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ANALYSIS AND DIMENSIONING OF THE FUEL SUPPLY SYSTEM OF BULK-CARRIER

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Abstract : In the context of the global oil crisis, in all fields, an optimization of fuel consumption and an improvement of the efficiency of energy installations are being attempted. Thus, the shipping and transport industry is converging towards this idea by implementing energy installations with increased yields and reduced consumption. At the same time, for this purpose, it is also tried to increase the efficiency through the appropriate preparation of the fuel or its burning in optimal conditions.
Thus, in this context, the chosen topic aims to deal with aspects related to the dimensioning of the fuel supply system for a 178,000 tdw universal Bulk-Carrier. The ship is propelled by a B&W 8L60MC main engine that has been modernized in order to reduce consumption, noxious emissions and increase the energy efficiency index.
Bulk-Carrier ships are intended for the transport of various goods in bulk: iron ore, grain, coal, phosphates and other similar goods.

Key words : marine propulsion engine, fuel consumption, bulk carrier.

1. INTRODUCTION

In the naval and transport industry, due to the global oil crisis, in recent years, the improvement of energy installations has been aimed at increasing efficiency but at the same time by decreasing their consumption.

In this sense, the International Maritime Organization (IMO) has the following objectives:

- maximizing the level of efficiency for new ships;
- stimulating the continuous technical development of all the components that influence the fuel efficiency of a ship
- separating measures based on technical projects from commercial and operational ones;
- comparing the energy efficiency of individual ships with similar ones that could do the same type of transport.

The chosen topic aims to deal with aspects related to the dimensioning of the fuel supply system for a 178000 tdw universal Bulk-Carrier. The vessel is powered by a B&W 8L60MC heavy fuel main engine.

Heavy fuels are those fuels characterized by high flash point, high viscosity, high water and sediment content, high sulfur content, low calorific value and high ash content.

The composition and structure of heavy fuels create, in the operation of naval engines, certain problems that cannot be neglected. If the calorific power is lower, the flow rate of the injection pump can be increased, but other factors cannot be neglected. Thus, sulphur, carbon and ash act differently and always result in different phenomena such as: wear and tear of the organs bordering the combustion chamber, clogging of injector holes, deposits of calamine, etc. The presence of water in a high percentage in heavy fuel has an influence on the quality of the fuel and implicitly on the combustion. The water content contributes to the abrasion effect due to the salts contained, generally sodium chloride.

There is a close correlation between the internal combustion engine and the fuel used. For a given type of engine, its performance in normal operation depends on the fuel used, respectively on its judicious choice, control and maintenance of its quality within the prescribed limits.

2. PRESENTATION OF VESSELS CARRYING PRODUCTS

Bulk carrier is a dry cargo ship intended for the a priori transport of ores or other bulk cargo.

Bulk-carrier vessels must provide superior operating conditions for the loading, transport and discharge of solid bulk cargoes, except for special cargoes such as cement. At the same time, like all transport ships, they must be able to navigate in ballast under appropriate conditions.

In general, these ships are intended to transport as main cargo: heavy ores (0.35- 0.45 m^3/ t), light ores

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(0.55- 0.60 m³/ t), coal, heavy grains (1.25- 1.30 m³/ t) and light grains (1.55-1.60 m³/t).

Universal bulk carriers must meet a number of specific requirements, among which: the capacity of the holds must be such as to allow the transport of various grades of solid bulk cargo, from heavy ores to light grains, at a draft corresponding to the lines load, and the variation of transverse stability in the case of transporting different loads should be minimal.

In addition, it must meet additional requirements, namely:

- ➢ to have a sufficient number of warehouses to ensure the simultaneous transport of different sorts or batches of grain and at the same time to minimize the replenishment of bags;
- ➢ not require longitudinal separations or supply wells;
- ➢ to allow a quick cleaning of warehouses and with minimal expenses;
- ➢ the value of the bending moments in different transport options should not affect the longitudinal strength of the ship;
- ➢ the volume and layout of the ballast tanks to ensure a satisfactory draft and the stability required for navigation in ballast.

