It also gives the statistics and some scenarios for fires and some recommendations for machine spaces. It presents problems of engine room fire safety, understood as a result of the analysis of different criteria. The engine room was chosen for analysis because many factors whose presence result in a fire could be found there in the way of combustible materials: fuel oil, lubrication oil, hydraulic oil and thermal oil consumed by the main engine, generator engine, boiler, thermal oil heater and hydraulic oil equipment, paints, solvents etc. Sources of potential fires are mainly the hot surfaces of exhaust gas pipes, turbochargers, boilers and waste oil incinerators, ignitions, sparks, static electricity etc. In addition, many engine room fires have an electrical source, such as electrical short-circuits and thermal overheating in the switchboards. Approximately 70% of fires in the engine room have typical scenarios: the outflow of combustible liquid and contact with a hot surface and can reach temperatures between 700–1000°C. They spread rapidly, their power and dynamism depending on the intensity of the outflow of the combustible liquid and its properties, but also the local conditions and the geometry of engine room as well.

Fire safety in engine rooms is determined both by good design and the company's and crew's focus on fire prevention. Some of the recommendations are high standards of cleanliness in the engine room, regular checks of materials used for insulating high temperature surfaces, attention to fire risks when repairs and maintenance works are carried out and many other factors.

Introduction

Many factors whose presence could result in a fire origin are found on ships. They are combustible materials, e.g.: fuels, oils, some cargoes, solvents, paints, etc. and sources of potential fires, e.g.: mainly hot surfaces, sparks, static electricity, fire etc. Firefighting conditions are different from those on land. Fires onboard ships are very hazardous and costly.

The fire protection of a ship is accomplished by so-called active and passive methods. First, include fire extinguishing appliances and media use. The passive methods are connected with restricted use of flammable materials, they determine the construction of the ship's bulkheads, separation of spaces with fire-resisting bulkheads and decks, fire protection of evacuation roads and division into main vertical zones. Furthermore, the crew should be adequately trained and with passengers, should act according to proper procedures in case of fire (Krystosik, 2010).

The engine room is the most hazardous region of the ship. Restricted space, oxygen, many potential ignition sources and a high amount of different flammable materials make this region particularly vulnerable to a fire's origin and its spread (Figure 1).

It is important to remember that the cost of an engine room fire can be about 1–4 million USD for a cargo vessel and much more for a passenger vessel. Engine room fires are also very dangerous for crew members working in that area and firefighters too (DNV, 2000).

Figure 1. Engine room fire (DASPOS, 2016)

Fire statistics

Most accidents happen on roads. Seas and oceans are safer means of transport (U.S. Coast Guard and Canadian Transportation Safety Board, 2011).

Annual Overview of Marine Casualties and Incidents 2014, a report from the European Maritime Safety Agency (EMSA, 2014), shows the number of casualty events by severity. Flooding/Foundering was the event that led to the highest number of very serious casualties between 2011 and 2013 (31%). It is followed by collision (20%) and fire/explosion (13%).

The total number of lives lost was 228 (62 in 2011, 92 in 2012 and 74 in 2013). 1,982 ships reported some damage, the largest category being cargo ships (48%). More than 50% of the occurrences happened in internal waters (archipelago, fairway, channel, river or port area).

Other statistics show that fires and explosions are placed in third or fourth place in statistics (Transportation Safety Board of Canada, 2014).

Statistics prepared by the Det Norske Veritas show that much more than half of fires originate in engine rooms. The most common scenario is flammable oil contacting a hot surface (Figure 2).

