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ANALYSIS OF THE INTERVENTION OF THE MILITARY FIREFIGHTERS TO EXTINGUISH THE FIRE PRODUCED AT THE HERCULES TUGBOAT

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Abstract. The paper presents a scenario of intervention in case of fire on a ship and the operation of fire limitation / control systems, with minimal material and human resources. The efficiency of the intervention consists precisely in the mode of operation. The mode of operation efficiency involves the description of the technical characteristics of the material and human resources of the intervention, their performances, the costs of the intervention, as well as the operating times. A fire at the HERCULES ship was chosen as a case study. There are present the characteristics, capacity, class symbols and equipment of the Hercules tugboat, as well as the fire-fighting installations present on board at the time of the fire. The fire started from the engine room where they were large quantities of electrical equipment and it burned smoldering, with large emissions of smoke, toxic gases and high temperature.
Key words: ship, characteristics, equipmnent.

1. INTRODUCTION

The multifunctional maritime tugboat with ice class "Hercules" (figure 1) [1], owned by the Romanian Agency for Saving Human Life at Sea (RASHLS), was built in the Braila Shipyard, between 1986-1988, with the final delivery to the beneficiary in 1989, after a project developed in 1984.
At the time of the event (26.10.2017), the tugboat was in berth no. 78 in Constanta harbor where it was in an extensive process of modernization and refurbishment since 2013, following which it was to perform the following functions:
- assistance and intervention in the maneuvering of sea and river vessels in port areas;
- line towing on the unlimited navigation area;
- extinguishing fires on ships, platforms and quay installations;
- the opening of waterways by ice in the coastal area of the Black Sea and on the course of the maritime Danube;
- rescue, towing, recovery of ships;
- saving lives at sea, crew recovery, emergency medical assistance;
- occasional transport of materials, equipment and personnel.

Fig.1. The Hercules tugboat [1].

The paper presents a scenario of intervention in case of fire on a ship and the operation of fire limitation / control systems, with minimal material and human resources. The efficiency of the intervention consists precisely in the mode of operation. The mode of operation efficiency involves the description of the technical characteristics of the material and human resources of the intervention, their performances, the costs of the intervention, as well as the operating times. A fire at the HERCULES ship was chosen as a case study.

2. MATERIALS AND METHODS

A fire at the *HERCULES ship* was chosen as a *case study*. There are present the characteristics, capacity, class symbols and equipment of the Hercules tugboat, as well as the fire-fighting installations present on board at the time of the fire.

2.1. Technical characteristics of HERCULES tugboats

Technical characteristics of HERCULES ship are [2]:
- maximum length- 68.73 m;
- LPP length - 62.00 m;
- width - 16.50 m;
- construction heigth - 7.90 m;
- draft: maximum draft at free board mark - 6.50 m;

- minimum draft with sailing bow - 4.00 m;
- maximum draft with sailing bow - 6.50 m;
- minimum draft with sailing stern - 5.30 m;
- maximum draft with sailing stern - 7.30 m.
- displacement - 4067 t;
- power - 2x3300 HP;
- speed: free march (100 % MCR) - 13.8 kt;
- economic free march (85 % MCR) - 12 - 12.5 kt;- in-line towing (85 % MCR) - 7 kt;
- autonomy: economic free march (85 % MCR) - 5000 Nm; towing (85 % MCR) - 3000 Nm;
- water and food supplies (10 crew) - 30 days; - water and food supplies (18 crew) - 50 days;
- trim: maximum trim in bow (0.5 % L) - 0.30 m; - maximum trim in stern (3 % L) - 1.80 m;
- crew: permanent crew - 10 people; auxiliary staff in specific missions - 8 people; persons saved according to class notation - 50 people.

- **Capacity**

The ship is equipped with ballast tanks, heavy fuel tanks, diesel tanks, oil tanks, fresh water tanks, technical water tanks, foam tanks and waste tanks, according to table 1, table 2, table 3, table 4, table 5, table 6, table 7, table 8 [4].

