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# Safety culture as an important factor of an engine room's fire safety

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**Abstract**

The human factor is one of the main reasons for fires in engine rooms and most of the scenarios are very similar. Fires in engine rooms are usually associated with fuel or oil leaking onto a hot surface. Furthermore, engine rooms are very inhospitable places to work. Noise, vibration and high temperatures are most frequently mentioned by crews as negative factors that influence their work. The adoption of a safety culture is one of the ways to increase the fire safety level in engine rooms. Understanding and accepting the necessity of building a safety culture among engine room crews can effectively influence their standard of work. Safety management procedures are an important part of building a safety culture. The change in labor standards must be built on a safety culture among crews.

## The human factor as a reason for fires in engine rooms

The fire safety of a ship's engine room largely depends on the actions taken by the crew; mainly the level of safety culture represented by them. Observance of the inspection regime, the inspections, care for technical condition, proper maintenance, the provision of the appropriate conditions and materials for exploitation, and care for cleanliness, are the factors that determine the level of safety in an engine room.

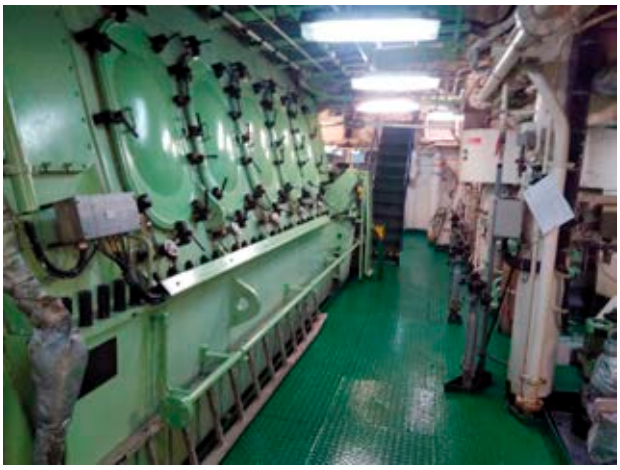

**Figure 1. An example of a well-kept marine engine room**

Any negligence or neglecting the required activities may lead to the late detection of, for example, leakage of the fuel and destruction of the insulation on hot surfaces, which may result in a high risk of an outbreak of a fire. Statistics show that 70% of fires in engine rooms show the same pattern: the outflow of a combustible liquid which then makes contact with a hot surface (Getka, 2011).

Despite the use of advanced technical fire safety measures, including detection and extinguishing installations, as well as safe construction and materials that meet safety standards, fires in engine rooms still occur. The engine compartment is the place where over 20% of accidents take place. The ship's deck (26.1%), the cargo hold and the tank areas (22.9%) are the three most common locations of casualties and accidents on ships, including fires (EMSA, 2019).

The human factor is the main reason for most major accidents on board ships, including fires (Figure 2). The erroneous actions of the crew account for 65.8% of the 4104 accidents analyzed by the European Maritime Safety Agency in their last report (EMSA, 2019). The erroneous actions of the crew during shipboard operations contributed to 65% of the total of 2666 events (EMSA, 2019), and on cargo ships the percentage is even higher: 68.6% of events (EMSA, 2019).

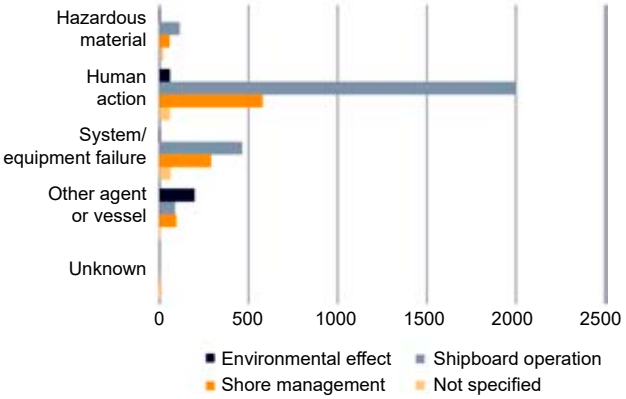


**Figure 2. The relationship between accidental events and their main contributing factors for 2011–2018 (EMSA, 2019)**

The reasons for the erroneous actions of the crew are the social environment – safety awareness (mentioned 130 times in the questionnaire), personal and manning – inadequate work methods (126), crew resource management – planning and coordination (106). All of these have been reported in shipboard operations on cargo ships (EMSA, 2019).

Most of the reported contributing factors related to "Human action" are presented in Figure 3.

The Annual Overview of Marine Casualties and Incidents 2018, prepared by EMSA (EMSA, 2018), shows that cargo ships (43.8%) are where most of the casualties and incidents occurred; in this group, general cargo has the lead position.

Generally, the number of serious and very serious casualties and incidents increased by 14.3 % (very serious) and 2.5% (serious) compared to the last 5 years. Navigation events were the most frequent cause (54.4%) in the last few years (Figure 3). Fires and explosions were qualified by EMSA as one of the top 6 main causes of accidents (EMSA, 2019), but what is important is that 17% of onboard injuries are caused by fires and explosions.

Most on-board fires originate in the engine room, where risk factors such as flammable materials and ignition sources are constantly present.