More than 50% of all engine room fires (excluding yard repairs) were caused by the combination of oil leakage with a hot surface. Whereas sources for oil leakage are numerous and difficult to reduce, it is relatively easy to identify and remove hot surfaces

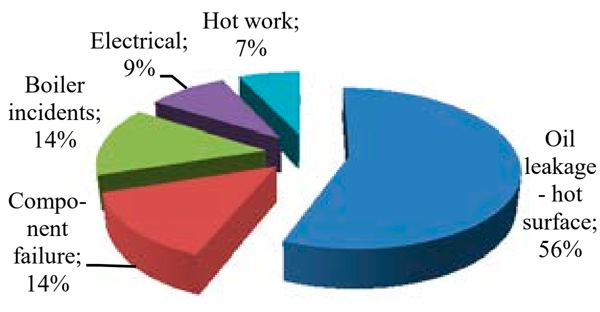

Figure 2. Causes of fire (based on: DNV, 2000)

(DNV, 2000). Fires caused by oil leakage onto hot spots are, in general, more serious than fires caused by other factors (DNV, 2016b).

In 2014, deficiencies in fire safety accounted for 13.43% of all deficiencies recorded (a decrease from 13.57% in 2013). The number of deficiencies in this area decreased from 6,657 in 2013 to 6,176 in 2014 (Port State Control, 2014).

Flammable materials and sources of ignition in engine rooms

An engine room is a place characterized by high a risk of fire occurrence. In particular, there is always danger of fire because of the presence of large volumes of fuel oil, lubrication oil, hydraulic oil and thermal oil consumed by the main engine, generator engine, boiler, thermal oil heater and hydraulic oil equipment, which are flammable materials. Additionally, many potential sources of ignition are present in engine rooms. Hot surfaces of exhaust gas pipes, turbochargers, boilers and waste oil incinerators are some amongst the most dangerous.

Engine room fires are one of the most important issues of fire safety on a ship. They can easily spread and cause serious causalities, such as loss of human life and disabling of the ship due to machinery damage. They can spread to other regions of the ship, such as accommodation spaces etc. Engine room fires often occur when ships are at sea, which can result in serious problems with navigation too. Engine room fires with serious consequences are, however, usually a result of multiple barriers failing in sequence, not of a single failure.

The engine room is a place where some areas should be emphasized as special cases, generating high potential risk. They are as follows: FO injection pipes, FO service pipes and FO valve-cooling oil pipes attached to the diesel engine, LO service pipes and hydraulic oil pipes attached to the diesel engine, flammable oil pipes, flammable oil pump and strainer, FO heater, LO heater and cooler, FO purifier, LO Purifier, FO burning unit for boiler, thermal oil heater, inert gas generator, incinerator, level gauge, fittings and oil tray of flammable oil tank, sounding pipe-head of double bottom FO tank, special pipe joint (threaded pipe joint, compression fitting joint etc.) and expansion joint in the flammable oil piping (NKK, 1994).

Flammable materials are: fuel oil, lubrication oil, hydraulic oil, thermal oil, waste oil and fuel additive. Most of fires occur due to the leakage and spray of flammable oil.

Examples of ignition sources are as follows: exhaust gas pipe, steam pipe, turbocharger, electrical equipment, boiler, thermal oil heater and incinerator, welding spatter, cigarettes, etc. (NKK, 1994).

Figure 3 presents the possible sources of fire in engine rooms in different conditions of exploitation. Most fires occur at sea. Places like a turbocharger, switchboard, generator engine, were highlighted as most dangerous. The fires did not occur uniformly at all locations in the engine room space. It is observed from the figure that the fires were concentrated at certain high-risk areas. Fires in the engine room were concentrated in areas where flammable oils are liable to leak easily, and in the vicinity of an ignition source such as a high-temperature surface or where there is electric equipment liable to generate sparks or overheating. Fuel oil pipes fitted to main engines, or generator engines, burner fuel injection pipes in boilers, exhaust gas pipes, turbochargers, and main switchboards are locations with a high fire risk. Countermeasures for preventing fires must be adopted as a top priority at these high fire-risk areas.

As shown in Figure 3, the lower floor level is the area with the minimum risk of fire when the ship is at sea. Fire could occur at the lower floor level, e.g. due to spraying of oil from a short sounding pipe during oil replenishing work when the ship is anchored, or due to sparks generated during welding or gas-cutting work at the time of repairs in a shipyard. This area may be considered prone to fires because of human errors during maintenance.