Table 1. Ballast tanks [4]

Tank	Tank name	Tank volume
1B	Forepeak	58 m^3
2B+3B	Deep tank (bow)	105 m^3
4B+5B	Deep tank (stern)	101 m^3
6B+7B	Afterpeak	176 m^3
Total		350 m^3

Table 2. Heavy fuel tank [4]

Tank	Tank name	Tank volume
1HF	Superabundance	16 m^3
2HF+3HF	Stock DF	60 m^3
4HF	Consumption	16 m^3
5HF	Decantation	16 m^3
6HF+7HF	Deep tank	202 m^3
8HF+9HF	Deep tank	146 m^3
Total		456 m^3

Table 3. Diesel tank [4]

Tank	Tank name	Tank volume
1D	Stock DF	62 m^3
2D+3D	Deep tank (stern)	294 m^3
4D+5D	Stock DF	80 m^3
6D	Superabundance	15 m^3
7D	Consumption	14 m^3
8D	Decantation	16 m^3
Total		481 m^3

Table 4. Oil tank [4]

Tank	Tank name	Tank volume
1O	DG used oil	1.4 m^3
2O	DG stock oil	6.7 m^3
3O+4O	MP stock oil	31 m^3
5O	MP used oil	11.5 m^3
6O+7O	MP circulating oil	13 m^3
8O	RI stock oil	2.2 m^3
9O	Pas stock oil	2.2 m^3
10O	Pas circulating oil	2.0 m^3
11O	Propeller oil change	2.0 m^3
12O	Post-oil	2.6 m^3
13O	MP expansion oil	1.6 m^3
Total		75.2 m^3

Table 5. Fresh water tank [4]

Tank	Tank name	Tank volume
1FW	Fresh water	109 m3
2FW (Sb+B)	Fresh water (cargo)	113 m3
3FW	Fresh water (consumption)	14.5 m3
Total		236.5 m3

Table 6. Technical water tank [4]

Tank	Tank name	Tank volume
4TW	Technical water	21 m3
5TW	Technical water	28 m3
Total		49 m3

Table 7. Foam tank [4]

Tank	Tank name	Tank volume
1F+2F	Foam	66 m3
Total		66 m3

Table 8. Waste tank [4]

Tank	Tank name	Tank volume
1W	DG oil	1.2 m^3
2W	Gearbox oil	1.7 m^3
3W	MP water	2.8 m^3
4W	Bilge	5.8 m^3
5W	Separator	2.8 m^3
6W	Stern	0.5 m^3
Total		14.8 m^3

- **The symbol of class**

The ship was built in accordance with the rules of the maritime RNR, to receive the class [3]:

RNR ------ CM  M --- 0 (1) G60 Tug

Notation:
- M/0 - maritime navigation in the unlimited area;
- (1) - the ship withstands the damage and flooding of a single compartment;
- G60 - summer-autumn navigation in all arctic areas;
- Tug - the ship used in towing actions.