Building a safety culture among the crews of ships is one of the effective methods that can be used to improve safety by limiting the influence of the human factor (Adamkiewicz & Krystosik-Gromadzińska, 2018). This aims to convince the crew of their co-responsibility for safety and the attitudes and activities, which may influence safety. Safety management, i.e. making regulations, mechanisms for motivating crewmembers, and training on land and sea is also very important. Of course, unlucky occurrences and accidents onboard are a part of a ship's operation; the personnel are only able to change the number of accidents and the consequences.

To better prevent fires in an engine room, high standards of work and an understanding of the importance of safety culture must consequently be required. The standards of ergonomics must be guaranteed for different working positions too. The management of engine room fire safety should the most significant element of the daily routine and activities conducted by the ship's engine room crew. Controls,

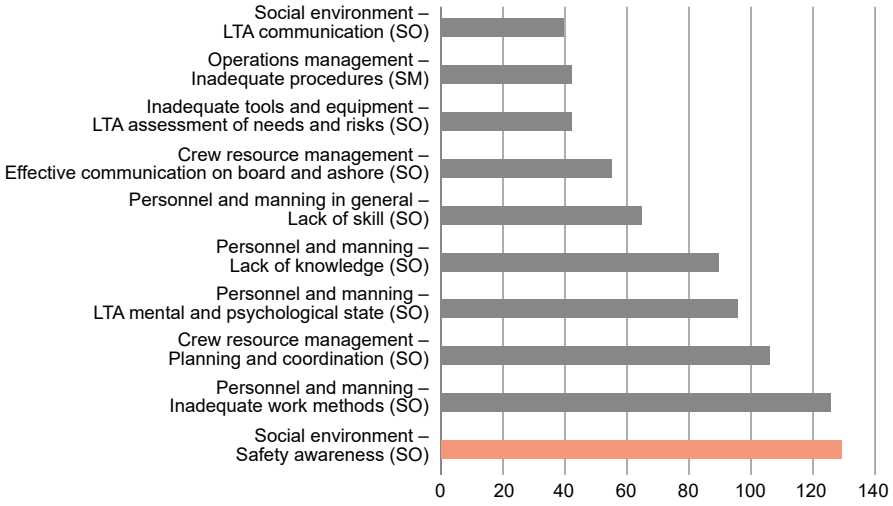


**Figure 3. Contributing factors related to "Human action" for 2011–2018 (EMSA, 2019)**

inspections, repairs, measurements, keeping the area in order and tidy as well as the other often tedious tasks, whenever performed with due and proper know-how supported by experience and care, may largely help to successfully maintain an acceptable fire safety level of the machinery space.

## Literature review

A complete literature review of maritime accidents covering 572 papers from 127 journals published from 1965 to 2014 has been carried out (Meifeng & Sung, 2019). The results of this review clearly indicate that the reasons for accidents have moved from naval architecture to human error. The research findings indicate that future research in maritime accidents will be multi-disciplinary, based on the use of multiple data sources and advanced research methods. Complex interactions between the natural environment, naval technology, human behavior, and the shipping market's conditions will be considered to be inseparable factors.

Statistical surveys of maritime accidents and their causes, which have confirmed the above assumptions regarding the influence of the human factor, have been conducted by Eliopoulou et al. (Eliopoulou, Papanikolaou & Voulgarellis, 2016). The research was aimed at evaluating the current level of safety for the majority of ship subtypes that are present in the world's merchant fleet. The human factor being the cause of most maritime accidents is also indicated in other research (Cordon, Mestre & Walliser, 2017), whose purpose was to identify the human factors in seafaring. Some factors such as situational awareness, adaptability, self-knowledge, group skills and others that influence safety were also identified. The influence of human factors on safety in shipping was also studied by Hetherington et al. (Hetherington, Flin & Mearns, 2006).

The role of the human factor in shipping has been examined also by Havold (Havold, 2007), Hystad et al. (Hystad, Nielsen & Eid, 2017), Berg (Berg, 2013), and Gausdal and Makarova (Gausdal & Makarova, 2017).

Bea (Bea, 1994), in his research on marine engineering, identified the following human error factors as the causes of accidents. These were: inadequate training (physical limitations, inadequate communication, bad judgment, fatigue and boredom), carelessness (wishful thinking, ignorance, negligence, folly and panic) and ego (laziness, greed, alcohol, mischief and violations) (Bea, 1994). The analysis also showed additional factors such as poor planning, training, understanding and interpersonal communication, low quality culture, cost-profit incentives, time pressure, rejection of information, ineffective monitoring and low worker morale.

The results of the research in the literature (Awal & Hasegawa, 2017) have shown that maritime accidents take place in a complex socio-technical context. In such accidents, a single root cause may be traced in the cause-effect chain, but this is not enough to prevent similar accidents in the future.

Due to the systematically growing influence of the human factor on safety, action should be taken to eliminate human errors; one such error in shipping is the safety culture on ships.

This subject was taken up in the research (Kim, Park & Park, 2016); they attempted to solve the problem of how to change the safety culture in both theory and practice at the level of the workplace, as well as determine the role of prevention culture at a national level.

The importance of nationality, sector and the organizational model of safety culture in relation to safety behaviors were examined by Nævestad et al. (Nævestad et al., 2019).

