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IMPROVEMENTS TO A FIRE SAFETY MANAGEMENT SYSTEM

Wojciech Zeńczak
Agata Krystosik-Gromadzińska
West Pomeranian University of Technology Szczecin, Poland

ABSTRACT

The statistics invariably show that most onboard fires originate in the engine room. In hazardous conditions, fires can spread to other rooms of the ship and cause the loss of human life, and can cause the ship to be out of service or lost completely. To prevent these serious consequences, the engine room crew should be aware of hazards and ways to prevent them. It is also advisable to support their routine activities and actions in critical situations with an appropriate management system.
For this reason, a survey was conducted at the beginning of 2019 of engine room crew members employed by a European shipowner, as a contribution to an analysis of fire safety management. Based on the results of the survey, some of the elements of the fire safety management system of the ship engine room are described. A properly constructed system that is understandable and accepted by the crew is one of the most important factors in increasing fire safety on a ship. Familiarisation with adequate procedures can significantly contribute to the successful prevention of accidents. This paper also proposes a checklist based on suggestions by the crew, which may be helpful in onboard fire prevention.

Keywords: fire safety; management system; engine room; ship accidents

ABBREVIATIONS

AE – auxiliary engine
FO – fuel oil
HFO – heavy fuel oil
IMO – International Maritime Organisation
LNG – liquid natural gas
LO – lubricating oil
MCC – motor control center
MDO – marine diesel oil
ME – main engine
MES – maritime evacuation system
EMSA – European Maritime Safety Agency
ER – engine room
SOLAS – Safety of Life at Sea

INTRODUCTION

Fires onboard ships differ from land-based ones, and are much more dangerous to crew and passengers. Not only is the chance of finding an evacuation route much lower, but escape via a life raft, lifeboat or maritime evacuation system is also much more difficult than escape in land-based situations. Abandonment of the ship is also no guarantee of safety, since the chances of surviving outside of the ship are determined by many unpredictable factors such as weather and the risk of hypothermia.

The Annual Overview of Marine Casualties and Incidents 2018, prepared by the European Maritime Safety Agency (EMSA) [7], gives information on the distribution of casualty events for each type of cargo ship (see Fig. 1). Container ships, general cargoes and bulk carriers are the categories of ships in which most fires originate.

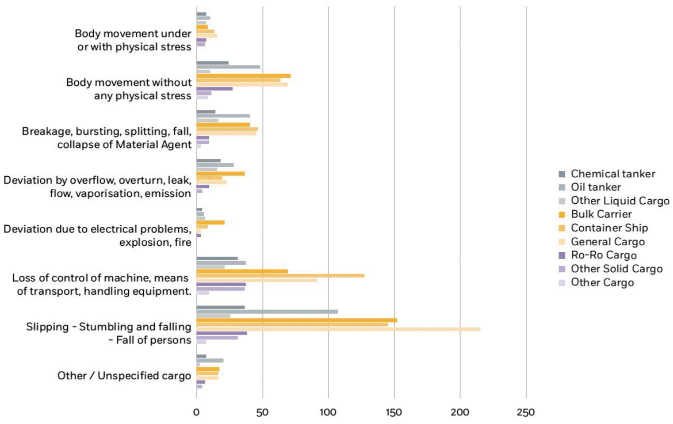

Fig. 1. Distribution of casualty events per cargo ship type for 2011–2017 [7]

Navigation events (loss of control, grounding/stranding, collision, contact) have been most frequent in recent years (Fig. 1), followed by fires and explosions, which have been assessed by EMSA as being in the top five causes of accidents [7, 25].

Most onboard fires originate in the engine room (ER). In hazardous conditions, these can spread to other parts of the ship and cause loss of human life, and may mean that the ship becomes out of service or is lost. The ER is a place where risk factors such as numerous sources of fire and flammable materials are located together within a small, cramped, hot space. The dangers of fire and explosion are determined by the type of fuel, and are different for merchant ships and warships. ER fires are associated with the risk of explosion in ships powered by dual fuel engines (MDO/LNG) due to the potential for a gas leak. In the case of fire and explosion, heavy damage and loss to the surroundings (including the environment), personnel and equipment are to be expected.

Approximately 60–70% of fires in ERs share a common scenario, based on the outflow of combustible liquid and contact with a hot surface. ER fires develop rapidly, and reach temperatures of 700–1000°C [12].

