R E P U B L I C O F B U L G A R I A

NATIONAL AIR, MARITIME AND RAIL ACCIDENT INVESTIGATION BOARD

FINAL REPORT
from
the investigation of a very serious marine accident –

FIRE IN BALLAST TANK OF M/V "BELLONA" AND DEATH OF A WORKER DURING SHIP REPAIRS ON 14.12.2021

2023

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FOREWORD:

The National Air, Maritime and Rail Accident Investigation Board (NAMRAIB) is an independent specialized state body under the Council of Ministers of the Republic of Bulgaria, which investigates marine accidents and incidents that occurred in the internal sea waters and in the territorial sea of the Republic of Bulgaria, occurred on or with a ship flying the Bulgarian flag, regardless of the place of the accident, affected other significant interests of the Republic of Bulgaria, affected river vessels sailing in the internal sea waters and in the territorial sea of the Republic of Bulgaria, or sea vessels sailing on the internal waterways.

The investigations carried out by the NAMRAIB are intended to contribute to the improvement of the safety of maritime transport and to the prevention of maritime accidents, by establishing the causes and circumstances of the occurrence of a particular accident, without drawing conclusions about the existence of fault or apportioning responsibility.

The investigation is carried out in accordance with Art. 79 of the Merchant Shipping Code and Regulation No. 23 of 24 October 2011 on the reporting and investigation of marine casualties and incidents in application of the International Maritime Organization (IMO) Code of Marine Casualty and Incident Investigation, as well as the secondary law of EU.

The analyzes and recommendations made in this report in no way give rise to a presumption of liability or guilt and, in content and style, the report is not prepared for use in legal proceedings.

Note: Materials from the investigation should not be used in legal proceedings or to settle commercial disputes, and the NAMRAIB cannot be a party to, nor involved in, such proceedings and disputes.

The report is published on the Internet, for public domain, on the official page of the Ministry of Transport, Information Technologies and Communications: https://www.mtitc.government.bg/ .

Events are reflected in local time (UTC+ 2).

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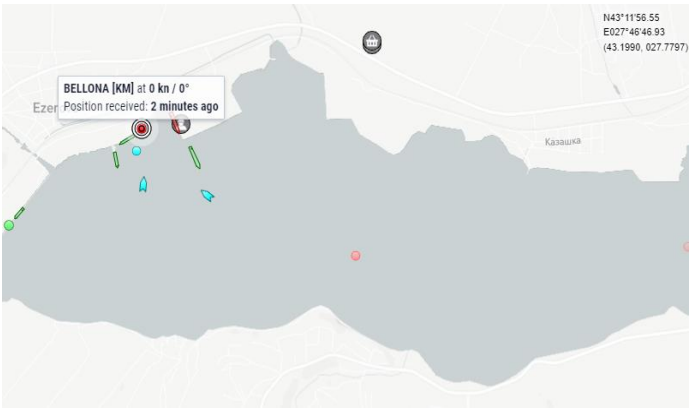
SUMMARY.



On 14.12.2021 in the ballast tank No. 3 port side of *m/v "BELLONA"*, during repair works at ship repair yard “MTG Delfin” JSC a fire broke out. The fire was extinguished, but the worker of the company "Galera 07" LTD, who was in the tank, died.

The Commission of investigation considered that the main reason that led to the very serious accident was a mechanical failure (rupture) of the methane hose of the gas-oxygen cutter located in the tank, which resulted in the leakage of a large amount of gas and its subsequent ignition by an unknown source of ignition (most likely defective cable with lighting fixtures, a string of light bulbs/lamps or so called "garland" type).

Contributing factors to the fire were non-observance of fire safety measures by those working in the ballast tank, lack of appropriate protective clothing, lack of forced ventilation to remove the released gas, lack of an automatic gas analyzer, as well as the lack of control by the persons in charge of "Gallery 07" LTD, charged with compliance with safety measures.

The Commission issued 7 safety recommendations to the management of the company "Galera 07" LTD.

1. FACTUAL INFORMATION.

1.1. SHIP, VOYAGE AND MARINE ACCIDENT INFORMATION.

1.1.1 SHIP DATA	
Name	*BELLONA*
Flag / Nationality	Romania
IMO	6514376
Call Sign	YP3354
MMSI	620956000
Ship owner	LUKOYL-Marin Bunker LLC
Harbour on registration	Constance
Ship operator	LUKOYL-Marin Bunker LLC
Classification organization	Russian Maritime Register
Type	Oil Products Tanker
Year build	1965
Gross tonnage	2,460 t.
Length overall	87.50 m.
Width	13.17 m.
Draught	6.5 m.
Deadweight (max.)	3,794 t.
Main engine	MAK 6M551AK

1.1.2 VOYAGE INFORMATION	
Last visited ports	Varna, Bulgaria - 27.11.2021 Burgas, Bulgaria - 25.11.2021
Port of departure	Burgas, Bulgaria
Destination	Varna, Bulgaria
Type of voyage	For class repair
Cargo information	Empty
Crew	6

1.1.3 MARINE ACCIDENT INFORMATION	
Date and time	14.12.2021, 09 : 15 h.
Type of accident	Very serious maritime accident - death of a worker during repair works on board the ship
Coordinates and location	43°11′ 56 ″ N ; 027°46′ 93″ E – “MTG Delfin” JSC , Varna Lake
Hydro-meteorological conditions	Visibility: very good , daylight , wind: W – 1 point, sea: 0 point, in reme – clear
Place on board	Onboard ballast tank #3, port side
Injured persons	Yes , a deceased member of the shore repair brigade
Consequences for the ship	No
Consequences for cargo	No
Environmental consequences	No

