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NUMERICAL ANALYSIS FOR THE DESIGN OF THE FUEL SYSTEM OF A SEA GOING TUG BOAT IN THE NIGER DELTA

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ABSTRACT

The fuel oil system is primarily used to ensure that fuel oil is delivered to the engine free from impurities and water. This system comprises of different components, sub-systems, piping and fittings, valves, pumps, filters, tanks and condition monitoring device amongst others. The components of this system were also designed and arranged according to Classification Society rules and regulations. The total fuel consumption of capacity of the booster pump for the main engines and the auxiliary engines were determined, with the view of the total voyage time, this gave clue for the design of the daily service tanks. The capacities of diesel fuel oil transfer pumps were critically calculated with various factors of safety and the storage tank capacities obtained. Fluid velocities and internal diameter of pipe were calculated from the continuity equation. Hence the capacities of flow through pipe in m^3 were determined and the diameters of various booster pumps on board the vessel were obtained through mathematical equations. All designs were carried out obeying classification rules relating to this capacity of the Sea-going Tug Boat bearing in mind the capacity of the load to be transported.

KEYWORDS: Tug Boat, fuel oil system, Pumps, Tanks, Pipe diameter, Fluid Velocity.

INTRODUCTION

The fuel oil system on board a vessel carries out the primary function of receiving fuel oil to the ship, performs adequate cleaning of the fuel and make it ready for the engine (i.e. in temperature, viscosity and pressure of the fuel being delivered). In as much as different fuel types are used, the system should be able to prepare the fuel to meet the requirement of the chosen or given engine to satisfy safe operation. It is also very important that the fuel components and sub-systems meet the requirements of classification agencies such as Lloyd's Register of shipping amongst others. On this note, the fuel oil system may be generally divided in three groups; fuel oil transfer system, fuel oil processing system and the fuel oil servicing system[1].

Fuel

There are some basic definitions of fuel. The crude oil is a mixture of hydrocarbons and contaminate with a wide range of boiling points. Usually it is distilled and further refined by cracking to improve the yield and/or quality of various petroleum products.

The Gas oils are clean, clean distillate (i.e. wide range of petroleum product, produced by distillation) that are shipped in desalinated clear tanks or containers, such as drums. These fuels oils are used for emergency diesel, life boat diesels, etc. which is used commercially ashore and is stable for long storage periods.

The marine diesel oil (MDO) are actually two different fuel oils. MDO - light, this is also known as distillate - Type MDO and HFO - heavy oil which has carbon residues as 0.2% (mass) and 1 .5% (mass) respectively.

The heavy residual fuel oil (HFO) has the highest viscosity and density of any product sold by a refinery as fuel oil. In many cases the ships' systems cannot handle these heavy residual fuel oils, so they are blended to produce a fuel that is suitable for use. The blended residual Riel oil or intermediate fuel oil (IFO) are mixtures of MDO and heavy residual fuel oils (HFO) are blended to improve the viscosity, density vanadium contents, carbon contents or other characteristics of a heavy fuel oil.

Most commercial steamship and motor ships, other than rivers and coastal vessels burn residual fuel because of their lower cost. The ship operators have specifications that reflect their capability to treat and clean the oil. These specifications are generally available from the various sponsoring organization such as international council on combustion engines amongst other. After clearing and treatment, the fuel should meet the engine manufacturer's specifications to enhance the smooth running of the propulsion system[2].

Similarly, high - speed diesel engines are generally operated on marine gas oil and marine diesel oil (distillate type) fuels. Most low and medium - speed diesel engine which have been appropriately designed are capable of burning residual fuels, because they have high tolerance to burn poor grade of fuel due to the time available for the combustion process to take place.

In other engine system the marine diesel fuel oil is used during starting and warm up of the engine after which the engine is "change - over" to heavy fuel for normal continues operation. It is also usual for diesel fuel oil to be used for a short time immediately before shutting down the engine thus ensuring that all pipes lines and working parts in fuel pumps and injectors are cleared off residuals. Figure 1 and 2 shows the internal arrangement of the propulsion system of a sea-going tug boat which make use of the fuel system majorly onboard the vessel.