The most frequent causes of damages to fuel systems' elements which result in leakages are vibrations of the machine and other systems elements. The cracking of pipelines resulting in fuel leakages is possible. The pressure in a fuel system may also cause flammable hydraulic mist in the air (Charchalis & Czyż, 2011). Hot gases or flames extracted from the engine room could heat the bulkheads to the temperature at which fire spreads through the

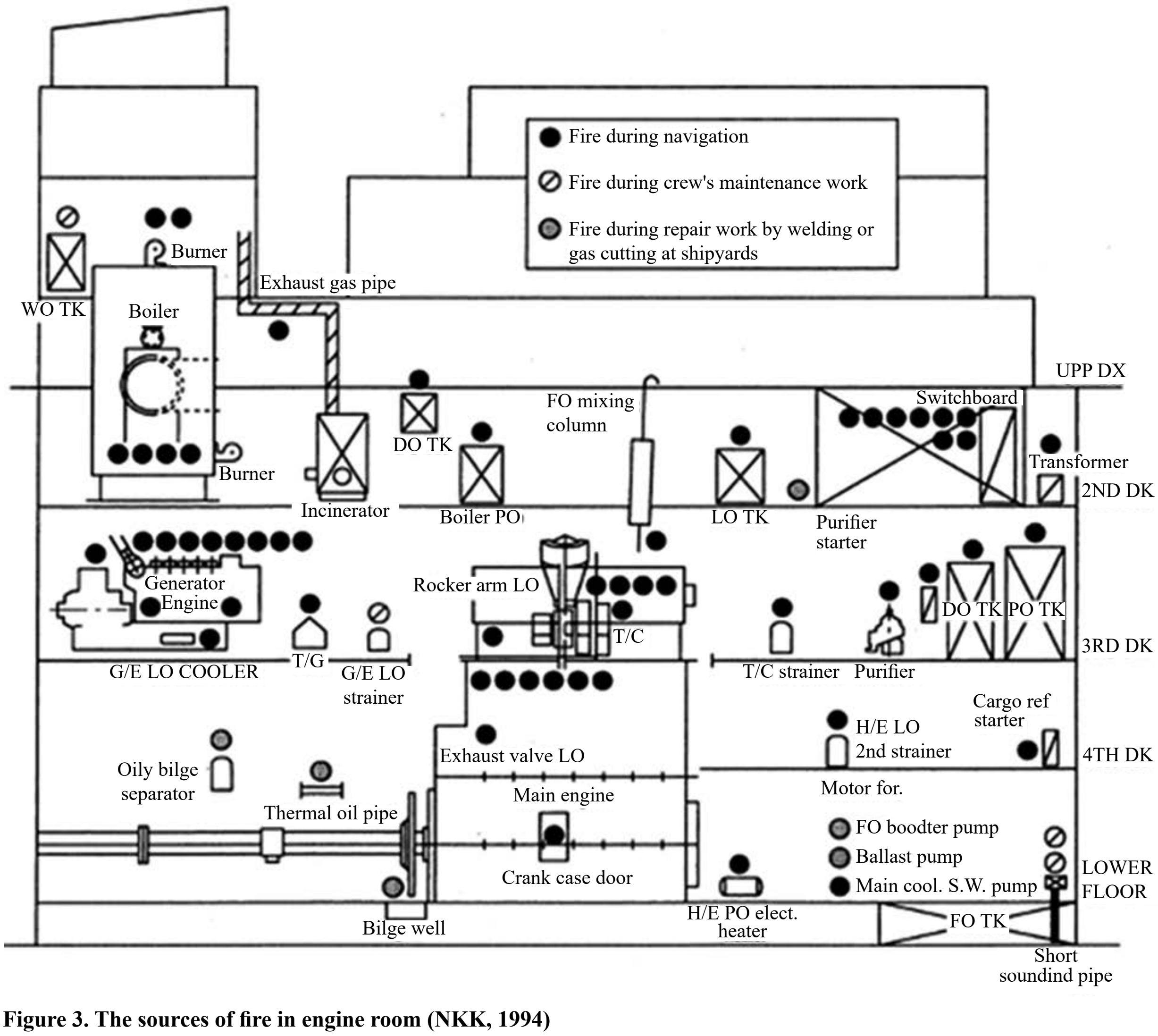

Figure 3. The sources of fire in engine room (NKK, 1994)