1.2. GENERAL INFORMATION ABOUT THE SHIP.

M/v "BELLONA" (**Fig.1**) was built in 1965 under the name "*STELLA ATLANTIC*" in the shipyard "OSKARSHAMNSVARVET - OSKARSHAMN", Sweden. Its first owner was the Swedish company Rederi A/B Bertil Skanse & Co ". It is mainly intended for the transportation of petroleum products. It has a double bottom, with the ballast tanks located on both sides. In 2009, it was purchased by the company "Lukoil Bulgaria Bunker Ltd ". At the time the report was completed, the vessel was in use from the company for the bunkering of ships in the ports of Bulgaria and Romania.

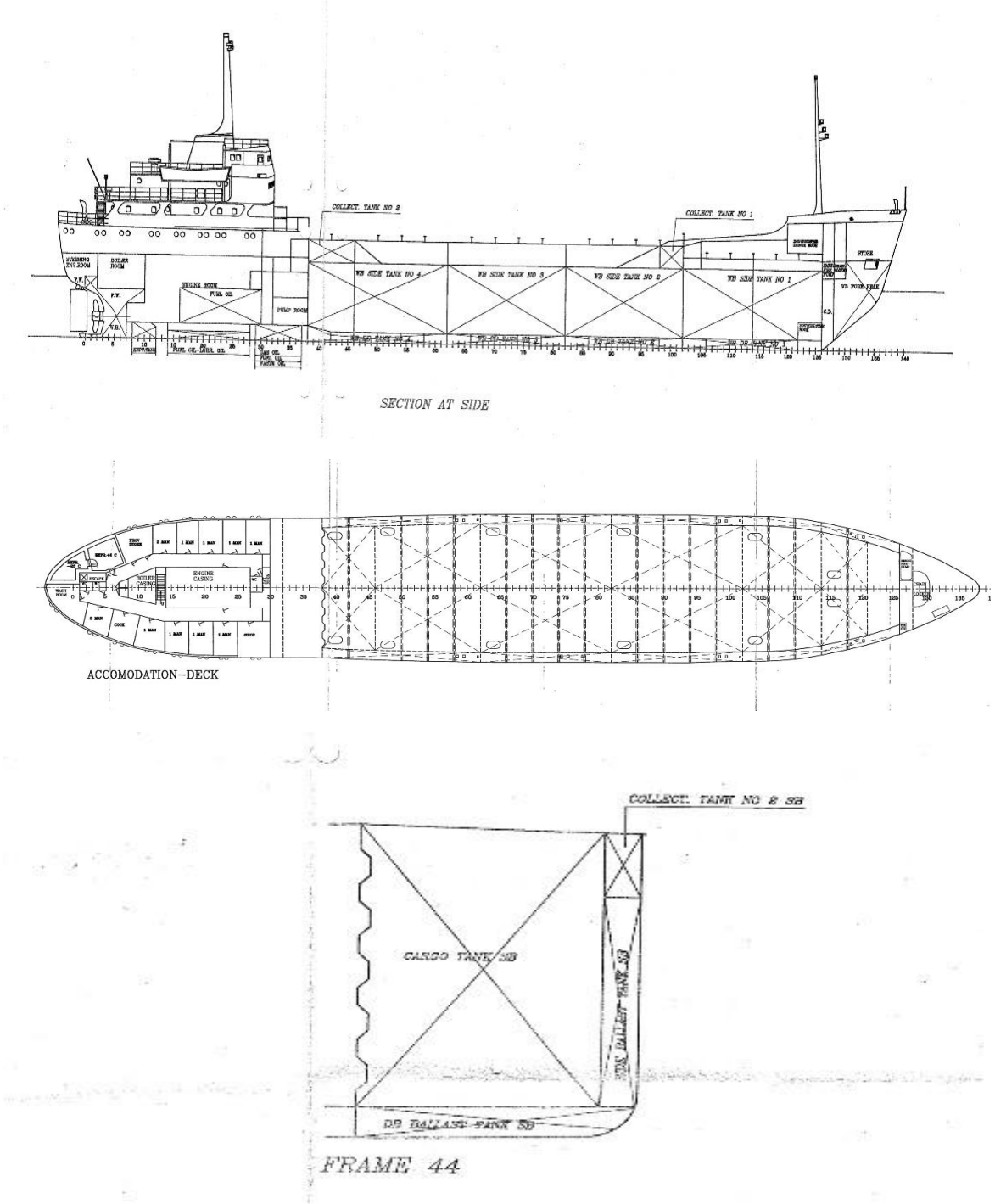


Fig.1. General arrangement of m/v "*BELLONA*" and drawing of ballast tank No. 3 p/s

1.3 . INFORMATION ABOUT THE DECEASED WORKER.

The deceased worker was 36 years old and had been working in the company "Galera 07" LTD for 2 years. He was a ship pipe fitter by profession. A preliminary medical examination declared him clinically fit to perform his duties. On 09.10.2019, an initial briefing on labor safety was held. Periodic briefing in the company was held on 01.07.2021. The job description of the deceased provides for liability in case of non-fulfillment of the rules for health and safety at work and fire safety. On 18.11.2021, another initial briefing was held at “MTG Delfin” JSC shipyard.