Moreover, the research conducted by Nævestad et al., 2019 indicates that the safety culture in transport, which largely determines the level of safety on board a ship, should be considered at different analytical levels. Determining its real impact is only possible by considering nationality, transport sector and organizational dependencies.

Nævestad et al. indicated age, position, vessel type and working conditions as factors that influence the safety behaviors and occupational injuries. The identification of maritime risks that are influenced by safety culture was considered in northern Europe in the literature (Ek, Mariner Olsson & Akselsson, 2012).

Research conducted in the literature (Arslan et al., 2016) has confirmed that most marine accidents are caused by human and organizational factors. The authors have therefore proposed a novel safety culture assessment and improvement framework to enhance maritime safety and introduced the preliminary results of the safety climate assessment within a company.

Human errors and the level of safety culture affect various aspects of a ship's safety. In the context of this publication, the factors related to fire safety have been highlighted. Research into the causes of fires and explosions on ships in the years 1990–2015 was conducted in the literature (Baalisampang et al., 2018).

In order to reduce human errors caused by the identified lack of familiarization with procedures

and scenarioizes as a contributing factor to maritime incidents, exercises should be conducted in both real and virtual environments to increase the level of knowledge and experience of the crew, especially for those who are young and those preparing to start work onboard; this topic was raised in the literature (Tvedt et al., 2018).

Fatigue is a serious problem that affects the safety and health of a crew. This was taken into consideration by Jepsen et al. (Jepsen, Zhao & van Leeuwen, 2015).

Human errors that occur in the engine room were chosen for analysis of quantitative maritime risk (Islam et al., 2018a). The very important human-machine interactions in the engine room were studied in order to assess the probability of human error during maintenance (Islam et al., 2018b), as well as the likelihood of human error in maritime operations (Islam et al., 2017).

Havold and Nesset (Havold & Nesset 2009) and Veiga (Veiga, 2002) described safety management problems. The culture of safe operation on board has been studied for different kinds of vessels (Ek, Runefors & Borell, 2014), as well as offshore units on the Norwegian Sea in the context of crew error (Rumawas & Asbjornslett, 2016) and on Greek coastal ships (Gemelos & Ventikos, 2008). Safety management as an important element of safety culture was examined by Hanchrow (Hanchrow, 2017), Kongsvik et al. (Kongsvik, Størkersen & Antonsen, 2014) and Wang (Wang, 2002).

## The engine room as a working environment – the ergonomic aspects of safety culture

Ships' engine rooms are inhospitable working environments; work safety culture in this area is very important. There are many factors that cause discomfort but there are also sources that pose a threat to human life and health. The most troublesome are high temperatures, humidity, noise, vibration and air pollution which are typical for ships that are rocking during bad weather conditions. These are factors that affect employees on a continuous basis and it is not possible to eliminate them. Attempts have been made to compensate for vibration or reduce noise, but they have not produced the desired effects. There are also activities aimed at individual employee protection and building a safety culture through effective work organization.

The problem in the operation of most engine rooms is also their poor maintenance and repairability. The positions in which the crew must perform the work can cause numerous musculoskeletal ailments as well as accidents. Individual protection measures, when inappropriate or of low quality, can cause increased discomfort. During their watch, the crew is exposed to toxic substances from consumables. Repairs, removal of broken parts, sometimes lasting hours and without the possibility of rest, which can also be conducted at night, are a reason for a reduction in the crew's psychophysical fitness. Musculoskeletal disorders are compounded by general exhaustion, often caused by insufficient sleep and lack of effective rest and regeneration.

Part of working in a marine engine room is also work done in front of computer monitors. This requires tracking indicators in the control and monitoring center and remote and direct regulation of parameters. The organization of both the work and rest also influences the safety and comfort at work. The division of duties and the layout of the watch, as well as relations between subordinates and management, determine the well-being of the crew (Milan, 1982; Kubacka, 1993; Krystosik-Gromadzińska, 2018a, 2018b).

Occupational diseases such as hearing loss, ailments caused by noise, infrasound noise and vibration: vibroacoustic disease, musculoskeletal disorders and others are the frequently occurring consequences of working in an engine room.

## 2019 survey results

At the beginning of 2019, a survey was conducted by the author's team on the crewmembers of one of the European shipowners (Figure 4); a total of about 100 engine crewmembers were examined. Over 80% of the questionnaires mentioned the

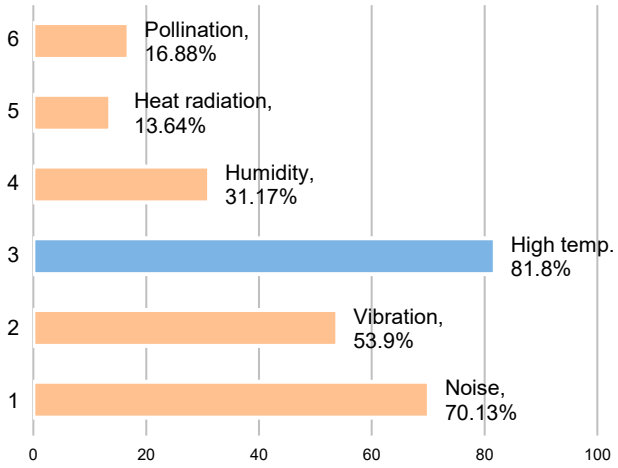


**Figure 4. The distribution of factors affecting the work environment in an engine room**

temperature as the most uncomfortable factor in the engine room; noise came in second position. The questionnaire allowed for the selection of more than one factor, therefore the sum of the responses exceeds 100%.

