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Aircraft, Maritime and Railway Accident Investigation Directorate
Maritime Accident Investigation Unit

FINAL REPORT

Investigation of very serious marine casualty –

FIRE IN ENGINE ROOM AND DEATH OF A CREW MEMBER OF *M/V „KARADENIZ 5"* ON 14.08.2018

2019

FOREWORD:

Extract from the Merchant Shipping Code:

Art. 79. *(Amended, SG № 41/2001, amended, SG № 113/2002, amended, SG № 87/2005, in force since 01.01.2006., amend., SG № 92/2011, amend., SG № 93/2017)*

(1) Investigation of marine casualties and incidents shall be carried out by investigating officers in the specialized unit for investigation of marine accidents and incidents at the Ministry of Transport, Information Technology and Communications.
(2) The investigation under para. 1 aims to contribute to enhancing the safety of maritime transport and preventing marine casualties by identifying the causes and circumstances of the occurrence of a particular accident without making any conclusions about the existence of fault or liability. The investigation under par. (1) shall be carried out separately and irrespectively of the criminal administrative penal or civil proceedings conducted in respect of the same marine accident and shall not be prevented, suspended or delayed by reasons of the conduct of such proceedings.
10) Any safety investigation shall end with a report drawn up in the form and content specified in the ordinance referred to in paragraph 13. Within 12 months from the date of the marine accident or incident, the head of the specialized unit under para. 1 shall publish the report, including the conclusions and recommendations contained therein, on the website of the Ministry of Transport, Information Technology and Communications. The conclusions and recommendations contained in the report cannot be used in the course of civil, administrative or disciplinary proceedings

Note: Investigation materials should not be used in litigation and/or settlement of trade disputes, and the specialized unit, or the Ministry of Transport, Information Technology and Communications, can neither be a party to nor involved in such proceedings and disputes.
The report is published on the Internet at the official website of the Ministry of Transport, Information Technology and Communications: https://www.mtitc.government.bg/.

All times stated are local time(UTC +3 hours).

Fig. 1 m/v "Karadeniz 5"

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SUMMARY

On 14.08.2018, at about 1730 *m/v "KARADENIZ 5"* sailed from Constanta, Romania, unladen and ballasted, to the island of Marmara. By 2110, the ship's captain and watchkeeping engineer from 20-00 hrs. shift(chief engineer)were in the messroom, and after a while they separated. Around 2130 a power problem (blackout) occured on the ship and the main engine stopped. Crew members heard a muffled blast and saw smoke and flames coming out of the engine room entrance and rising upwards the ship's funnel. The stationary CO_2 fire extinguishing system was triggered by command of the captain. In 3-5 minutes, the fire weakened and extincted. The crew availability checking detected the lack of the chief engineer. The same was found at the bottom of the engine room in a helpless condition and a little later he died. At 2200, the ship's radio officer connected to the ship traffic control tower in Varna and reported for the marine casualty - fire and death of a crew member.

The Director of the Directorate of Maritime Administration-Varna(DMA-Varna) was informed about this. A tug was sent from the Navigation Maritime Bulgare(NMB) for the salvage of *m/v "KARADENIZ 5"*.

A few hours later, the motor tug *"Fegda"* arrived at the scene of the accident, and the ship was tugged to the quay of "Odessos" Shipyard.

The specialized Maritime Accidents Investigation Unit classified the accident as a "Very Serious Casualty"[1]. The investigation of the accident was carried out by a commission consisting of inspectors from the specialized unit.

As a result of the investigation, the Commission came to the following conclusions:

The main reason that had led to the very serious casualty (fire and death of a crew member) was the spillage of fuel from the fuel oil service tanks through the non-standard overflow pipe inside the engine room(ER). Its design has differed from that provided in the original design of the fuel oil system.

A contributing cause that had led to the accident was failure to comply with the rules and good maritime practice in the execution of the watchkeeping duties by the chief engineer.

The Commission issued recommendations to the shipowner to improve the safety by incorporating mounting of fuel oil service tanks standard ventilation pipes and discussing the possibility/advisability of installing additional level switches/sensors.

[1] In accordance with the definition given in IMO Code for the Investigation of Marine accidents and Incidents, transposed in Ordinance № 23 on Reporting and Investigating Accidents in Maritime Spaces from 24.10.2011, in § 1, item 6 of the Additional Provisions: " Very serious casualty is a ship accident resulting in its total loss, loss of life or heavy pollution. "

1. FACTUAL INFORMATION.

1.1. VESSEL'S DATA	
Name	*KARADENIZ - 5*
Flag/nationality	Turkey
IMO №	7816513
Call Sign	TCAY9
MMSI	271002106
Ship owner	Alabanda Deniz Tasimaciligi Ltd.
Port of registration	Istanbul
Operator	Eco Shipping Co.
Classification authority	Turk Loydu
Type	General Cargo Ship
Date of construction	1981
Shipyard	Dortler Shipyard Tula - Istanbul, Turkey.
Gross tonnage	996 t
Net tonnage	675 t
Length (max)	74.75 m
Width (max)	11.25 m
Draft	5.20 m
Deadweight	1 875 t
Main engine	1 x SKL 6NVD 48A-2U – 736 kW max.