From a constructive point of view, universal bulk carriers are of three types:

- → Bulking with ballast tanks
- → Bulkhead with two longitudinal partitions
- → Bulk carriers with tween deck upper warehouses

2.1. *Classification of bulk-carrier ships*

Bulk carrier is a dry cargo ship intended for the a priori transport of ores or other bulk cargo.

Depending on the tonnage, bulk ships are classified as follows:

- Small <10000 tdw;
- Handy size 10000-35000 tdw;
- Handymax 35000-55000 tdw;
- Panamax 60000-80000 tdw;
- Capsize 80000-200000 tdw;
- VLBC > 200000 tdw.

Figure 1. shows the distribution of ships larger than 5000 tdw in percentage. Thus, handy size ships have the highest percentage, around 33.4%, followed by handymax with 28.6%. Thus, it can be observed that large ships, with a tonnage of over 80,000, such as Capsize and VLBC, are in smaller proportions, namely around 13% of the total existing bulk carriers.

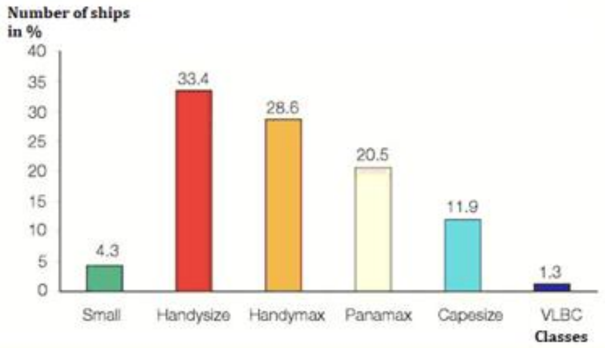

Figure 1 The distribution of ships by classes

When we refer to the tonnage of ships, we notice from figure 2. that bulk carriers with large tonnage are more numerous than those with small tonnage.

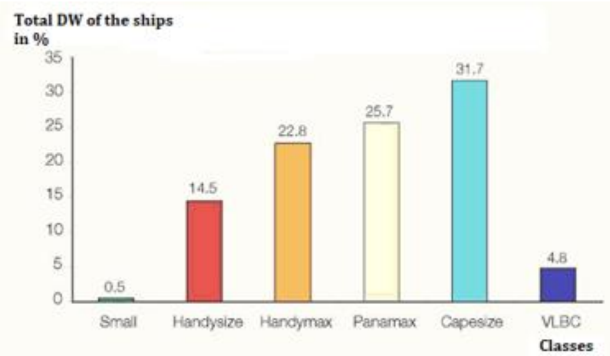

Figure 2. Distribution of bulk vessels according to tonnage.

2.2. *Characteristics of the prototype ship*

The prototype ship (figure 3) is a universal CAPESIZE type bulk carrier (100,000 ÷ 180,000 tdw) intended for the transport of various bulk goods: iron ore, grains, coal, phosphates and similar. The dimensions of the ship are:

- Maximum length
$$L_{max} = 291.80\ m$$
- Floating length
$$L_{cwl} = 285.79\ m$$
- Length between perpendiculars
$$L_{pp} = 282.20\ m$$
- Width
$$B = 45.00\ m$$
- Draft (calculation / sampling)
$$T = 16.50 / 18.42\ m$$
- Construction height
$$H = 24.75\ m$$

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- Deadweight (at the calculation / sampling draft)

$$D_w = 172{,}420.8 \,/\, 178{,}000 \; tdw$$

- Marching speed

$$v_N = 14.90 \; Nd$$

Figure 3. Prototype ship

The ship has a single continuous deck with a bulkhead at the bow, a dune at the stern, a single line of masts and the machinery compartment as well as the hold with the living arrangements and navigation control are also located at the stern.

The cargo space is divided into nine warehouses of practically equal length (approx. 15 m) with self-cleaning (typical octagonal section with bilge and deck tanks - wing tanks). All nine warehouses are equipped with MacGregor side-rolling type covers operated electro hydraulically (the pumps and the rest of the hydraulic aggregates related to the actuation of the covers are located in a roof located on the main deck between warehouses 4 - 5). The covers of the magazine openings have two segments each with lateral displacement towards the edges, unlike the small ones, they are provided with a group of 2 covers each. Also, its own loading-unloading facility is absent, the ship using the existing infrastructure in the specialized ports operated.

