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WORLD MARITIME UNIVERSITY

MALMO - SWEDEN

UTILIZATION OF DIESEL ENGINE IN HARBOUR MARINE CRAFTS

BY

Beneberu Tadesse

ETHIOPIA

A dissertation submitted to the World Maritime University in partial fulfillment of the requirements for the award of the degree of Master of Science in Maritime Education Training (Engineering).

Year of graduation 1992

I certify that all material in this dissertation which is not my own work has been identified and that no material is included for which a degree has been previously conferred upon me.

The contents of this dissertation reflects my personal views and are not necessarily endorsed by the University.

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I wish to express my gratitude to the Canadian Government who through ICOD made possible my two years study at the World Maritime University.
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Finally my heart felt thanks to the Ethiopian Marine Transport Authority's management for forwarding my name to the World Maritime University for nomination.

Abstract

Utilization, as defined by the Longman Dictionary of the Contemporary English is "to make good use of".
In the same manner, utilization of a marine diesel engine on board a marine vessel is to be able to operate the engine to its designed capacity as to obtain the maximum service with minimum operating costs.

Thanks to the modern technology that most of the marine diesel engine's failures arising from low quality material and design have dramatically reduced.

Machinery failures related to incorrect operation constitute a significant part of the total failures. Disregarding a simple operating procedure or failure to correct minor faults in good time, may cause a more serious problem. This happens quite often, specially where marine environment effect on machinery is not that much appreciated. In most of the cases marine machineries are operating under the influence of the unstable sea conditions. Load variation, excessive vibration and corrosion are common on machines operating at sea.

Inadequate training, lack of efficient operational organization and administration also leads to inefficiency and early failure of machinery.

This paper tries to highlight some of the major factors that could enhance efficient operation of a marine vessel in general and ship's machinery in particular.
The emphasis will be on the main propulsion unit, that is the main diesel engine.

Starting by the development of diesel engines as an introduction, ways and means of maintaining good operation of a marine vessel, fuel oil, lubricating oil and diesel engine cooling system will be discussed through chapters two to five.

Chapter six will conclude by stressing the need for training, good operational organization and management.

As a recommendation, the need for establishment of a harbour marine vessel's technical supervision section is given. This is my strongest belief that if the marine vessel's technical supervision section is established, much of the present problems such as untimely failures of machines, acute shortages of spare parts will be reduced. Most of all mishandling of machines due to lack of proper training and inefficient use of spare parts will improve, which will enhance efficiency, safety and dependability.

CHAPTER ONE

INTRODUCTION

1.1 Diesel engine development.

In about 1892, Dr. Rudolf Diesel's invention, the high compression self ignited engine became operational. It was intended to burn coal but later, in 1898 fuel oil burning engine was developed and it was named, Diesel Engine.

The diesel engine application shown progress first in the rail ways and around 1905 the French Navy began using diesel engine in the marine field. As technology developed, new and better engines were built or the previously built once were improved and developed.
The main driving forces behind these developments or new inventions were always, economy, efficiency and safety.

The demand for fuel efficient engine is always high up on the engine selection criteria list. This means, an engine has to operate efficiently, safely for a long time at a reasonable operational costs. To meet this demands, different types of engines have been built and still are being built with improved power delivering capacity, specially in the marine field a tremendous progress have been made.
The steam turbine gave way to the gas turbine and after some time the gas turbine was taken over by the slow speed cross head diesel engine family. At present diesel engines are the most popular prime movers all over the world.

In marine application, the two stroke cycle slow speed cross head diesel engine is known for its high power delivering capacity. It is directly coupled to the propeller shaft to drive a large diameter propeller which can exert a high torque. It burns low grade fuels and has a high thermal efficiency and being two stroke cycle, it dose not need components like intake valves, which is a reduction in maintenance and simplicity of engine construction. As a result today, many of the worlds larger ocean going vessels are propelled by this type of diesel engine. The slow speed diesel engines range from 60 to 120 rev/min. Fig. 1 shows a MAN B&W L70MC type slow speed engine.

The over all advantages of diesel engines over the others, like gasoline engines, gas turbine engines and steam turbine engines are:

1. low specific fuel consumption;
2. burns cheap fuel as compared to gasoline engines;
3. compact and simple to operate as compared to steam engines;
4. safe operation, as diesel fuel is less flammable;
5. economy at light load.

Diesel engines are more advantageous when compared to other engines in many ways but still there are some minor disadvantages.

Cost. Initial cost of a diesel engine is higher than the gasoline engine. Because of the high pressure diesel engine produces during operation, its construction has to be sturdier and quality materials have to be used.

Weight. Diesel engine weighs more than the gasoline engine for the same power output. Ships are very sensitive to weight as it affects stability.

Space. A high power output engine requires heavy and large components which will occupy large areas.
This is one of the disadvantages for the slow speed diesel engine's ship board usage. On board ships, space is very much important for cargo stowage.

Two-stroke cycle slow speed diesel engine.

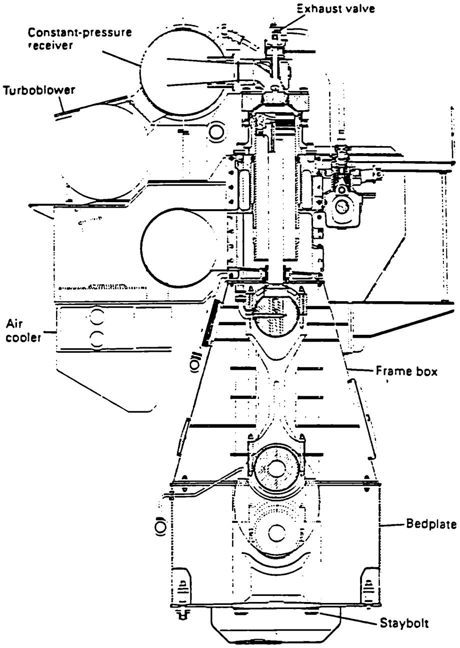


Fig. 1 MAN B&W L70MC Engine

From D.A. Taylor's Introduction to Marine Engineering, Second edition

Ships like car ferries, passenger ferries and container carriers, where over head height is very much needed, the bulky slow speed cross head diesel engine is not appreciated.

To overcome these deficiencies, an other family of diesel engine, the medium speed diesel engine has been developed. These are engines in the range of 250 to 750 rev/min. Those in the range of 400 to 1000 rev/min. are categorized as the medium high speed diesel engines. The medium speed diesel engines have shown advantages in providing better power to weight ratio and power to size ratio. Initial cost is also lower than the bulky slow speed diesel engines for the same power. For marine propulsion, the medium speed diesel engine requires gearbox and couplings and the smaller cylinder sizes necessitated an increase in the number of units. These seems an additional maintenance and operational costs but the increased speed will compensate some of these extra costs. At the present development stage of both types of diesel engines, it is impossible for one to claim advantage over the other. Because both are needed for certain types of operation and they are very efficient, dependable and economical in their respective types of operation. Fig. 2 shows a " V " type Pielestick medium speed engine.

Future development of medium speed diesel engine is towards higher power outputs per cylinder. Some medium speed diesel engines, fitted on LPG, product tankers, fast refrigerated vessels and container ships have shown satisfactory operating conditions. However, the search for high power output is forcing engine builders towards the increase of the size of components. This means the loss of one of the advantages, namely, size, which have been enjoyed by medium speed diesel engine family for a long time.

Four-stroke cycle medium speed diesel engine.

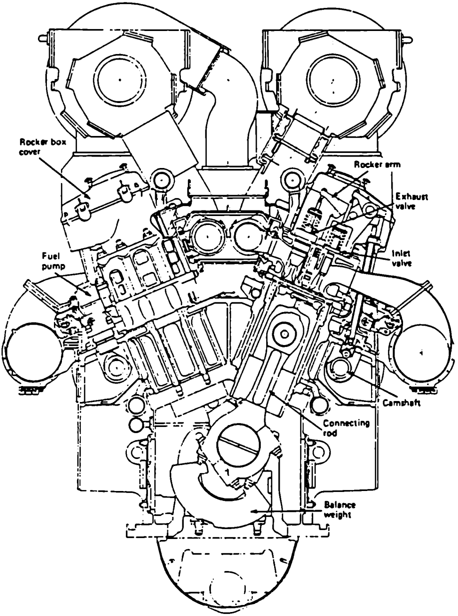


Fig.2 " V " type Pielestick PC4 diesel engine.

Taken from Introduction to Marine Engineering, seconmd edition.

The following figures give some ideas of the trend.

cylinder bore ---------- 560 mm.
Stroke --------------- 600 mm.
Speed --------------- 400 rev/min.
Power per cylinder ----- 1000 kw

Over all dimensions of a 12 cylinder "V" type engine.
Length ---------------- 9.5 m
Height ---------------- 4.0 m
Fuel consumption ------ 200 g/kwh
Thermal efficiency ---- 42%
(From Reeds Marine Engineering series vol. 2 pg. 175).

The main criterias for a diesel engine selection are:

1. Low initial cost
2. High level of reliability.
3. Reduced weight and fuel efficiency.
4. Low toxic gas emission.
5. Simplified maintenance system.
6. High power output.

Modern technology has achieved in making highly efficient engines. To exploit this highly sophisticated achievement of technology, certain operating principles have to be followed. Adequate knowledge of the working principles of the engine has to be a pre-requisite for efficient engine operation. The quality of material of the components and design will be useless without the proper operational procedures.

The sea is such a harsh environment for machines, that extra care and understanding of the exact operating principles of a machine have to be understood properly. It is a challenging working environment both to the machine and the operator. Various external forces such as wave, current, wind, etc. are acting on marine machinery. The reciprocating pistons and rotating crankshaft of an engine generates certain amount of vibration forces. In addition to these, the motion of the sea generates an other external vibration forces on the engine. All these have a significant impact on efficiency of a marine engine. The corrosive nature of the sea water is an other source of problem to machines operating in the sea environment. Through understanding of the nature of the sea environment and experience, can one achieve successful marine engine operation.

1.2 Assab port and diesel engine operating experience.

1.2.1 Experience on high speed diesel engines.

The Assab Port administration operates all the cargo handling equipment like cranes, towing tractors, fork lifts, heavy trucks and gasoline engines.

There is a well established maintenance and repair shop operated by the port administration. The shop is sub-divided into sections to facilitate maintenance and repair of the different types of equipment. For example, a heavy truck maintenance section has all the necessary tools and man power to carry out the required maintenance and repair on all the heavy trucks. The same is true for the other sections.

Trained man power is no problem in these fields as the country's education system incorporates technical high schools and a polytechnic institute to train young students as mechanics, auto-electricians, body repair, machinists, etc. Every year, a certain number of newly graduated recruits will join the organization.

A variety of high speed diesel engines from almost all the major engine manufacturers in the world can be encountered here, and they are well operated and maintained.

The fact that the work shop is mainly established to handle the shore equipment maintenance and repair, gave it the opportunity of having the necessary financial and material support from the administration. Unlike the marine vessels, the shore based machines are in a better position, with regard to maintenance organization.

1.2.2 Medium speed marine diesel engine experience.

The Assab Port's experience on the marine diesel engine is not developed as it had on the high speed diesel engines mostly used for land based operations.

Although the country's shore line stretches over 860 nautical miles, there has been no significant marine activity for a long time.

There are various reasons but the main reasons are:

a. **Environment** - the severe climatic conditions of the Red Sea coast is not suitable for permanent settling.

The temperature averages 37 degrees centigrade most of the year and in summer there is a sand storm which covers most of the sea coast. This type of climatic conditions stretches 120 km. inland in all fronts.

b. **Lack of valuable raw materials.** So far there is no commercially valuable raw material which could have attracted foreign investors and as a result, ports and shipping would have developed long time ago. Or the country's weak economy is an able to develop to boost export and import. These and many others hampered the development of the Red Sea coast, which is also a reason for the lack of knowledge of any thing marine.

However, the world is changing and technology is gradually reaching every corner of the earth.

As Ethiopia is a part of the world community, technological development is gradually showing its effect on the country as a whole.