1.2. VOYAGE INFORMATION	
Last visited ports	Constanta, Romania 13.08. 2018 Gemlik, Turkey 09.08. 2018 Gemlik, Turkey 05.08.2018 Constanta, Romania 29.07.2018
Sail Port	Constanta, Romania
Destination	Badalan, Maramara island
Type of voyage	International
Load Information	Unladen, ballasted
Crew	9 persons, Turkish citizens
Passengers	0
Working language	Turkish

1.3. INFORMATION ABOUT THE MARINE CASULATY	
Date and time	14.08.2018, 2140
Type of incident	Very serious marine casualty – fire in ER, which led to the death of a crew member.
Position and coordinates	43°35' N; 028°45' E – Black Sea
Weather conditions	Very good visibility, night, wind: NE- 4 BN, waves: 1- 2 BN, clouds - clear
Place on board	Engine room
Injured persons	Chief engineer dead
Consequences for the ship	Partialy burnt main switch board/MSB/, cable lines, lighting fixtures, insulation in ER.
Consequences for the load	None
Consequences for the environment	None

1.4 INFORMATION ABOUT THE SHIP

M/v "KARADENIZ - 5" is a double decked general cargo ship, with a steel hull. The ship was built in 1981 in Turkey. The propulsion system consists of 1 main engine(ME), type SKL 6NVD 48A-2U, with a power of 736 kW. A 40 kW electrical shaft generator is connected to it (by a belt drive), which is used during a voyage to meet the electrical power requirements. The ship is equipped with 3 pcs. auxiliary diesel generator - 2 pcs. "Mercedes OM 352 and 352A" with a capacity of 67 and 150 kW, and a 40 kW diesel generator "Lister". In addition, the ship is equipped with an emergency diesel generator "Teksan". All of them: the main engine (ME) and auxiliaries work with light diesel oil. The port and emergency diesel generators are located in a room, situated on the ship's forecastle superstructure. The ship is under the supervision of the classification organization "Turk Loydu" and has valid conventional documents. In May 2016, during dry dock repairs, hull and equipment inspections have been carried out for the renewal of a new 5-year class of the ship. Periodically, according to Port State Control(PSC), *m/v "KARADENIZ 5"* has been inspected in different ports, with non-essential comments being made.

1.5 INFORMATION ABOUT SHIP'S FUEL OIL SYSTEM.

- The original design of the fuel oil system according to the scheme(**Fig. 1**) shows the individual tanks, mechanisms and piping connections between them. On this scheme, the following can be seen and noted:
- D.O. settling tanks and D.O. service tanks have vent pipes with exits on the main deck;
- D.O. service tanks overflow pipes are directly connected to D.O. settling tanks;
- D.O. settling tanks overflow pipes are connected to a diesel fuel drain tank (D.O. drain tank).
- Fuel oill tanks are not equipped with level switches or sensors for an automatic shutdown of the fuel oil transfer pump when reaching a certain level in the tanks.

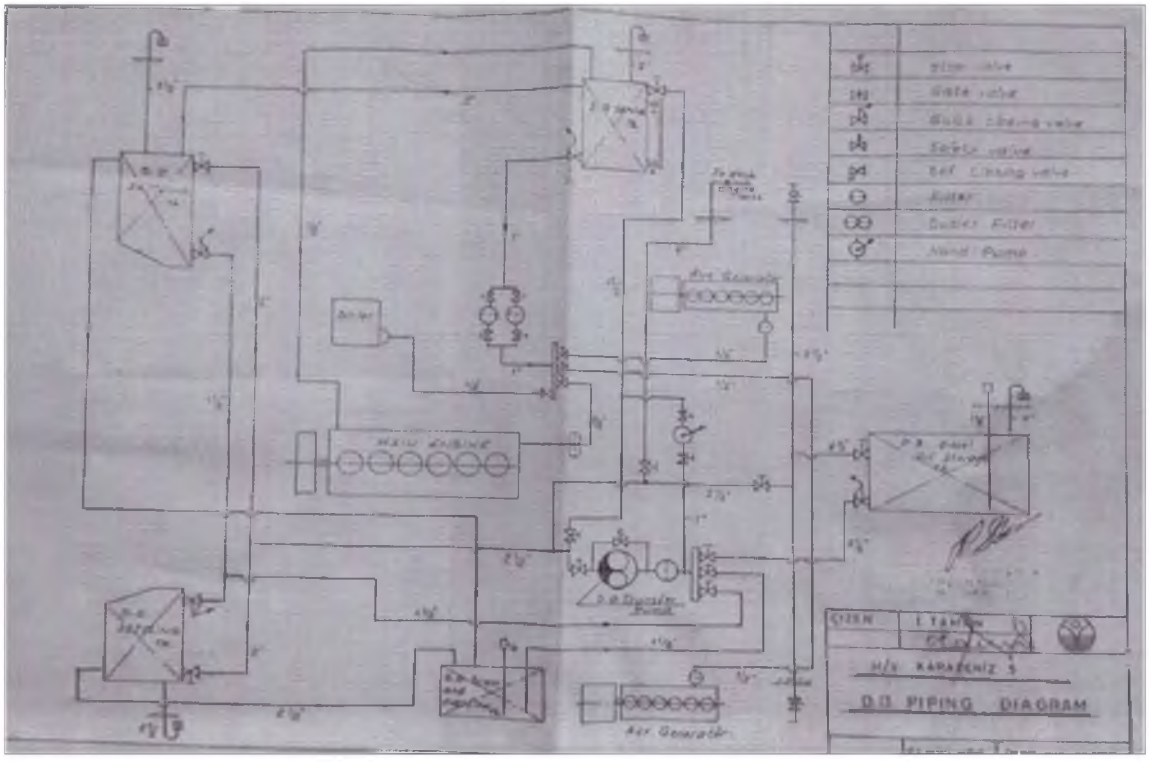

Fig. 1

In this constructive layot of the fuel oil system all fuel transfer operations must be

performed by a member of the engine room staff. This generally means that the engineer must open/close the relevant valves, turn on the pump, monitor visually the fuel level in the tanks, and stop the pump when the operation is complete. In case of inattention, the fuel oil(when filling up the D.O. service tanks, for example), would overflow from D.O. service tanks through the overflow pipes in D.O. settling ones and from there in D.O. drain tank. A situation may arise in which D.O. drain tank can also be filled up. The fuel then would overflow through the vent pipes that usually lead to the main deck.

Ships that are not oil tankers and have a gross tonnage greater than 400 tonnes must have on board "Oil Record Book Part I" (Machinery space operations). It reflects on-board operations related to accepting fuel or lubricating oil, ballasting/cleaning of fuel tanks, discharge of bilge water, etc.