The warehouses are built to allow operation with grapples, therefore having a reinforced double bottom ceiling for an admissible load of 20 tons/m2 (warehouses 2,4,6 and 8) and 35 tons/m2 (warehouses 1,3,5, 7 and 9). The warehouses are naturally ventilated, their mechanical ventilation installation being therefore absent.

The main engine is designed for operation with heavy fuel (H.F.O. – heavy fuel oil) with a maximum viscosity of 380 cSt, the consumption in running mode at a speed of 14.60 Nd being approx. 58.20 tons / 24 h and an autonomy of 23800 Mm.

The ship's speed on a starboard keel and at summer draft T = 16.50 m, with a clean hull in deep water, with wind and waves up to 20 on the Beaufort scale (Bf 2 or sea margin 15%), is 14.90 Nd at 85% of maximum continuous power (85 % MCR).

The ballast installation is equipped with two self-priming centrifugal electric pumps, with a flow rate of 3,000 m3/h at a pressure of 35 mCA, the capacity of the ballast tanks being 52,643 m3.

The bilge installation is equipped with an electric piston pump with a flow rate of 320 m3/h at a pressure of 40 mCA. The bilge water from the CM is discharged overboard through a bilge separator in the areas where international legislation allows it and only under conditions where the concentration of hydrocarbons in the discharged water is less than 15 ppm.

3. SIZING OF MAIN ENGINE TANKS

Fuel tanks are used in equipping ships to store fuel. Fuel tanks are divided into several categories: storage tanks (bunkers), settling tanks, service (consumption) tanks, fuel overflow tanks.

On marine ships, the storage tanks are located in the double bottom. They are provided with filling and emptying pipes, ventilation pipes, System for measuring the fuel level, manholes.

The fuel is loaded into the storage tanks using transfer pumps or quayside means. A coarse filter is provided on the boarding pipe to remove foreign bodies that would be in the fuel.

From the storage tanks, the fuel is taken and sent to the settling tanks and further to the service tank that feeds the main engine.

The settling and service tanks, according to LLOYD REGISTER norms, are located in the engine compartment. In order to ensure a good service in operation, increased safety in operation and to make it possible to clean them, these tanks are executed in pairs.

In order to ensure the circulation of fuel from these tanks, they are equipped with coils heated with steam, which ensure an optimal temperature of the fuel inside them. The storage tanks are heated to ensure a fuel temperature of 40 [ºC], and in the settling tanks, the temperature is 60 [ºC].

The volume of each tank is determined from the condition of covering at least the fuel consumption of the main engine during 4 hours of operation. When calculating the volume of consumption tanks, the need for them to be installed in the car compartment must be taken into account. In installations where the main engine is fuelled with heavy fuel, the volume of the consumption tank for diesel will be allowed within the limits of 20 - 25 [%] of the volume of the consumption tank for heavy fuel.

The quantities of fuel for making a trip are determined taking into account the operating regimes of the ship's energy installation, using relation (1):

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$$\sum G = G_{march} + G_{st} \quad (1)$$

where:
- G_{march} - represents fuel consumption in navigation mode,
- G_{st} - fuel consumption during the stationary period.
The autonomy of the ship and the stationary period are adopted at 1000 hours, of which: 760 hours of marching and 240 stationary hours. During the 760 hours of marching, it was considered to be working:

- the main engine,
- two auxiliary engines
- recovery boiler (gas);

during the 240 h of stationary operation, only one auxiliary engine and the auxiliary heating (with burner) are considered to be operating.
Taking into account the above, we have relation (2):

$$\sum G = G_{march} + 0 = C_h \cdot t_{ME} \cdot 10^{-3} [t] \quad (2)$$

where:
- C_h - fuel consumption of the main engine;
- t_{ME} - duration of operation of the main engine;
The amount of heavy fuel required for the main engine will be determined using relation (3):

$$G_{c\,HFO} = C_{h\,HFO} \cdot t_{ME} \cdot 10^{-3} = = 3{,}341.876559 \cdot 760 \cdot 10^{-3} = 2{,}539.826185 [t] \quad (3)$$

where:
- $C_h = C_{h\,HFO} = 3{,}341.876559\ [l/h]$
- $t_{ME} = 760\ [h]$

For ships where the main engine runs on heavy fuel (H.F.O.), a quantity of medium viscosity fuel, diesel, is added, representing (15 ÷ 20) [%] of the quantity of heavy fuel required by the main engine, which will be used for its supply when starting, stopping and in the maneuvering area.