To prevent fires in the ER, the management of fire safety in the ER should form part of all stages of its existence, starting with the design process, continuing in everyday operation, and finally in the inspections conducted by competent and properly qualified agencies and societies. Risk-based assessments of safety in a wider sense, including fire safety, and analysis should also be included [11].

The most important element of this process is the daily routine activities conducted by the ship's ER crew. Controls, overhauls, inspections, repairs, measurements, and keeping spaces tidy and in order may be tedious tasks, but when performed using due and proper procedures supported by experience and care may greatly help in successfully maintaining an acceptable fire safety level in the machinery space.

There is strong evidence that the human element is the main reason for many major accidents, including fires. Erroneous actions by humans are the reason for most accidents during shore management and shipboard operations (57.8% of 1,654 analysed accidents) [7]. Erroneous human actions during shipboard operations are responsible for 70.1% of the total number of fires, and 76.4% of those on cargo ships [7].

LITERATURE REVIEW

A study conducted in [1] of the factors related to human error in marine engineering identified the following factors: inadequate training (physical limitations, inadequate communication, bad judgement, fatigue, boredom), carelessness (wishful thinking, ignorance, negligence, folly, panic) and ego (laziness, greed, alcohol, mischief, violations). Further analysis identified poor planning/training, poor communication, a low-quality culture, cost-profit incentives, time pressure, the rejection information, ineffective monitoring and low morale of workers. Hence, in safety management, human factors should be analysed in detail.

A literature review on the topic of accidents in shipping, the influence of human errors and interventions to make shipping safer was carried out in [16]. A monograph to be used by chief engineers and others to assess the likelihood of human error in maritime operations was presented in [19], and the authors proposed an assessment tool for the likelihood of human error. The importance of proper communication in English to improve safety in shipping was highlighted [20].

The issue of safety management has been considered [14, 27], and the human factors in water transport have also been studied [2, 9, 15, 17]. Problems with the work culture onboard have been studied for different kinds of ships [6], offshore units, and in the context of crew errors [27], on Greek coastal vessels [10] and for Filipino shipmates [22].

The results of extensive studies concerning safety culture in the Finnish maritime sector have also been presented [26]. The basis for this study was a set of questionnaires and interviews with many representatives of Finnish maritime organisations. It was recommended that a maritime regulatory regime should be developed and a "learning the incident" approach should be well understood by the crew, becoming an element of onboard safety culture [23]. The role of a leader in the safety building process has been described [3, 4, 24], and safety management as an element of safety culture was addressed in [14, 21, 28]. The authors have discussed the human factor in relation to accidents in the maritime industry, and have identified the need for changes in management systems and work cultures to safety-oriented ones.

REGULATIONS AND RECOMMENDATIONS FOR FIRE SAFETY IN THE ENGINE ROOM

It is generally accepted that rules are the best approach to fire prevention. In Ch.II-2 of the Safety of Life at Sea (SOLAS) Convention [18], the International Maritime Organisation (IMO) provides the key regulatory framework for fire safety on board ships. The objectives of fire safety are to prevent the occurrence of fire and explosions; to reduce the risk to life caused by fire; to reduce the risk of damage caused by fire to the ship, its cargo and the environment; to contain, control and suppress fires and explosions within the compartment of origin; and to provide adequate and readily accessible means of escape for passengers and crew. In order to achieve these fire safety objectives, the following functional requirements are presented by the IMO: division of the ship into main vertical and horizontal zones by thermal and structural boundaries; separation of accommodation spaces from the remainder of the ship by thermal and structural boundaries; restricted use of combustible materials; detection of any fire in the zone of its origin; containment and extinction of any fire in the space of origin; protection of means of escape and access for fire-fighting; ready availability of fire-extinguishing appliances; and minimisation of the possibility of ignition of flammable cargo vapour. These principles underpin the philosophy of fire safety on board vessels [18].

The ER is a region of the ship where the prevention of ignition of combustible materials, and especially flammable liquids or gases, should be the most important aim, and functional requirements for this are are mentioned in SOLAS. In addition to the regulations set out in the convention, an analysis of fire safety should cover the relationships between the people on board.