In situ inspections on board the ship, including in the engine room, were carried out in the presence of crew members. During these surveys, the following facts were identified:

- the fuel oil level in D.O. service tanks is not visible through the level gauges glass. When checked and judged by the Commission, supplemented by the words of crew members, they were filled, their level being above the top of the level gauges' glass, i.e. overfilled;
- the design of the overflow pipes from D.O. service to D.O. settling tanks is different from that of the original design (**Fig.2,** position 2);

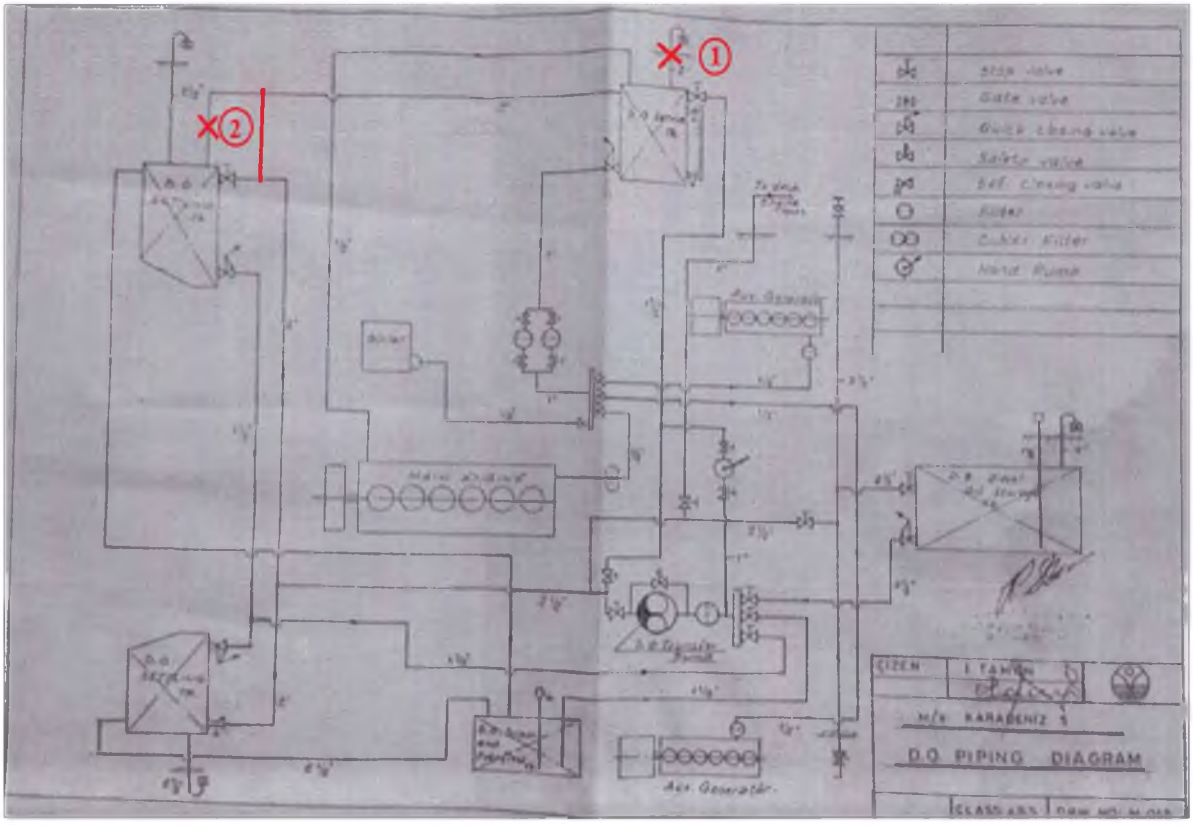

Fig. 2

- the commission did not find D.O. service tanks' vent pipes despite the requested and received active assistance from the members of the engine room staff **(Fig.2,** position 1**)**;
- Instead of standard constructed and installed vent pipes, the Commission found their probable "substitute" (**Fig. 3**), located at the bottom of the funnel, connected to ER just above the ME;

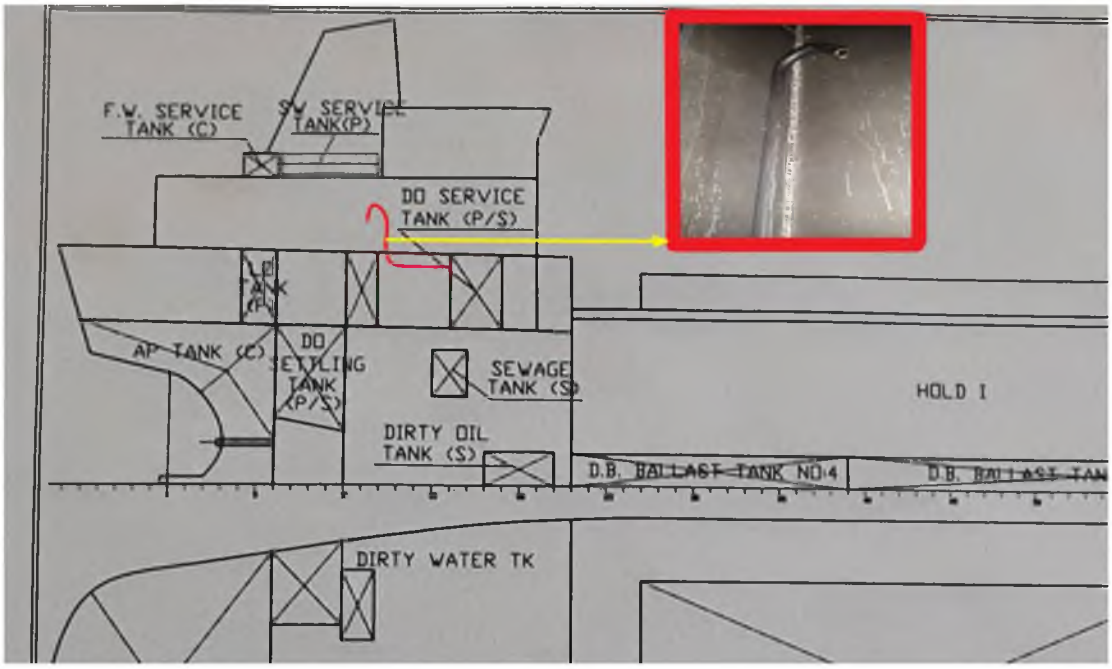

Fig. 3

- D.O. settling tanks vent pipes were mounted according to the project (**Fig. 4**)