The amount of diesel fuel required by the main engine is calculated with relation (4):

$$G_{c\,DIES} = (0.15 \div 0.20) \cdot G_{CHFO} = = 0.18 \cdot 2{,}539.826185 = 457.1687133\ [t] \quad (4)$$

3.1. Storage tanks volume

For the embarkation of heavy fuel (H.F.O.) and medium viscosity fuel (diesel) the required volumes will be calculated with the relations (5) and (6):

$$V_{c\,HFO} = c_1 \cdot c_2 \left(\frac{G_{c\,HFO}}{\rho_{c\,HFO}}\right) [m^3] \quad (5)$$

$$V_{c\,DIES} = c_1 \cdot c_2 \left(\frac{G_{c\,DIES}}{\rho_{c\,DIES}}\right) [m^3] \quad (6)$$

where:
- $c_1 = 1.15 \div 1.20$ - is a coefficient by which a surplus of fuel is admitted, c_2 for unforeseen situations;
- $c_2 = 1.07 \div 1.10$ - is a coefficient that takes into account the reduction in the volume of the tanks due to the residual fuel adhering to the walls of the storage spaces.
- $\rho_0\ [t/m^3]$- is the fuel density

Is chosen:
$c_1 = 1.20;\ c_2 = 1.08$
The values are known:
$\rho_{c\,HFO} = 990 [kg/m^3]$
$\rho_{c\,DIES} = 840 [kg/m^3]$

We replace these values in relations (5) and (6) and obtain the following values (7) and (8):

$$V_{c\,HFO} = 1.20 \cdot 1.08 \cdot \left(\frac{2{,}539.826185}{0.990}\right) = 3{,}324.863369\ [m^3] \approx 3{,}325\ [m^3] \quad (7)$$

$$V_{c\,DIES} = 1.20 \cdot 1.08 \cdot \left(\frac{457.1687133}{0.840}\right) = 705.346015\ [m^3] \approx 705.4\ [m^3] \quad (8)$$

Also here it is taken into account the fact that the burner boiler works when stationary, and the fuel used by it is also stored in the tanks intended to feed the main engine.

Knowing the hourly consumption of heavy fuel of the boiler of $C_h = 1\ l/h\ HFO$, we can determine with relations (9) and (10), the quantity required for boarding and the equivalent volume, calculated for 240 h of operation.

$$G'_{c\,HFO} = 1 \cdot 240 = 240\ [t] \quad (9)$$

$$G'_{c\,DIES} = 0{,}15 \cdot 240 = 36\ [t] \quad (10)$$

$$V'_{c\,HFO} = c_1 \cdot c_2 \left(\frac{G'_{c\,HFO}}{\rho_{c\,HFO}}\right) [m^3] \quad (11)$$

$$V'_{c\,DIES} = c_1 \cdot c_2 \left(\frac{G'_{c\,DIES}}{\rho_{c\,DIES}}\right) [m^3] \quad (12)$$

where:
- $c_1 = 1.15 \div 1.20$ - is a coefficient by which a surplus of fuel is admitted, c_2 for unforeseen situations;
- $c_2 = 1.07 \div 1.10$ - is a coefficient that takes into account the reduction in the volume of the tanks due to the residual fuel adhering to the walls of the storage spaces.

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- ρ_0 $[t/m^3]$- is the fuel density

Is chosen:
$c_1 = 1.20;\ c_2 = 1.08$
The values are known:
$\rho_{cHFO} = 990[kg/m^3]$
$\rho_{cDIES} = 840[kg/m^3]$

We replace these values in relations (11) and (12) and obtain the following values (13) and (14):

$$V'_{c\,HFO} = 1.20 \cdot 1.08 \cdot \left(\frac{240}{0.990}\right) = 314.1818182\ [m^3] \approx 314.182\ [m^3] \quad (13)$$

$$V'_{c\,DIES} = 1.20 \cdot 1.08 \cdot \left(\frac{36}{0.840}\right) = 55.54285714\ [m^3] \approx 55.543\ [m^3] \quad (14)$$