2. DESCRIPTION.

On 14.12.2021 the *m/v "BELLONA"* was located in the ship repair yard "MTG Delfin" JSC for class repair. On board the ship different repair activities were carried out. ”MTG Delfin” JSC has concluded a contract with a subcontractor company "Galera 07" LTD. Part from the activities were assigned on workers from this one company. On 13.12.2021, two workers carried out hot works related to dismantling and replacement of a ballast valve from the pipeline in ballast tank №3 P/S (**Fig.2**).

Fig.2. Manhole of ballast tank No. 3 – port side

The workers cut with gas-oxygen cutter the nuts on the studs of the flange joint of the valve (**Fig.3**).

Fig.3. General view of the studs of the ballast pipe (top view)

The execution of hot works from the workers of the company “Galera 07” LTD was carried out according to "Welding instruction" dated 01.08.2012. It describes the conditions under which electric arc or gas-flame devices can be used.

Section VI of it is dedicated to the safety measures at gas cutting and welding. Some of them relevant to the investigation are described below:

6.3 *When working indoors with propane-butane, the hoses must not release any gas at all. Gas hoses should be 10-40 metres in length and their connection should be done only by means of nipple-screw connections.*

6.9 *It is prohibited to place acetylene and oxygen hoses near an open fire……..and leave them in tanks, vessels, etc. after finishing work.*

6.11 *Do not allow leakage of acetylene in tanks, vessels, double bottoms, small rooms and the like.*

6.12 In *winter time, when the pipeline hoses freeze, defrost with steam or warm water……..*

On 14.12.2021, at 08:00 in the morning, the brigade of ship pipe fitters was located at the base of the company "Galera 07" LTD in the village of Ezerovo. The foreman in the company distributed the tasks and the day's work to be done on the ship. To the workers who cut the stud nuts the day before on flange connection of the ballast valve, was assigned to mechanically dismantle it from the site. In this one day hot works in ballast tank No. 3 were no foreseen.

Around 07:20, an inspection of the tank for toxic and explosive gases and vapors was carried out by a firefighter of “MTG Delfin" JSC, and the atmosphere in the tank was found to be safe, for which a protocol was drawn up.

After distributing the work and preparing the necessary equipment, the brigade went to the ship. The foreman instructed the two workers to take a third person - for security - before entering the ballast tank, as he himself would be late. When he later got on board the ship, he saw the two workers setting up the equipment they would be working with.

The equipment, which was prepared for work in the ballast tank, included a metal hammer, a metal bronze awl, a gas-oxygen cutter and hoses attached to it, and a means of

illuminating the tank, which consisted of a cable with connected to it light bulbs ("garland" type). The two hoses mentioned - one was for combustible gas, methane, with a working pressure of 1 bar, and a hose for oxygen, with a working pressure of 4.5 bar.

The foreman entered the ship's superstructure to form the necessary documents for hot work that was to be carried out elsewhere on the ship. According to the his testimony, he intended to issue a certificate for fire works in ballast tank No. 3 - port side, although such were not provided for.

Before the entry in the tank, one of the workers (the deceased one) opened shut-off valves for gas (methane) and oxygen from the general supply line of the shipyard to the cutter that was in the tank. The cutter with the hoses was left the night before at the manhole of the tank, and was subsequently brought inside.

After lowering the cutter and part of the hoses into the tank, one of the workers (the surviving one) put it into operation at the request of the injured worker, in order the latter to dry his working gloves. The cutter was put into operation by opening the taps on the same to ensure an inflow of methane and oxygen and supplying an open fire (lighter for oxygen or other). The drying of the gloves took about 2 minutes, after which the taps of the cutter were closed (confirmed both by the witness statements of the surviving worker and by the inspection carried out after the fire). After terminating the operation of the cutter, the same one with the hoses was suspended by the surviving worker through a technological hatch from a nearby bulkhead in the tank.

The injured worker began to "knock" the ballast valve studs out of the flange joint, realizing that he needed a bigger awl to do so.

A little later the other worker came out from the tank and went to take a bigger awl from ashore, with the injured piper remaining in the tank without a third person, who was outside the tank and visually observed him.

At the return, the surviving worker saw smoke, coming out from the ballast tank, and when approaching, he noticed that the hoses for methane and oxygen, which entered the tank, were on fire. The worker began to shout to close the valves for gas and oxygen of the main line on the pier and undertook actions for pulling the burning hoses and the cutter from the tank, while at the same time repeatedly calling out the name of the remaining in the tank worker.

During the pulling, only part of the hoses were pulled onto the deck, the rest, heavily burnt, fell into pieces and fell together in the cutter to the bottom of the tank.

The worker then unfolded a fire hose with water. The just arrived foreman and another worker joined in helping the worker. The foreman also ordered the gas and oxygen to be shut off centrally and entered the tank with the water hose to extinguish the fire. Along with him, the newly arrived worker entered also the tank. Due to the heavy smoke, however, they went outside, while the foreman equipped himself with a mask and helmet and re-entered the tank, calling the injured worker by name. He managed to feel the body of the worker under the ballast pipeline motionless. A foreman tried to grab him and pull him up. As a result of the efforts made and shouting, despite the mask, he inhales a lot of smoke and feels that he was starting to lose consciousness. He got out of the tank into the fresh air again. At that time, the firefighters from the shipyard fire service arrived and also entered the tank. As a result the fire was extinguished out, but the worker was found with burnt body and without signs on life. The result of the autopsy of the deceased worker indicated as the cause of death a III-IV degree flame burn on 100% of the body surface. Staying alive in a fire situation has been established. The presence of alcohol and narcotic substances, as well as lifetime mechanical traumatic injuries, have not been established.