Fig. 4

- high level of bilge waters in ER reaching almost to the main engine's flywheel;
- high diesel oil/oil substance (about 15%) in the bilge waters;
- there were no records in the engine log for the day, 14.08.2018

1.6 SHORE AUTHORITIES PARTICIPATION

At 2200, the ship's radio officer, by the command of the captain, connected to the vessel traffic control tower - Varna. He reported the accident and asked for an urgent medical help. The Director of the Maritime Administration (DMA) -Varna was notified for the situation and ordered a rescue boat to head for a medical evacuation operation. At the same time, he activated the asylum plan for the reception of *m/v "KARADENIZ 5"* which begun to drift to the shore. A little later, a traffic tower operator received a message from the ship and informed the director of the DMA-Varna that the chief engineer had died. The director ordered the rescue boat to return back to Varna port and contacted Navigation Maritime Bulgare (NMB) to send a tug to rescue *m/v "KARADENIZ 5"*. A few hours later (about 1530 on 15.08.2018) *"Fegda"* tug arrived at the scene of the accident and the ship was tugged to the quay of "Odessos" shipyard.

In general, the vessel traffic control tower operators in Varna were in contact with the crew of the ship, constantly following its movement for which they had informed the director of DMA-Varna. He, in turn, had undertaken, within his capabilities, the necessary measures to assist and help the ship.

2.0 DESCRIPTION

On 14.08.2018, at about 1730 *m/v "KARADENIZ 5"* sailed from Constanta, Romania, unladen and ballasted, to the island of Marmara. During the voyage, the main engine was operating, with the electrical power supply being produced by the shaft generator connected to the engine. At 2000, the chief engineer had gone on watch in the ER. By 2100 *m/v "KARADENIZ 5"* was located abeam the village of Krapets, at about 11 nm from the coast (**Fig. 5**). The weather in the region was clear and good visibility, waves 1-2 BN and low wind from the northeast.

(Fig. 5)

According to the captain's statements at that time, he was in the messroom with the chief engineer, drinking tea. A little later, they split up and set off to perform their watch duties. Around 2130 a power problem (blackout) occured on the ship and the main engine stopped. The second engineer, resting after watch in his cabin, headed to the ER. Together with other crew members, they heard a muffled blast and saw smoke and flames coming out through ER entrance and rising upwards the ship funnel. The captain gave an order to activate the stationary CO_2 fire extinguishing system. In about 3-5 minutes the force of the fire decreased and the fire in the main fire center/the funnel/ extincted. The other few local combustion places had been extinguished in situ by the crew. The captain summoned the crew at the "muster station" to check the staff. The inspection revealed that the chief engineer was missing. At the same moment, cries for help were heard in the engine room. The second engineer tried to call out the chief engineer by name. Initially, no answer was heard, but after a while, the chief engineer answered, crying for help. Then the second engineer put on a fire clothing and entered the engine room where he saw the chief engineer laying on the lowest platform, moaning from the pain of the burns. He tried to get him out, but due to the heavy smothering smoke he was forced to leave the ER in need of pure air. At 2200, the ship's radio officer, by the command of the captain, connected with the vessel traffic control tower in Varna and announced the accident as he asked medical help. The second engineer, in about 3-5 minutes, went back into the engine room and he found out that the chief engineer had died. A few hours later (0330 on 15.08.2018) at the scene of the accident *"Fegda"* tug arrived and the ship was tugged to "Odessos" Shipyard quay. During its stay on the quay the ship was visited by the commission, which carried out an initial and subsequent in situ inspections. During the on board visits, the Commission encountered some difficulties in its work due to following reasons:

- the regular lighting in the engine room was disconnected due to the fire and the ship

was powered by the shore power supply with one or two temporary lines/cables, one of which for the ER.

- because crew members were not speaking English, the process of collecting information and clarifying the facts was significantly hampered.

During the inspections attention was paid to the status of the electrical system. The main switchboard consists of 4 sections: section of diesel generators №1 and № 2, the port diesel generator and the shaft generator. All sections were switched to zero position which meant that whatever had been electricaly powered until the time of the accident was manually switched off by the crew subsequently (**Fig. 6**)

Fig. 6

No serious damages or traces of short-circuits in the control and measuring installations were found on the main switchboard (**Fig.** 7)