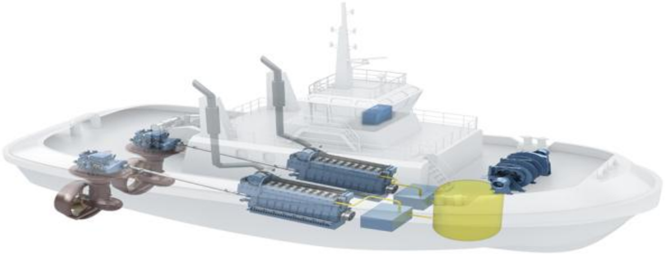

Figure 1: Internal arrangement of the propulsion system of a tug boat (Source Rolls-Royce).[3]

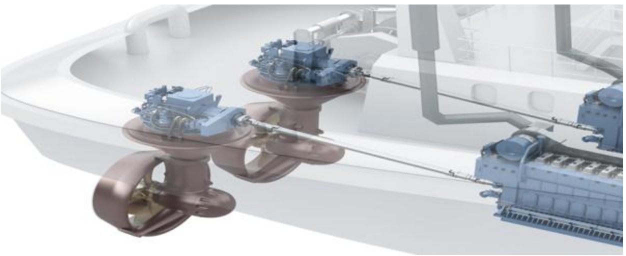

Figure 2: Internal arrangement showing the main engine and the propeller of a tug boat (Source Rolls-Royce).[4]

FUEL PROPERTIES

Viscosity

Viscosity is a measure of a fuel's resistance to flow. The viscosity of a petroleum oil increase when the oil is cooled and decreases when it is heated. For this reason, the viscosity value of oil must always be associated with the temperature at which the viscosity was determined.

The viscosity of a fuel is an indication of the ability to pump, treat and atomize the fuel. It is also a rough indication of the carbon, ash and asphaltene content of a fuel oil. The Viscosity, the easier it is to separate the water and solid particles from the fuel.

Specific Gravity

Practically all liquid petroleum are handled and sold on volume basis - by the gallon, barrel, cubic meter etc. Yet, in most case, it is desirable to know the weight of the fuel quantity. The specific gravity of a fuel is defined as the ratio of the weight of a given volume of the product at 60F (15.5°C) to the weight of an equal volume of water at the same temperature. Specific gravity is determined by floating a hydrometer in the fuel and noting the point at which the fuel intersects the hydrometer scale. The density of the fuel must be specific because it has some effect of the hull resistance and powering of the tug boat which must be considered in the design[5]. Due to the special nature of work of the tug boat a critical analysis of the stress and resistance must be taken into consideration[6].

Ignition Qualities

In diesel engines there is always a delay between the start of fuel injection and the start of ignition, or burning of the fuel. The ignition quality of a distillate/residual fuel is indicated by the octane number. The lower the octane number of the fuel the greater the ignition delay, and the longer the period of time between fuel injection and the beginning of the rapid pressure rise associated with fuel ignition and combustion.

Heating Value

The heating value of a fuel is related to its specific gravity (density) and its sulphur content. The specific gravity of oil increases the carbon-to-hydrogen ratio increase. There are two types of heating values; the lower-heating value and the higher heating value.

The Flash Point

The flash point of a fuel is the minimum temperature at which enough fuel vapour will exist to support momentary .combustion when an ignition source is present near the fuel surface. This is not related to its quality, the flash point is staled to ensure that the fuel can be handled safely.

The Pour Point

The pour point of a fuel is a measure of the temperature at which a fuel will lose its fluid characteristics. The pour point is related to the quality of the fuel, it is only an indication of how cool a fuel can be before it becomes unpumpable. Fuels of the same viscosity may have pour points that are quite different. The pour point depends on the type of crude, the method of refining and the additives used. Other properties (chemical) in the fuel may include

- sulphur content
- Carbon residual/asphaltene
- Compatibility
- Vanadium/nickel content
- Sodium content
- Oxidation product
- Water, sediment, catalytic fine
- Ash content amongst other

THE FUEL OIL SYSTEM COMPONENT

The fuel oil system provides an adequate flow of clean and water free fuel to the engine. These systems consist of tanks, transfer pumps, filter and strainers, piping and valves and condition monitoring devices. Figure 3 shows the typical Fuel oil System of a standard vessel with slight modification for the tug boat because it uses diesel oil fuel with little or no impurities.

Relevant Lloyd's Regulations and Requirement for Fuel Oil System

The rules and regulations of Lloyd's register of shipping are to be striking ashore to in order to enhance the prospective or required effect for design calculation of the various components and sun-systems in the fuel oil system and are suitable for the intended purpose and duty. The fuel oil system consist of the tanks, pumps, strainers, piping, valves, fittings and condition monitoring devices amongst others.