3.2. The volume of settlings tanks

The volume of the settling tank is determined using relation (15):

$$V_s = \frac{c_1 \cdot c_2 \cdot 4 \cdot (c_e \cdot P_e)}{\rho_c}\ [m^3] \quad (15)$$

where:
- $c_1 = 1 \div 6$ - represents the number of carts during which the propulsion engine will be fed from the respective tank;
- $c_2 = 1.07 \div 1.10$ - coefficient of increase of the reservoir capacity due to its clogging with viscous residues;
- c_e $[kg/kw \cdot h]$ - actual fuel consumption
- P_e $[kw]$- effective engine power

The volume of the settling tank must ensure the supply of the engine for a period of 24 hours.
Is chosen:
$c_1 = 6;\ c_2 = 1.08$
The values are known:
$c_e = C_{HFO} = 0.24142\ [kg\,/\,kwh]$;
$P_{e\,HFO} = 13{,}842.76764\ [kw]$;
$\rho_{c\,HFO} = 990\ [kg/m^3]$.

Substituting with the known values, we obtain relation (16):

$$V_{d\,HFO} = 6 \cdot 1.08 \cdot \left(\frac{4 \cdot 0.24142 \cdot 13{,}842.76764}{990}\right) = 87.4976 \approx 87.5\ [m^3] \quad (16)$$

For diesel, the volume of the tank is determined with the relationship (17):

$$V_{d\,DIES} = (0{,}20 \div 0.25) \cdot V_{d\,HFO} = 0.2 \cdot 87.5 = 17.5\ [m^3] \quad (17)$$

According to the provisions of Lloyd Register, the heavy fuel (HFO) installation must be provided with two settling tanks.

The total volume of settling tanks results from relations (18) and (19):

$$V^t_{d\,HFO} = 2 \cdot V_{d\,HFO} = 2 \cdot 87.5 = 175\ [m^3] \quad (18)$$

$$V^t_{d\,DIES} = 2 \cdot V_{d\,DIES} = 2 \cdot 17.5 = 35\ [m^3] \quad (19)$$

3.3. Service tank

The volume of the service tank is calculated with relation (20):

$$V_s = c_1 c_2 \cdot 4 \cdot \frac{c_e \cdot P_e}{\rho_c}\ [m^3] \quad (20)$$

where:
- $c_1 = 1 \div 6$ represents the number of carts during which the main engine will be fed from the service tank, the other coefficients having the same meaning as when calculating the volume of the settling tank.

I adopt:
$c_1 = 6;\ c_2 = 1.08$
Substituting with the known values, we obtain (21):

$$V_{s\,HFO} = 6 \cdot 1.08 \cdot \left(4 \cdot 0.24142 \cdot \frac{13{,}842.76764}{990}\right) \approx 87.5\ [m^3] \quad (21)$$

The volume of the service tank for diesel is determined with relation (22):

$$V_{s\,DIES} = (0{,}20 \div 0.25) \cdot V_{s\,HFO} = 0.22 \cdot V_{s\,HFO} = 0.22 \cdot 87.5 = 19.25\ [m^3] \quad (22)$$

According to the provisions of Lloyd Register, there are two service tanks for HFO and two for diesel.

The total volume of the tanks is given by relations (23) and (24):

$$V^t_{s\,HFO} = 2 \cdot V_{s\,HFO} = 2 \cdot 87.5 = 175\ [m^3] \quad (23)$$

$$V^t_{s\,DIES} = 2 \cdot V_{s\,DIES} = 2 \cdot 19.25 = 38.5\ [m^3] \quad (24)$$

Figure 4 presents a model of a service tank

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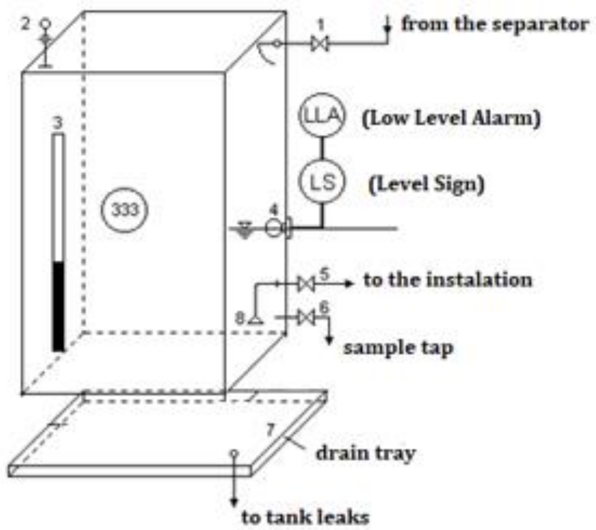