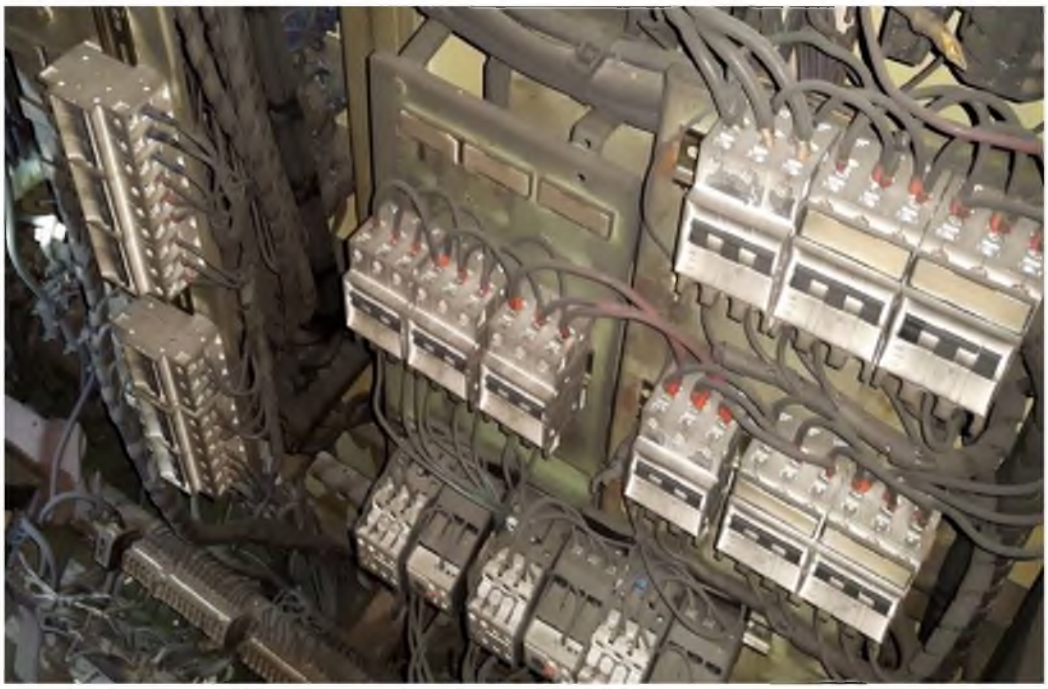

Fig. 7

Cable lines and routes in the area of fire were partially melted insulation and charcoal due to high temperature. No short-circuits/melted wires caused by a short circuit with the presence of a typical "melting" had been detected. Some of the translucent fuses of the strip lighting had traces of a high-temperature impact - partially melted and charred. The electrical shaft generator had the largest visible damage caused by the fire.

Fig.8 shows the emergency signaling system, warning the staff in the ER when starting the stationary CO_2 fire extinguishing system. The external view did not indicate any damages to the signaling system.

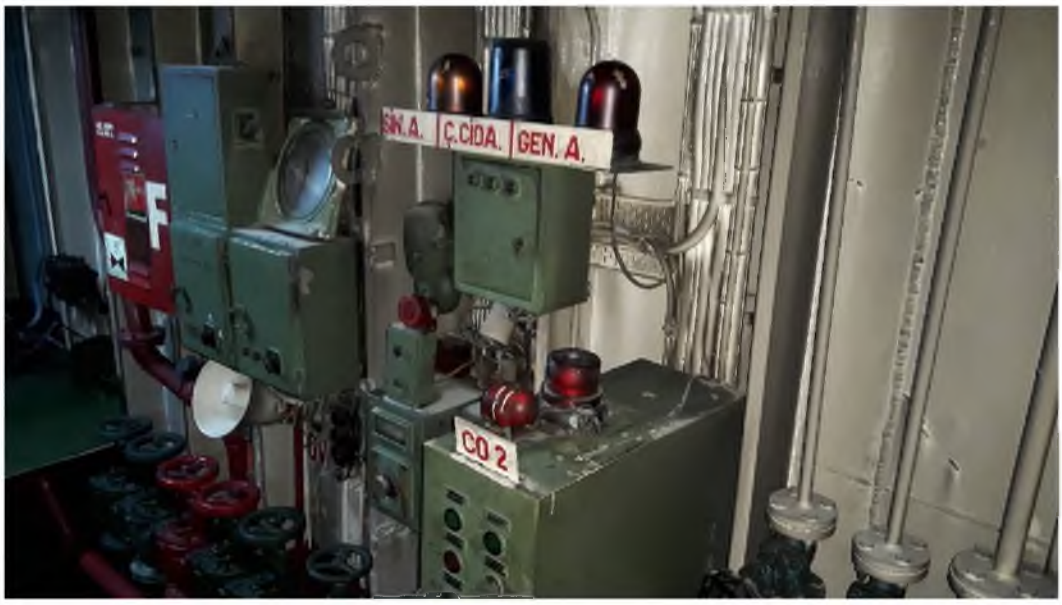

Fig. 8

2.1 CONSEQUENCES FOR THE SHIP

Due to the nature of the fire (voluminous) and the relatively short time (3-5 minutes) of its duration as a whole, no major damages were caused to the ship. The damages to the mechanisms in the engine room, visible during the inspection, were relatively small and were expressed in:
- partially burnt devices and automatic circuit breakers of the main switchboard/MSB/;
- burnt insulation of cable lines, lighting fixtures, etc.;
- partial damages to the electrical power shaft generator;
- burned insulation of the air duct to the turbo-compressor of the ME;
- damaged turbo-compressor level indicator glass;
- burnt paint on the walls, partitions and smoken areas of ER, especially at its top.

During the inspections no residues of combustible materials were found which could have been in ER before the fire. It is particularly characteristic that the main damages and traces from the fire are located at the rear part of ER, near the entrance and the lower part of the funnel. They were visibly located from the platform on the 2nd level on which various auxiliary mechanisms are mounted and up to the funnel **(Fig. 9).** These auxiliary mechanisms such as diesel generators, boiler, compressors and others had no damages by the fire.

Fig. 9

3. ANALYSIS.

3.1. CAUSE OF THE FIRE ON BOARD THE SHIP.

The use of liquid fuel oils and combustion processes on board the ships lead to a high risk of fire in ER. The economical use of space in ER leads to the proximity of high temperature components which are potential sources of ignition, high concentration of electrical appliances (also potential sources of ignition), close to mechanisms and systems that operate at relatively high pressures with flammable liquids.