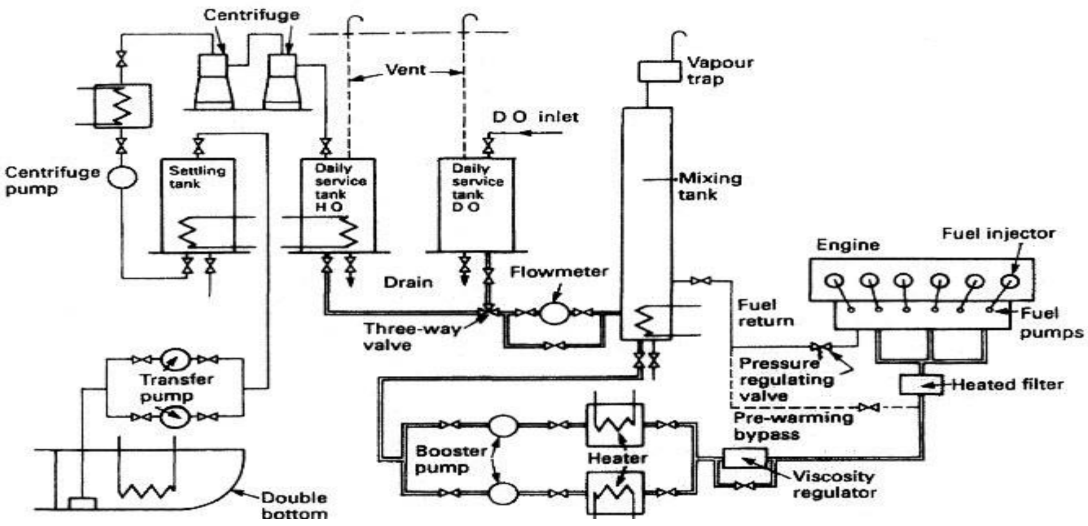

Figure 3. The Fuel oil System[7]

Fuel Oil Tanks

1. Tanks in which oil is heated are to be provided with suitable means for ascertaining the temperature of the oil.
2. The spaces in which oil fuel settling and service tanks are fitted are to be well ventilated and easy to access.
3. In general, the minimum thickness of the plating of tanks when they do not form part of the structure of the ship is to be 5mm.

Fuel Oil Pumps

1. Where a power driven pumps is necessary for transferring oil fuel, a standby pump is to be provided and connected ready for use, alternatively emergency connections may be made to one of the unit pumps control of pumps, the power supply to all independently driven oil transfer pumps is to be capable of being stopped outside the space which will always be accessible in event of fire outbreak.[8]
2. All pumps used in connection with oil fuel are to be provided with effective escape valves which are to be close circuit, i.e. discharging back to the suction side of the pumps and to be adjusted to operate at a pressure of 0.34N/mm^2 above that of the pump escape valve.

Piping and Fittings

1. Oil pipe materials are made of seamless steel or other approved material having welded flanges and joints, the flange are to be machines and the jointed material which is to be imperious to oil heated to higher temperature (150°C) so that the flanges practically metal to metal.

2. Transfer, suction and other low pressure oil pipes and all piping through oil storage tanks are to be made of cast iron or steel having flanged joints suitable for a working pressure of not less than 0.69 N/mm^2. Oil pipes within the engine are filtered to be where they can be readily inspected and repaired and after jointing they are to be tested to 0.34 N/mm^2 or twice the maximum working pressure which even is greater.

3. Every oil fuel suction pipe from a double bottom tank to be fitted with a valve or cock. The valve and cock forming part of the fuel installation are to be capable of being controlled from readily accessible positions which in the engine room is usually above the working platform.

Precautions against Fire

1. Settling and daily service oil fuel tanks and oil filters are not to be situated immediately above boilers and other highly heated surfaces.

2. Oil fuel pressure pipes are to be led wherever practicable, remote from heating surfaces and electrical appliance, but where this is impracticable the pipe are to have a minimum number of joints and are to be led in well lighted and readily position.

Condition Monitoring Devices

Tanks in which oil is heated are to be provided with suitable means for ascertaining the temperature of the oil. Where thermometers or temperature sensing devices are not fitted in blind pockets, are warning notice, in raised letters, is to be fitted adjacent to the fitting starting "Don't remove unless tank is drain".[9]

Special considerations in the design of the fuel system of the tug boat

To enhance the working condition of the tug boat at full load and other sea conditions we must take a critical account of the structural capability, stability of the vessel during bunkering and offloading [10] and [11].