3. ANALYSIS.

The purpose of the safety investigation is to establish the circumstances and facts that contributed to the accident, in order to serve as a basis for making safety recommendations to prevent similar accidents in the future.

The analysis of the accident was carried out on the basis of the collected evidence, witness statements and the prepared fire-engineering expertise.

3.1. Theoretical aspects of fire.

3.1.1. Basic concepts and terms regarding the occurrence of fires.

A fire needs the following three components to start:

- heat – to reach ignition/self ignition temperature;
- fuel or combustible material/s;
- oxygen – to support the combustion process.

Together they form a chemical reaction that leads to a situation called a fire. Schematically, this is normally represented by the fire triangle **(Fig.4).**

Atmospheric air normally, at sea level, has an oxygen content of about 21% by volume.

Fig.4. The fire triangle

Possible sources of heat/ignition in this case could be:

- electrical discharge (arc/spark);
- static electricity;
- the exposed parts of light bulbs (the glass bulb);
- spark when working with hand tools;
- excessive heating of electric cables or part of them, short circuit;
- open flame.

The available combustible materials in the specific case are generally:

- increased concentration of methane gas in the tank;
- workers' clothing, including PPE;
- the presence of electrical cables and lighting in the tank;
- rags etc.;
- residual products at the bottom of the tank.

3.1.2. Equipment for knocking out the studs of the flange joint of the ballast valve.

To knock out the studs of the flange connection of the ballast valve in the tank were brought metal hammer with a wooden handle and a weight of 2 kg. and a bronze awl with a diameter of 20 mm. and 400 mm long. They were found at the scene of the accident at the bottom of the ballast tank.

3.1.3. Oxygen gas cutter.

The gas-oxygen cutter is an item of equipment designed for gas-flame cutting of metals. Hoses for gas (in this case methane) and oxygen were attached to it.

During the inspection of the accident site, it was found that the cutter was located at the bottom of the tank with the taps closed, which confirmed the testimony of the surviving pipe fitter about closing the taps after ceasing unregulated activity - drying work gloves. Apparently, the cutter fell to the bottom after burning the methane and oxygen hoses.

The location of the deceased's body (under the ballast pipe) gives reason to assume that he did not attempt to operate (ignite) the cutter after leaving the ballast tank of his colleague, given that the cutter was attached to an opening above the pipe.

The examination of the cutter in laboratory conditions showed the presence of a defect, thermal-metallurgical damage of the metal, located at 125÷135 mm. from the regulation valve for the combustible gas and at 210÷220 mm. from the place (tip) of the outlet of the gas mixture. The results of the research gave reason to consider that the defect in depth did not reach the internal opening of the cutter, with a developed crack, that is, there is no possibility of gas or combustible mixture under pressure leaking into the tank.

These facts gave reason to claim that it was not a defect of the type of leakage of metal elements of the cutter, i.e. without a cause-and-effect relationship with the occurrence of the fire. Therefore, the cutter at the time of the fire was operational, but in a "defective condition" compared to the regulatory requirements as new one.

The above was also laid down as a conclusion of the appointed fire technical expertise, and the Commission agreed with this finding.

3.1.4. Hoses for combustible gas (methane) and cutting gas (oxygen).

The facts stated in the fire technical expertise showed the following:

The results of the performed fractographic, defectoscopic and traceographic microscopic examination showed the presence of destructive damage concerning 100 % of the section of the inner rubber layer, 100% of the frame (textile braid) and incomplete destruction of the section of the outer rubber layer.

Microscopic examination in laboratory conditions of the combustible gas (methane) hose in its undamaged part of the fire proved a number of defects such as - operational "filling" contamination, a "passage" of microcracks in the tension zone, a "passage" of microcracks near the longitudinal color marking.

As a result, the fire technical expertise, with which the commission of inquiry also agrees, showed the following:

At the time of the accident, the hose carrying combustible gas (methane) to the cutter was technically defective, with the development of a destructive failure and leakage/pressure release of flammable and explosive fluid inside the ballast tank. The combustible gas hose was unsafe for intended use in enclosed or semi-enclosed rooms/spaces.

At the time of the accident, the hose conducting the cutting gas (oxygen), during its examination, no evidence was found for an expert statement regarding technical malfunctions related to defecting and destruction of the frame and inner layer. **However, a check valve for backfire was found to be missing on the cutter in relation to the oxygen hose.**

The Commission, on the basis of the findings objectified in the fire technical expertise, considered that a direct cause-and-effect relationship for the fire that occurred in ballast tank

No. 3 P/S had the hose for the combustible gas (methane), which was faulty/unfit for the activity, for which it was intended.

3.1.5. Used light source in ballast tank No. 3 - port side.

For lighting inside the tank, a portable cable with electric bulbs connected to it (a "garland" type) was used.

According to the fire technical examination, the lighting device consisted of an electrical cable (three-wire), rubberized, with bulbs attached to it, U = 24 V. The bulbs were located at a distance of about 1 m. from each other. According to witnesses, the light bulbs did not have a protective ceiling or grid. Power was supplied from a portable electrical panel located on the deck to the side of the tank manhole. The "garland" was installed about 2-3 meters from the bottom of the tank - fixing by placing in a wall opening.