bulkheads, especially when they are insufficiently insulated or the insulation is not tight enough. More than 60 percent of ship fires have similar scenarios: their source is in the engine room, they spread over the engine room and through the casing to the superstructure where accommodation spaces are located. The ways that fire spreads are cables lines, ventilation ducts, shafts, bulkheads, open doors and pipes with unsuitable insulation.

An engine room fire has a typically sharp nature. It progresses rapidly to full development (without initial phase). The dynamism of a fire depends on intensity of the outflowing combustible liquid, its properties, local conditions, geometry etc. The fire's power is, in the early stage, roughly equal to the quantity of heat produced per unit of time by burning the leaking fuel. Subsequently, the power of the fire increases due to combustion of other combustible materials in the room, including, primarily, the insulation of electric cables. In terms of quantity and intensity of the heat release in machinery spaces, cable insulations are second in the order of the source of risk. Fires in machinery spaces are much more intense and dynamic, especially in the initial phase, compared to fires in accommodation spaces (Getka, 2011).

Fire protection methods

Recognition of the importance of fire prevention issues forth from the many papers and documents dealing with the problem. Although fire safety has always been a primary concern, little progress was made to make ships safer until the disaster of the Titanic. Nowadays, most regulations pertaining to the fire safety are derived from the International Convention for Safety of Life at Sea, 1974 (IMO, 2015). There are basic principles listed in SOLAS, which form the basic philosophy of fire protection.

Thus, fire safety encompasses the obligation to prevent fire from originating or to immediately stop it. Active methods of fire protection describe fire extinguishing appliances and means (used by crew). Passive methods describe the construction of the ship itself (the restricted use of combustible materials, separation of spaces by fire-resistant bulkheads, decks or air gaps, fire protection of evacuation roads and division into main vertical zones). A balance between the four methods of fire protection (active, passive, human factor elimination, safety management) should ensure the highest safety level.

The philosophy of fire protection is to prevent the occurrence of fire and explosion; reduce the risk to life caused by fire; reduce the risk of damage caused by fire to the vessel, its cargo and the environment; contain, control and suppress fire and explosion in the compartment of origin and to provide adequate and readily accessible means of escape for crew.

Structural (passive) fire protection methods gives some recommendations. They say that the vessel should be subdivided by thermal and structural boundaries; thermal insulation of boundaries should have due regard to the fire risk of the space and adjacent spaces; the fire integrity of the divisions should be maintained at openings and penetrations (IMO, 2015).

For example, machine space should be separated by A-class division. The rules give the type of A-class (A-60, A-0), e.g. machinery space category A by A-60, with service spaces of high fire risk, ro-ro spaces or vehicle spaces, accommodation spaces, control stations, corridors and staircases etc.

Increased attention should also be paid to insulation's surface in spaces where penetration of oil products is possible. The arrangements for storage, distribution and utilization of the oil fuel should be such as to ensure the safety of the vessel and persons on board.

Oil fuel lines should be located as far as possible from hot surfaces, electrical installations or other potential sources of ignition. They should be properly screened or protected to eliminate oil spray or oil leakage contacting hot surfaces. The numerous joints should be properly insulated etc.

Active methods of fire protection in engine rooms are connected with fire extinguishing, fire detection and fire-alarm systems. Approved methods should be installed in all Category 'A' machinery spaces and cargo pump rooms. The choice of extinguishing medium should be suitable for defined areas. The most commonly used in the machinery spaces of cargo vessels are foam, carbon dioxide gas, dry powder or other approved mediums suitable for extinguishing oil fires. The firefighting equipment should be in accordance with the minimum recommendations (IMO, 2015).