2. MATERIALS AND METHODS

Fuel system design calculations for component, piping and fittings for the Tug boat engines and generators.

The capacity of the engines for the design of the fuel system included

The Starboard side Main Engine - 955KW and 1800 rpm
The Port side Main Engine - 955KW and 1800 rpm
The Starboard side Aux-Engine - 82KW and 1500 rpm
The Port side Aux-Engine - 82KW and 1500 rpm

FI-FI pump set - 133KW and 1800 rpm

General Data for Diesel Fuel Oil (D.F.O)

- Net Calorific value of D.F.O. = 42700 KJ/kg
- Mean overall heat transfer coefficient of fuel = 760 KJ/M2 deg hr
- Specific gravity of .D.F.0. = 900 kg/m3
- Specific heat of D.F.O. = 1.82KJ/kg°C
- Viscosity of diesel fuel oil -5-15 cst at 20°C

Other parameters of the tug boat

Length of Boat	-	28m
Breadth of Boat	-	9m
Moulded depth of Boat	-	4.5m
Gross Tonnage	-	180
Net Tonnage	-	55

Fuel Consumption of Engines

Specific fuel consumption of main engine = 200g/KWhr

s.f.c. = 0.200 kg/KW hr

Total fuel consumption of main engine (B)

$$B = sfc\ x\ SPO \tag{1}$$

Where:-

sfc = Specific fuel' consumption

SPO = Maximum continues shaft power output

By simple substitution

$$B = \frac{0.200kg}{KWhr}\ x\ 955KW = \frac{191Kg}{hr} = \frac{53g}{sec}$$

.'. For the port and starboard main engines

$$B = 2\ x \frac{191Kg}{hr} = 106g/sec$$

Specific fuel consumption for main engine for a voyage (B_H) is assumed a voyage is 7 days

Total number of hours = 24 x 7 = 168hrs

$$B_H = f\ x\ H\ x\ B \tag{2}$$

Where:

f = Correction coefficient = 1.05

H= Total hours for voyage = 168 hrs

B = Total fuel consumption = 382 kg/hr / voyage

By simple substitution

$$B_H = 67.4 \, {}^{tons}/_{voyage}$$

Specific fuel consumption for the auxiliary engine = 205g/KW hr = 0.205 kg/KW hr

Total fuel consumption for auxiliary engine

$$B = sfc \; x \; SPO$$

By simple substitution B = 0.205 x 82 (KW x kg/KW.hr) = 4.67 g/sec

For both auxiliary engines B = 2 x 16.81 kg/hr = 9.34g/sec

Specific fuel consumption for auxiliary engine for a voyage (B_A)

$$B_A = f \; x \; H \; x \; B \tag{3}$$

by substituting the values

f = 1.05

H = 168hrs

B = 33.62 kg/hr

We have that

$$B_A = 1.05 \; x \; 168 \; x \frac{33.62 \frac{Kg}{hr}}{Voyage} = 5.931 \; tons/voyage$$

Total fuel consumption for main and auxiliary engine for a voyage of seven day is

$$B_O = B_A + B_M = [5.931 + 67.385] \, {}^{tons}/_{Voyage}$$

Capacity of Fuel Oil Booster Pump

The capacity of fuel oil booster pump

$$Q = \frac{f_p \; X \; sfc \; x \; SPO}{\rho} \tag{4}$$

Where:-

f_p = fuel oil circulation coefficient, (assume f_p = 2-3)

sfc = Specific fuel consumption (kg/KW hr)

S.P.O. = Shaft power output (KW)

ρ = Density of fuel oil (kg/m^3)