The laboratory examination of the electric cable, found on the deck near the tank, ("garland" cable), objectified in the fire technical expertise, proved the presence of damage to the electric cable on the insulation, bearing traces of burning and bending of one of the cores. A defective linear black zone in the insulation was recognized along the length of the conductive core (with the bent section) near the burnt sheath of the cable.

The above gave reason to draw the conclusion indicated in the fire technical expertise, with which the Commission agreed, that the "garland" type lighting device used was technically defective and was a possible source of ignition of the methane in the ballast tank.

3.2. Found missing equipment and violated safety measures that could have prevented the fatal fire from occurring.

3.2.1. Fire equipment near the manhole of ballast tank No. 3.

The investigation did not have evidence that at the time the pipe fitters entered to start work in the tank or at the time the fire broke out, there was ready fire-fighting equipment (a sprinkler and a fire hose connected to a fire hydrant of fire mains under pressure).

According to the testimony of the surviving fitter, the foreman and other persons, this was submitted subsequently, after pulling the burning hoses.

3.2.2. Observer of those working in the ballast tank.

When working in confined and/or enclosed spaces, the presence of an observer (security guard) who is tasked with responding appropriately in the event of an accident/incident or any need of those working in the premises is key to the safety or protection of human life. As a rule, spaces are associated with the danger of lack of oxygen, rapid accumulation of dangerous/flammable or toxic gases, etc.

In this case, the presence of a security guard outside the ballast tank, visually observing the interior of the tank in combination with fire fighting equipment placed in readiness, would have resulted in avoiding the lethal end of the injured worker.

3.2.3. Forced ventilation.

According to the "Regulations on labor safety in welding and metal cutting" **No. D-08-002** , as well as according to the requirements of a number of other regulatory documents, safety systems of various shipping companies and last but not least good maritime practice, work in closed /semi-enclosed spaces on a ship require forced continuous ventilation of the air therein. This is of key importance for ensuring safe air parameters such as sufficient oxygen to support normal life activity of workers, removal of flammable or toxic gases, etc.

Forced ventilation in ballast tank No. 3 was not provided.

The Commission considered that the provision of forced ventilation would reduce the methane content below the necessary concentration for a fire of similar intensity.

3.2.4. Automatic portable gas analyzer .

An automatic gas analyzer is a portable detector that can detect flammable and toxic gases. Most often, models use a natural diffusion sampling method and a high-sensitivity sensor. When such gases are detected, the device emits a light and sound signal.

The use of such a device when operating in Ballast Tank No. 3 would have resulted in the early detection of a combustible gas leak, which would have given time to take action to evacuate the workers before the fire occurred.

3.2.5. Use of clothing for gas flame cutting activities.

According to the "Regulations on labor safety for welding and metal cutting" **No. D-08-002** , the worker should be dressed in tarpaulin clothing, rubber boots and a helmet covering his head and hair or with a shield and a mask that allows the helmet to be attached.

According to the testimony of the survivor, when the two workers entered the tank, they were wearing working overalls that were not fireproof. Safety helmets were not used, probably due to the narrow space of the tank.

In this case, the investigative Commision considered the above to be a violation of the rules for safe work when using equipment for gas flame cutting in the conditions of a confined space.

The use of appropriate clothing by the deceased worker could have saved his life in the event of a fire, giving him time for a quick evacuation.

3.3. Chronology and conditions of the fire in ballast tank №3.

3.3.1. Events and conditions regarding the ballast tank №3 on 13.12.2021.

On 12.12.2021, it was decided, by using a gas-oxygen cutter, to cut the nuts of the studs from the flanges, holding the ballast valve in place. This was due to the fact that because of strong corrosion, it was very difficult, almost impossible to unscrew them with a wrench.

On the morning of 13.12.2021, the workers from the “Galera 007” started preparing and working in the tank.

- the condition of the atmosphere in the ship's tanks was measured by an employee of “MTG Delphin" JSC;
- gas-free document was issued because the atmosphere was safe;
- an act of hot works was drawn up by an employee of the company "Gallery 007" LTD;
- lighting was installed in the tank by using a portable 24V electrical panel on the deck, and "garland" etc. ;
- a gas cutter was connected to shore supply (so-called “pots”) with methane and oxygen;
- the necessary tools were delivered – iron hammer, bronze awl, mask, etc.;
- three workers entered the ballast tank, cutting with the gas cutter 5 nuts of the studs (from a total of 8 pcs.);
- after the work was done, they took out the cuter and the hoses on the deck.

3.3.2. Events and conditions on 14.12.2021 (the day of the accident).

On 14.12.2021, it was not planned to carry out hot works in the ballast tank.

- regardless of this, in the morning, a firefighter from the shipyard measured the atmosphere ;
- two workers turned on the lighting in the tank from the 24V portable panel;
- they brought down the gas cutter into the tank again;
- one of them ignited the cutter for about 2 minutes to dry their gloves, then stopped it and hanged it on one of the partitions in the tank;
- a little later they tryied to knock out the studs with the hammer and awl;
- due to the very limited space to work in the tank, they did not succeed;
- one of them went to the shore to take a awl of greater length;
- on his return, after about 5 minutes, he saw thick smoke coming out of the tank;
- actions were taken to extinguish the fire.