As a result, in the early 60s, Assab Port was constructed immediately followed by the foundation of the Ethiopian Shipping Lines. It is then that the Assab Port started harbor marine vessels operation. Today the port has grown in its cargo handling capacity and about 80% of the country's import and export are handled through this port.

To facilitate the ever growing port activities, three harbor tugs were bought between 1980 and 1988. The previous tugs were less powerful (about 750 HP maximum), and their machinery operating systems were not so that with minimum working knowledge of a diesel engine, minimum operation was possible. But the present day marine engines are very complicated and they need more knowledge of engineering to operate efficiently with an acceptable safety standard.
A lot of sensitive electronics, electrical and pneumatic control systems are used.

The new tugs main engines are all four-stroke cycle, six cylinder, in-line, trunk piston type, turbo-charged and air cooled medium speed diesel engines.
Even though, it is only a practical knowledge gained over the years without any formal training, there are many operators of medium diesel engines like the UK. built, model BSC 37-E Allen diesel engines, Japanese 6MG25CX, 6MG20BX, Yanmar diesel engines, MWM, etc.
How ever small a marine vessel, it is a complex vehicle which must be able to operate for a long time with a high degree of reliability. The machinery on board are mostly working in relation to one an other as a system. The system's complexity vary from vessel to vessel but a modern tug, at least has a main engine, more than two diesel generator, compressors, steering gears, gearbox, various pumps, pneumatic remote control system, switch board and control panel. To operate these complex system efficiently, adequate knowledge of the systems working principles have to be understood thoroughly.

1.3 Harbour marine crafts and Assab Port. Harbor marine crafts are those vessels which are engaged in specialized services such as pushing or pulling in harbour where maneuvering is difficult for the bigger ships.

Modern tugs are multi-purpose vessels whose activities ranges from ship handling in port to deep sea towing. Fire fighting, anti-pollution, salvage, rescue missions, coastal light house services, etc. are a few of the tugs activities In general, tugs are the beginning and end of the port operations. Without tugs, ports are nothing and without efficient port services, shipping can not be effective in the world trade.

Shipping is a very sophisticated and competitive industry. One of the areas of competition is reduction of the ship's time in port as much as possible. The time a ship takes to load and unload have a special meaning to a ship operator. Because much of the profit a ship makes depend on how it complies with its pre-set schedules.

Ports are obliged to facilitate ships operation in harbour otherwise, it will lose credibly which lead to loss of customers. This is against the interest of the port and the country as a whole.

Geographical location, capacity and significance of the port to shipping are also determinant to ports activities Therefore, it is important to look at the over view of port of Assab in brief to be able to appreciate harbor tugs activities.

Location-- Assab Port is located on the Red Sea coast of Ethiopia. It is near to the Straight of Bab el Mandeb, the southern outlet of the Red Sea.

Ships that sail from South-East Asia, on their way to Europe mostly call at Assab for refueling, to load fresh water and even for a minor maintenance.

Capacity-- The port can accommodate six ships of 15,000 GRT. at a time. There is a sea berth for crude oil tankers and two oil product loading terminals. A new container terminal is under construction to handle container ships. This shows that the port has a potential of becoming an important logistical centre between Asia and Europe.

Significance-- Besides its being near the international shipping crossroads, the port is the main outlet for the country. Eighty percent of the countries imports and exports are handled through this port. The national shipping fleet, whose home port is Assab, have grown both in number and cargo carrying capacity. Over the last ten years the number has increased from a few coastal cargo ships to over ten sea going ships with a variety of cargo carrying capacity. The easy approach and suitable anchorage area of the Port of Assab is also another attraction for ships sailing the Red Sea. So, there is a demand for tug services throughout the year.

1.4 Operational constraints.

a. Lack of trained man power.

Trained man power is vital to any type of operational success. The highly sophisticated modern day machines need substantial technical knowledge to operate.
Marine oriented machines are even more demanding than the land based machines.
To acquire skill, training is a must. In Ethiopia, the absence of marine training institute is one of the causes for the inefficient operation of marine oriented machines.

The national shipping lines trains its officers abroad. For the port administration, who only operates tugs and pilot boats, sending personnel abroad for training is uneconomical. On the other hand, port is such an important and multi-purpose industry which generates the much needed foreign currency. It is also quiet obvious that no country in the world can develop with out having some sort of trade with an other country. Therefore, port and its equipment have to be operated in a manner compatible to the international standard.

Equipment operation based on practical knowledge will have some deficiency. In the world of severe competition, quick and correct solution to a problem are what matters most. Trial and error or time consuming trouble shooting method is not appreciated, because time is money specially in the shipping business. The degree of efficiency with which the port operates is a measure of its ability to attract customers. To fulfill these important task, operators and maintenance personnel have to be trained. Short term training programs like skill upgrading courses and on the job training could be an effective way of increasing efficiency and safety.

b. **Organizational deficiency.**

The harbor marine crafts are operated by the Port administration. Administration and the day to day operation of the vessels are the responsibility of the harbour master, while the technical and manning of the engine room crew is controlled by the Port's engineering division.

As the two departments have no proper communication or co-ordinated operating system, there is always misunderstanding, specially concerning maintenance.

The harbor master who is usually not a technical person favors, the " run up to breakdown", policy. In his view, a tug should not be out of operation for inspection or any sort of preventive maintenance. His reasoning is that stopping a tug for a simple inspection is unnecessary waste of hire time. As there is no technical supervisor, who can program and plan maintenance schedules, and be able to convince the administration on the importance of planned maintenance, the harbor vessels will continue to be poorly operated. Some signs of lack of timely maintenance are already visible on the harbour marine crafts such as reduced pulling or pushing power, reduced speed, increased vibration of propellor and high exhaust temperature even at half load.

c. **Working environment.**

The Red Sea coast as a whole is very hot and dusty. The salt concentration is the highest of all the seas (40 per thousand). Any metallic equipment operating in this type of climate condition is very much exposed to corrosion. Sea water pumps, pipes and coolers are the most vulnerable parts of the engine. The consumption of such components are usually very high for vessels operating in the Red Sea. The lubricating oil, fresh water and air coolers need cleaning at least in an interval of three months, which is an increase in ship's out of hire. Above all, the discomfort the climate creates on operators is a serious problem. In the normal circumstances, air conditioner or at least ventilators have to be used to stay in a closed space. Engine rooms are naturally very hot even when the outside temperature is cold. One can imagine how severe the engine room could be when the open air temperature soars above 37 deg. centigrade.

Watch keeping may be carried out from a closed air conditioned room but the real trouble is when the need for maintenance arises. It needs a real devotion to carry out a satisfactory job in such severe climatic conditions.

d. **Spare parts.**

Maintenance and repair costs are the major expenses for a marine vessel operator. The cost of spare parts, man hour and the vessels off hire added together can be quite a huge some of money. Therefore, every marine vessel operator's prime objective is to reduce the maintenance and repair costs. This needs a very strict management of spare parts which calls for:

- effective use of spare parts;
- monitoring and recording of operating conditions of components so that effective utilization up to

maximum wear limit could be achieved;

- set priorities as to which part needs replacement, based on records of machinery operating conditions;
- keeping high and low limits of the spare parts and request purchase in good time.

The timing of requesting purchases is very important due to various reasons.

The main reasons being:

1. the ever present shortage of foreign currency;
2. the unstable world market;
3. rigid bureaucratic working systems in the various ministries who are responsible for transferring money to a foreign bank;
4. geographical distance between the manufacturer and purchaser plus the time it takes to arrive at its destination.

In many occasions, i have witnessed a vessel lay out of operation due to lack of some kind of spare part for up to a year until the grant for foreign currency was secured and a minimum of a month after an urgent purchase order has reached the manufacturer. In view of all these, good and effective spare parts management is crucial for a harbour marine vessel operator like the Assab Port administration. It is crucial because the Port's access to foreign currency is through the Ministry of Transport, Cabinet Ministers and through the National Bank. To pass through this jungle of bureaucracy needs quite an effort and above all it takes the most precious time. Therefore, it is better to start as early as possible.

To be in control of the unexpected situations, it is good to have an efficient spare parts control system, keep data on operating components to make intelligent prediction as to when the component needs replacement. It is important to keep in mind that good organizing and planning are always the key factor to all of these.

CHAPTER TWO

MAINTAINING GOOD OPERATION OF A MARINE VESSEL

2.1 Efficient operation of a diesel engine

Even though every machine on board a marine vessel is very important, it is through the main engine that the individual machines output is interpreted into work, that is the vessels movement from place to place. Therefore, efficient operation of a main marine diesel engine is to be able to run all machineries on board to their maximum allowable capacity until a pre-determined maintenance period. These requires:

a. standard operation of all auxiliary machines like lube oil pump, fresh water pump, fuel pump, turbo-charger, air cooler, etc.

b. lubricating and cooling efficiency;

c. fuel quality and operating efficiency of fuel equipment such as fuel filters, purifiers and fuel injection nozzles;

d. types of operation and environment;

e. operation and maintenance quality;

f. management and organizational quality.

Considering that the engine performance with regard to material design and construction quality is at the highest possible level, control of the above mentioned factors will lead to a successful engine operation.

Since the ultimate goal of a shipboard machines are to facilitate a marine vessel operation, the efficiency of engine room machinery means, the efficiency of the vessel. But a marine vessel's efficiency also is influenced other factors such as, propeller and hull efficiency.

a. **Hull efficiency** - is the ratio between the useful work done on the ship and the work done on the propeller or other propulsion devices in a given time, that is the effective power and thrust power respectively.

Fouling, corrosion and quality of paint affect hull efficiency. Timely docking and application of the right type of paint is important in keeping the hull efficiency.

b. **Propeller efficiency.** The overall propeller efficiency is equal to thrust developed divided by delivered horse power. Hull construction, specially the aft part of the ship, size (larger diameter propellers are more efficient), shape and number of blades have considerable effect on propeller efficiency.

There are various types of propeller designs applied for different types of operations. The most common design being the fixed pitch propeller and the variable pitch propeller used on most of larger ships while the cycloidal and ducted propellers are mostly used by tugs, ferries and coastal vessels where high maneuverability is required. Fouling and erosion, specially near the leading edges of propellers are the main causes of propeller drag and cavitation. Failure to clean propeller between certain intervals may lead to increase in fractional resistance resulting in a significant decrease in propeller efficiency. Propellers can be cleaned by divers without even docking the vessel. When cleaning the propeller, care must be taken not to use metal scrapers as the surface of the propeller could be easily roughened and increase resistance. A wooden scraper or wire brush has to be used when cleaning marine fouling.

2.2 Operational procedures.

Every engine is accompanied by an operation manual which usually is provided by the engine manufacturer. The simplest and safest method of operation is to follow the engine manufacturer's operational manual with the necessary adjustments to suit own operating conditions and environment.

Successful engine operation depends greatly on how effectively the pre-start preparatory work have been done. In a 4-stroke medium speed, 6 cylinder, in-line, trunk piston type, turbo-charged, locally started (engine side), diesel engine, the following items are usually checked.

Lubricating oil------ Mainly quantity check up.
Cooling water ------ System venting to get rid of air from the system.
Starting air tank---- Quantity in the air tank and venting the system to get rid of moisture formed in the system.

Turning the engine -- This helps to check if camshaft, crankshaft and other moving parts are freely rotating.

These are a few of the preparatory procedures for starting an engine. These may look very simple in terms of operation but they are quite essential to the engine's well being. Doing the same job again and again may become routine and boring. In such circumstances, forgetfulness may easily develop and an important operational procedure could be overlooked which may lead to a serious trouble.
For example, priming an engine with lubricating oil before starting is essential and it is also an easy job. But failure to carry out this simple task may lead to a serious trouble. Such as wearing of main and crank-pin shell-bearing, broken piston rings and scratching of the internal wall of cylinder liners. Simple and minor operation, when over looked can be fatal to the whole system.

Starting. If pre-starting preparations are satisfactorily accomplished, engine starting is no problem. Ensure that all moving parts of an engine are properly primed by hand or by running oil priming pump. Venting the engine with compressed air through the vent cocks before starting will clean the combustion chamber from settled carbon deposit as well as ensuring the free turning of all moving parts of the engine.