The factors that were mentioned by the crew as being the most troublesome during their work are difficult to eliminate, but proper preparation of workstations and their organization, as well as equipping employees with individual protection measures, such as hearing protectors, can contribute to reducing their impact.

Limiting their impact translates into an increase in the level of safety and this is directly related to the work culture and safety culture in the engine room. Human errors affecting safety often result from fatigue, which is affected by working conditions.

The selected results of more detailed ergonomic diagnoses, made by the author in previous years, concerning the working methods that were taken into consideration have been shown below.

The diagnosed strain was divided into physical strain and mental strain; the factors that the crew considered to be most important are presented below. The full survey questionnaire contained over 300 questions; not all were answered. The most common answers were:

- The engine room workspace is not spacious enough, especially when other workers are present. It is often difficult to perform maintenance and renew the appropriate consumables.
- The arrangement of the equipment and machines does not guarantee an appropriate position during the work. The working position is often not appropriate and cannot be corrected.
- The size of the tools is not suitable for all types of work.
- There is a danger of burn injuries.
- The work demands the use of self-protection equipment, which prevents or disturbs the crew from receiving personal information and hampers their work.
- The machines are a significant source of noise, vibration and radiation, which have an impact on their work.
- The work takes place in very uncomfortable conditions due to the high temperature, humidity, air movement and heat flush. The work is performed in extreme conditions and the breaks are not adjusted to it.
- The work requires an intense use of sight in conditions of artificial illumination. It requires hearing and engagement of touch too.
- The amount of information overwhelms the human brain, and the information must be remembered for a long time.
- It is possible to simultaneously receive signals from different sources.
- The work does not guarantee flexibility for effort and rest.
- The work produces high stress.

Other, more detailed results are presented in additional articles in the literature (Krystosik-Gromadzińska, 2015a; 2015b; 2018a; 2018b).

The limited possibility of compensating the crew for their work through recreation is also a very important problem on the ship. Crews stay in the same place with the same people from several days to several months. Furthermore, the biological rhythm of work and rest is disturbed as a result of changes in the time and climate zones. Readiness to start work and primarily relying on oneself is a huge psychological burden onboard (Milan, 1982; Kubacka, 1993).

The monotony and monotype of the performed tasks also have a negative effect on the crew. It is also not easy for the crew to bear the cultural and social isolation, as well as separation from their families. Altogether these are the reasons for the physical and mental overload; they could be partly reduced by the appropriate level of safety culture at work.

Due to the problems in conducting ergonomic diagnoses, as a result of the need to answer too many detailed questions, additional research was also carried out. The crew had to give short answers to several questions that were prepared by the author's team. In the opinion of over 100 crewmembers, the psychophysical conditions were evaluated. The stress level was accepted by almost 54% of the crew; 42% defined it as high. Only about 4% thought that the stress level was low. The rest and regeneration conditions were accepted by 81% of the crew; about 6% considered it to be very good or adequate.

These results show that the crews are well organized and accept the working conditions. Stress is a problem, but crewmembers are trained to compensate for it and they have the possibility to do so onboard. Detailed information concerning this ergonomic diagnosis has been presented in the literature (Zeńczak & Krystosik-Gromadzińska, 2019).

## Safety culture in the engine room

A high level of safety culture at work can significantly contribute to an improvement in the safety devices as well as the comfort of the work. Awareness

of threats and taking action to eliminate or limit them translates into better working conditions.

The aim of building a safety culture is to first shape and modify the behaviors, beliefs and attitudes of the crews, so that they independently become responsible for their own safety, as well as that of their co-workers and technical facilities. Building a safety culture is a process that takes place in the relationship between the individual and the group (Adamkiewicz & Krystosik-Gromadzińska, 2018).

The safety culture of a single crewmember is influenced by the safety culture of the group and safety management procedures too. The most desirable attitude is "I understand and accept"; this is usually the result of the whole process and is preceded by different attitudes like "I want", "I must" and by the least desirable attitude "Punishment avoidance". Only a good understanding and acceptance of the principles of a good safety culture can guarantee an increase in the level of safety. The attitude of avoiding fines can contribute to success to a small extent. Responsibility for oneself and other crewmembers, internal motivation and conviction are the way to change the situation in the engine room. The proper safety management will be helpful in building the safety culture, e.g. creating legal acts, operating procedures and communication, tools to support daily machine handling, motivation mechanisms of the crew members and training on land and onboard the ship.

Fire safety management in a ship's machinery space may be defined as a series of regulations, procedures and actions performed at various stages of the existence of the object by the personnel directly operating the machinery, the equipment and the installations in the engine room, who are directly responsible for its safety. The personnel involved in the ship's engine room fire safety management are thus apart from the ship's crew, the ship owner and classification society, and the inspectors, as well as the designers and shipbuilders.