3.4. Main inferences.

The analysis of the facts and events shown above allow the following conclusions to be drawn:

3.4.1. The bringing down of the gas cutter into the tank on 14.12.2021 was carried out arbitrarily by the two workers. The idea of drying the gloves could be realized on the deck of the ship, in the open air. It's more likely that they put it in to cut the remaining 3 nuts or to heat it up to make it easier to drive the studs out.

3.4.2. The use of this type of lighting (garland) was determined by the possibility of better illumination of the workplace. At the same time, the contacts of the electrical panel are not unnecessarily occupied in case of single, safe portable 24V lamps.

Fig.5. Portable 24 V lamp

Then, to achieve a similar degree of illumination, several such lamps would be needed. It would also create unnecessary cable clutter in the tank's already limited space. However, this does not negate the requirement that the bulbs of the garland, as well as itself, be designed for work in a potentially fire- and explosive-hazardous environment. Measuring the atmosphere is a necessary initial condition for hot works, but the possibility of gas leakage - methane or oxygen - must always be considered. Oxygen, unlike methane, is not combustible, it supports combustion as an oxidizer. The dangerous thing about it is that in an environment rich in oxygen **(over 24%)** the workers' materials, clothes, hair, etc. are saturated with oxygen. This sharply reduces their ignition temperature and they become highly flammable.

3.4.3. Examination of the remains of the hoses indicates that the oxygen hose was in good condition before the fire. Structural deformations were found along the methane hose with partial local destruction of the hose. That is, it was a potential gas leak hazard. It was likely that such a leak began shortly after it was hung on the bulkhead of the tank. The reason for this could be its strong bending and exposure/opening of its damaged sections.

Fig.6. The remains of the hoses on the deck

3.4.4. As already indicated, when removed from the tank and during the inspection, the taps of the cutter were closed**(Fig.7**).

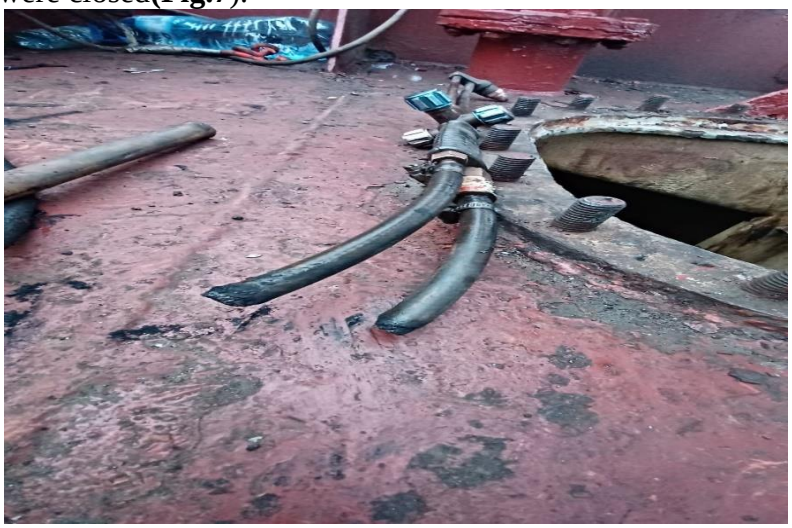


Fig.7. The used gas cutter, after removing from the tank

This means that no gas/oxygen could have inadvertently leaked out of it.

Despite the mentioned in item 3.2.3. malfunctions during its examination in laboratory conditions, the cutter was considered to be functional, suitable for use, although not quite upright compared to new one. Similar deformations could occured during its use - impacts, heating, etc.

3.5. Probable mechanism for the occurrence of the fire in ballast tank No. 3, port side of *m/v "BELLONA* ".

On the basis of the collected evidence, the performed fire technical expertise and a comparison of the relevant facts and circumstances, the Commission considers that the mechanism of the occurrence of the fire is as follows:

After discontinuing the operation of the gas-oxygen cutter for performing an unregulated activity "drying work gloves", when the cutter's taps were closed and the cutter was suspended (transferred) through a process opening from the nearby bulkhead in the tank, an unrecognizable leak of combustible gas (methane) began. The defect of the gas hose(methane) spreaded in the frame from the tension zone (bent position) of the outer rubber layer. After the surviving worker exited the tank to find a longer breach, continued unrecognizable increased gas leakage towards the manhole (up), incomplete failure of the hose in the failure zone with release of a composite (rubber and frame material) fracture piece/debris (proven in laboratory tests)

In addition to the flow of gas up to the tank, the relatively small space of the tank was also gassed. The gas concentration increased, not yet reaching explosive values, but approaching values sufficient to cause an intense fire.

To close the fire triangle (**Fig.4**) only an ignition source was needed.

The fire engineering expertise indicated 4 possible versions for a probable source of ignition:

- open fire regarding the operation of the cutter;
- mechanical sparks when using a hammer and an awl to knock out the studs of the flange joint of the ballast valve;
- electric sparks or other type of heating related to the technically defective electric "garland";
- open fire with regard to smoking.

The assumption of the credibility of the first version did not correspond to the facts established during the laboratory tests and inspections – stopping/closing the three valves of the

cutter and hanging it in a hanging position, discovering the cutter with closed valves at the bottom of the tank in the residual water as a result of its falling due to burning of the hoses.

In the second version, there was no correspondence with the absence of an explosion, the massive presence of products of corrosive destruction of the fasteners of the ballast valve, as well as the data on the temporary suspension of work with a view to supplying a longer tool.