The compressed air (30 kg/cm. square) from air tank is connected by pipe to air distributor valve mounted on the camshaft. The distributor valve is connected to each starting air valve on the individual cylinder units, so that when control air valve is opened, any piston at its top dead center will be pushed down and at the same time rotating the crankshaft which in turn starts the reciprocating action of the piston.
The starting air valve has to be checked from time to time to ensure the proper operation of the springs that operate the pilot valves in the starting air valves. Occasional lapping of the valves will also help to increase the gas sealing capacity so that the combustion chamber pressure will be maintained.

After starting.
Checking lubricating oil - oil flow through the system must have a uniform pressure. The pressure at a point in the system may build up due to some obstruction in the system and may look normal. High pressure through a narrowed clearance may not mean normal and low oil pressure through a wider clearance does not mean low pressure. Therefore, the best way of ensuring the correct oil pressure in the system is by measuring at the highest point in the system.

The major reasons for oil pressure failures are:

1. Faulty lubricating oil filter.
2. Faulty pump.
3. Worn out shell-bearing.
4. Loss of viscosity.
5. Air in the system.
6. Empty lubricating oil tank.

Fresh water temperature and pressure.
Fresh water is the common cooling agent for engine parts such as cylinder head, cylinder block and turbo-charger casings. These parts of the engine are under the influence of high exhaust gas temperature produced in the combustion chamber. Excessive heating as well as over cooling have to be avoided, as over cooling may lead to cracking, due to thermal stress, heating may also cause the burning of exhaust valves and pistons.

Fresh water temperature control means, the efficient operation of, sea water pump, good combustion, which in turn calls for fuel valve efficiency, fuel quality and fuel injection characteristics.

Exhaust gas temperature. Exhaust gas measured at the outlet of each cylinder head must not differ greatly from each other.
High exhaust temperature may mean one of the followings.

a. engine over load;
b. faulty combustion process;
c. inefficient fuel valves, fuel injectors and nozzles;
d. poor viscosity oil.

All these may exert some sort of stress and strain on the engine. Close monitoring of engine temperature could help to analyze the operating conditions of the greater parts of the engine components.
Turbo-charger inlet/outlet air temperature. The air density in the combustion chamber determines the maximum weight of fuel that can be effectively burnt per working stroke and the maximum power that can be developed in the engine. Increasing intake air density, increases the amount of fuel burnt in the combustion chamber which increases piston speed and consequently, the increase of engine power output.

Turbo-charger is the means by which intake air density

could be increased. Most turbo-chargers are driven by the exhaust gas released from each unit of the engine. The compressor and the turbine are mounted on a common shaft so that when the exhaust gas drives the turbine side, the compressor will compress air from the surrounding and sends it through the intake manifold to each cylinder.

About 35 % of the total heat energy in the fuel is wasted to exhaust gases, (Pounder's Marine Diesel Engine, sixth edition, pg. 52). So, it is economical to use wasted exhaust gas to drive air compressor and obtain a substantial engine power output at low fuel consumption.

Exhaust gas turbo-charged single-acting, four-stroke cycle marine diesel engine can deliver, three times as much as an engine without turbo-charger (naturally aspirated engine). On the compression process, the air temperature will rise and loses some of its density. The air cooler is to lower the air temperature by allowing sea water to flow inside the cooling tubes and the compressed air passing over sea water at the same time transferring its heat to the sea water. Once the temperature is lowered, the density of the air will increase before it gets into the combustion chamber. Therefore, monitoring the inlet/outlet air temperature at air cooler is very essential in maintaining engine efficiency. **Crankcase explosion.**

The main causes of crankcase explosion are:

1. rich mixture of oil vapor, air and heat source;
2. when crankcase door is opened before the engine is sufficiently cooled;
3. excessive blow-by due to poor sealing capacity of piston rings;
4. bearing failure;
5. loose connecting rod bearing bolt may strike against the crankcase wall, which may lead to the

breaking of the crankcase wall or if not strong enough to break the wall, it will create enough spark to initiate explosion.

Safety measures to be considered:

1. Avoid excessive blow-by by maintaining good operating conditions of piston rings.
2. Ensure all the moving parts in the crankcase tightened to the right torque.
3. Control crankcase temperature, avoid oil mist formation and maintain crankcase breathers.
4. If possible, install oil mist detecting device to ensure more reliable and safe operation.

In a normal operating engine, crankcase explosion never happens. Therefore, ensuring the proper functioning of all component parts is the best way of avoiding any kind of engine failure.

Stopping the engine. After a long operation, stopping the engine procedures have to be properly accomplished.
Long before stopping, gradual reduction of speed and load have substantial contribution to the health of the engine. Lubricating oil, cooling water and the moving parts of the engine are under the influence of high temperature during operation. These high temperatures need to be reduced before stopping the engine. If an engine is stopped with its components at high temperature, seizure of bearing or piston rings may occur. After shutting down the engine, running oil and cooling water pumps for a certain period of time is very essential to the engine life. All the relevant informations are provided by the manufacturer in the engine operation instruction manuals. Good operators, mostly follow the manufacturers instruction in addition to own experience.

2.3 Engine control

The basic function of engine control is to be able to run an engine at a pre-determined operating level.
By increasing or decreasing the amount of fuel flow to the combustion chamber, engine speed can be increased or decreased. Increasing or decreasing engine speed, increases or decreases the engine output which is a combination of power and rotational speed. That means by controlling engine speed (output), engine load can be regulated.

The amount of fuel to the injection nozzle depends on the effective stroke of the fuel pump plungers. Therefore, the basic idea of engine control is the setting of fuel pump output to react to the rotation speed of the engine.
Fuel setting is usually done by an all speed governor, a device that senses engine speed and actuates the fuel pump to maintain the speed according to a given signal.

The fuel pump plunger is linked to the governor through a rack so that when command signal is sent to the governor, the fuel pump plunger is moved to increase or decrease its stroke and the amount of fuel vary accordingly.
Fuel rack markings have to be watched and adjusted according to engine shop test results. Fuel pump plunger increase or decrease of stroke on one of the fuel pump plunger will affect the unit's combustion pressure, by introducing excess or insufficient fuel into the combustion chamber. One defective unit could upset the over all power delivery of the engine.

It is important to measure compression pressure, record fuel rack markings and fuel pump plunger stroke from time to time to compare it with previous results or engine shop tests.
Fuel injection control is very important both for economy and for the safety of the engine that in recent years computer controlled injection system has been developed and

is being used on board many vessels.
The advantages claimed for computerized fuel injection system was:

- improved performance under varying operational conditions;
- engine operation down to one-sixth of its rated speed was achieved compared to one-forth the conventional control.

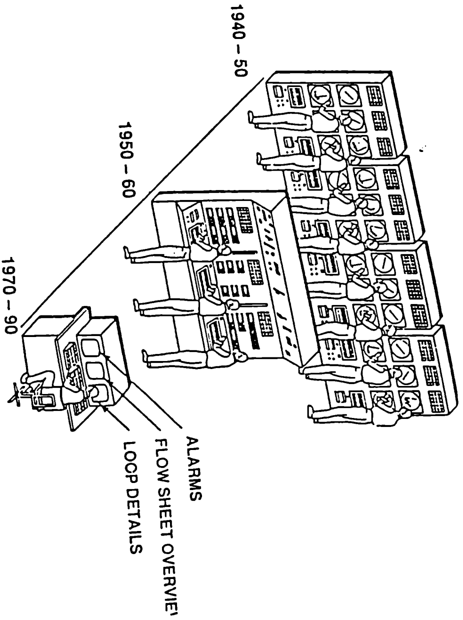
Main engine control system has subsidiary control systems like lubricating oil pressure and temperature control, fuel oil viscosity control, fuel oil purifier control, cooling water temperature and pressure control for jacket, pistons and exhaust valves.

Modern marine vessels are mostly controlled from a centralized station like control room or the bridge. The development of pneumatic transmission technique enhanced the centralized control system. In the 60s, electronic instrumentation hardware based on transistor technology become available for shipboard machinery control system. Signal receiving and display instruments were so miniaturized that a very limited space is required for installing control station.
See fig. 1 for the development of shipboard control panel.

Recently, the introduction of systems based on microprocessor hardware even strengthened the centralized control system.
Central operating system components consist:

1. Sensing devices - that measure temperature, pressure, flow, position, torque, speed, fluid levels, etc.
2. Transmitting devices - convert the information sensed by the sensing devices installed in the line into a physically realizable common law energy signal, so that it can be transmitted to the receiving or control devices.

Fig. 3 Evolution of engine control panel. Taken from Modern Engineer's manual, v. 2, by Alan Osbourn.



Standard transmission signal and media are:

a. Pneumatic - 3 to 15 psi, 3 to 27 psi, 0 to 60 psi
b. Electric - 1 to 5 volt, -10 to 0 volt, +10 volt.
c. Digital transmission d. Fiber optics.
d. Fiber optics.

3. Receiving devices - are those which convert the trahsmitted signal into useful information for observation by the operator.
4. Indicator and recorder - are devices that are manipulated by receivers so that operators may observe the information relating to the function of the engine spaces. These takes the form of light, strip indicators, chart recorders, gauges, and provide sound and sight information to the watch engineer and maintenance crew.

As the trend in shipping is unmanned machinery space, centralized operating system, mainly from the bridge, might be common.

2.4 Engine performance recording

Engine performance records enable us to plan and program operations, maintenance and update spare parts. Performance records can be categorized into two parts.

a. Operating records.
b. Accounting records.

a. Operating records - is to know the present operating conditions of the engine. All relevant parameters such as cooling water temperature, lubricating oil pressure and temperature, turbo-charger air pressure and temperature, electrical and other load data will be recorded. Comparing the data will help to know the different components operating conditions. And if any abnormality develops, immediate corrective measures could be taken. Operating records are good references as to what remedial action has to be taken in cases of component failure.

b. **Accounting records**. These are records which help to analyze how efficiently an engine has been operated. Fuel oil costs, lubricant costs, spare part costs, labor and maintenance costs are good indicators of whether the entire operation is healthy or not. By analyzing this data, some adjustments could be recommended and operating weaknesses could be rectified and corrected.

2.5 Maintenance.

Maintenance is any action which is carried out to return or restore an item to an acceptable standard. (D. A. Taylor pg. 119). Every engine manufacturer provides adequate maintenance and operating informations for every engine it manufactures. These informations are the results of various tests carried out at the factory and data collected over a long term of the actual engine operations.

Such informations are very useful as a general guide but certain adjustments are needed for a particular type of engine operating conditions. Fore example, an engine builder's instruction on cleaning lubricating oil cooler or fresh water cooler may be every six months for a certain type of engine. But for ships operating in the Red Sea, six months oppression without cleaning lube oil cooler will definitely lead to total clogging of the elements of the cooler. Therefore, maintenance of engine components have to be done according to the particular operating and environmental conditions.

There are various types of maintenance policies. Various ship operators apply different maintenance policies. The easiest and simplest policy is to operate the engine up to components seizure or breakdown. But in this type of policy the risk of early failure of the machine is very high and the level of production or power delivering capacity may reduce earlier than intended.

Above all, safety and reliability of machines without maintenance facility is very low. The main idea of using machines are to increase production level and without proper maintenance, machines are unable to perform to the required level. Therefore, adopting a proper and suitable maintenance policy is inevitable. General maintenance policies are:

1. Repair only policy
2. Preventive maintenance policy.
3. Management service technique.
4. Optimal maintenance policy.

1. **Repair only policy**. This type of policy promotes the, "operate till breakdown", policy. It discourages inspections and corrections until component seizes functioning or total breakdown. The time spent on inspection and correction is considered as waste of labor and unnecessary increase of ships down time. In this type of policy, minor faults can develop into more complicated problems and increase the frequency of down time.

On the other hand, there are a few rare cases where components operate without any failure for a long time. Such rare cases usually encourage some ship operators to adopt the repair only policy.

In the modern sophisticated equipment operation, such policy may not have acceptance.