Engine room fire safety is also subject to the Owner's actions; these include the provision of the correct consumables, planning of repairs and inspections, and good selection of the crew working with the machinery, who should be adequately trained and experienced and are provided with safe working conditions and the possibility to properly rest. This also includes planning of test alarms for various hazard scenarios and observation of compliance with the requirements regarding training courses in land centers.

The classifiers and the other inspectors are responsible for the control of the condition of the ship's engine room and ensuring that all the formal requirements are met by the crew.

The last and the major link in the safety management chain are the crewmembers who directly influence the maintenance at the acceptable safety level. The performance, negligence or omission, in respect of specific activities will most likely be translated into a reduction or increase in the safety level. The most significant activities in terms of engine room fire safety, that are performed by the crew, comprise the control of the fuel installation tightness, leakage disclosure, control of the insulation of hot surfaces, control of equipment and installations based on the accepted regulations and procedural requirements. The crew should also care for order and tidiness in the engine room, which would help them to promptly notice even the smallest leakages which may become a cause of fire in the engine room.

The crew must train in the procedures for different scenarios in accordance with international legislation and the safety management book. The training must be carried out with accuracy and the full involvement of the crew and repeated if necessary.

In order to improve the fire safety level in the designing phase, the correct layout of the machinery space should be planned; chiefly the distance between the potentially flammable materials and leakage sources. It is important to adequately plan the routes of the piping; flexible joints should not be excessively bent. Easy access to potential risk objects and proper illumination should be provided for ease of inspection.

In order to identify the components of safety culture that influence fire safety in an engine room, the author's simplified analysis is presented in Figures 5–7. They indicate the factors that determine the possibilities of a fire's origin and spread, including safety management as an important factor to encourage fire safety in an engine room. They are components that should be remembered and understood by the crew members as part of the safety culture in the engine room. Figure 5 describes the possibilities of sources of ignition, leaks, splashes or sprays; the reasons for which should be regularly checked by the crew. High standards of work, which are possible for the crew to reach, and understanding the sense of safety culture, may noticeably reduce the chance of the occurrence of sources of ignition and leaks, splashes and sprays which are the most common reasons for an engine room fire. More detailed procedures and instructions to identify fire and control its spread are presented in Figure 6.