The most likely was the third version of the source of ignition with regard to the ignition of the combustible gas mixture from electric sparks or heated surfaces from the lighting fixtures of the electric "garland", as well as burning of the cable sheath.

The Commission basically agreed with the stated most likely version, regarding the ignition source, but considered that each of the four versions had some probability, incl. and the fourth version, although there was no definite evidence that the deceased was a smoker or had a means of ignition (lighter, matches, etc.).

The ignition of the methane in the tank leads to the ignition of the clothing and thermal injuries of the deceased, the ignition of the methane and oxygen hoses, the growth of the fire vertically and the "fire closing" of the manhole of the tank, which was the only possible evacuation exit.

The deceased pipe fitter failed to initiate a rescue response to evacuate. Burning of the methane and oxygen hoses caused the cutter to fall to the bottom of the tank.

The actions taken by the surviving pipe fitter and the foreman to rescue the injured in the tank and extinguish the fire essentially did not change the fatal outcome.

4. CONCLUSIONS.

The Commission considers it most likely that the gassing of the tank and the creation of a hazardous atmosphere occurred when methane leaked from the hose. At the same time, the question remains open as to why the deceased failed to notice this. As it’s know, methane is a colorless and odorless gas, lighter than air. In such gases (methane, propane-butane, etc.) used in household and industry, special aromas with a specific smell are added. This enables their identification as they leak into the air. The probable explanation for this is the characteristic of the workplace - ballast tank, with sediments at the bottom, high humidity, corroded parts, which reduces the effect of flavoring agents .

Regarding the possible source of ignition:

- electric discharge (arc/spark);

According to research, electric arcing/sparking can occur even at low operating voltages. This can happen if, for example, the glass bubble of the light bulb is broken, even unintentionally. Then rapid oxidation of the filament and its destruction begins. At some point, it begins to fall apart into parts, with micro-gaps appearing between them. It is there that an electrical discharge leading to an arc/spark can occur. This scenario is most likely to be realized in practice. The dependence of the minimum breakdown voltage on the air gap is shown in **Fig.8.**

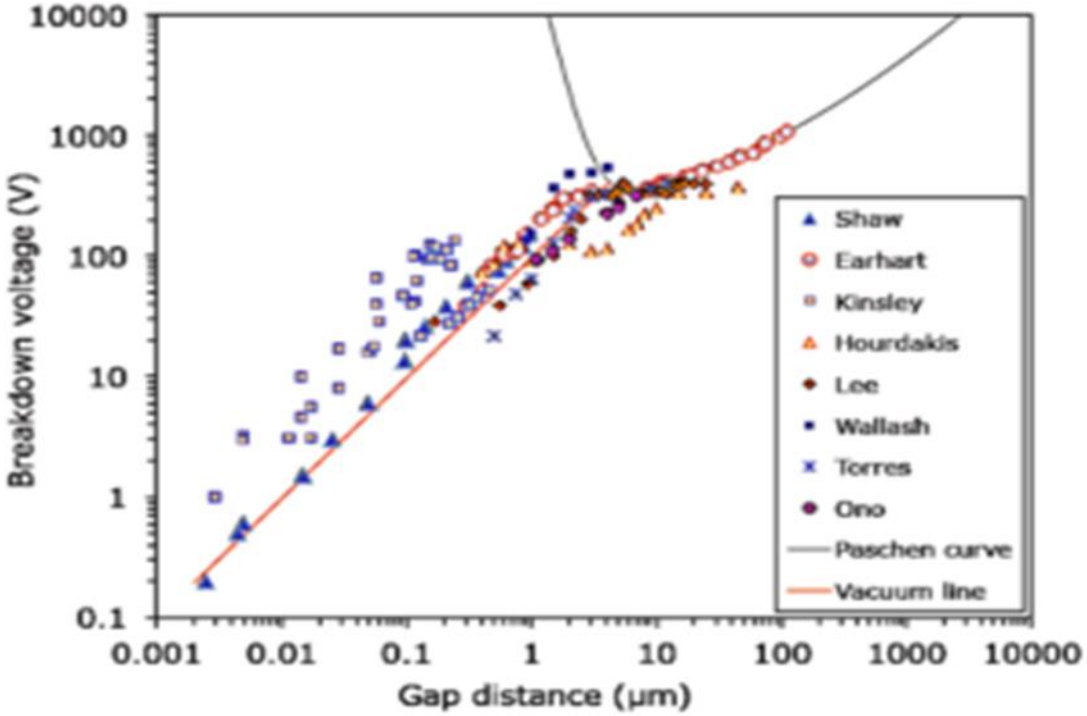


Fig.8. The dependence of the minimum breakdown voltage on the air gap.

- static electricity;

As already stated, static electricity occurs during the movement of fluids through the ship's pipelines, especially in the cargo/discharge pipelines. Since the ship went out for repairs empty, without cargo, this probability is very small.

- the exposed parts of light bulbs (the glass bulb);

The heating temperatures of glass bulbs used in string lights are in the order of: 40 W - 145°C, 25 W - 100°C. Considering the dependence shown in the graph of **Fig.9**, it can be seen that these temperatures are much lower, that is, it could not be a cause for fire.