- **Ship equipment**

Main engines: 2 x MAN – RESITA 6L40/54A reversible, 2 x 3300 HP/430 rpm; consumption: fuel - 150 (+5 %) g/HPh; oil – 1.29 g/HPh.
Gearboxes: 2 x RENK RESITA, 3.5:1
Diesel generators: 2 x DG SULZER CEGIELSKI SAL – 25 630 kVA, 750 rpm; 2 x Ge Ax 630 kVA, 1500 rpm; 1 x DG stationary 156 kVA, 600 HP/750 rpm.
Propeller: 2 x EPR, De 4100 mm, z4, 123 rpm.
Guvernance: 2 x HYDROSTER MS200 TEI 250 kNm elecrohydraulic, ±35º în 28 sec.
Bowthruster: 1 x ZAMECH N1,6 290 kW/1500 rpm, De 1550 mm, Dt 1,600 mm, Lt 2150 mm
Tow: 2 x winch MENEROM, 2 x 25 tf dynamic, 2 x 50 tf static, 800 m towline 51 mm, 6.75 m/min;
- hook 50 tf towline max. 160 mm.
Manoeuvre: 2 x anchor 2,000 kg, 1 anchor winch/manoeuvre 30 tf, caliber chain 40, 107 m/min; 4 x 160 m rope.
Goods transfer: 1 x hydraulic winch MENAROM, 20 t, 120 m cable 16 mm; 1 x platform for people and goods.
External FI-FI installation: 2 x electric pumps RND-V-350-300-280 1000 m^3/h, 8 bar, 200 kW, 1470 rpm; 4 x water/foam cannons TASA7000, 420 m^3/h foam, 7 bar, jet lenght 40 m; 1 x installation with spray water curtain DN15.
*Rescue equipmen*t: 2 x diesel lifeboats, 44 people; 2 x inflatable rafts 20 people; 2 x quick release lifebuoys; 2 x lifebuoys; 50 x life jackets; 1 x service boat 6 people, outboard engine.
Navigation equipment and systems: compass magnetic, type KMOT 2; daytime running lights; ECDIS, type GTD-15Q Koden Japan; gyrocompass SIMRAD, type GC80/85; loch electromagnetic, type LEM-2; echo sound, type SIMRAD SKKIPER with repeater; GPS Philips, type MK10; GPS JRC, type J-NAV500; main radar KELVIN HUGENS; secondary radar RACAL-DECCA; AIS transponder JRC, type JHS-182; weather station; automatic pilot, type PZL, Poland.
Radio communications equipment:
-equipment SOLAS GMDSS: 3 x portable radiotelephones GMDSS, type AXIS 250; EPIRB, type McMurdo E3; 2 x transponder McMurdo type RT9; NAVTEX, type SAIT LO-KATA 2; radiotelephone VHF/DSC. type SEA 7157 class A; radiotelephone VHF/DSC. type NCM 1770 JRC; immersed C Thrane & Thrane, type TT-3020B; radiotelephone SSB MF/HF, type SEA300 W.;
-equipment NON SOLAS: 1 x portable radiotelephone VHF, type ICOM; 2 x portable radiotelephone VHF, type Triton MP100; 4 x radiotelephone UHF marine ICOM; 1 x radiotelephone VHF, type Motorola Triton II.

2.2. The firefighting instalation of HERCULES tugboats

The Hercules tugboat is equipped with the following types of fire-fighting installations, as follows (Panaitescu et al., 2007), [5]:
- water extinguishing system;
- CO_2 fire extinguishing system;
- fire extinguishing system with water spray;
- external Fi - Fi installation: fix fire extinguishing system; portable fire extinguishing system; water curtain protection installation.

- *Water extinguishing system*

The characteristics of the water extinguishing system are the following:
- the installation is served by two fire pumps, which are also ballast pumps, bilge and general services pumps (Panaitescu et al., 2007), [5]. The pumps are located in different compartments, separated by a wall of class "A0";
- the total capacity of the fire pumps is 4/3 of the capacity of the bilge pump required by the class, respectively minimum 70 m^3/h (the minimum capacity of each pump is 30 m^3/h);
- the pipes and hydrants are placed in such a way as to avoid freezing of the water in the installation and to allow quick connection to the fire hoses. The fire line is provided with means of emptying the installation;
- the isolation valves are provided on the main pipe in order to isolate it from the engine/DG room;
- two hydrants are provided in the engine/DG room;
- the number of hydrants and their position is chosen so that at least two simultaneous water jets from two different hydrants reach any part of the ship;
- the minimum hydrant pressure is 2.5 bar;
- an international shore connection is provided;
- the material of the fire hoses is non-perishable. The fire hoses are provided with the necessary couplings and have a minimum length of 10 m, and the maximum will not exceed: 15 m in the engine/DG room; 20 m in other spaces and open decks
- the diameter of the fire nozzles is standardized: 12 mm, 16 mm or 19 mm.