I oil booster pump for the main engine (Q_{BM})

$$Q_{BM} = \frac{f_p \; X \; sfc \; x \; SPO}{\rho}$$

Where:-

f_p = 3

sfc = 0.200 kg/KW hr

S.P.O. = 955KW

ρ = 900 kg/m^3

By substitution

$Q_{BM} = 1.76 \times 10^{-4}$ m^3/s

Similarly, the capacity of fuel oil booster pump for the auxiliary engines (Q_{BA})

$$Q_{BA} = \frac{f_p\, X\, sfc\ x\ SPO}{\rho}$$

f_p = 3

sfc = 0.205 kg/KW hr

S.P.O. = 82 KW

ρ = 900 kg/m^3

By substitution

$Q_{BA} = 1.56 \times 10^{-5}$m^3/s

Capacity of D.F.O. Storage tank

Total capacity of diesel fuel oil (D.F.O.) storage tank (F_{ST})

$$F_{ST} = \frac{Total\ fuel\ consumption\ main\ and\ auxilliary\ engines}{fuel\ density} \tag{5}$$

$$F_{ST} = \frac{B}{\rho} = \frac{B_A + B_M}{\rho} \tag{6}$$

where:-

B = 73315 Kg

ρ = 900 kg/m^3

By substitution

Total capacity of D.F.O. storage tank $F_{ST} = \frac{73315}{900} = 81.46m^3$

Capacity of D.F.O. Daily Service Tank

The capacity of diesel fuel oil daily service tank (F_{DT})

$$F_{DT} = \frac{sfc\ x\ SPO\ x\ T\ x\ n\ x\ i}{\rho}$$

ρ = Density of diesel fuel oil

s.f. c. = Total specific fuel consumption = (0.205 + 0.2) kg/KW hr

S.P.O. = Total shaft power output= (955 + 82) KW

T = time = 1 hr

n = number of generators = 2

i =1.1 (90% filling of tank) = 1.1

By simple substitution

$F_{DT} = 1.027\ m^3$

Capacity of D.F.O. Transfer pump

The capacity of diesel fuel oil transfer pump may be assessed from the relation

$$Q_{DFO} = \frac{V_{ST}}{t} \quad (7)$$

Q_{DFO} = D.F.0. Transfer pump capacity

V_{ST} = D.F.0. Service tank capacity = 1.0 m^3

t = time of filling = 1/5hr = 12min

$$Q_{DFO} = \frac{1.0}{1/5} = 5\,{}^{m^3}\!/_{hr}$$

Capacity of Dirty Oil Tank

The capacity of density .oil tank should be equal to or greater than the capacity of the diesel fuel oil daily service tank.

CALCULATION OF MAJOR PIPE DIAMETER

Pipes and fitting form an indispensable part of a ship's power plant, more so they carry and control flow of fluid at different temperature and pressure. In pipe selection, the system would be regarded a failure initially or during service for reasons such as:

- It does not perform the required function
- It does not give the specific output
- It is expensive to run
- It wears out before its designed working life
- It incurs regular fault.

Therefore, in the selection of the pipe work the choice between high investments with reduced maintenance cost are considerable against low initial investment with high maintenance. Hence, materials chosen must meet all the specified requirement and have a high level of reliability.[12, 13]

Similarly, in installation, the correct materials for the duty (e.g. fuel oil, required and flexible structure) must be utilized e.t.c. The materials for fuel oil piping are specified by Lloyd's Register of shipping is seemlier mild steel.

Pipe Diameter and Fluid Velocities

The life of the pipe depends to a high degree on the adherence to critical design velocities. The effect of normal velocity is negligible on the more resistance alloys, but a velocity and turbulence increase, the life span of pipe is reduced - e.g. corrosion of tube.

Note:- The calculated velocity V, must not exceed the limit velocity V_{MAX}. The internal diameter of pipe can be calculated from the continuity equation.

$$Q = A \, x \, V \tag{8}$$

Where:-

Q = Discharge

v = velocity

A = Area

$$Q = A \, x \, V = \frac{\pi {D_L}^2}{4} \, x \, C\sqrt{D} \tag{9}$$

$$Velocity = C\sqrt{D} \le V_{MAX}$$

1m = 1000mm

$$Q = \frac{\pi {D_L}^2 \, x \, C\sqrt{1000} \, x \, \sqrt{D}}{4}$$

$$Q = \frac{\pi\sqrt{1000}}{4} \, x \, C \, x \, {D_L}^{2.5}$$

$$Q = 24.84 \, x \, C \, x \, {D_L}^2$$

By making D, the subject of relation

$${D_L}^{2.5} = \frac{Q}{24.84 \, x \, C}$$

$$D_L = \left[\frac{Q}{24{,}84 \, x \, C}\right]^{0.4}$$

Where:-

Q = Capacity of flow through pipe in m^3

V = Fluid Velocity in m/s

D_L = Internal diameter of pipe in mm

C = Flow coefficient obtainable from reference table

V_{MAX} = Maximum allowable velocity of flow through pipe in m/s.