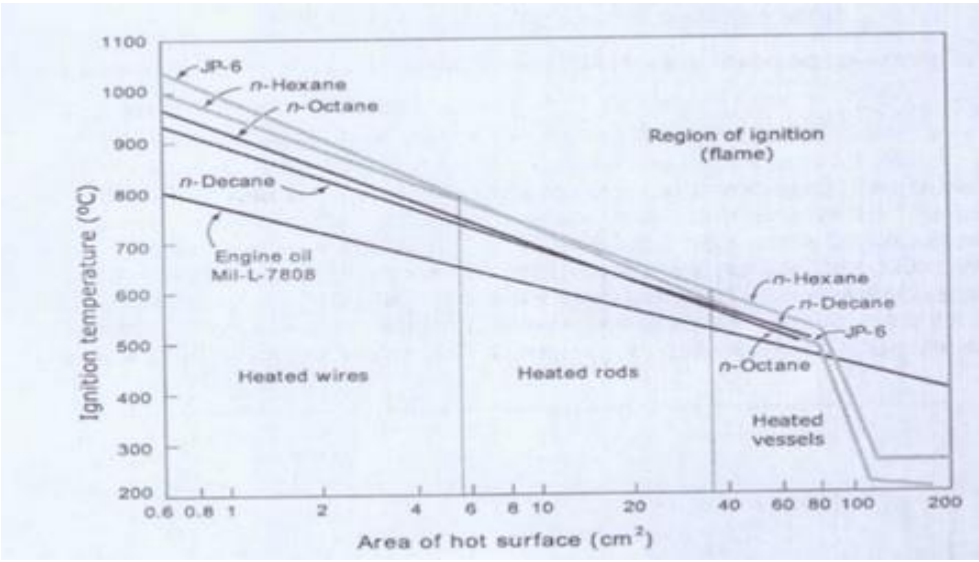


Fig.9. Effect of a hot surface area on the ignition of several types of fuel vapors

- spark when working with hand tools;

The hand tools used - an iron hammer and a bronze awl - could cause sparks when working with them. It was found that while the two workers were in the tank, they used them to knock out the studs . It is not clear whether the injured worker, when left alone, did not use them. But the following must be taken into account in the evaluation – firstly, methane, being lighter than air, begins to accumulate in the upper part of the tank. Second, the tap is located in

the lower part of the tank - that is, there will be a dangerous concentration at the latest. Considering all this, (as well as the material of the awl), a fire is unlikely to occur when using the tools.

- excessive heating of electric cables or part of them, short circuit;

An unburnt part of the electrical cable of the garland was found during the on-site inspection. Partial damage to its insulation could be seen on the cable. This indicated that such an exposed part of the cable would at some point come into contact with parts of the deck or the tank. In this case, a short-circuit mode would occur. It could be accompanied by the flow of high current, heating and possible electric arcing/sparking. Given that a low voltage (24V) was used, it is unlikely to cause a fire.

- **discovered flame, for example smoking**.

During their training to obtain a legal qualification, welders, in addition to purely technical things, also learn about the characteristics of individual gases and the dangers of working with them. This is especially important for fire operations in confined spaces. When they start work, they are given an initial instruction on health and safety, followed by periodic ones. Before starting activities related to the use of gas-cutting equipment, additional instructions are given on the specific hazards at work. Furthermore, there was no conclusive evidence of the presence of matches/cigarettes prior to the incident. Therefore, it can be assumed that the cause of ignition from an open fire/cigarette was unlikely because it goes against good practice and the instinct of human self-preservation.

4.1 . MAIN CAUSE OF THE ACCIDENT.

The Commission considers that the main reason that led to the very serious accident was a mechanical failure (rupture) of the methane hose of the gas-oxygen cutter located in the tank, which resulted in the leakage of a large amount of gas and its subsequent ignition by an unknown security source of ignition (most likely defective cable with lighting fixtures, "garland" type).

4.2 . FACTORS CONTRIBUTING TO THE ACCIDENT.

Contributing factors to the fire were:

- non-observance of safety measures during fire works by those working in the ballast tank;
- lack of appropriate protective clothing;
- lack of forced ventilation to remove the released gas;
- lack of an automatic gas analyzer;
- lack of control by the responsible persons of "Galera 07" OOD, charged with compliance with safety measures.

5. SAFETY RECOMMENDATIONS:

In view of the provided Report of the results of the inspection of "Galera 07" OOD by the Executive Agency "General Labor Inspectorate" and Report of the results of the investigation of the accident by the National Insurance Institute, Territorial Division - Varna, together with the objectified in their actions and recommendations, the Commission made the following safety recommendations:

5.1. To the company "Galera 07" OOD:

BG/2023_R1: A minimum of one automatic gas analyzer should be provided when working in a closed/restricted space on a ship.

BG/2023_R2: When working in a closed/restricted space on a ship, working fire-fighting equipment should be provided in the immediate vicinity of the entrance/exit of the same.

BG/2023_R3: When working in a closed/restricted room on a ship, forced ventilation of the air in the same should be ensured.

BG/2023_R4: When working in a closed/restricted room on a ship, a security guard/observer at the entrance/exit of the room must be provided at all times to maintain visual and/or radio contact with the workers.

BG/2023_R5: To carry out a mandatory inspection of the equipment during fire works, immediately before the start of the working day.

BG/2023_R6: To develop an effective methodology and detailed instruction for risk assessment when working in a closed/confined space on a ship.

BG/2023_R7: To update the "Welding Instruction" from 01.08.2012. with specific and detailed activities, safety measures, control actions and instructions.