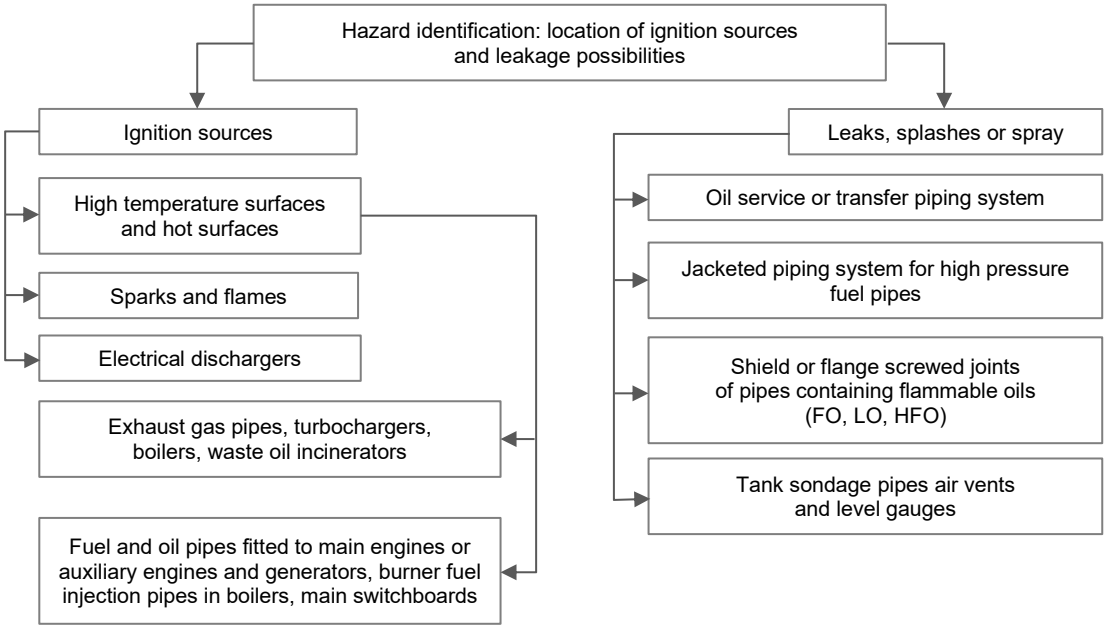


**Figure 5. The list of ignition sources and leaks to be checked regularly by the crew**

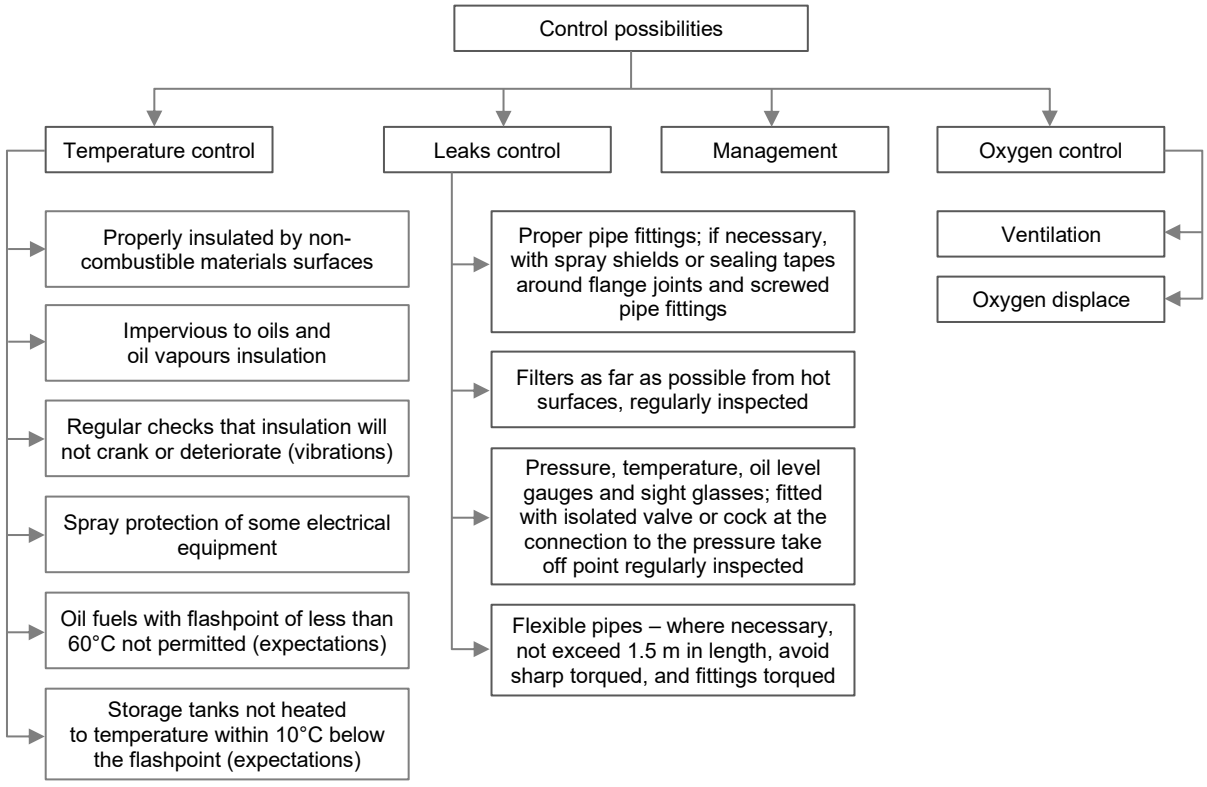


**Figure 6. Identification of a fire's origin and spread control possibilities**

In order to better control the level of fire safety in the engine room, adequate management procedures must be implemented. Parts of these procedures are activities delegated to the crew which are presented in Figure 7. Although they are highlighted separately, they should be well known, understood and performed by the crew for whom the safety culture is the exponent according to which all duties are performed.

Fire safety management components are important parts of the safety culture onboard, which should be taken into consideration during daily inspections but also when preparing long-term schedules and inspection plans for engine rooms.