The result, in case of fuel or luboil leakage or spraying is fire in the ships' engine room. Such a scenario arises in approximately 70% of fires in ER associated with leakage of fuel or lubricating oil. Vapors from the fuel may form highly flammable/explosive mixture with air. The mixture of hydrocarbons and air containing between 2% and 5% of hydrocarbon vapors can easily be ignited by an open flame or a spark. The ignition temperature of hydrocarbon mixtures for diesel fuels is in the range of 60-100°C. On the other hand, the auto-ignition temperature of the hydrocarbon mixture may be about 400 °C or lower. For most diesel fuels it is in the range of 300 ÷ 350 °C. Burning also occurs if the flammable mixture is in contact

with a hot surface which temperature is equal to or higher than the ignition one. For example, the temperature of the unshielded/non-isolated exhaust collectors of diesel engines can reach values of 450-500 °C.

Fires in the engine rooms have a typically rapid nature of development. The fire proceeds rapidly as it passes through full development - without any initial phase, which is characteristic for fires in compartments with slow speed of combustion process - with specific areas of combustion, in white color, close to the initial fire hearth. The strength of the flames and the fire dynamics depend on the intensity of the outgoing fuel fluid and its properties as well as on the conditions and geometry of the space in ER. At best, in the event of a small leak of fuel oil, the flammable liquid reaches the bottom of the compartments, between the solid engine-room floor plates and the bottom of the engine-room. Then the fire develops and works less violently, with a probability of extinction. This weakening of the fire is due to the impact of the bilge waters and the lack of a large volume of air in the bilge area. The second scenario may be a fire with a large fuel oil leak, with a spill on the hot engine housing and the exhaust system, other mechanisms in ER and continuing on floor plates of the ER. This creates a fuel-air mixture that can be ignited immediately by the hot surface of the engine exhaust gas colectors or other ignition source (eg. spark). Taking into account the nature of the damage and the traces of fire development, it can be assumed that the fire in the ER of *m/v "KARADENIZ 5"* had been rather of the second type.

On 14.08.2018, *m/v "KARADENIZ 5"*sailed from Constanta port to Marmara Island. Around 2100 the captain and the chief engineer were in the messroom. Based on an analysis of the collected information and facts**(**forensic expertise, testimonies of eyewitnesses, etc.**)** the commission considered that, when mounting watch, the chief engineer had started the fuel oil transfer pump to transfer diesel fuel oil from D.O. settling tanks to D.O. service tanks. Due to he had left the ER and gone to the messroom, no one directly observed the fuel level in D.O. service tanks. Due to the structural changes in the fuel oil system, the fuel from D.O. service tanks located above M.E. (**Fig. 10**),

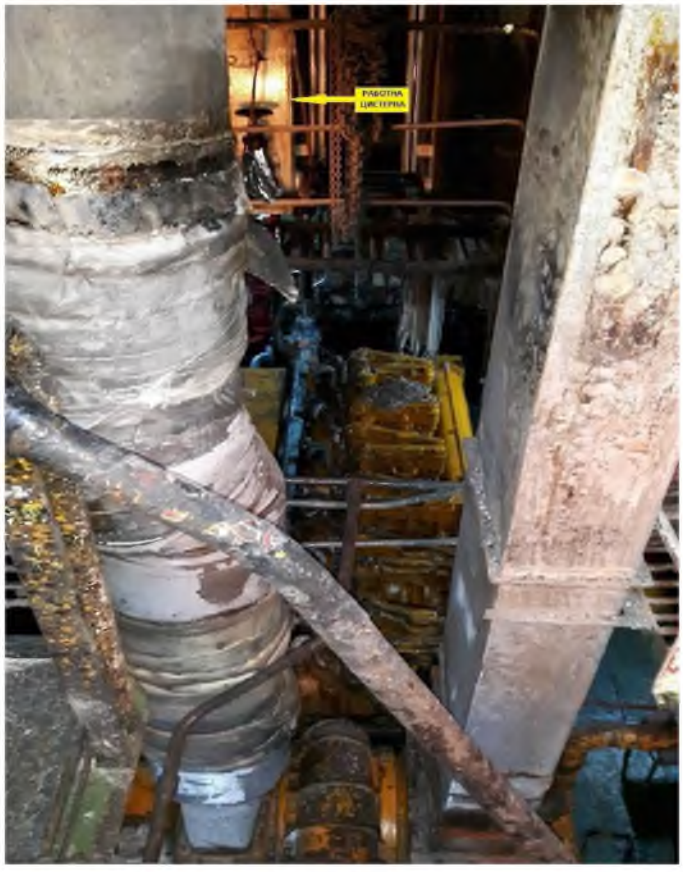

Fig. 10

began to overflow through the pipe in the ER. **(Fig. 3)** onto the M.E., and thence into the bilge space. Falling on the hot parts of the main engine, especially onto the turbo-compressor area, part of the fuel evaporated, mixing with the air in the ER. The engine flywheel is covered with a protective casing with holes for the engine manual rotation lever. A part of the fuel falling on it, by the action of centrifugal forces, had been sprayed onto the inside of the casing and through the holes in the casing extends outwardly in the form of a dispersion. As a result of this, a flamable fuel-air mixture was formed in the engine room, mainly in its stern part and the funnel area. By 2130, after leaving the captain, the chief engineer had gone down to the ER. While he was inside the engine room, this fuel-air mixture had ignited by the contact with non-insulated parts of M.E. exhaust system or from a spark from the collector brushes of the engine shaft generator. As the engine shaft generator was the only mechanism with serious fire damages and taking into account the blackout, the commission came to a conclusion that the ignition had been most likely caused by sparks in its collector brushes. Such sparks are typical for such type of electric machines. The ignition and combustion of the generated fuel-air mixture had an explosive character, it had proceeded at high speed, temperature and upward direction of the smoke in the rear part of ER. This resulted in a damage to the engine shaft generator, partial damages to MSB and a blackout. As a result of the blackout the electrical power supply to the electric consumers was impossible and had led to the suspension of the operating till the moment ones. This also stopped the operation of the fuel oil transfer pump. At the same time the fuel flow through the "vent pipe" from D.O. service tanks had stopped. As a result, the possibility of continuing evaporation, furthur formation of flamable mixture and combustion of diesel fuel was reduced.