Figure 4. Service tank

Centring the values of the determined volumes, we obtain Table 1 of the form:

Table 1. Necessary volume of fuel tanks

Tank volume	*HFO [m^3]*	*DIESEL [m^3]*
V_c	3,325	705.4
V_c'	314.182	55.543
V_d	175	35
V	175	38.5

4. FILTRATION SYSTEM

Depending on their use, filters are classified into:
- pre-purification filters;
- crude purification filters;
- preventive purification filters;
- fine purification filters.

The first three filter systems are intended to protect the fuel supply system until the suction of the fuel pumps. They are mounted on the fuel boarding piping (pre-purification filters) being typified with simple constructive elements:
- cylindrical casing (pot);
- sealing cover with clingherit or marsitunit gasket;
- cap fastening system;
- tin filter sieve;
- sieve with very small meshes (up to 400 [μm]).

The raw purification filters are usually mounted at the suction of the separators. The preventive purification filters are in the equipment of the sensitive elements in the system (viscometer, flowmeter). These are filters with higher fineness having filter elements made of microporous paper with a fineness of 50 ÷ 150 [μm].

The fine cleaning filter ensures the supply of the highest purity fuel to the high pressure system through the injection pump and injector. From a constructive point of view, the first three types of filters are very varied, being used as filter materials:
- wire sieve;
- metal discs with interstices between them;
- wire filters;
- artificial felt;
- cotton fabrics.

Fine filters must retain about 98 ÷ 99 [%] of particles with sizes between 2 ÷ 7 [μm] and are made up of:
- cotton threads;
- slag wool;
- paper.

The sizing of the filters (or the verification of the correct sizing) consists in determining the filtering surface, and depending on this the dimensions of the filter. The fuel installation of the reference ship is equipped with the filters mentioned in Table 2:

Table 2 The filters in the ship′s fuel installation

Filter type	No of pieces	D_n [mm]	Filter ratio	Fine filtration [mm]
Dual main engine fuel filter	1	65	24	0.5
Double fuel filter boiler of 27,500 [kg steam/h]	1	65	24	0.5
Double fuel filter boiler of 2,000 [kg steam/h]	1	-	-	-
Double filter pumps continuous transfer	1	65	24	0.5

An example of a filter element is shown in the figure 5.

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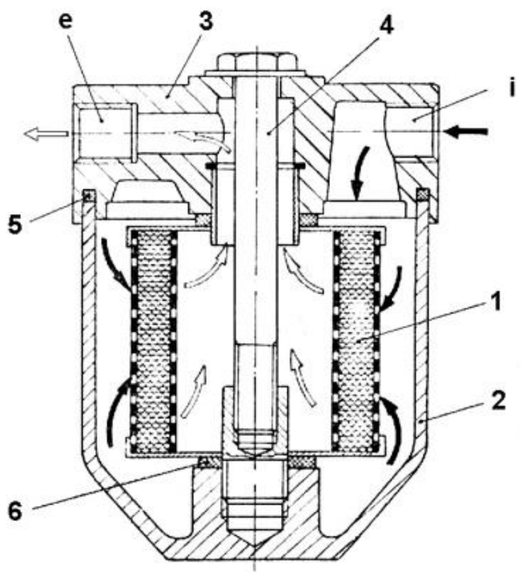

Figure 5. Raw diesel filter with felt filter element: 1 – casing; 2 – cover; 3 – assembly screw; 4 and 5 – sealing gaskets

5. SIZING PUMPS USED IN THE MAIN ENGINE FUEL

The pumps used in the fuel supply system are of the volumetric type:

- ***piston pumps*** - have a maximum suction height, and the practical flow rate changes with the increase in the resistance on the discharge path. The disadvantage of piston pumps is their complicated construction, the mass and dimensions of the piston pump are greater than those of gear or screw pumps
- ***gear pumps*** - they are simple constructions safe in operation, easy to service in operation, with small mass and dimensions, their cost is lower than that of piston pumps. These advantages have led to their spread in naval fuel installations
- ***screw pumps*** - they have become widely used in naval installations for the circulation of viscous liquids. The main disadvantages of these pumps are their complex construction and because of this, their cost is high compared to that of gear pumps.