- *CO_2 fire extinguishing systems*

The ship is equipped with a fixed CO_2 fire extinguishing system designed to extinguish the fire in the following compartments, by triggering the following groups of batteries:
- engine room26 bottles; rudder machine room 4 bottles; central control station 4 bottles; paint warehouse 2 bottles; DG muffler – P 2 bottles; DG muffler – center 2 bottles; DG muffler – Sb 2 bottles; auxiliary boiler muffler 2 bottles; recovery boiler and MP piping - P; 2 bottles; recovery boiler and MP piping – Sb, 2 bottles.

The CO_2 plant is located outside the protected areas, it is heated and ventilated. There are 26 CO_2 cylinders in the boiler, each loaded with 30 kg CO_2. The transmission/distribution piping and CO_2 exhaust nozzles shall be located so as to ensure a uniform distribution of CO_2. In the engine room, the nozzles are located both under the straw and at the top of the compartment.
Distribution pipes do not pass through living spaces or cooled spaces. The installation is only triggered after approx. two minutes after entry into operation of the respective acoustic and optical warning system. The CO_2 transmission and distribution piping are made of steel and are protected against corrosion inside and outside.
The plant is designed to release 85 % of CO_2 in two minutes.

- *Fire-fighting system with water spray*

The fixed local fire extinguisher is provided because the fuel separator, boiler and other oil separation equipment are not located in different compartments, as well as the fact that the category compartment of engine room of category "A" exceeds the volume of 500 m^3. The system ensures the protection of the engine room without the need to stop the engines, evacuate the personnel or seal the compartment. It protects the following areas:
- danger zone of internal combustion engines, used for the propulsion of the ship, or of power generators;
- boiler area;
- the area of the fuel separators.

Activation of the fixed local fire extinguishing system triggers a different visual-audible alarm in a protected area and at a supervised station. The alarm indicates that the system has been activated and does not replace other devices/alarm in case of fire.
External Fi – Fi installation
The external Fi - Fi fire extinguishing system consists of: fix fire extinguishing system; portable fire extinguishing system; protective firefighters equipment.

- *Fix fire extinguishing systems*

The installation is served by two drowned centrifugal electric pumps, each with the following characteristics: Q=400 m^3/h and H=120 m WC. They supply four cannons of water/foam and operate in the event of a breakdown in the ship's fire extinguishing system.
The pumps are provided with overheating protection by a safety valve when operating at low flow rates. When starting the pumps, when the suction valve is closed, it will be prevented by an audible and visual alarm system.
The speed of the fluid on the suction does not exceed 2 m/s.
The Kingston caisson is located in the central area of the double bottom and ensures a good water supply to the pumps, regardless of the movement of the ship. The suction pipes only supply the pumps to extinguish the fire outside the dashboard. The caisson and the suction pipe of the installation are not used additionally for other purposes.
The system is emptied during the winter through the drain valves located in the lowest points of the piping.
The valves on the suction and discharge pipes of the pumps have diameters over 450 mm and are equipped with manual and remote operation.
The piping system is made of drawn steel, galvanized, protected against seawater corrosion. The pipes that supply the hydrants on the deck are different from the main pipes that supply the monitors.
The ship is also equipped with a foam fire extinguisher.
Water/foam cannons are operated and controlled by a remote controller system located in a space with visibility in any direction. In addition, each monitor is operated manually, locally. The local manual control is disconnected from the remote controller point, and the remote control is disconnected from a location near each monitor. The monitors are positioned so that they can allow a horizontal movement of at least 90º (45º on either side of a plane parallel to the diametrical plane), or a vertical movement sufficient to meet the required characteristics of the water jet. The area of action is unobstructed (equipment or other body structures of the ship).

- *Portable fire extinguishing system*

In the portable fire extinguishing system, four hydrants are provided on each dashboard, which are supplied by the pumps that supply the monitors provided the pressure is reduced so as to allow the safe handling of fire hoses. A box of fire hoses complete with spray/jet nozzles is provided. The fire hoses have a diameter between 45 and 70 mm and a length of 20 m.