FIRE SAFETY MANAGEMENT SYSTEM: A SIMPLIFIED ANALYSIS

A fire safety management system for a ship's ER may be defined as a series of regulations, procedures and actions performed at various stages in the existence of the object by the personnel, directly and indirectly, operating the machinery, equipment and installations and the personnel directly responsible for its safety. The engine room is the place where most marine casualties and accidents occur (Fig. 2), accounting for 1,810 out of 8,040 over the years 2011–2016.

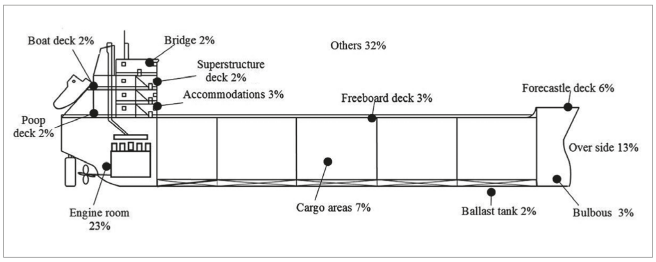

Fig. 2. Distribution of marine casualties and accidents, based on [1]

The personnel involved in the ship's ER fire safety management are the ship's crew, the owner, the classification society, inspectors, designers and shipbuilders.

Fire safety depends to a large extent on the design of the ER, and in particular the proper mutual arrangement of risk objects (potential ignition sources and flammable materials), provision of machinery space with effective structural protection elements and correctly selected and designed fire extinguishers installed in suitable places as well as portable fire extinguishing equipment.

In order to improve the fire safety level in the design phase, a correct plan for the arrangement of machinery should be made, chiefly in respect of the distances between potentially flammable materials and sources of leakage. It is also very important to design adequate routes for piping, and any flexible joints used should not be excessively bent. Easy access to potential risk objects and proper illumination should be provided for inspection.

ER fire safety is also dependent on the owner's actions. These include the provision of correct consumables (types and amounts), the planning of repairs and inspections, and the selection of effective machinery crew who are adequately trained and experienced, and are provided with safe working conditions and the possibility of resting properly. This also includes the planning of test alarms for various hazard scenarios, and compliance with requirements regarding training courses in land-based centres.

Classifiers and other inspectors are responsible for control of the condition of the ship's ER and for the crew meeting all formal requirements.

The last and most important link in the chain of safety management are the crew members, who have a direct influence on the maintenance of an acceptable level of safety. Performing or failing to perform specific activities, or acts of negligence or omission, are likely to be translated into effects on the level of safety. The most significant activities in terms of ER fire safety performed by the crew involve the control of fuel and oil installations with respect to tightness, leakage disclosure, splashes and sprays, control of insulation of hot surfaces, control of equipment and installations on the basis of the accepted regulations and procedural requirements.

Det Norske Veritas–Germanischer Lloyd recommends that areas such as potentially hot surfaces are examined. These include the engine bedplate and cylinder box, indicator valves, cylinder hoods, the exhaust pipe from each cylinder, the tie-in to the exhaust manifold, the exhaust manifold, and in particular overlaps between steel sheets and lagging, foundation and lifting lugs on exhaust ducts, turbochargers (especially flanges), and cut-outs for pressure/temperature sensors, etc. [5].

The potential sources of fuel leakage that should be checked include flexible hoses, couplings, clogged filters and fractured pipes. Attention should be paid to the installation, location and condition of all of these components. It is recommended that fuel oil and lubricating oil systems within the ER on ships in operation are periodically inspected by the shipowner in addition to class inspections [5].

DNV has been conducting temperature analyses of so-called trouble areas in the engine room. The most dangerous trouble areas are generally the exhaust duct insulation (260°C), the indicator valve (260°C), cut-outs for sensors (230°C), flanges between the exhaust manifold and exhaust duct (no insulation; 230°C) and the steel plate covering the exhaust manifold (gaps in insulation with no overlap between; 320°C) [5].

The locations of possible leakages and sources that could cause their ignition are shown in Fig. 3. These should be placed under special supervision.