The emergency diesel generator had not switched on to the ship's electrical system due to MSB failures. In practice, the only possibility of suppressing a fire of this nature and scale in the ER. had been the use of the stationary CO_2 fire extinguishing system. In summary, the cause of the fire was the fuel oil overflow from D.O. service tanks, through the overflow pipe with its subsequent fall on the heated parts of the ME and in the bilge space. As a result, an explosive mixture had been formed which was ignited by a source of ignition (sparks from the collector brushes of the engine shaft generator).

3.2 CAUSE OF CHIEF ENGINEER'S DEATH

With the autopsy performed on the chief engineer's body, a combined trauma has been found, with the following injuries:

a) Thermal trauma:

- 2^{nd} grade burns in the area of the face, neck, chest, limbs, or about 75% of the body surface;
- burns of the upper respiratory tract mucosa;
- swelling of the brain and blood stasis in the internal organs
- 40% concentration of carboxyhemoglobin.

(b) mechanical trauma:

- contusion wounds and bruises on the head
- internal bleeding in the organs
- a wound on the foot of the left foot

3.2.1 The direct cause of death was the thermal shock developed as a result of the burns resulting from the high temperature developed at the outbreak of the fire. Skin injuries had been the result of local high temperature impacts and had a characteristic of flame burns. The amount of carbohymoglobin in the blood (40%) was a clear indication that the victim had been alive in the situation of the fire and indirectly indicated that death occurred relatively quickly after the effervescency of the toxic carbon monoxide (CO).

3.2.2 As an aggravating circumstance for the death, it could be pointed the location of the emergency exit of the ER. (**Fig. 11**). In cases of fire in engine rooms, which happen relatively often, the crews must be able to safely leave the ER. The basic routes requirements for evacuation from the ER are pointed in SOLAS-1974 Convention, as amended. Detailed

requirements for the ER evacuation routes on cargo vessels are included in SOLAS-1974 Regulation II-2/13.4.2, as amended. These requirements for evacuation routes from category A(total propulsion power of at least 375 kW) engine room provide one of the following evacuation conditions:

1) two sets of steel ladders as far as possible apart from each other, leading to doors in the upper section of the engine room from which there must be an access to the open deck. One of the stairs shall be located within a protected enclosure meeting the requirements for A-60 fire compartments throughout the height from the lowest level of the engine room to the level of exit to a safe area.

2) a steel ladder leading from the lowest level of the machine space to the exit at the top of the room providing access to the deck and additionally at a location away from the entrance of such a ladder resulting in a safe escape route from the lower part of the engine room to the open deck.

Exemption from the requirement for two evacuation exits from ER. shall apply to small crafts with a gross tonnage of less than 1 000 tonnes, taking into account the width and shape of the upper section of the engine room. Administration may also exempt cargo ships with gross tonnage below 1 000 tons, from the duty to protect with a fire barrier the steel ladder leading to the exit in the upper part of the engine room. *M/v "KARADENIZ 5"s* gross tonnage is 996 t, i.e. it does not formally fall under the requirements of p.1. In this case, the emergency exit starts at the base of the main ladder at the entrance of ER and goes through the funnel on the upper deck. In fact, the two ladders are located very close, even connected at entrance of the ER. This makes it almost impossible to use such an emergency exit in an event of a fire or the development of the fire in the rear part of ER in the funnel area, as had happened in practice. To a greater extent, its function is mainly related to the maintenance and operation of the ship rather than its role as a real emergency exit.

Fig.11

3.3. ANALYSIS OF HUMAN FACTOR.

3.3.1 ANALYSIS OF CREW ACTIONS

In general, the crew had acted rapidly in the on-board situation. As a result, the fire was suppressed relatively early, without major damages to the ship, despite the crew's stressful condition. At the same time, the following facts should be noted:

- during the investigation and the conversations with the crew, the location of the chief engineer at the time of the fire outbreak was contradictory;
- the chief engineer during his watch was absent for a long time from the ER during which time the machines and mechanisms, including the fuel oil system, had worked without a direct supervision.
- the stationary CO_2 system has valid documents demonstrating its suitability for operation;
- on the CO_2 system release box there is a list of instructions - both in Turkish and English. It is clearly stated what actions and in what sequence they must be performed before the system to be started. The first and most important of them (point first) is to check for the presence of people in the ER. (**Fig. 12**).