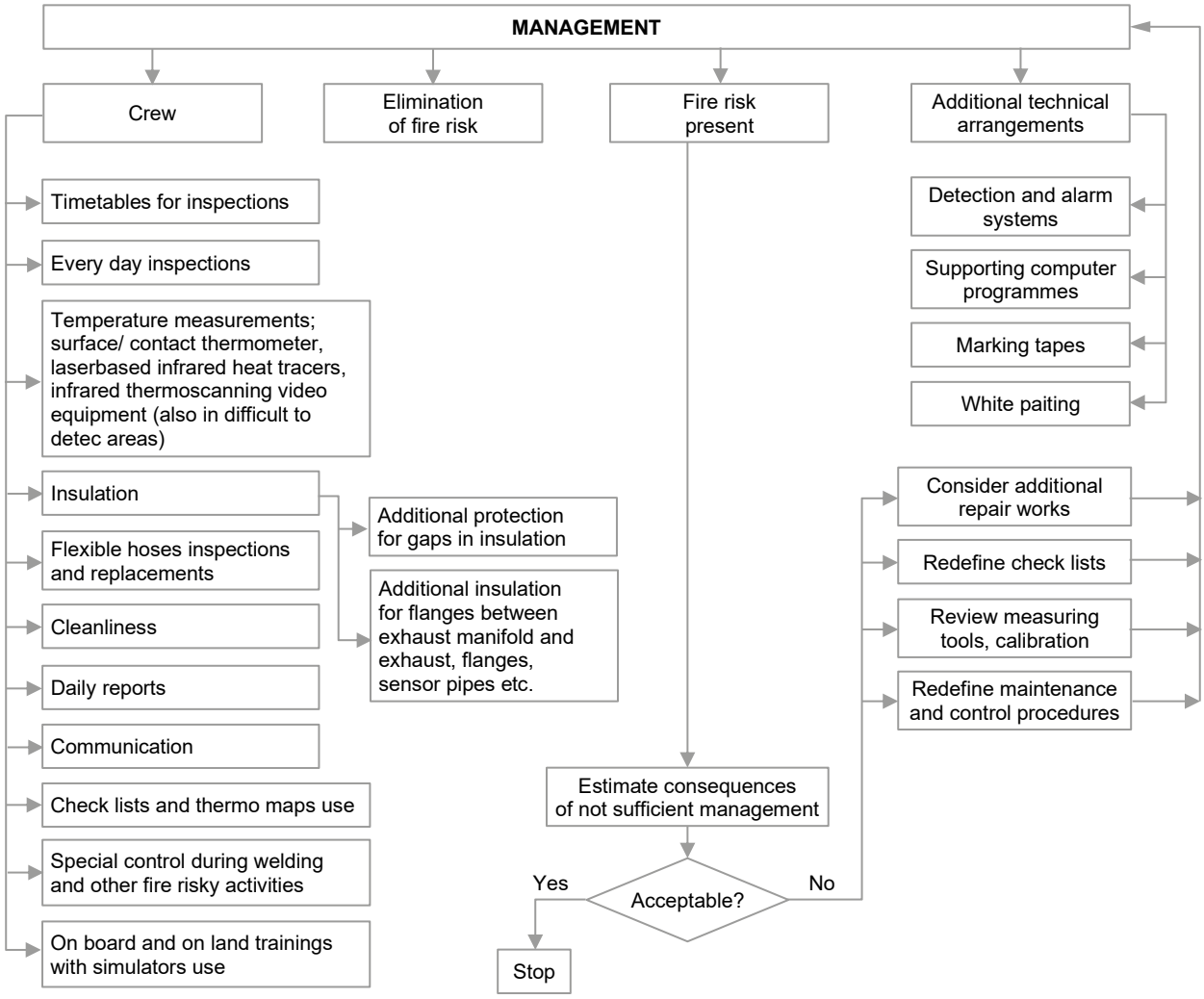


**Figure 7. Fire safety management activities dedicated to crew members**

## Conclusions

The fire safety of a ship's power plant largely depends on the actions taken by the crew. It is possible to reduce the number of accidents by increasing the work standards by building a safety culture among the engine room's crews. This is the process that requires, on the one hand, appropriate safety management, but on the other hand, requires the direct involvement of each of the crewmembers. An attitude of acceptance and understanding of the requirements of the work standards and the responsibility for one's own safety and that of other crew members is the goal; the achievement of which will significantly contribute to an improvement in safety. The acceptance of high safety culture standards is the aim that is to be achieved, regardless of nationality, ship type or the operational tasks performed. This is the process that requires actions connected not only with safety itself but also ergonomic aspects, as well as psychological and health aspects.

## References


1. Adamkiewicz, A. & Krystosik-Gromadzińska, A. (2018) Modelling safety culture among crews of seafaring vessels. *New Trends in Production Engineering* 1, 1, pp. 95–101.
2. Arslan, V., Kurt, R.E., Turan, O. & De Wolff, L. (2016) Safety culture assessment and implementation framework to enhance maritime safety. *Transportation Research Procedia* 14, pp. 3895–3904.
3. Awal, Z.I. & Hasegawa, K. (2017) A study on accident theories and application to maritime accidents. *Procedia Engineering* 194, pp. 298–306.
4. Baalisampang, T., Abbassi, R., Garaniya, V., Khan, F. & Dadashzadeh, M. (2018) Review and analysis of fire and explosion accidents in maritime transportation. *Ocean Engineering* 158, pp. 350–366.
5. Bea, R.G. (1994) *The role of human error in design, construction, and reliability of marine structures*. Report No. SSC-378. U.S. Coast Guard Ship Structure Committee.
6. Berg, H.P. (2013) Human Factors and Safety Culture in Maritime Safety. *International Journal on Marine Navigation and Safety of Sea Transportation* 7(3), pp. 343–352.
7. Cordon, J.R., Mestre, J.M. & Walliser, J. (2017) Human factors in seafaring: The role of situation awareness. *Safety Science* 93, pp. 256–265.