2. **Preventive maintenance policy**. This policy is based on programed maintenance policy. Its main purpose is to reduce the number of breakdown until the next designated major overhaul. Although, this system is not 100% breakdown free it reduces the frequency of component failure, ensures safety, reliability and high level operation. Preventive maintenance comprises inspection, correction and replacement of faulty components. This type of maintenance is usually carried out by the ships crew when the ship is off hire. In general, preventive maintenance policy seems the best policy provided suitable decisions are made like how often should inspection and correction have to be done

on a particular component.

3. Management service technique.

Management service technique is based on:

a. Identifying the problem.

b. Collection of data as to find out what type of maintenance has to be done and previous history of the particular equipment.

c. Decide what type of maintenance is needed.

d. Arrange the necessary spare parts.

e. Plan maintenance.

f. Organize maintenance team.

g. Estimate duration and the cost of maintenance.

4. The optimal maintenance policy.

The optimal maintenance policy relies on vast data collection and analysis of different factors involved in the operation. A sound judgement and good experience are the basic requirement for optimal maintenance policy. Modern economic conditions require ships to operate with minimum down time in between planned overhauls. To fulfill these conditions, ships and machinery designers have developed a system design. A system design takes into account the different interacting components which co-operate to accomplish a defined objective. A ships system comprises, the hull, propeller, machinery, piping and all the relevant equipment that are related to the movement of the ship. Out of the whole system, some are very essential, whose failure may take the ship out of operation.

For example, lubricating oil and cooling system failures are not tolerated in a running engine. Therefore, a stand by oil pump and water pump are fitted in the system to ensure redundancy of the whole system.

In harbour service vessels such as tugs, redundancy of almost all equipment is very essential. Once in harbour, a ship and its cargo safety is mostly dependent on the efficiency of harbour tugs.

A very valuable and at times very dangerous cargo is carried by ships. At sea, the ship's safety is ensured by the total efficient operation of its machinery and personnel. But in harbour, ships are limited in using their own power due to the limited maneuvering space. That is why ships rely on tugs for berthing and unberthing.
Therefore, the efficiency and dependability of tugs is very important in port operation. Efficiency and dependability can be ensured only through a standard and established maintenance policy.

It is the unexpected failure of machineries that are bothersome and difficult to cope with. Because an unexpected failure usually happens without pre-warning or by accident and it is impossible to exactly plan for such failures. However, general planning can be done based on experience and past history of the machines or the vessel in general.

The general causes of sudden failure could be attributed to poor design, defective manufacturing and severe operating conditions. The development of technology and long experience of engine builders have generally reduced the rate of sudden failures of machines. But there is always a very important factor which technology can not solve fully, **the human factor**. Human failures seems never to be avoided completely. Therefore, planing for unexpected failure has to be done as much as possible. Closer monitoring and recording conditions of operating machinery are very important to control such failures.

The common unexpected failures are:

a. Breakage - piston rings, gear teeth, crankshaft which is very rare.

b. Cracking - cylinder cover, cylinder liners, pistons, structural parts such as bed plates.

c. Burning - piston surfaces, turbo-charger walls.

d. Wear (excessive) - bearing, cam rollers, piston
rings, cylinder liners.

e. Fouling - injection nozzles, exhaust valves, piston
rings, turbo-charger blades.

By constant checking of these and other parts of the operating engine, unexpected failure could be minimized if not totally avoided.

CHAPTER THREE

FUEL OIL QUALITY AND ENGINE PERFORMANCE

3.1 Sources of fuel oil

Petroleum product fuels are the main sources of fuel for diesel engines.

There are other types of fuel sources like natural gas, coal, etc. but so far, petroleum product fuels are the most conveniently used fuel in the diesel engines.

Petroleum (crude) oil is a naturally occurring substance, usually dark brown liquid found under the Earth's surface. Its formation is a complicated chemical process undergone through various stages over a long period of time.

According to experts, it is not an everlasting resources and some day the oil wells may dry. But at present, the world is dependent for its fuel needs on a small number of countries such as the Middle East, some parts of South East Asia, Venezuela, North Sea and North Africa. The whole world is at the mercy of a few oil rich countries. Experience has shown that in many occasions, the world has faced serious energy crisis due to irregularity of oil supply. These and other factors such as environmental conditions initiated many researchers to look for other fuel sources. Out of the various researches undertaken, coal has been found the most promising but the limited technological know how of coal handling and liquifying is not yet up to the standard, specially in regard to environment. Otherwise, coal is more cheaper and yields more energy than fuel oil. Until the day comes when more cheaper and environment friendly fuel source is available, petroleum product fuels will continue influencing diesel engine operation.

Table 1

Main origins of crude oil and its characteristics.

	Iran light	Arab light	Libya	Venezuela
Density at 14 deg. C. g/ml	0.856	0.858	0.823	0.900
Viscosity at 50 deg. C.	4.7	3.9	10.4	11.6
Pour point 0 deg.	-15	-34	-34	-48
Sulphur %	1.4	1.8	0.2	1.6
Conardson %	3.5	3.7	1.8	5.8

(Collected from class lecture)

Fuel oil is almost everything to an engine, it influences design, performance, durability, economical feasibility and above all many of the operational problems are related to the fuel the engine is using. Therefore, as a marine diesel engine operator, the basic knowledge of petroleum product fuels, such as its compositions, refining processes, properties handling and treatment are very important.

Chemical composition of crude oil. Crude oil is a complex mixture of hydrogen and carbon, which in general is called hydrocarbons. It also contains some other elements in a smaller quantity such as sulphur, nitrogen, oxygen compound and some other metallic compounds of vanadium and iron.

The chemical structure of hydrocarbons in crude oils can be classified into three groups.

They are: 1. Paraffins

2. Naphtenes

3. Aromatics/Asphaltenes

The proportion and types of the above three groups contained in a crude oil determine the general characteristics of the product produced from the crude oil.

Crude oil containing a high proportion of low molecular weight (low carbon number) hydrocarbons, such as Arabian light crudes give high yield of petroleum gases, gasoline (Naphtha), Kerosen, turbo-jet fuel, and distillate gas oil or diesel fuel oil. Kerosen, petrol and gas oil are called middle distillates, which are usually extracted in large quantities from the type of Libyan crude oil.

Analysis of crude oil distillation shows that all type of crude oils have high residue contents, ranging from 38% to 81%. This residue is the source of fuel for large marine diesel engines, and boilers.
These days the medium speed diesel engines are also becoming dependent on the residual fuel oil. Residual fuel oil is the left over, that is the remaining part after many of the more valuable part of the crude oils are extracted. It contains some amount of sulphur, vanadium, sodium and other unwanted elements, which creates unfavorable operating conditions for engine component parts that are working in relation to combustion process.

Refining process.
Some basic knowledge of crude oil refining process is beneficial to an engine operator. Because the methods and degree of the refining of any crude oil and its natural properties determine the quality and quantity of the various products to be burnt in all types of engines.

Refining crude oil starts with distillation at atmospheric pressure. In the process, the distillate is separated into various fractions according to its volatility.
See fig. 4, a typical fractionating tower.
The basic refining process is called fractional distillation . This is based on the fact that different compounds in the crude oil have increasingly higher boiling ranges.

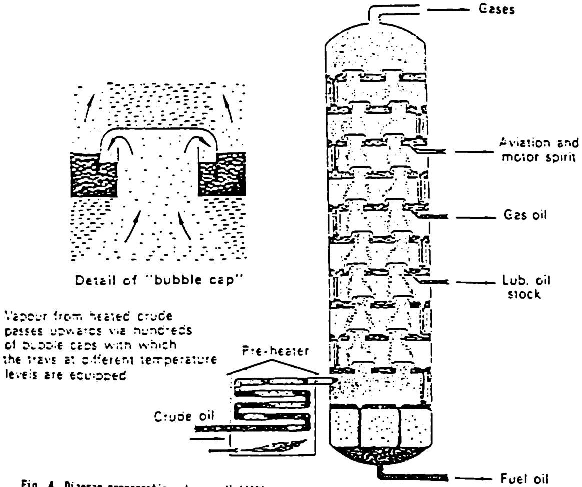


Fig. 4 Diagram representing tower distilling crude oil into its various fraction.
Taken from Lubricatioin of Industrial Marine Machinery, second edition.

The higher the carbon atoms in a hydrocarbon molecule, the higher the boiling point. The boiling points usually range from 20 degree centigrade to 400 degree centigrade at atmospheric pressure. The lower the boiling point of a fraction the smaller the average size of its constituent molecules.

Crude oil is heated gradually to about 420 degree centigrade and passed to the lower part of a tall cylindrical column - a fractionating tower at atmospheric pressure. The tower is fitted with a series of transverse trays comprising bubble caps. According to the number of fractions required and depending upon the type of the original crude oil, different products are produced. The lightest and most volatile hydrocarbons are released first as vapors. The heavier vapors settle at the middle of the tower, while the least volatile once settle at the bottom of the fractionating tower. As the vapors rise to the top of the tower through the bubble caps, they cool down and recondense into liquids. The flow of the vaporized oil is continuous so that the condensed liquids are collected in the bubble trays. At suitable intervals, starting from the top of the tower, the different fractions, with increasing boiling ranges are drawn off from a series of condensing trays. The lightest fraction is a mixture of gases and raw gasoline or naphtha, which at temperatures of about 170 degree centigrade pass out of the top of the tower into a condenser. At this point, the uncondensed gases will be separated to be used for other purposes such as heating and by further treatment, it can be utilized as liquid propane and butane for industrial purposes. The remaining extracts are raw gasoline which needs further treatment and blending with high quality products before using it as gasoline and naphtha. The next stage is for white spirit, turbo - jet fuel and kerosen. Further down is the section for gas oil with boiling range of 235 to 380 degree centigrade. This gas oil has to pass through a hydrofining plant to reduce its sulphur content to about 0.5%.

Hydrofining, a desulphurization process is carried out depending on the sulphur content of the gas oil to meet the specification standards such as the British standard, BS 2869 (1983), class A1 and A2.

The lighter gas oil (diesel oil) is used to run high speed diesel engines, while the heavier gas oils are used by medium speed diesel engines, usually referred to as MDO.

Depending on the original crude oil quality, 40% to 80% will remain undistilled in the refining process. paraffinic crudes leave less residue and aromatic /asphaltic crudes leave very high percentage of residue. The undistilled crude (residue) has a very high viscosity, ranging from about 80 cSt at 50 degree centigrade to 1000 cSt at 50 degree centigrade. This is the major source for ships banker and some industrial plants.

As refining technology is becoming sophisticated, crude oil is over exploited leaving behind a small quantity and the lowest quality residual fuel oil.

Economical reasons forced marine diesel engine operators to use the heaviest fuel oil. In response to this, diesel engine manufacturers developed engines that can burn the lowest quality petroleum product, heavy fuel oil. Heavy fuel oil, which was confined only to the use of industrial boilers and slow speed cross head marine diesel engines, now began to be used in the medium speed diesel engine family. These days, even some high speed diesel engines that are in the range of 1000 rev/min. have began using heavy fuel oil. On the other hand, heavy fuel oil quality is getting worse with no prospect of improvement in the near future. Other products like petrol, kerosen and gas are more in demand for various applications and they are very expensive too. These made the oil producers to concentrate on the more quality and expensive products only, consequently, highly complex refining system is developed.

See fig. 5, for a typical distillation flow.

The modern refining methods almost extracts every bit of valuable parts of the crude oil leaving behind a residue which has no use except for the marine diesel engines.

The only hope for diesel engine operators is, technology of machinery building also develops and cope up with the ever deteriorating fuel quality. The other way of coping with bad fuel quality are understanding the type of fuel to be used for the particular engine and carry out efficient fuel handling, fuel equipment maintenance and fuel treatment.

3.2 Fuel oil classification

Many types and sizes of engines use various petroleum product fuels. The engine types and sizes range from high speed engines used for commercial vehicles to cross head slow speed marine diesel engines.