- *Protective equipment for firefighters*

Four firefighting suits are provided, which are stored in a safe and easily accessible area on the open deck. Each suit contains the following:
-compressed air breathing apparatus, plus a spare cylinder, the capacity of the cylinder is at least 1,200 l;
- fireproof protective clothing with flashlight.
The ship is equipped with a complete compressor with all the fittings necessary to refill the cylinders of the respirators. Its capacity is enough to fill the bottles in less than 30 minutes. The compressor is equipped with an air filter and oil separator.

- *Water curtain protection system*

The open decks are provided with sufficient drainage pipes and openings in the parapets to drain the water accumuleted during the operation of the protection systems with water curtains.

2.2. Case study

- *Methods of intervention*

On 26.10.2017, at 12.04, the Dispatch Office within the Constanta Port Fire Detachment was notified through

The National Emergency Call System 112, about the occurrence of a fire at a ship. The event took place at the Hercules Tugboat (figure 2)[2], owned by RASHLS, a tugboat that is being repaired/refurbished in berth no. 78, inside the Constanta harbor. The fire stated from the engine room where they were large quantities of electrical equipment, and it burned smoldering, with large emissions of smoke, toxic gases and high temperature.
Guard no. 1 of the Constanta Port Fire Detachment intervened with a special vehicle for operative work, 3 (three) fire trucks with water and foam and a SMURD type B ambulance, on the itinerary: the subunit headquarters - Berth no. 78. All the vehicle traveled 4 km, alert time: 1 min 30 sec., response time: 6 min.

Fig. 2. Fire on Hercules tugboat. [2]

In order to locate and extinguish the fire, the following intervention technique was used, as follows:
- Guard no. 1 from Constanta Port Fire Detachment: 3 (three) fire trucks with water and foam (2 x A9000 and 1 x A2003); a SMURD type B ambulance; a special vehicle for operational work,
-Private Emergency Services (PES S.C. CONSAL Trading S.R.L.), intervened with: a fire truck with water and foam; a fire escaper; a towing motor pump,
- Guard from Constanta City Fire Department, who went to support, at the order of the chief inspector, intervened with: a fire truck with water and foam (A9000); a special vehicle for operative work.
- Task force (unit command): a special vehicle for operative work.

- *Scenario description*

Following the reconnaissance by the detachment commander, it was found that there was an open flame in the engine room, with high smoke emissions, toxic gases and high temperature, but the outbreak was not located.
In the first phase, around 12.14, firefighters intervened inside the engine room, to extinguish the fire, with a type B hose line, distributor and a type C hose line up to the engine room, the device was made from the fire truck A9000 within Constanta Port Fire Detachment. Several teams of two firefighter servants accompanied by the fire detachment commander and the shift leader entered in the engine room, but the fire could not be located.
Also in the first phase, two cooling sectors were created, initially on the deck of the ship and later it was operated from the outside of the deck to the inside of the deck by opening 4 (four) covers, the device was made from the fire truck of PES CONSAL, this being composed of a type B hose line, distributor and two type C hose lines, each line cooling two warehouses, alternately. These sectors were coordinated by the deputy detachment commander, respectively by the training leader of PES CONSAL, throughout the intervention.
In the second phase at around 13.40, the fire detachment commander, who was also the commander of the action, took the decision, in consultation with RASHLS representatives, to use another access route, namely a well on the deck which descended two floors, to had access to the engine room. At around 14.00, a team of two firefighters with a foam-generating pipe from the fire truck A9000 within the Constanta Port Fire Detachment were lowered into the well, and they acted with foam inside the engine room until they were taken off to the deck due to an explosion of a fire extinguisher under pressure. At the time of the explosion, around 14.00, chief inspector of Military Fire Unit was on the ship and had taken command of the intervention, thus becoming the commander of the action. After the explosion, another team was introduced, consisting of two firefighting servants who acted with foam through the same well. At this stage the fire was located.
In the third phase of the intervention, the action of the teams that acted, in the first phase, inside the ship was resumed, in the sense that several teams were formed that acted alternately under the command of the fire detachment commander and the shift leader and coordinated from outside by the first deputy of chief inspector. They managed to extinguish the fire, initially adopting the previous device, then acting with a type B hose line and foam generating pipe from the distributor, thus canceling the type C hose line they had used before.
Also in this phase, the crew arrived to support from Constanta City Fire Detachment, under the command of the fire detachment commander, formed a foam device, consisting of a type B hose line from the fire truck A9000 to flood the ship's two chimneys alternately.
The water supply of all the fire truck was made with the help of the PES CONSAL motor pump.
The A2003 special vehicle from the Constanta Port Fire Detachment was in the operative reserve, it did not act, but accessories and breathing apparatus were used. The crew of this fire truck actively participated in extinguishing the fire in the intervention teams.
The mechanical escalator from PES CONSAL was in operational reserve, not being used in extinguishing