The simplest emergency procedure imaginable for crew in case of fire onboard, is the word fire itself. The acronym FIRE is the instruction for what to do. F – stands for find the fire; locate its source. I – stands for inspect, isolate and extinguish, then R – for report, raise the alarm, inform crew, and finally E – for Extinguish. The crew should remember not to put itself in danger (Hope, 2016).

To minimize the consequences of fire spread, crew members are regularly trained to act properly in case of a fire and its spread. They are obliged to take part in courses organized by land training centers and onboard exercises, which are organized to let the crew fix their duties, to understand the proper chain of command, to get to know the ship's architecture better and to try to cope with stress factors. During simulated alarms, each member of the crew has to prove the knowledge of their duties and of how to use the equipment correctly.

To ensure the adequate level of fire safety, engineering analysis of fire risk evaluation should be undertaken. This should include, at the very least, identification of possible fire and explosion hazards; identification of the potential ignition sources; identification of the fire growth potential and fire dynamics; identification of the smoke and toxic effluent generation potential; identification of the possibility of spreading fire, smoke or toxic effluents to other areas (IMO, 2015).

Typical scenarios- examples

Typical scenarios of engine room fire involve hot surfaces and oil leakage. Two examples of typical fire scenarios described by IMO are presented below.

First Scenario

The ship's fire detection system indicated a fire in the engine room (4 hours after the ship departed from port. 2. The second engineer investigated and found that diesel generator No. 3 was on fire, caused by the failure of a flexible fuel hose (long-term rubbing and chafing; the maintenance of the generator's flexible fuel hoses was inadequate and hoses longer than specified by the generator manufacturer had been used). He raised the alarm and discharged a portable extinguisher towards the fire and stopped the engine-room ventilation fans before retreating from the engine room. The crew assembled quickly, operated systems to stop the engine room pumps, fuel tanks, quick-closing valves and prepared to fight the fire. The fire was put out by the engine room Halon fixed fire-extinguishing system (IMO, 2016).

Second Scenario

The No. 4 diesel generator on the 45,000 gt container ship suffered a catastrophic failure, which resulted in disabling the generator and the outbreak of a fire (one or more of the connecting rod palm nuts or counterweight nuts had not been sufficiently tightened – or over-tightened – during recent overhauls and the resultant failure of one of the retaining studs was the initiator of the catastrophic engine failure). The crew members were evacuated and the fixed carbon dioxide (CO_2) fire-extinguishing system was used. The decision to use the CO_2 system was prudent, and together with the prompt use of the ship's fire dampers, remote valves and emergency stops reduced the severity of the damage to the generator room (IMO, 2016).

Some recommendations for engine room fire safety

Engine room fire safety comes as a result of good design, company, crew, authorities and classification societies work (Gard, 2016). The classification societies pay attention to measures onboard. The diagram below (Figure 4) shows some of the recommendations, the elements of so-called safety culture onboard.

The most dangerous possibilities in engine rooms from point of view of ignition are hot surfaces. Most fuel oils may spontaneously ignite if they hit surfaces with temperatures above 250°C. Class rules require that all surfaces above 220°C are shielded or insulated. As commonly noted by surveyors, such protection is often impaired under operation.

The Det Norske Veritas recommends the examination of the following potential hot surfaces: engine "body", indicator valves, cylinder hoods, exhaust pipe from each cylinder, tie-in to exhaust manifold, exhaust manifold, particularly overlaps between steel sheets and laggings, foundation and lifting lugs on exhaust ducts, turbochargers, particularly connecting flanges, cut-outs for pressure/temperature sensors, etc. (DNV, 2016a).

Recommended for checking in case of potential fuel leakage sources are flexible hoses, couplings, clogged filters and fractured pipes. Attention should be paid to installation, location and condition of all these components. It is recommended that the oil systems in engine rooms on ships in operation are also inspected periodically by the owner, as an addition to class inspections (DNV, 2016a).