Fuel oils may be classified as:

a. Distillate - comprised of kerosen, autodiesel, etc.
b. Marine diesel oil (MDO) - distillate and heavy fuel oil blended, in which distillate fuel is in a larger proportion.
c. Residual or heavy fuel oil.

a. **Distillate.** Distillate fuels are further divided into several groups according to their use. For the purpose of domestic heating and for some limited transport vehicles in large cities, where permissible sulphur oxides and nitrogen oxides are very low (usually about 1.5%), very light distillate fuel like **kerosen** is used.

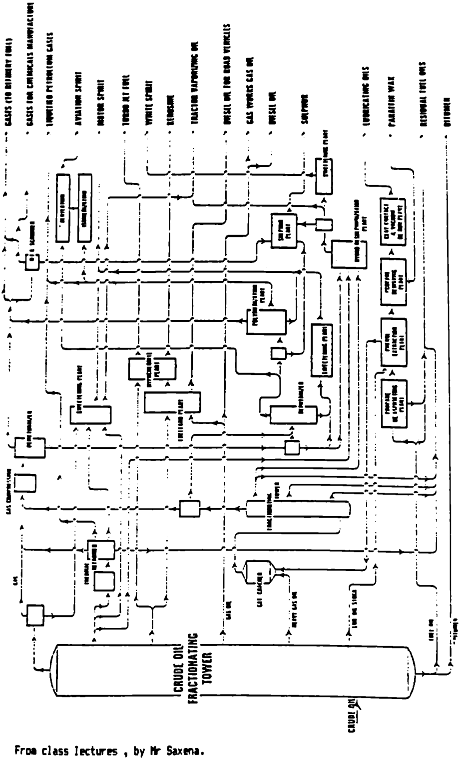


Fig. 5 Typical distillation flow chart. In practice more than one fractionating is needed to produce the range of main products shown.

From class lectures , by Mr Saxena.

Many countries have different standards like the UK BS 2869 :1983, class C1 and class C2. and the United States ASTM D396 and D975. (ASTM stands for, American Society for Testing Materials).

The fuel oil sold as **autodiesel** fuel oil for commercial vessels, passenger transport and high speed rail car engines is the high cetane number light distillate gas oils In many countries, desulphurization of such fuel is required to reduce its sulphur content.

b. **Marine diesel oil (MDO)**- this is the type of fuel oil used by medium speed and medium high speed diesel engines. Occasionally, slow speed direct drive marine diesel engines are also using MDO, specially during maneuvering, where frequent starting and stopping is required. The maximum viscosity limit for MDO is 14 cSt at 40 degree centigrade, cetane index 35 and sulphur content 2.0%. This is according to the BS - MA 100/82 specification. Currently, this is accepted as a standard by many of diesel engine operators, but in some areas poor quality MDO is sold which contain appreciable amount of fuel oil quality deteriorating substances such as sulphur, vanadium, sodium, etc.

Due to the modern refining technique of thermal cracking, visbreaking, and catalytic cracking, blending distillate fuel with residual fuel to produce MDO is common. As a result, the ignition and burning properties of such blends are very poor. High deposit formation, black smoking and high exhaust temperatures are common which leads to the reduction of engine efficiency.

Table 2

common MDO specification

Property	Middle East	Venezuela	North Sea
SG at 15/15 *	0.850	0.862	0.860
Redwood 1 viscosity at 100 DEG.	38	46	44.5
Kinematic viscosity **	4.72	7.3	6.82
Closed flash point ***	210/98.9	180/82	180/82
Pour point ***	15/-9.4	6/-15	46/7.8
Cetane number	54	38	43
Conardson carbon residue %	neg.	nil	2
Sodium content (ppm)	nil	nil	1
Vanadium content (ppm)	nil	nil	1
Sulphur content (% mass)	1.3	0.92	0.20
Ash content (% mass)	neg.	nil	0.05

compiled from Modern marine Engineers Manual v.1 In the table, * mean, SG is in degree centigrade

** Kinematic viscosity is at 40 deg.c.in cSt (centi Stock second).

*** Flash point and pour points are in deg. F

c. **Residual (heavy fuel)** oil - as pointed out earlier is the left over of the crude oil refining process. Modern refining technique such as vacuum and catalytic cracking have worsened the quality of the residual fuel oil. Depending upon the initial quality of the crude oil, the residue has to be blended with certain percentage of distillates to meet the required viscosity standard. The standard varies from as low as 31 cSt at 50 degree centigrade to as high as 700 cSt at 50 degree centigrade. The main problems of burning heavy fuel oil are, storage and combustion quality.

Storage – heavy fuel oil easily settles down in the storage tank and forms sludge which is very troublesome for cleaning and if allowed to accumulate, it may get into the fuel system and damage fuel pumps and components around the combustion chamber.

Combustion quality

The most significant problems of heavy fuel burning are:

- fouling of fuel injection nozzles, exhaust passages and turbo-chargers gas side;
- uneven burning variation in ignition delay and steeping ignition pressure gradient.

These are the causes for excessive thermal loading, increased exhaust emission, critical piston ring and liner wear. In the long run these will lead to high fuel consumption and total component damage.

Thanks to technology, many of the problems that have been the main causes of exhaust valve burning and high wear rate of cylinder liner and piston rings are under control. The high temperature resisting materials such as **nimonic valves** and the use of high **alkalinity (high TBN)** lubricating oils have made possible the use of the lowest quality fuel. The other problem is, heavy fuel oil has very poor ignition quality. This is mainly as a result of blending with aromatic diluents like light cycle oil to improve viscosity of the heavy fuel oil.

Low ignition quality leads to long ignition delay which means introduction of large quantities of fuel oil before full ignition takes place. Then, the accumulated fuel suddenly starts burning, developing high and violent pressure in the combustion chamber. The sudden and violent combustion pressure brings about mechanical shock and high local gas turbulence increasing temperatures of components.

3.3 **Fuel oil properties.**

Most land based plants, harbour service crafts and inland water way operating vessels are using distillate fuel oils. For protecting environment, many countries prohibit the use of heavy fuel oil on land, but for the sea going vessels, there is no restriction, therefore, heavy fuel oils are largely used by the sea going vessels.

Ignition quality is the most important property for the distillate fuel oils, because combustion is completed in a fraction of a second. Shorter ignition lag (time from starting of injection to beginning of combustion), is very essential. Ignition lag (ignition quality) is the cetane number, which is a parameter valued on the scale of 15 to 100. High value indicates, good quality, that is how close the fuel quality approaches the behavior of the reference compound, n-cetane, a hydrocarbon compound that has the shortest lag among liquid fuels.

From table 2, we observe that the high paraffinic Middle East distillates have highest sulphur content. The ash contents of the fuel oil from the three places are negligible or nil. Vanadium and sodium are also nil, therefore, the combustion will be clean and effective.

The relevant fuel oil properties are:

a. **Specific gravity.**

Specific gravity (relative density) is one of the most important properties of fuel oils. It is defined as the ratio of a given volume of the fuel at a stated temperature to the weight of an equal volume of fresh water at a stated temperature.

Specific gravity of fuel oil vary with change in temperature, therefore, it is calculated at a fixed or standard temperature. The universal standard temperature at which the specific gravity of oil is reported is at 60 deg.

F. for both fuel and water. Usually it is quoted at either 15 deg. centigrade or 60/60 deg. Fahrenheit.

b. **Density** - which is almost identical to specific gravity (SG), is the mass per unit volume of a substance expressed in units such g/cm. cube for solids, g/ml. for liquids, and g/l for gases. The same test method is used for both SG and density.
To calculate volume to weight and weight to volume of marine bankers, SG is important. Marine bankers are bought in weight, therefore, the lower the SG, the greater the volume per ton.

As fuel oil is burnt volumetrically, the greater the volume, the greater the heating value. In industry in general, it is common practice to purchase liquid fuels by volume. The higher the SG, the greater the heating value (or specific energy) per liter. For both distillates and residual fuel, SG is a useful guide to the origin of the fuel and consequently to its combustion characteristics.

Low SG indicates paraffinic fuel with good ignition properties when burnt in diesel engines, while high SG indicates mainly aromatic or asphaltic fuel with poor combustion properties. Paraffinic fuel oils have SG of 0.83 to 0.86, and aromatic fuels have about 0.88 to 0.91. Heavy cracking refining method of fuel oil increases specific gravity, for example, aromatic fuel gravity to as high as 1.0.

Maximum SG of fuel oil in which undesirable solids and water can be conveniently separated by ordinary centrifuge is 0.99, but recent highly developed centrifuges have been able to clean effectively fuels with density as high as 1.010.

c. **Flash point** - as defined by the Institute of Petroleum

(IP), is the temperature to which the oil must be heated under prescribed conditions for sufficient vapor to be given off to form an inflammable mixture with air. The most widely used apparatus for distillate and residual fuel's flash point testing are the Pensky - Martens (PM), and ASTM D93/IP34 methods.

Flash points for common petroleum products are:

gasoline ------- 32 deg. F.

gas oil ------- 175 to 220 deg. F.

heavy fuel ------ 170 to 280 deg. F. and for

lubricating oil -- 400 deg. F and above.

The identification of fuel oil flash point is useful for the prevention of fire. On board ships the minimum permissible closed flash point of fuels carried in open storage tanks is 60 deg. centigrade or 140 deg. Fahrenheit. Gasoline or kerosen used for life boat or emergency generators must be stored in sealed containers.

d. **Pour point of oil** - is defined as 3 deg. centigrade above that temperature at which the oil just fails to flow when cooled. IP method is used to determine pour point of oil. All diesel fuel, specially residual, contain some paraffin wax in solution at normal ambient temperature. As the temperature falls the wax commences to come out of solution in the form of crystals, the temperature at which it is first observable being the cloud point. It is this crystals as the temperature decreases, that prevent the flow of the fuel.

e. **Water content.** A limited amount of water in solution can be found in crude oil, not exceeding 100 ppm. However, distillate fuels should not contain visible amount of water. In case of external contamination, it should not exceed 0.25%. Above all, salt water contact with fuel must be avoided as much as possible, because it corrodes the fuel system and enhances carbon formation in the engine combustion systems.

To identify water in fuel, a simple test tube will be filled with fuel and is allowed to stand at a warm place. Provided the water is not emulsified, it should settle distinctly after a certain period of time.
Current specification for residual fuel water content is 1.0 % maximum.

f. **Viscosity or flow properties of fuel** – is a measure of liquidity expressed in seconds or degrees.
For proper atomization, fuel oil must have certain viscosity. To reduce viscosity or increase its fluidity, it has to be heated. The knowledge of viscosity of fuel will help to decide to what extent the fuel has to be heated to maintain the proper flow pressure in the system.

There are two types of flow:
1. In a smaller bore tube, the flow is smooth and even, follows stream line parallel to the tube axis. This is called viscous, lamilar or stream line flow. The property of the liquid that resists this type of flow is viscosity.

2. In a large bore pipe, the flow is uneven and turbulent eddies are formed. This turbulent flow and viscosity have limited influence on the type of flow, but specific gravity and density have influence on turbulent flow.
Three methods are used to determine viscosity.
They are:

1. **Redwood viscosimeter** – 50 cc at temperature of 70 deg.F., comparative liquid is rape oil and time required for flow is 100 seconds.
2. **Egler viscosimeter** – 200 cc at 68 deg. F., water as comparative liquid and time required for flow is 170 sec.
3. **Saybolt universal** – 60 cc at 70 deg.F. water is the comparative liquid and time for flow is 50 sec.

g. **Ash** content. This is the amount of totally none combustible materials contained in the fuel oils.
The main ash forming compounds are:

1. organometallic compounds remaining from the crude oil;
2. dirt, sand and scale;
3. metallic catalyst fines from modern refineries.

Effects of organometallic compounds.

Vanadium - it acts as a catalyst in promoting the formation of corrosive sulfuric acid and increases corrosive wear. Specially under suitable conditions, it is the main cause for high temperature corrosion of exhaust valves.

Sodium - It is usually found as organometallic compound in residual fuels. 50 to 40 ppm causes no harm but in the presence of salt water, sodium content increases and become quite harmful. Sodium reacts chemically with vanadium and oxygen to form complex oxides which are highly corrosive at high temperature.
Exhaust valves, turbo-charger and nozzles are parts the most affected by the oxides of sodium.