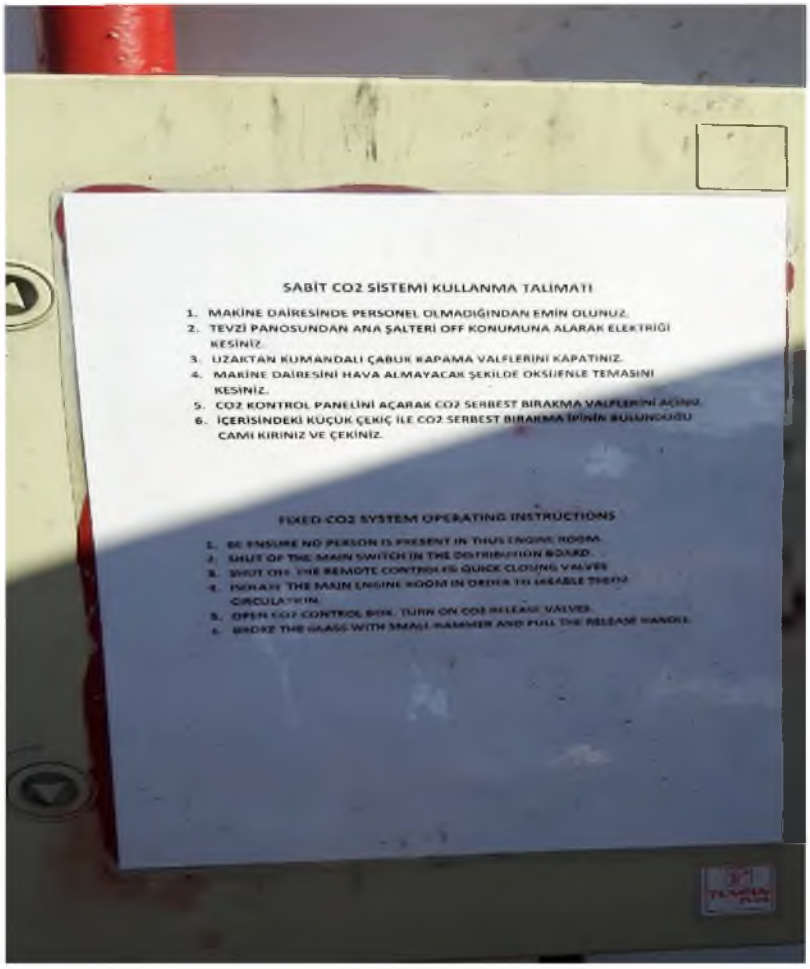

Fig. 12

The system design requires the standard starting procedure to be carried out by pulling out the handle in the CO_2 release box. The box is protected by a glass cover to avoid unplanned or wrong actions (**Fig. 13**). This handle is connected to the actuators (levers) of the valves mounted on the CO_2 bottles by a thin wire. These bottles, a total of 5 pieces, are located in a separate room in an immediate vicinity of the release box. (**Fig. 14**). After breaking the glass cover with a small hammer, pulling the handle with subsequent opening of the cylinder valves it becomes possible the gas to enter in the ER. Point six of the instructions said namely this. In the picture, however, it can be seen that the glass cover of the case is whole and intact.

Fig. 13

Fig. 14

It also impresses with the different position in which the CO_2 cylinder valve actuators themselves are located. On three of them, the actuators' levers are in the vertical position, i.e. the cylinder valves are in the closed position. On the other two levers are rather horizontal, one of them even hanging on the cord separately from the bottle.

The SOLAS 1974 Chapter II-2, Regulation 10, as amended, sets requirements for CO_2 systems installed on ships. One standard bottle contains about 44.5 kg. liquefied CO_2 gas at a pressure P = 64 bar (25°C). This amount of liquefied gas takes up a volume of gaseous form in the protected space of ~ 25 m^3**(**at a ratio of 0.56 m^3/kg**)**. For engine rooms, the required gas mixing ratio according to the convention is 35÷40% of the full volume of the ER. CO_2 gas is 50% heavier than air, effectively extinguishes fires, and the fire extinguishing effect begins to work vigorously at a volume concentration of 30% and upwards. This impact on the fire can be described in general as follows:

- when mixed with room air containing about 21% free oxygen, CO_2 reduces the total level of unbound oxygen to values below which the combustion process is not possible. These values are in the most common range of 10÷12% for gases, 13÷15% for solids.

The impact of carbon dioxide on the human body depends on the volume concentration of the gas, the most typical being:

- at a concentration of up to 9% - relatively safe (no fatal outcome), with very short stays (several minutes) in such an environment, with symptoms such as dizziness, nausea, dizziness, tachycardia etc.;

- at a concentration ≥20% - immediate loss of consciousness, death.

The volume of the ER, calculated on the basis of the available drawings of the ship, is about 350÷360 m^3. When using all 5 bottles in the ER this would create an atmosphere with a CO_2 concentration of about 32÷34% (with O_2 ~ 11÷13%). When using only 2 bottles in the ER this would create an atmosphere with a CO_2 concentration of about 12-14%(at O_2 ~ 15÷ 17%). Based on the mentioned above and an analysis of the crew's actions, the commission considers that:

- the procedure for starting up the CO_2 system had not been followed as instructed;
- the crew manually opened only 2 of the 5 CO_2 gas cylinders' valves;
- the strength of the fire had decreased to a greater extent due to the combustion of the already formed fuel-air mixture than by the impact of CO_2 gas;
- non-compliance with the instructions for CO_2 system use was not a determining major factor for chief engineer's death;
- their actions during the fire had been somewhat chaotic.

4. CONCLUSIONS

4.1. MAIN CAUSE OF THE ACCIDENT.

The main cause that led to the very serious casualty (fire and death of a crew member) was the fuel oil spilling from the D.O. service tanks through the non-standard overflow pipe inside the ER. Its construction differs from that provided in the original design of the fuel oil system.

4.2. CONTRIBUTING CAUSE LEADING TO THE ACCIDENT.

A contributing cause was non-compliance with the rules and good maritime practice when performing the duties of a chief engineer on watch.

5. ACTIONS UNDERTAKEN.

5.1. BY M/V KARADENIZ 5 SHIPOWNER - ALABANDA LTD:

1. ship repair works had been carried out, generally including:

- a repair of the shaft generator for electric power;
- a main engine turbo compressor repair;
- a reconstruction of main switchboard and lighting in ER.;
- cleaning and painting in ER.

2. a new vent pipe was installed to D.O. service tanks at the place of the existing one,

Fig. 15

(Fig. 15), which has not appropriate to ship's design.

6. SAFETY RECOMMENDATIONS TO THE SHIPOWNER OF "KARADENIZ5":

6.1. The ship's fuel system to be restored in accordance with the initial design, as for this purpose:

- an installation of a standard vent pipes for D.O. service tanks (such as those of D.O. settling tanks). The pipe on **Fig. 15** can be considered as a temporary solution;
- a new inspection of the overflow pipelines connection point (from D.O. service tanks) and its possible change as it is under the project.

6.2. It is possible to discuss and assess the advisability of installing additional level switches/sensors, at least to D.O. service tanks. Such sensors (float or an other type), for an automatic stop of the fuel transfer pump, would reduce/exclude the possibility of overfilling the tanks.