As aforementioned, most engine room fires occur as a result of oil leakage contacting hot surfaces. To minimize this possibility of fire origin, updated design for integrated insulation box and turbocharger end insulation could be implemented. The integrated insulation box and turbocharger end insulation is an optimized mating with the retrofit design of insulation box and Wärtsilä Bellow and connection insulation. The aim of the retrofit design is to fulfill all

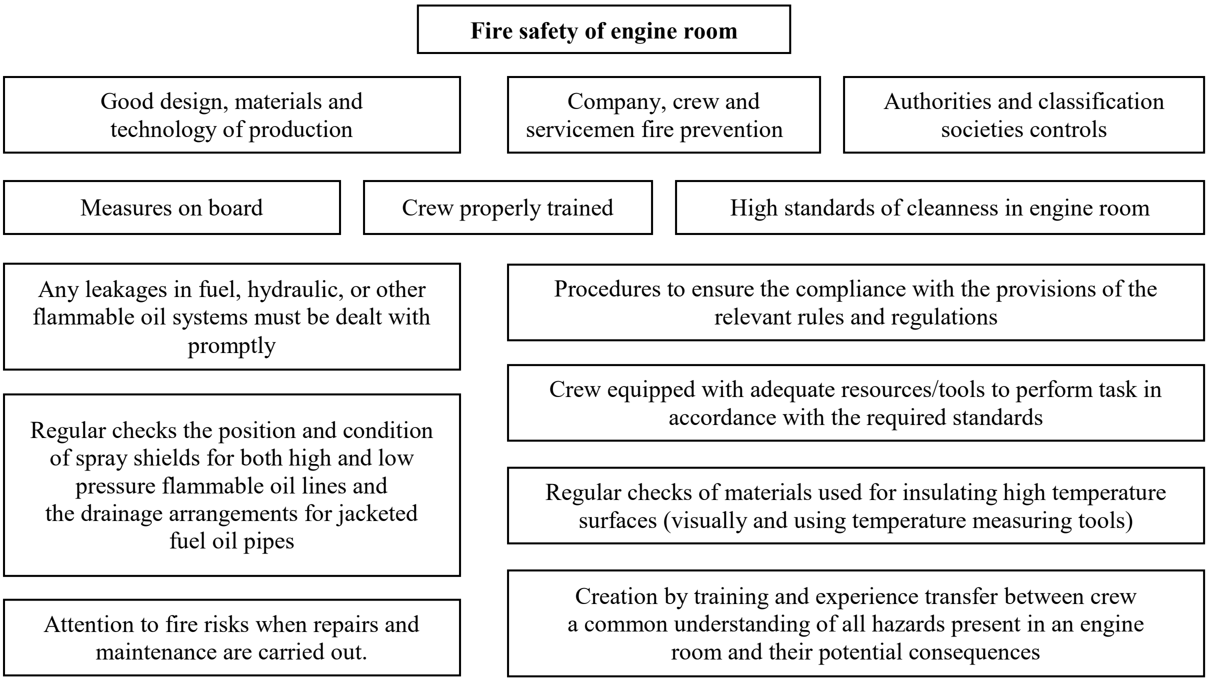

Figure 4. Fire safety in the engine room – some recommendations (based on: Gard, 2016)

actual requirements in terms of hotspot propagation and fire prevention. The updated design is available for Wärtsilä 46 both inline and V-engines (Wärtsilä, 2016).

Conclusions

The engine room is a place characterized by high risk of fire occurrence and spread. Restricted space, oxygen, many potential ignition sources and high amounts of different flammable materials make this region very particularly vulnerable to a fire's commencement and its spread. Engine room fire rapidly becomes fully developed. Many different factors whose presence could result in a fire are present onboard and it's impossible to eliminate them. Good design, arrangement, responsibility and experience are the key to protecting an engine room from fire during its use. Passive and active methods of fire protection are used to eliminate the potential for fire and its spread. They are connected with the construction itself and with the use of fire extinguishing systems and portable means. Machine space is separated by A-class division, hot surfaces are insulated etc.