Sulphur content - The amount of sulphur content in the residual fuel depends upon the origin of crude oil. Usually it is no more than 3.5% but with cracked aromatic/asphaltic residues, the sulphur content may go up to 4.5 to 5.0%.
It promotes corrosive wear of piston rings and liners as well as deposit formation in the piston ring zone.

Aluminum - It is originated from being used as catalyst in the modern refining complex in the process of cracking heavy residual fuel oil into lower viscosity fuel. Aluminium catalyst help to increase the yield of gas oil and gasoline distillates.
The residual fuel obtained from this type of refining

process contain some amount of aluminium.
The British Standard for marine fuel (BS - MA100/ 1982), sets the safe quantity for large marine engines to about 300 ppm.

This catalyst is extremely hard and abrasive at high temperatures and causes severe wear to fuel oil pumps and injectors.

Identifying organo-metallic compounds.
Some of these objectionable substances can be reveled by simple tests and some are so complicated that they need sophisticated test equipment and specialists. So, test on board ships is impossible.

Atomic absorption spectroscope is an advanced laboratory analytical instrument for identifying organometallic compounds such as vanadium, sodium and nickel.

Determining the amount of sulphur content can be done in many ways, but the most commonly applied for distillate and residual fuel oil test is IP 61/ASTM D155. This method is known as the " bomb method". Sulphur content is expressed in percentage (%). Almost all the big refining companies have the right type of equipment and specialists to operate the test machines and carry out the sophisticated laboratory analysis. They are also cooperative to their customers to do the required testing and provide advices. In general, efficient fuel treatment such as filtration, centrifuging and careful fuel storage system usually keeps fuel oils free of these objectionable substances.

3.4 Fuel oil treatment

The power of an engine depend upon the complete burning of fuel in the combustion chamber. To achieve complete burning, fuel delivery pressure has to be very high and the spray nozzles have to be in good conditions. Uncleaned fuel oil damages fuel pump, injection nozzles and in general leads to poor combustion. All these necessitated fuel oil treatment.

Although many responsible oil companies keep their products clean, there are various ways for fuel oil contamination. Delivery tanks may be rusty or if barges are used, there are possibilities of water getting into the barge. On board ships also water is a constant contamination threat. Therefore, Fuel oil treatment before use is inevitable. For distillate fuels, simple (conventional) filters but with adequate fine filtration area could be sufficient. For heavy fuel oil filtration, more elaborate cleaning process is required.

The process may comprise:

- heating;
- centrifuging;
- settling tanks;
- group of filters fitted in series.

Medium speed diesel engines using distillates are more sensitive to contaminants than slow speed diesel engines burning heavy fuel oil.

Separation of solids and water is relatively easier in the case of distillates because the specific gravity of distillates is lower than solids and water.

The present day fuel for marine diesel engine is not at all in its best quality. On the other hand, high power out put and longer service period are required from marine diesel engines, which without clean fuel is impossible.

To reconcile these conflicting interests, use of efficient filters and purifiers are necessary.

Types of filters.

There are various types of filters with different filtering capacity.

1. **Coarse filters** -these are to separate solid particles of at least below 15 microns. In the high speed diesel engines filters have to be able to separate particle size of up to two microns. Coarse filters are usually fitted near the outlet of the storage tank.

2. **Fine filters** - there are two types of fine filters, **absorbent and adsorbent.**

Absorbent filters - can separate more finer substances from the fuel. It is made of cotton waste, paper, wood pulp, etc. More of the harmful substances that managed to pass the coarse filter will be caught here. Dirt, sludge, carbon and metal particles will be absorbed in this type of filter.

Adsorbent filters - are type of filters that holds solids by adhesion. Soluble impurities such as gums, tar, resin, asphaltenes and acids can be removed by adsorbent filters.

3. **Volkes "Microfelt" fuel filters.**

These are designed to provide fine filtration of distillate and residual fuels.

Fig. 6 shows Volks Microfelt filters. They are usually installed close to the engine in duplex and operate at full flow. With distillate fuel at ambient temperature, about 3.5 to 35 ton/h of fuel can be filtered (from class lecture). In the case of heavy fuel oil with operating temperature of 150 deg. centigrade, the filtering capacity will be halved.

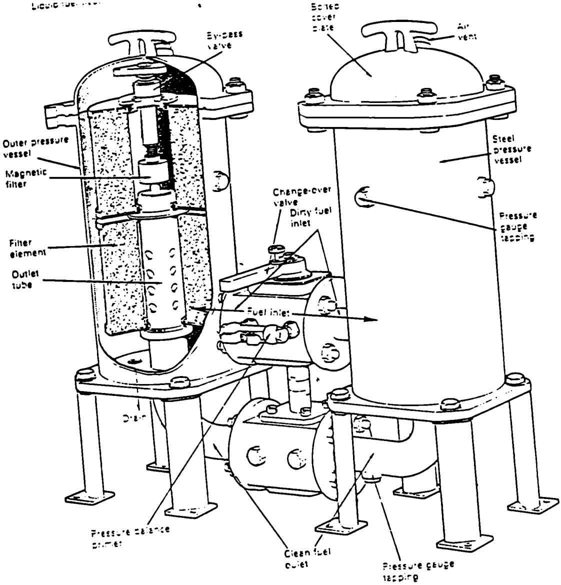


Fig.6 Volks duplex Microfelt fuel filter.

Taken from Industrial Marine Fuels

Reference book.

The material component of a disposable microfelt filter element is a dense synthetic felt, which is water and acid resistant and presents a very large filtration area.
The element is encased in a corrosion resistant wire mesh so that in case of element collapse, the filtering material will not have a chance of getting into the engine.

4. Centrifugal separators.

The centrifuges are very effective in cleaning both type of fuels, distillate and high viscosity fuels. Water and other unwanted materials in the fuel will be effectively separated. Efficient and well maintained centrifuge can remove particle size of up to 3.5 to 5 microns. The effective burning of high viscosity fuel oil is possible mainly due to the development of efficient centrifuges.

The static fuel filters separate solids from liquid fuel depending upon the particle size, while centrifuges separate out solids on a particle weight basis.

Some diesel engine operators may prefer static filters due to the high cost of additional centrifuges. Static filters may be less costly and simple in construction compared to centrifuges. But the static filter elements have to be changed very often and it may not be efficient in removing some types of contaminants from the fuel oil. Even though centrifuges may be expensive initially, its reliability in removing all types of objectionable substances is very high, which will be a considerable contribution to the performance of the engine in general and increase life expectancy of fuel equipment in particular.

On board marine vessels, the probability of sea water mixing with fuel is very high and sea water contamination is very harmful to an engine. Primarily, it corrodes fuel pump plungers and secondly, by reacting with some elements produced in the process of combustion, it promotes the corrosion of valves, piston rings, nozzle tips and turbo-charges.

The inefficient operation of these components in turn affect the engine performance and leads to high financial loses through spare part cost, labour and ships down time. In view of all these, installation of purifiers may save a lot of unnecessary expenses and keep the high performance of the engine by constant supply of clean fuel oil.
After all, technology has developed highly efficient centrifuges which are self cleaning and require very little maintenance.

Types of centrifuges.

The separation of solids, semi-solids and water from oil by centrifuge is based on the effect of centrifugal force on liquids and solids having different specific gravities or relative densities. It works on the same principle as gravity settling tank in which the more dense matter settle to the bottom of the tank. But in case of settling by centrifugal force, the separating force is very high.

There are two types of centrifuges. They are, the **single chamber long tubular bowl type** and the **multiple conical disk type**.

Tubular bowl type - this is the type which has a long relatively small diameter tubular bowl.
The length /diameter ratio is about 6:1. This type of centrifuges rely on high rotation speed (1200 - 1500 rev/min.) to efficiently separate fuel from contaminants. It is effective but cannot be adopted to self cleaning.

When fuel oils are heavily contaminated, cleaning has to be done very frequently, because solids will build up in the bowl and decreases the efficiency drastically. Despite its simplicity and relatively cheap cost, the tubular bowl type centrifuges are limited to the purification of fuel oil for smaller diesel engines. This is because of its inability to clean large quantities of fuel at full load and its being not suitable for automatic self cleaning.

Multiple conical disk type - this type of centrifuge is efficient and self cleaning, therefor, most marine vessels burning heavy fuel oil and distillates are utilizing the multiple conical disk type. Alfa - Laval, Westfalia and Mitsubishi are the main developer of these types of centrifuges.
Fig. 7, Alfa- Laval Alfax self cleaning centrifuge.

Factors that influence efficiency of centrifuges are:
1. Rate of separation
2. Temperature
3. Viscosity of the oil.
4. Angular velocity of the centrifuge bowl.
5. The inner and outer radii of the disks.
6. The number of disks.
7. The position of the oil-water interface
8. Specific gravity, specially in the heavy cracked fuel oils

Purifying, that is separating water from fuel oil, is done by fitting gravity disk which regulate the water outlet. The disk diameter is very important here. The internal diameter of the gravity disk is determined by the difference of density (specific gravity) between the fuel oil and water.
Choosing the correct size of the gravity disk determines the separating capacity of the centrifuge. The disk size varies according to the fuel density, viscosity and the flow rate of the fuel to be purified.

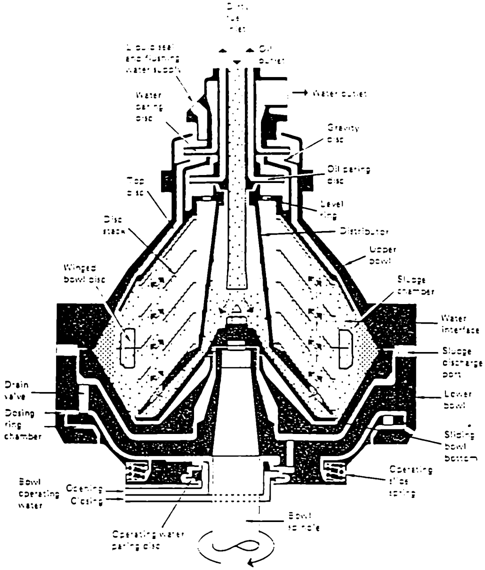


Fig.7 Alfa Laval self cleaning centrifuge.

Taken from Introduction to Marine Engineering

D.A. Taylor

The bigger the gravity disk, the efficient the separation, but care must be exercised when choosing the disk size in order not to damage the water seal and loose oil with the water being discharged. The density of water and fuel difference vary with temperature.
Fig. 8 shows the cross section of a purifier.

The currently accepted standard temperature to centrifuge residual fuel oils is at 98 deg. centigrade, however, above 80 deg.centigrade, the density difference between residual fuel and water remains constant. Sea water which has higher density is easy to separate than fresh water.
For example, the relative density of sea water at 15 deg. centigrade is 1.04, at 40 deg. centigrade is 0.992, at 80 deg. centigrade is 0.972 and at 95 deg. centigrade, 0.961.

Centrifuges arrangement.
A reliable method of cleaning fuel oil on board ship is installing at least two centrifuges to be operated in parallel. This is very effective where fuel contamination is at high risk. The first centrifuge removes solids, sludge and water, while the second as a clarifier, removes any fine solids still remaining in the fuel. The efficiency of separation can be increased by raising the temperature, as a clarifier is not fitted with water seal. This system can efficiently remove very fine abrasive foreign matters such as catalyst fines.