We adopt the gear pump. The pump consisted of a housing in which two gears rotate on two axes. One of the wheels is considered driving (driven by the engine), the other driven. The play between these wheels and the pump body makes it impossible to direct the liquid in a direction other than the one commanded by the pump. The liquid is drawn by the gaps between the teeth, from the suction chamber to the discharge chamber. In order to protect the pump in the event that the pressure in the installation increases a lot, a safety valve (a by-pass) is provided for the discharge, which allows the creation of a circuit between discharge and suction, thus reducing the pressure.

A pronounced drop in the pump flow is determined by the increase in the clearance between the gears and the pump body.

The flow of this pump is calculated with the formula (25):

$$Q = 2 \cdot Z \cdot n \cdot q \ [m^3/min] \quad (25)$$

where:
2 - the number of gears;
Z - the number of gaps between the teeth (equal to that of the teeth)
n – speed (rpm)
q - the volume of an interval between two teeth $[m^3]$

$$q = f \cdot b \ [m^3] \quad (26)$$

where:
- f - the surface of the interval between two teeth, $[m^2]$
- b - tooth length $[m]$

The flow that the pump must ensure is determined with the relation (27):

$$Q = \Psi \cdot Q_c \ [m^3/h] \quad (27)$$

where:
- Ψ=1.3÷2 safety coefficient; I adopt Ψ=1.3

Actual flow is calculated using the formula (28):

$$Q_c = \frac{C_e \cdot P_e}{\gamma_c} \quad (28)$$

where
- C_e - effective fuel consumption, [kg/kwh]
- P_e - effective engine power, [kw]
- γ_c - specific weight of fuel, [kg/m3]

In formula (27), enter the known data and calculate the values through relation (29):

- For heavy fuel (HFO):

$$Q_{HFO} = \frac{1.3 \cdot 0.24142 \cdot 13{,}842.76764}{990} \approx 4.4 \ [m^3/h] \quad (29)$$

According to the technical documentation of the engine (B & W 8L60MC), we have:

- Circulation pump
  - circulation pump flow rate: 7.7 [m3/h]
  - suction pressure at the circulation pump: 4 [bar]
  - discharge pressure at the circulation pump: 10 bar

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- working temperature, maximum: 150 [ºC]
- viscosity: 20 [cSt]

- Feed pump
  - feed pump flow rate: 3.4 [m^3/h]
  - suction pressure of the feed pump: 4 [bar]
  - discharge pressure of the feed pump: 0 bar
  - working temperature, minimum: 50 [ºC]
  - viscosity, maximum: 700 [cSt]

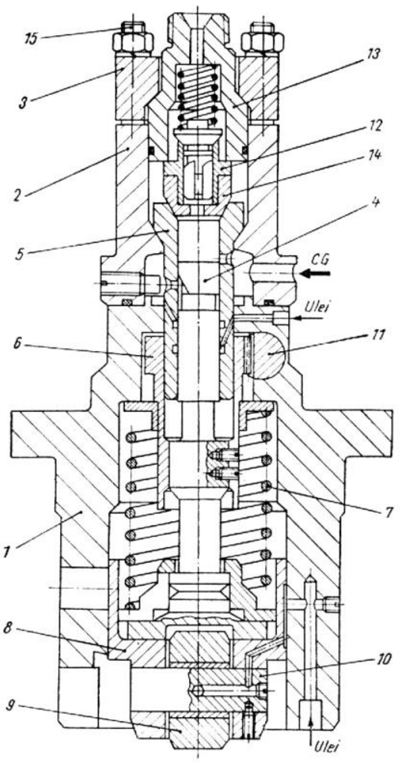

Figure 6 Fuel pump – assembly drawing:
1 – main body; 2 – secondary body; 3 – flange; 4 – piston-drawer; 5 – the cylinder of the discharge element; 6 – bushing; 7 – spring; 8 – taches; 9 – roller; 10 – roller axis; 11 – gear rack; 12 – discharge valve body; 13 – discharge connection; 14 – intermediate piece for centring and tightening; 15 – bolts