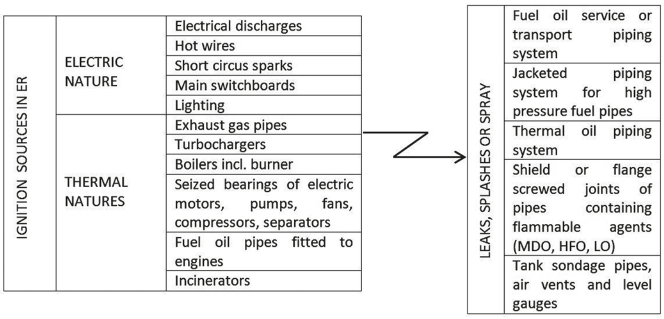

Fig. 3. Identification of ignition sources and leaks

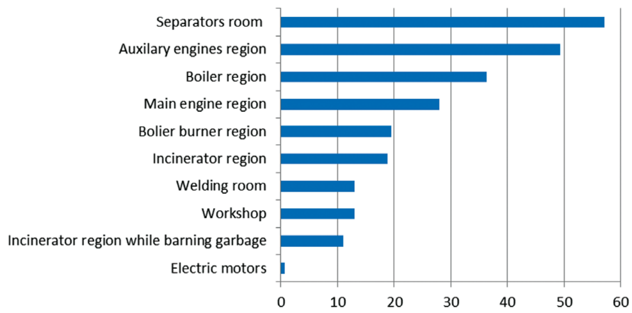

Fig. 4. Places requiring special supervision in the engine room as a percentage of respondents

SURVEY ON FIRE SAFETY IN THE ENGINE ROOM

In order to confirm the factors that have been identified as affecting fire safety in a ship's ER, a list of control questions was formulated in the form of a survey with both closed and open questions, and this was presented at the beginning of 2019 to the ER crew employed by a European shipowner. There were three types of questions: questions with only one possible answer, questions with more than one answer to choose from, and open questions with space for the respondent to write their own answers.

The number of responses in each case was related to the total number of surveys and was presented as a percentage. In the case of questions where it was possible to select several responses, the sum of the responses could exceed 100%. Some of the questions were omitted by the respondents, and in this case, the sum of the responses was less than 100%. Only questions for which only one answer was possible and where all the respondents answered gave a total of 100%.

In total, 154 completed surveys were received. Due to the use of satellite internet connections, feedback from the crew was very fast. This demonstrates that the subject of fire safety is an important issue, and that the crews of ERs understand the need to take action to increase the level of safety and actively engage in this.

The aim of the survey was to ask the crew to identify the fire risk facilities in the ER, to assess the impact of a number of factors on the safety and comfort of both work and leisure, and to obtaining the crews' opinions on formal tools for increasing safety.

Among the factors causing a psychophysical load on the various workplaces in the ship's engine room, translating into the level of fire safety, a majority of respondents highlighted high temperatures (81.8%), noise (70.1%), an insufficient number of crew members (85.7%) and the multinationality of the crew (58.3%). Crew members also pointed to the problem of high levels of stress associated with their work (65%).

Fig. 4 shows the places identified by the crew members as requiring special supervision in the ER as a percentage of the responses to the survey. It can be seen that the respondents identified the separators and auxiliary rooms as requiring the greatest supervision, and the electrical motors as requiring the least. An equally dangerous place, according to the survey, is the region of the auxiliary engine.

To control the risk of fire in the ER and to keep it to an acceptable level, the actions referred to above should be carried out regularly. The crew should also take proper care to ensure order and tidiness in the ER, as this can help in promptly noticing even the smallest leakages which may become a cause of fire.

The crew must be trained in procedures for different scenarios, in accordance with international legislation and safety management processes. This training must be carried out accurately and with the full involvement of the crew, and should repeated if necessary.

With regard to the development of the fire safety management system, the opinions of the machinery crew based on their practical experience are also extremely important. The respondents were therefore asked about actions that could contribute to increasing the level of fire safety in the ER.

Fig. 5 shows the results of the investigation, with the value for each measure expressed as a percentage of respondents.

Respondents mainly highlighted the good education of the crew, including thinking about and maintaining cleanliness and order. In second place, they mentioned additional courses and training alarms. Only 0.65% of respondents believed that additional instructions or procedures were needed. These attitudes by the crew indicate that the management system should be relatively simple, without excessive formalism.