Fuel related problems on board ships.
Residual fuel related problems.
In the combustion process, ash and corrosive products are formed in varying quantity, depending on the type and origin of the fuel. Specially with the combustion of residual fuel oils the amount of organometallic compounds such as vanadium, nickel and iron are significant. The vanadium content of 500 to 600 ppm is considered as high and if fuel is contaminated by sea water, the sodium

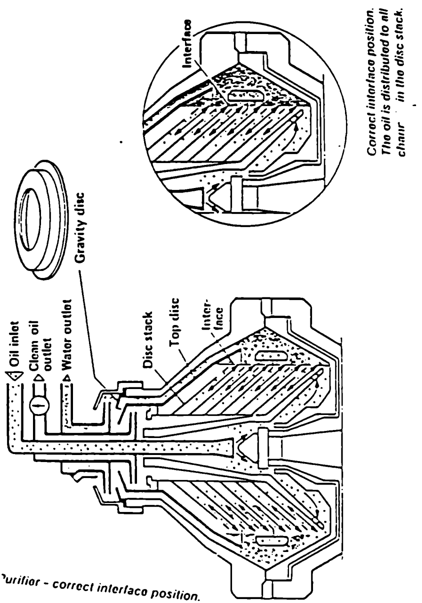


Fig 8 Purifier - correct interface position.

From Class lecture -by Mr Saxena

content can be as high as 300 ppm.
In the two-stroke cross head type engines, cylinder lubricants have high alkaline additive contents based mainly on calcium and barium.

Trunk type marine diesel engines with additives of detergent/dispersent oils have high alkaline reserve which also have high chemical content. A 70 TBN (Total Base Number) cylinder oil additive content is in the order of 30 to 35 % (class note). This plays a significant role in the formation of ash decomposed during combustion. The residual fuel become dissociated as the carbon and hydrogen burn in a temperature which may range up to 1750 to 1850 deg. centigrade during combustion. In this process the vanadium compounds decompose and react with oxygen to form oxides (Vanadium petroxide). At the high temperature generated during the combustion process, the oxides will liquify. Vanadium Pentoxide has a melting or (solidification) point of 670 deg. centigrade at atmospheric pressure. Similarly, sodium, iron and nickel oxidize rapidly during combustion. Sulphur burns to form sulphur dioxide and a limited amount of sulphur trioxide.

The high gas temperature in the combustion chamber rapidly fall down to 340 to 420 deg. centigrade as soon as the exhaust valve or port opens, which leads to a complicated solidification of the intermediate products. Most of the product will escape with the exhaust gases in a very finely divided form of ash.

Possible reactions taking place during residual fuel combustion :

Sodium chloride + Sulfuric acid ---> Sodium Sulfate + chloric acid (HCl).

Sodium sulfate + Sodium Chloride ---> Sodium bi-sulfate + chloric acid.

The method of evaluating the effects of various ash forming compounds from residual fuel oils upon metal corrosion is called stiction. Stiction is the lowest temperature at which an ash deposit will fuse sufficiently to adhere to a none metallic surface in a controlled atmosphere. Engine parts such as piston crown, exhaust valve head, exhaust valve seat are exposed to the danger of corrosion.

Common problems of burning heavy fuel oil and their causes.

a. Difficulty in pumping --- high viscosity
b. Low temperature corrosion -- Sulphur
c. High deposits, wear, fouling and heavy smoke --- conardson carbon residue
d. Slow burning and heavy smoke --- asphaltens
e. High temperature corrosion and fouling --- vanadium, sodium
f. Abrasive wear --- ash
g. Corrosive wear --- water contamination.

Effect of distillate fuel combustion on exhaust valves. Distillate fuels are usually vanadium free, but high content of sodium and barium based lubricating oil additive with carbon from incomplete combustion products are causes of exhaust valve corrosion. In the combustion process, very hard deposit of calcium or barium sulfate builds up on the valve surface forming a protective seal between valve face and seat, but some worn out piston ring chips or liners may get trapped as the valve opens and closes. The hard brittle surface deposit will chipped away and creates exhaust gas leakage which leads to local overheating as well as corrosion and erosion of the valve surface.

Typical fuel problems and some of the solutions.

Problems	Solutions
Fuel system sludging. High water contaminant and fuel polymerization causes precipitation of sludges -- filters block, injector patterns suffer and fuel stratifies.	Inhibit polymerization and disperse sludge into combustible state. Demulsify water
High temperature corrosion. A combination of sulphur, sodium and vanadium contaminants result in a highly corrosive molten ash which attack metals causing extreme damage and failure.	Modify ash to raise melting temperatures ash then ejected with exhaust gas steam
Low temperature corrosion. Acid dew point passed by exhaust gas over cooling, excess air in combustion area and high sulphur dioxide ---> sulphur trioxide conversion rate, specially from -high sulphur fuels to sulfuric acid corrosion.	A combustion catalyst enables a reduction of excess air in boil- ers, reducing mono - atomic oxygen available for sulphur dioxide to sulphur trioxide conversion, sulphur trioxide chemically inhibit.
Carbonaceous ash deposition. Free carbon from combustion process binds particles together to form deposits	Combustion catalyst increase carbon to CO2 conversion.

Tarry carbonaceous ash deposit.
(diesels)

Incomplete fuel combustion, pre-heat temperatures too high, burner/injector malfunctions, air cooler restriction, timing defect, high conardso carbon fuel, resulting in excessive free carbon.	Check and adjust pre-mechanical functions and use combustion catalyst to suppress free carbon formation by encouraging rapid and even burning.

Deterioration of power output.

Ash and carbon deposits in combustion zone and exhaust system causing general loss of efficiency in boilers and diesels.	Combined ash modifier and combustion catalyst reduces ash and carbon deposition.

Various products are available for treating the above pointed fuel oil problems.
These are:

Fuelcare) for treating sludge.
Gambrake)

Valvecare) For high temperature corrosion
Dieselite) treatment

Dual purpose plus)
Dieselite) Carbonaceous ash deposit in diesel engine.

3.5 The unifuel ship.

The high cost of fuel and the unstable condition of its continuous supply is a constant worry for diesel engine operators and manufacturers. Earlier it was only the larger slow speed diesel engines that were burning heavy fuel oil, which is relatively cheap. This initiated the engine builders to modify or build auxiliary engines to burn heavy fuel oil which led to a single fuel ship.

A unifuel ship operates on the principle of:

- all engines run on bunker fuel oil;
- only one grade of fuel is on board;
- there is no fuel blending;
- auxiliary engines are started and stopped on heavy fuel oil (banker).
- part load operation is on banker fuel.

At present this is applicable only on engines with minimum power capacity of 600 KW at 720 to 1,000 rpm and minimum sea electrical loading should be 450 KW.

Advantages:

- considerable saving in investment;
- uniform savings in maintenance;
- substantial savings in fuel costs;
- one bigger system is more advantageous than two smaller system;
- combustion efficiency and operation of engines are better than when run on blended fuel

3.6 **Fuel deterioration by micro-organisms.** Micro-organisms can be a real threat to fuel quality. They corrode fuel tanks, piping, fuel pumps and injection nozzles. According to William O'Brien Jr. of the technical director of Drew Ameroid, light and medium grade fuel are more vulnerable to micro-organisms deterioration because they provide ready source of food.

The main growth found in fuel are bacteria, fungi and certain type of yeast. This contaminants are easily transportable and can enter fuel storage tanks through air vents and other openings.

Shore storage tanks are more suitable for micro-biological growth. The presence of even small amount of water in the fuel or storage tank enhances the growth of these hazardous organisms. They feed on substances like carbon, hydrogen and sulphur. Their growth rate, according to Mr. O'Brien is directly proportional to increases in temperature.

Symptoms of micro-organisms in fuel:

- Objectionable odor like rotten eggs smell.
- Discoloring or blackening of copper bearing metals.
- The presence of green, black, or brown slimes in fuel tanks.
- Corrosion under deposits on tank bottoms.

Major effects of micro-organisms:

- Blockage of fuel lines and hence flow restriction leading to poor atomization of fuel into the cylinder.
- Severe metal loss in fuel tank and pipings. For example, 12mm thick steel plate can be fully penetrated in six months time (MER June 1991).
- Water emulsification and energy loss because the microbe consumes or eat away all the hydrocarbon in the fuel.

The difficulties of combating microbes:

- centrifuges can not remove all the microbial contaminants;
- oil soluble treatment is not cost effective as high dose level is required for effective kill;
- application of biocide is effective but present commercial biocides are non-fuel system.

Therefore, the best and easiest way to prevent micro-organism growth is good house cleaning, that is preventing water from mixing with fuel, cleaning and keeping the system dry as much as possible. Efficient filtration system is also very effective.

For harbour marine service crafts, where fueling in most cases happens to be from shore tank, contracting micro-organism is highly likely.
In my experience (at Assab Port), shore storage tanks are hardly cleaned except when the need for welding arises due to leakage. It seems that no body is aware of the danger of micro-biological growth in the fuel tanks. Untimely failure of fuel pumps, fuel injection nozzle orifice widening and loss of pressure have never been traced back to the fuel storage tank.

CHAPTER FOUR

DIESEL ENGINE LUBRICATING OIL CONDITION MONITORING TO PROMOTE ENGINE SERVICE LIFE.

4.1 History of lubricants.

Prior to petroleum product lubricants, animal fat and vegetable oils were used as lubricants. Oil from animal fat was extracted by heating or boiling fatty tissues of animals. Vegetable oils such as castor oil, olive oil, etc. were extracted by pressing or by chemical extraction with solvents. For the steam reciprocating engine, which was on development stage at the beginning of the 18th. century, these types of lubricants were used quite satisfactorily. In those days, lubricant type was determined by the area in which the ship was trading. Rape vegetable oil and olive oil were popular because they were fairly distributed all over the world and it was cheap too. However, as the steam reciprocating engines were developing, better and efficient lubricating oil were needed.

Birth of petroleum product lubricating oil.

Petroleum product lubricating oil were introduced commercially around 1850. In 1859, the discovery of crude oil in America, boosted the availability of lubricating oil. However, the simple distillation method of extracting lube oil, the only method known to man during that time, cold not satisfy the need for the high quality lubrication required by the newly developed steam engines. The mixing of petroleum based lube oil and fixed oil (animal and vegetable oil) were tried to improve the lubricating conditions. It worked satisfactorily for the time being but with the development of steam turbine, new lubrication characteristics were required. The gearing system and bearings built on the steam turbine to propel ships, needed fluid film lubrication.

In such circumstances, low viscosity lubricating oil is an ideal criteria of lubricant to reduce fluid friction. As the speed is high and load on the bearing was low and as there is considerable heat by conduction through the rotor, the lower the viscosity of the oil, the more efficient the cooling. On the other hand, for lubricating the gears which have high tooth loading, low viscosity oil would not be adequate. Therefore, a high viscosity oil was needed to prevent excessive wear.

The invention of internal combustion engine in the 1890's, again further complicated the function of lubricating oil.

4.2 Main functions of lubricating oil in internal combustion engines.

The basic functions of lubricating oil, whether in reciprocating engine, turbine or internal combustion engine are:

- Prevent metal to metal contact to reduce friction force;
- Provide seal between liner and piston rings to prevent combustion gases from getting into the crankcase, which could lead to lube oil contamination, specially in the trunk piston type medium speed dieŝel engines;
- Cooling internal moving parts of the engine;
- Clean the internal parts of the engine.

With the development of the diesel engine, the need for high quality lubrication was inevitable. The poor quality fuel oil the diesel engines are burning today also more complicated the characteristics of wear.

The general classification of wear in internal combustion engines are:

a. Friction wear.

b. Abrasive wear.

c. Corrosive wear.

a. **Friction wear**. Friction wear occurs where ever there is motion. When two solid bodies are in contact, move in relation to each other, resistance force is created in attempt to stop the motion. William Lefter, in his book Petroleum refining, second edition for non-technical person, pg. 142 stated that, "The annual cost of wear is estimated in billions of dollars, perhaps even more than the cost of metallic corrosion".

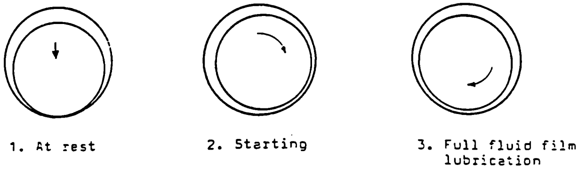
The rate of wear can be reduced by applying fluid layer between the two surfaces of the moving bodies. The liquid fluid converts the external friction created by the two solid bodies to an internal friction between the components of which the fluid is comprised. For example consider lubricating conditions of a cylindrical journal bearing. In the stationary condition, the shaft journal is resting on the shell bearing. The shell bearing has groves through which oil is generated. If a turning moment is applied to the shaft, the journal will roll up the bearing because of friction.