6. INJECTORS

The injector is the last component element of the injection equipment, with the role of introducing fuel into the engine cylinders, its fine atomization and the fine distribution of atomized droplets in the combustion chamber. For this purpose, the injector is provided with a sprayer, in which one or more calibrated spray holes are machined. As such, the fine atomization of the fuel is crucially dependent on the construction of the atomizer.

The uniform distribution of sprayed droplets is influenced by the construction of the sprayer but also depends on the organized movement of the air (swirl and swish) in the combustion chamber of the engine.

Injectors are classified according to the criterion of controlling the spray coefficient by a needle-shaped valve, as follows:

- the needle opening command - leads to the solution of a hydraulic injector (hydraulic command) with the diesel to be injected;
- the shape of the needle tip - for this type of injector that works on the engine with unitary combustion chambers we can say that the injector will have the valve - needle with a conical tip.

Thus, diesel injectors with needle valve are closed injectors on the injection equipment with the injection pump separated from the engine.

The advantages of closed injectors are:

- the beginning of the injection occurs at high pressure (100 bar), adjustable by changing a helical spring, which benefits the fineness of the spraying and the penetration of the jet;
- the end of the injection takes place at high pressures with beneficial effects on the penetration of the jet and the burning of the last fractions of injected fuel;
- the dripping and penetration of the flame and hot gases on the channeling from the injector is eliminated.

The disadvantages related to the complication of the technology and the existence of moving parts that determine their wear and, sometimes, seizure, as well as the vibration of the spring-spring system, are eliminated in practice in whole or in part by the proper construction and operation of closed hydraulic injectors.

The body of the injector is made of carburizing quality carbon steel (OLC 15), manufactured by forging. The flat surface of the injector, which is also the limiter of the needle stroke, carbonitriding and hardening (minimum 50 HRC) to avoid deformation and ensure proper tightness.

The sprayers are made from special steels (body from OE-18 CrNi 20), and the needle from (Rp5LS). The sprayer body mates with the needle so that the clearance in the sealing portion is within the prescribed limits (1.5 … 3 μm). Once paired, the sprayer body and needle become a non-interchangeable assembly.

7. CONCLUSIONS

The fuel installation of marine main engines must meet the following requirements:

• must ensure the formation of the fuel mixture in good conditions;

• must ensure the continuous flow of fuel to the injection pump;

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• must ensure the appropriate dosing of the fuel quantity in accordance with the engine's operating regime;
• must ensure the protection of the fuel against contamination with external mechanical impurities and water;
• must ensure the storage of a sufficient amount of fuel for the operation of the engine for a certain duration.

In this paper, we calculated the fuel installation of the main engine by dimensioning the main component elements of the installation such as: storage, settling and service (consumption) tanks.

We also chose the type of fuel supply pump of the main engine - gear pump and determined the flow rate of the chosen pump.

8. REFERENCES

[1] Buzbuchi N and Manea L,(1996). *Naval Engines. Processes and characteristics*, Didactic and Pedagogical Publishing House Bucharest, Romania.

[2] Buzbuchi N and Sabau A,(2001). *Naval internal combustion engines. Constuction and calculation*, Ex Ponto Publish House, Constanta, Romania.

[3] Manea L, Manea A, Buzbuchi N, Dragalina A and Sabau A, (2001). *Thermal engines in the port aria,* Matrix Rom Publish House, vol II: Calculus, Bucharest, Romania.

[4] The MC Engine Basic Research and Test Results, MAN B&W, Diesel Teglholmen Works, Copenhagen, 1993.

[5] https://eur-lex.europa.eu/legal-content/RO/TXT/PDF/

[6] https://www.theengineerspost.com/types-of-ships/

[7] https://www.researchgate.net/figure/Distribution-of-ship-types-across-classes

[8] the prototype ship's internal documentation