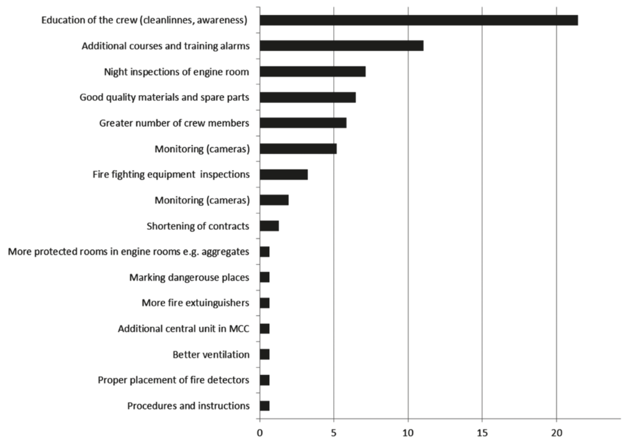

Fig. 5. Actions that can contribute to an increase in the fire safety level in the ER, expressed as a percentage of respondents

Each new fire safety management system, or changes in the existing one, should take into account its current state. Therefore, the crew members were also asked about training, knowledge of rules and conducting post-accident analyses. The results are shown in Fig. 6.

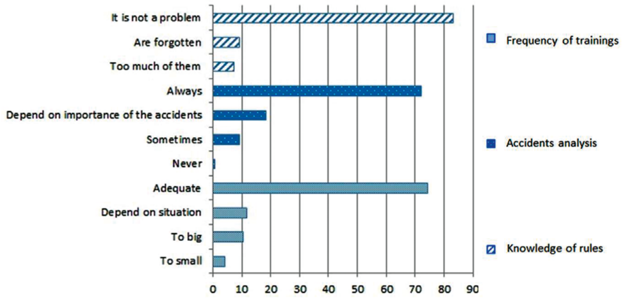

Fig. 6. Training, knowledge of rules and accident analyses, as percentages of respondents

It can be seen that the knowledge of fire safety rules was very good (83.1%). The answers to the questionnaire also indicated that the causes of fire in the ER were always analysed by the crew, and 74% of respondents believed that the frequency of training was adequate.

ELEMENTS OF ENGINE ROOM FIRE SAFETY MANAGEMENT: PROPOSAL FOR IMPROVEMENT

It must be remembered that fire safety in the ER is an outcome of the combined efforts of the crew, servicemen, owner, authorities and classification societies. Of course, good design, appropriate materials and technology of production, and active and passive means of fire protection are important, but the real level of fire safety is connected with everyday conditions and crew maintenance. This is also reflected in the answers to the survey of crew members (Fig. 5).

For good operation and proper usage of the safety management system, it needs to be accepted by the crew and user friendly. The crew members were therefore asked about formal tools used to increase safety, such as checklists and procedures. The crew were also asked which types of forms, such as traditional paper-based ones or smartphone applications, were the most appropriate. The results are shown in Fig. 7.

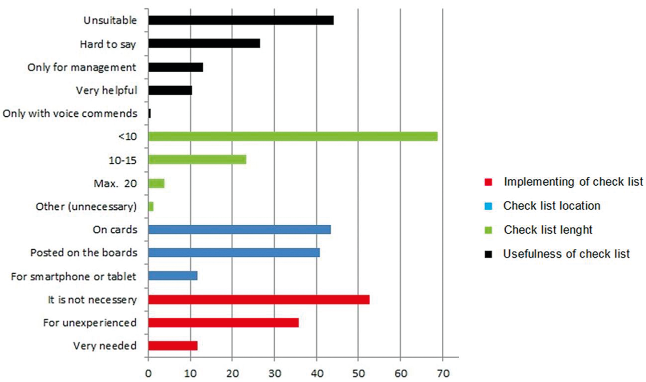

Fig. 7. Implementing of the checklist, its usefulness, length and location as the percentage of respondents

When analysing the results presented in Fig. 7, it can be seen that there are high levels of confidence in their own knowledge and self-confidence among the crew members. Most respondents did not see the need to use checklists, or thought that they could be useful only for less experienced crew members. Their usefulness is very limited under conditions of firefighting due to the need for rapid action, but they can be useful in everyday control and preventive activities. According to the respondents, the checklist should be as short as possible; 69% thought that it should not have more than 10 points. The most useful form of presentation was considered to be printed cards (43.5%), followed by display on boards (40.9%) and only 11.7% thought that displaying checklists on smartphones or tablets would be most effective.