or rescue operations, but only as a means of transport of the motor pump.
The special vehicle for operative work, from Constanta Port Fire Detachment, transported 20 air cylinders from the subunit; this aspect was taken care of by the head of the garage, who organized this logistics sector.
The first aid crew of the SMURD type B ambulance within the Constanta Port Fire Detachment provided emergency medical assistance at the fire scene.

- *Resources of intervention*

During the intervention, the representatives of RASHLS made available to the commander of the action and showed them the scheme, plans and surveys of the ship that helped the intervention personnel for the orientation inside it. Access to the site of the outbreak of the fire was difficult due to smoke and toxic gases emitted by the combustion of electrical insulation, as well as due to the heat accumulated in the engine room and last but not least the particularity of ship fires (narrow spaces, low visibility, heat accumulation).
As the fire only occurred in the engine room, the material damage was minimal in the sense that the fire did not spread since the arrival of fire crews, resulting in the burning of electrical installations, panels and equipment, as well as paint on the walls. The walls of the engine room had just been painted.
Preliminary research conducted immediately after the fire and the statement of the personnel on board of the ship revealed that the fire occurred during the modernization works when a worker performing an autogenous welding work, in the engine room, perforated a wall of a tank fuel (diesel).
Through the hole, the fuel in the tank leaked and ignited on the wall, also igniting the paint with which it was freshly covered. Because the level of diesel in the tank was not much higher than the height of the hole, the amount of diesel leaking from the tank was minimal, but enough to set the engine room on fire.
The personnel on board panicked, initially a worker tried to extinguish the fire with two fire extinguishers, but failed due to the fact that all personnel were evacuated at the same time as the fire was announced through The National Emergency Call System 112. The vessel's vulnerability [7] has been compromised.

3. CONCLUSIONS

In the case of seagoing ships anchored in ports and awaiting entry into the shipyards for repairs, as well as in ships in double or triple berth, the risk of fire is particularly high due to the following factors:
- malfunction of some installations and equipment or even decommissioning of some component parts;
- supervision by a small number of people;
- the appearance of some commercial companies whose object of activity/provision of naval services, is executed with a low qualified labor force, compared to the labor force and the endowments from the existing shipyards;
- non-compliance with fire prevention and extinguishing regulations, regarding the degassing of tanks, the evacuation of fuel and lubricant and the evacuation of oil residues from the bilge;
- lack of permanent and effective control over fire safety.

The degree of vulnerability of a ship to be repaired is determined by the following factors:
- the execution of temporary works to ensure the operation of facilities strictly necessary for the activities taking place on board the ship;
- incompletion of the endowments of certain subassemblies;
- there is no longer a strict record of combustible materials, which end up being stored in places where this is prohibited;
- in the event of a fire, the information is sent late to the dispatcher of the shipping company and to the port authority, due to the fact that the personnel of such ships is reduced.
- running the crews working in areas of high temperatures, smoke and toxic gases and ensuring the conditions of recovery of forces and medical supervision;
- providing reserves of forces and means, equipment, fuel, lubricants, extinguishing agents and accessories.

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