Fluid Design Velocities

Table 1 shows the fluid design velocity for tug boats at the suction and discharge pipes for the transfer pumps.

Table 1: The fluid design velocity.[14]

Service	Fluid Velocity C=V (m/s)	V_{MAX} (m/s)
Fuel oil service discharge	$0.09\sqrt{D_L}$	1.8
Fuel oil service suction	$0.06\sqrt{D_L}$	1.2
Fuel oil transfer suction	$0.06\sqrt{D_L}$	1.8
Fuel oil transfer discharge	$0.12\sqrt{D_L}$	4.5
Diesel oil transfer Suction	$0.12\sqrt{D_L}$	2.1
Diesel oil transfer discharge	$0.30\sqrt{D_L}$	3.65

Pipe Calculation, Selection and Flow Velocities

Diameter of D.F.O. transfer pump

Diameter of diesel fuel oil transfer pump suction pipe

We have generally as

$$D_L = \left[\frac{Q}{24{,}84\ x\ C}\right]^{0.4}$$

For the transfer pump

$Q = 5m^3/hr = 1.04\ x10^{-3}m^3/s$

From the table

C = 0.12suction and C = 0.30 discharge

By simple substitution

$$D_L = \left[\frac{Q}{24{,}84\ x\ C}\right]^{0.4} = 41mm$$

Selected pipe diameter is 40mm

=> Suction velocity $V_{Suct} = C\sqrt{D_L}$

$$V_{Suct} = 0.12\sqrt{0.041}$$

0.024m/s < 1.8m/s

Diameter of diesel fuel oil transfer pump discharge pipe

C = 0.30.

By simple substitution

$$D_L = \left[\frac{1.04\ x\ 10}{24{,}84\ x\ 0.30}\right]^{0.4} = 29mm$$

Selected pipe diameter is 30mm

$V_{disch} = C\sqrt{D_L}$

$$V_{disch} = 0.3\sqrt{0.029}$$

0.051 m/s < 4.5 m/s

3.2 Diameter of Booster Pump

Diameter of main engine Booster pump suction pipe

Generally we know that

$$D_L = \left[\frac{Q_{BP}}{24{,}84\ x\ C}\right]^{0.4}$$

Q_{BP} = Booster pump capacity of main engine

$Q_{BP} = 0.037\ m^3/hr = 0.177\ x\ 10^{-3}\ m^3/s$

C = 0.12 suction

C = 0.30 discharge

By simple substitution

$$D_L = \left[\frac{0.177\ x\ 10^{-3}}{24.84\ x\ 0.12}\right]^{0.4} = 20.4mm$$

Selected standard pipe diameter is 20 mm

$V_{Suct} = C\sqrt{D_L}$

$$V_{Suct} = 0.12\sqrt{0.0204} = 0.017 m/s$$

0.017 m/s < 1.8m/s (V^MAX)