Based on the results of the survey and the recommendations of classification societies, a solution for the fire safety management system in the ship's engine room can be proposed.

Fig. 8 characterises the main components of a fire safety system for an ER, partly based on [8]. Most of these are related to the knowledge and experience of the crew, and maintenance operations.

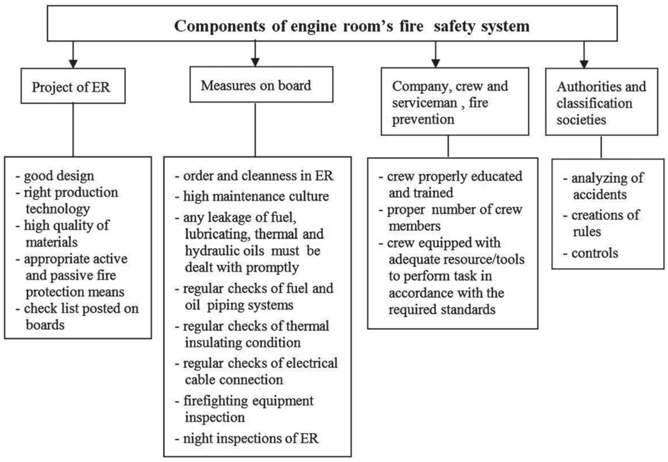

Fig. 8. Components of the fire safety system of an engine room

One of the most important components of the fire safety system of an ER is a checklist for everyday use, which we propose as one of the additional elements of the safety management system. In order to better prevent fires, the person on watch should use a printed copy in a survey of the ER and check the most important fire risk objects to decide if they are safe or unsafe by ticking "v" or "x" as appropriate. An example checklist (Table 1) is presented below. As suggested by responders, this is a user-friendly list that is ready to print for daily inspections, and contains only nine points. It can be easily modified to fit different types of ERs and different arrangements. Due to its simplicity, it can be easily transformed for smartphone applications, or even as a part of an e-management system dedicated to fire safety of the ER. For the inspection of surface temperatures, it is recommended to use devices that can take remote temperature measurements, such as pyrometers and infrared thermometers.

Tab. 1. Example checklist for fire safety inspection of an engine room

No	Inspection Items	Check					
		Cleanliness & orderliness	Oil or fuel spill	Leakages	Isolation	Machines working correctly	Surface temperature
1	Separator	☐	☐	☐	☐	☐	☐
2	AE	☐	☐	☐	☐	☐	☐
3	ME	☐	☐	☐	☐	☐	☐
4	Boiler & burner	☐	☐	☐	☐	☐	☐
5	Incinerator	☐	☐	☐	☐	☐	☐
6	FO piping system	☐	☐	☐	☐		
7	LO piping system	☐	☐	☐			
8	E-motors					☐	☐
9	Workshop	☐					
Comments:							

CONCLUSION

Onboard engine room fires may spread in and beyond machinery spaces, thus causing the loss of the entire vessel. They constitute a danger to the health and life of both the crew and passengers. Their most frequent cause is leakage from a fuel installation onto a hot surface.

Fire safety crew management is an important factor in preventing fires more efficiently. The results of a survey were presented in which crew members employed by a European ship owner were asked about the risk factors of fires and methods to prevent them. Their answers were used to improve a crew fire management system, and in drawing up a checklist.

The respondents identified that the separators and auxiliary rooms were the riskiest objects in the engine room, and highlighted good crew education, thinking, maintaining cleanliness, order, additional courses and training alarms as the most effective ways to improve fire safety. In the opinions of the respondents, additional tools to improve fire safety management were not necessary; if introduced, these should be short, such as checklists to be used as printed cards. In accordance with the crew's recommendations, an example checklist for everyday inspections of the ER was presented.

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CONTACT WITH THE AUTHORS

Wojciech Zeńczak
e-mail: Wojciech.Zenczak@zut.edu.pl

West Pomeranian University of Technology Szczecin
Piastów AV. 41, 71-065 Szczecin
Poland

Agata Krystosik-Gromadzińska
e-mail: agata.krystosik@zut.edu.pl

West Pomeranian University of Technology Szczecin
Piastów AV. 41, 71-065 Szczecin
Poland