8. Ek, Å., Mariner Olsson, U.M. & Akselsson, K.R. (2012) Safety Culture Onboard Ships. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* 44, 27, pp. 320–322.
9. Ek, Å., Runefors, M. & Borell, J. (2014) Relationship between safety culture aspects – A work process to enable interpretation. *Marine Policy* 44, pp. 179–186.
10. Eliopoulou, E., Papanikolaou, A. & Voulgarellis, M. (2016) Statistical analysis of ship accidents and review of safety level. *Safety Science* 85, pp. 282–292.
11. EMSA (2017) *Annual overview of marine casualties and incident 2017*. European Maritime Safety Agency.
12. EMSA (2018) *Seafarers' statistics in the EU. Statistical review* (*2016 data STCW-IS*). EMSA.2017.AJ7463. European Maritime Safety Agency.
13. EMSA (2019) *Annual overview of marine casualties and incident* 2019. European Maritime Safety Agency.
14. Gausdal, A.H. & Makarova, J. (2017) Trust and Safety Onboard. *WMU Journal of Maritime Affairs* 16(2), pp. 197–217.
15. Gemelos, I.C. & Ventikos, N.P. (2008) Safety in Greek Coastal Shipping: The Role and Risk of Human Factor Revisited. *WMU Journal of Maritime Affairs* 7(1), pp. 31–49.
16. Getka, R. (2011) Evacuation routes prom machinery spaces – quantity, construction and layout. *Scientific Journals Maritime University of Szczecin, Zeszyty Naukowe Akademia Morska w Szczecinie* 28 (100), pp. 19–26.
17. Hanchrow, G.A. (2017) International Safety Management – Safety Management Systems and the Challenges of Changing a Culture. *TransNav: International Journal on Maritime Navigation and Safety of Sea Transportation* 11 (1), pp. 125–131.
18. Havold, J.I. (2007) National cultures and safety orientation: A study of seafarers working for Norwegian shipping companies. *Work and Stress* 21 (2), pp. 173–195.
19. Havold, J.I. & Nesset, E. (2009) From safety culture to safety orientation: Validation and simplification of a safety orientation scale using a sample of seafarers working for Norwegian ship owners. *Safety Science* 47 (3), pp. 305–326.
20. Hetherington, C., Flin, R. & Mearns, K. (2006) Safety in shipping: The human element. *Journal of Safety Research* 37 (4), pp. 401–411.
21. Hystad, S.W., Nielsen, M.B. & Eid, J. (2017) The impact of sleep quality, fatigue and safety climate on the perceptions of accident risk among seafarers. *European Review of Applied Psychology – Revue Europeenne de Psychologie Appliquee* 67 (5), pp. 259–267.
22. Islam, R., Khan, F., Abbassi, R. & Garaniya, V. (2018a) Human errors assessment during maintenance operations of marine systems – what are the effective environmental facts? *Safety Science* 107, pp. 85–98.
23. Islam, R., Khan, F., Abbassi, R. & Garaniya, V. (2018b) Human factor probability assessment during maintenance activities of marine systems. *Safety and Health at Work* 9, pp. 42–54.
24. Islam, R., Yu, H., Abbassi, R., Garaniya, V. & Khan, F. (2017) Development of a monograph for human error likelihood assessment in marine operations. *Safety Science* 91, pp. 33–39.
25. Jepsen, J.R., Zhao, Z. & van Leeuwen, W.M.A. (2015) Seafarer fatigue: a review of risk factors, consequences for seafarers' health and safety and options for mitigation. *International Maritime Health* 66 (2), pp. 106–117.
26. Kim, Y., Park, J. & Park, M. (2016) Creating a Culture of Prevention in Occupational Safety and Health Practice. *Safety and Health at Work* 7 (2), pp. 89–96.
27. Kongsvik, T.Ø., Størkersen, K.V. & Antonsen, S. (2014) The relationship between regulation, safety management systems and safety culture in the maritime industry. In: Steenbergen et al. (eds). *Safety, Reliability and Risk Analysis: Beyond the Horizon*. 22nd Annual Conference on European Safety and Reliability (ESREL). Amsterdam, Netherlands, September 2013. London: Taylor & Francis Group, pp. 467–473.
28. Krystosik-Gromadzińska, A. (2015a) Analiza ergonomiczna stanowiska pracy – operator siłowni okrętowej. In: Zwolińska, D. (ed.), *Bezpieczeństwo pracy: środowisko, zarządzanie*. *T. 1*. Katowice: Wyższa Szkoła Zarządzania Ochroną Pracy, pp. 129–140.
29. Krystosik-Gromadzińska, A. (2015b) Bezpieczeństwo i ergonomia pracy na statku, *Logistyka* 3, pp. 1035–1041.
30. Krystosik-Gromadzińska, A. (2018a) Ergonomic assessment of selected work stations on a merchant ship. *International Journal of Occupational Safety and Ergonomics* 24, 1, pp. 91–99.
31. Krystosik-Gromadzińska, A. (2018b) Improvement of work safety and comfort during engine room exploitation and repair works. *Zeszyty Naukowe Akademii Morskiej w Gdyni, Scientific Journal of Gdynia Maritime University* 108, pp. 81–91 (in Polish).
32. Kubacka, M. (1993) *Ergonomia w oceanotechnice*. Gdańsk: CTO.
33. Meifeng, L. & Sung, S. (2019) Half-century research developments in maritime accidents: Future directions. *Accident Analysis and Prevention* 123, pp. 448–460.
34. Milan, L. (1982) *Zarys ergonomii okrętowej cz. I i II*. Gdynia: Wyższa Szkoła Morska.
35. Nævestad, T.-O., Phillips, R.O., Størkersen, K.V. & Yannis, A.L.G. (2019) Safety culture in maritime transport in Norway and Greece: Exploring national, sectorial and organizational influences on unsafe behaviours and work accidents. *Marine Policy* 99, pp. 1–13.
36. Rumawas, V. & Asbjornslett, B.E. (2016) Human factors on offshore supply vessels in the Norwegian Sea – an explanatory survey. *International Journal of Maritime Engineering* 158, A1–A14.
37. Tvedt, S., Oltedal, H., Batalden, B.M. & Oliveira, M. (2018) Way-finding on-board training for maritime vessels. *Entertainment Computing* 26, pp. 30–40.
38. Veiga, J.L. (2002) Safety culture in shipping. *WMU Journal of Maritime Affairs* 1, 1, pp. 17–31.
39. Wang, J. (2002) A brief review of marine and offshore safety assessment. *Marine Technology and SNAME News* 39(2), pp. 77–85.
40. Zeńczak, W. & Krystosik-Gromadzińska, A. (2019) Improvements to a fire safety management system. *Polish Maritime Research* 26, 4 (104), pp. 117–123.