Attention should be paid to measures onboard, to examine so-called checkpoints in the engine room regularly and with care. The simplest recommendation is cleanness of engine room. There are modern integrated insulation boxes to eliminate potential fire sources and many other ideas to improve fire safety.

We must be aware that it is very unlikely that we will ever completely succeed in the full elimination of fire occurrence in engine rooms from either technical or man-made causes. Nevertheless we are bound to search for optimal technical solutions, which would at least minimize such risk.

References

1. Charchalis, A. & Czyż, S. (2011) Analysis of fire hazard and safety requirements of a sea vessel engine room. *Journal of Kones* 18, 2. pp. 49–56.
2. DASPOS (2016) [Online] Available from: http://daspos.com [Accessed: April 11, 2016]
3. DNV (2000) [Online] Available from: http://www.dnv.pl/Binaries/Engine%20Rooms%20Fires_tcm144-9834.pdf [Accessed: April 6, 2016]
4. DNV (2016a) [Online] Available from: http://www.dnv.pl/Binaries/Hot%20Surfaces%20Paper_tcm144-9837.pdf [Accessed: April 6, 2016]
5. DNV (2016b) [Online] Available from : http://www.dnv.pl/industry/maritime/servicessolutions/cmc/marine_systems/firesafety/engine_room_fire/ [Accessed: April 6, 2016]
6. EMSA (2014) Annual overview of marine casualties and incidents 2014. European Maritime Safety Agency.
7. Gard (2016) [Online] Available from: www.gard.no [Accessed: April 6, 2016]
8. Getka, R. (2011) Drogi ewakuacji z pomieszczeń maszynowych – liczba wyjść, konstrukcja i rozmieszczenie. *Scientific Journals Maritime University of Szczecin* 28 (100) z. 1. pp. 19–26.
9. Hope, R. (2016) *Training Pakage TDM01*. [Online] Available from: http://www.splashmaritime.com.au/Marops/data/rescue/Rescexer/Workshop/Ccex/Fireaboard7.pdf [Accessed: April 18, 2016]

10. IMO (2015) Międzynarodowa Organizacja Morska. Międzynarodowa konwencja o bezpieczeństwie życia na morzu. Tekst jednolity polski.
11. IMO (2016) [Online] Available from: http://www.imo.org/en/OurWork/MSAS/Casualties/Documents/Consolidated%20version%20of%20Lessons%20Learned/Consolidated%20version%20Fire%20explosion.pdf [Accessed: April 7, 2016]
12. IMO (2016) Comprehensive review to SOLAS chapter II-2, Result of the research on applicability of Formal Safety Assessment to comprehensive review to SOLAS chapter II-2.
13. Krystosik, A. (2010) Dislocation of objects on a aship as a method of fire protection. *Archivum Combustionis* 30, 4. pp. 427–434.
14. NKK (1994) Nippon Kaiji Kokai. *Engine room fire*. Guidance to fire prevention, Japan.
15. Port State Control (2014) Adjusting Course, The Paris Memorandum id Understanding on Port State Control. Annual Report.
16. Transportation Safety Board of Canada (2014) Statistical Summar-Marine Occurences 2014. [Online] Available from: http://www.tsb.gc.ca/eng/stats/marine/2014/ssem-ssmo-2014.asp [Accessed: March 30, 2016]
17. U.S. Coast Guard and Canadian Transportation Safety Board (2011) Fatality rates based on census data published by the U.S. Department of Labor, Bureau of Labor Statistics, Census of Fatal Occupational Injuries (2002–2011) Marine casualties based on U.S. Coast Guard and Canadian Transportation Safety Board data.
18. Wärtsilä 2016 [Online] Available from: http://www.wartsila.com/docs/default-source/Service-catalogue-files/Engine-Services---4-stroke/wartsila-solas-solutions.pdf?sfvrsn=0 [Accessed: April 7, 2016]