Diameter of main engine booster pump discharge pipe

$$D_L = \left[\frac{Q_{BP}}{24.84\ x\ C}\right]^{0.4}$$

For this C = 0.3

By simple substitution

$$D_L = \left[\frac{0.177\ x\ 10}{24.84\ x\ 0.3}\right]^{0.4} = 14mm$$

Selected standard pipe diameter is 15 mm

$V_{Suct} = C\sqrt{D_L}$

$$V_{Suct} = 0.3\sqrt{0.014} = 0.0357$$

0.0357 m/s < VMAX = 4.5m

Diameter of auxiliary engine booster pump suction pipe

Generally

$$D_L = \left[\frac{Q_{BA}}{24.84\ x\ C}\right]^{0.4}$$

Q_{BA} = Booster pump capacity of auxiliary engine

Q_{BA} = 0 0156-x 10^{-3} m^3/sec

C =0.12 for suction

C = 0.30 for discharge

.'. By simple substitution

$$D_L = \left[\frac{0.0156\ x\ 10}{24.84\ x\ 0.12}\right]^{0.4} = 7.7mm$$

Selected standard pipe diameter is 1.0 mm

$$V_{Suct} = C\sqrt{D_L}$$

$$V_{Suct} = 0.12\sqrt{0.0077} = 0.011$$

0.011 m/s < V_{MAX} = 2.1 m/s

Diameter of auxiliary engine booster pump discharge pipe

Generally

$$D_L = \left[\frac{Q_{BA}}{24.84\ x\ C}\right]^{0.4} = 0.00535m$$

= 5.35 mm

Selected standard pipe diameter is 10mm

$$V_{Suct} = C\sqrt{D_L}$$

$$V_{Suct} = 0.3\sqrt{0.00535} = 0.022$$

0.022 m/s < V_{MAX} =3.0m/s

3. RESULTS DISCUSSIONS

The design of the fuel system for a sea going tug boat has shown that specific fuel consumption for main engine for a voyage (B_H) with the assumption that a voyage is 7 days is seen as $67.4\ tons/voyage$ while that of the auxiliary engine is put at $5.931\ tons/voyage$ bringing the total fuel consumption as $73.331\ tons/voyage$. The fuel oil booster pumps capacities for the main and auxiliary engines are designed to be 1.76 x 10^{-4} m^3/s and 1.56 x $10^{-5}$$m^3$/s respectively. Similarly the design capacities for the storage and daily service tanks for the diesel fuel oil is seen to be $81.46m^3$ and 1.03 m^3 respectively. With these figure the design of the fuel system for a sea going tug boat can make a voyage for 7days successfully without having any fuel challenge. All designs were done in accordance to the Lloyd's specification rules and regulations for a sea going tug boat. It is important to state here that this is for a still and calm weather operation, bearing in mind a design allowance should be given for harsh weather operations for the tug boat.

4. CONCLUSION

The fuel oil system is primarily used to ensure that fuel oil is delivered to the engine free from impurities and water. This system comprises of different components, sub-systems, piping and fittings, valves, pumps, filters tanks and condition monitoring device amongst other. Because of special operation of the tug boat, components of the fuel system were also designed and arranged according to Classification Society rules and regulations. It is important to state here that this is for a still and calm weather operation, bearing in mind a design allowance should be given for harsh weather operations for the tug boat.

5. REFERENCE

1. Caterpillar Engine Division (1990), Caterpillar Marine Engines Application and Installation Guide, Printed in USA.
2. Detroit Engine Division (1990), Detroit Diesel Engines Manuel (Series 149), Printed in Holland.
3. Neil Gilliver (2014), Rolls Royce to Power Asia first gas Powered Tug, available online www.safty4sea.com 25/04/2015.
4. Azimuth Drive (2015) Related Keywords and Suggestions, available online, www.suggest-keywords.com 25/04/2015.
5. Dick, I. F., & Nitonye, S. (2015). Effect of fluid density on ship hull resistance and powering. *International Journal of Engineering Research and General Science*, 3 (1), 615-630. (http://www.ijergs.org).
6. Nitonye Samson, (2015). Stress and Resistance Analysis for the Design of a Work Barge, *International Journal of Scientific and Engineering Research, (IJSER) India* Vol.6 No: 5, (pn-1064974).(http://www.ijser.org).
7. Woodward Governor (2015), Fuel oil System for a Diesel Engine, available online, www.machineryspace.com 25/04/2015.

8. Lloyd's Register of Shipping (1976), Lloyd's Rules and Regulations for the Construction and Classification of Steel Ships. Liody's Publisher
9. Roy L. Harrington, (1976), Marine Engineering. The Society of Naval Architect and Marine Engineering.
10. Nitonye, S, and Adumene, S. (2014). Numerical and Experimental Analysis for the stability of a 2500 Tonnes Offshore Work Boat. *International Journal of Applied Science and Engineering*, 3 (6), 1041-1053. (http://www.ijaser.com)
11. Nitonye, S., Ogbonnaya, E. A., & Ejabefio, K. (2013). Stability analysis for the design of 5000-tonnes Offshore Work Barge. *International Journal of Engineering and Technology*, 3 (9), 849-857. (http://www.ijet.journal.org)
12. Urbanski P, Nierojewski K and Douglas I.E. (1983), Methodology for Determining the Main Characteristics of Auxiliary Machines in Marine Diesel Power Plant. Department of Marine Engineering, Rivers State University of Science and Technology Port Harcourt.
13. Inegiyemiema, M., & Nitonye, S. (2015). Hydrodynamic analysis of a column structure of a petroleum storage tank. *International Journal of Scientific and Engineering Research*, 5 (1), 739-752. (http://www.ijser.org)
14. The Engineering ToolBox, (2015) Flow of liquids, gases and vapors – typical Pipe- fluid velocities, available online www.engineeringtoolbox.com/fluid-velocities-pipes 25/04/2015.