See Fig.9, for formation of an oil wedge in a simple bearing.

At continued rotation, the journal will slip in relation to the shell bearing and the lubricating oil inside the bearing will be drawn between the shaft and the shell bearing. This is accomplished because of the adhering characteristics and internal friction of lubricating oil. As the speed of rotation of the shaft journal increases, oil will be drawn in between the journal and shell bearing to create a cushion for the shaft journal. At this condition, the friction is entirely between the liquid itself.

In the above condition, the higher the viscosity of the lubricating oil, the greater is the load to which the bearing can be exposed, and the higher the speed of rotation, the lower the viscosity of the oil needs to be for a given load.

Formation of an oil wedge in a simple bearing



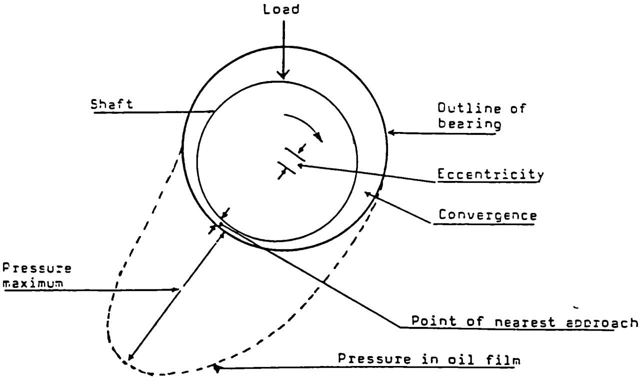


Fig. 9 Principle of librication of journal bearing.

From handouts given by Mr. Saxena (lecturer).

The use of high viscosity oil will give rise to greater friction loses, which in turn will result in higher temperature. High temperature will reduce the viscosity of the oil, which reduce friction losses.
Even though, complete elimination of friction is impossible, with the correct choice of lubricating oil, friction wear of components can be minimized.

At the start of the rotation of the shaft journal, friction is high, the reason being that there is metallic contact between the shaft and the bearing material. As the speed increases gradually, oil wedge is formed between the shaft journal and the shell bearing, as a result oil film is formed to prevent metal to metal contact. At a certain speed full oil film is formed to the point where friction is at its lowest. Further increase of rotation speed beyond that point will give rise to an increase in friction.

In a diesel engine operation, the main and important task of an engine operator regarding lubricating oil have to be:

- To check the lube oil type and quality if it corresponds to his engines specification;
- For slow-speed diesel engines two types of oil are used (the crankcase or system oil and cylinder oil), therefore, make sure that the two types of oil do not mix.
- In the trunk piston medium speed diesel engine, only one type of oil is used but combustion gas contamination is highly likely.
- Efficient operation of piston rings, filters and centrifuging have to be ensured. Sampling of used oils at a certain interval of service time is also important.
- Keep clean all oil storage tanks and avoid any solid or liquid contaminants from getting into the oil system.

b. Abrasive wear. Abrasive wear is caused by ash from incomplete combustion of the fuel and some foreign matters burnt during the combustion process. The lubricating oil has to overcome these severe operating conditions and lubricate the engine components satisfactorily.

c. Corrosive wear. Corrosive wear is caused by moisture and acidic product formed during combustion. Very high lubricating efficiency is required to minimize the effect of the very poor quality of the fuel used in the diesel engines of today.

4.3 Lubrication oil properties.

The severe operating conditions of internal combustion engines require stable and adequate lubrication.

That is the lubricating oil has to have a property that does not change significantly with the progressively increasing engine operating temperatures.

However severe the operating environment, the oil must be able to maintain its characteristics of detergency, dispersancy, thermal and oxidative stability. The control of deposits on the piston crown, ring lands, grooves, piston skirts and air scavenge places are dependent on the oil property.

Lubricating oil properties can be divided into two, the **physical** and **performance** properties.

The physical properties like specific gravity, density, flash point, etc. are important indicators of lubricating oil properties. But properties like Neutralization Number and viscosity are decisive properties for lubrication oil.

Neutralization number – is a measure of acidic contents in the lubricating oil.

Total base number (TBN) – is a measure of the basic constituents of lubricating oil.

It is the amount of acid expressed in terms of the equivalent number of milligrams of potassium hydroxide needed to neutralize one gram of the sample.

Sulfated ash is a measure of the amount of ash forming additives in a lubricating oil.

Viscosity - is the most important characteristics of lubricating oil, because viscosity of oil indicates its body or relative fluidity and it is a measure of the molecules to sliding past one another or, the internal friction.

Performance properties.

Performance properties are defined based on the real full scale equipment applications. Every major lubricant supplier and equipment manufacturer has test procedures which are used along with industry recognized procedures for screening or approving lubricants.

The most common tests is the extreme pressure (EP) test for determining anti-wear properties of lubricating oil for automotive gears, industrial type gears and engine crankcase.

For example, to determine the level of anti-wear protection of lubricants, the four-ball test method is used. It is run at loads between 1 and 40 kg, temperature between ambient and 95 degree centigrade and for duration of one or two hours. The test result is the average scar diameter in millimeters on the three fixed balls.

4.4 Main causes of lubricating oil deterioration.

Petroleum based lubricating oils are refined products of crude oil. As crude oil is basically a combination of different substances in which some of them are harmful to be used as lubricant or fuel oil, it needs refining. Modern refineries are so sophisticated that a good quality lubricating oil can be produced. In most cases, oil product deterioration happens after the product left the refinery. Lubricating oil quality may deteriorate by accident but mainly it happens through the process of operation.

Water contamination - Water and oil may mix in coolers and as water has no lubricating capacity, it promotes rust, destroys detergents and dispersent properties of oil.

Dilution - The most threatening lubricating oil contaminant is fuel oil, residual fuel in particular. This can occur through inefficient injector operation, fuel pump leaks into the crankcase in the case of trunk type medium speed diesel engine, or poor combustion.
Most medium speed diesel engines have a common lubrication system for crankcase, camshaft and cylinders. If fuel pump plunger lubrication is common to the system, extensive mixing between fuel and lubricant takes place frequently. Heavy fuel contamination can cause reduced thermal efficiency. This in turn increases viscosity and also cause sludge build up, crankshaft varnish, plugged piston rings, excessive deposits under piston crown, blocked lubricating oil filters and excessive deposits in lubricating oil purifiers.

Oxidation - Excessive high temperature is an other source for oil deterioration. Medium speed, trunk piston - as opposed to cross head piston - engines have become increasingly popular in ships with a need for low head room engines. Such engines now produce more than 1500 hp per cylinder. During such high power development, extremely high temperature and pressure can develop in the combustion chamber. Lubricating oils are expected to withstand such extreme operating conditions and lubricate as well as cool the components exposed to such extreme operating conditions. All this will raise the risk of lubricating oil oxidation.

The very poor quality fuels of today are even more demanding on the compatibility of oil.
The engine builders are improving the diesel engines to suit the present deteriorating conditions of fuel by

modifying some components or developing parts.
Fuel economy is always the prime mover for engine development. The most significant developments done to improve fuel economy were introduction of the more efficient turbo-charger, increased maximum firing pressure and optimization of stroke to bore ratio by the slow-speed and medium speed diesel engine builders. This developments have a major influence on component and lubricant requirements.

Still the marine engine builders are further looking for highly reliable fuel-efficient engine, with a maintenance interval of 20,000 running hours.
To achieve this goal, the need for more technological development on engine components design and the need for quality material had been justified. Equally important is the quality of lubricating oil to adopt to the high thermal and mechanical stresses generated by the high pressure and temperature of the combustion process.

Increased pressure in the combustion chamber means:

a) Increased mechanical loads at top dead centre and at the main and connecting rod bearings.
b) Increased thermal load on components.
c) Increased load on lubricating oil film.
d) Increased temperature of the oil

All these leads to the deterioration of the lubricating oil, which in turn hinders the engine performance and in its extreme case, hastens the termination of component service life. Besides economical disaster, it may endanger human life and environment.

4.5 Used oil analysis.

Used oil analysis is a means of monitoring overall machinery health. This is very important in the modern day world where time is money and the important means of being a step ahead in the harsh competition and make some useful profits is by avoiding unnecessary stoppage of machinery. There is not enough time to disassemble a component for the sake of inspection. Everything has to be planned in advance so that operation will be programed and maintenance time will be calculated in terms of money. To meet such operating conditions, machinery condition monitoring is required. The best and exact way of machinery condition monitoring is the used oil analysis method.

As almost all means of economical development is geared to the use of machinery, the effective health monitoring system will give a strong boost to economical development. One of the strong economical infrastructure of any society is the transport section like air, land and sea transport. It is no where the petroleum products are more used in the above mentioned section of the economy than in any other field, specially in the marine field, where different sizes and types of machinery are operated.

Used oil analysis help to evaluate machinery operating conditions, which in turn can be used as a guide in planing operation, maintenance, spare parts inventory and budgeting.

The main data available from oil laboratory analysis are:

- density
- flash point
- viscosity
- neutralization number
- content of water
- soluble acid
- total base number (TBN)
- content of sediment
- pour point
- sulfate ash

Major oil supplying companies and machinery builders do these analysis for their customers when ever they are

asked. Proper sample from the right spot and clear labeling of the sample is very important.
Very sophisticated laboratory test machines are available today. For example, the spectrometer, differential infrared spectroscopy, particle counting and ferrography are all used to diagnosis oil to evaluate equipment operating conditions and expected service life.

Latest development on oil analysis technique is the Progressive Fast Analysis (AFP) method.
This method includes wear and contaminant analysis to assist in the diagnosis of equipment performance.
Since wear particles have distinctive characteristics, it is possible to identify a variety of wear conditions. These includes:

1. Normal rubbing wear
2. Fatigue chunks (such as from gear surface wear)
3. Spheres (fatigue cracks in rolling bearing
4. Laminar particles
5. Severe wear particles
6. Cutting wear particles
7. Corrosive wear particles
8. Oxide particles (including rust)
9. Non-ferrous metallic particles
10. Non-metallic crystalline particles
11. Non-metallic amorphous particles.

These shows that these type of test covers almost every angle that are useful to monitor oil conditions.

Possible results of sample oil analysis

Element	Origin	possible defect
Iron	-Liner rings, cams tappets, etc.	Wear
chromium	-Chromium plated parts, cooling water (sodium or potassium chromate, anti-corrosive additives)	Wear Leaking in cooling circuit.
Aluminium	-piston and bearings	Wear
Silicon	-atmospheric dust, piston, anti-foam additives in the lubricant.	Engine wear. Leaking in cooling circuit.
Lead	-Bearing -Residue of fuel combustion	Wear
Copper	-Bearing, bushes.	Wear
Calcium	-lubricant additives.	Wear
Sodium	-Water	coolant leak
Vanadium	-Fuel	Fuel leak
Barium	-Additive, coolant	Coolant leak

(Texaco Worldwide Marine fuel - lubricants News Letter)
These are the general guides obtained from analysis of the used lubricating oil.

As technology is growing, the design and construction of machines have improved tremendously. With maximum efficiency, safety and long term service at minimum maintenance cost, high performance level is expected from any machine. Opening a machine for check up based on

running hours is no more economical.
By oil condition monitoring through used oil analysis it is possible to exactly pinpoint if any part of the component is having some defect. Other engine condition monitoring methods such as exhaust gas analysis, vibration, oil consumption, etc. added to the used oil analysis methods are very effective in determining the status of an engine.

Realizing the importance of used oil analysis, Mobile Oil and Loyd's Register carried out used oil laboratory analysis on 2600 samples taken from 130 ships. The test method used waş, Inductively Coupled Plasma Atomic Emission Spectrometry (ICPAES). This is a powerful machine, that the analysis could be done effectively on wear debris and contaminants.

CHAPTER FIVE

DIESEL ENGINE COOLING

5.1 The need for cooling.

The engine components are mostly constructed from steel, cast iron, bronze and light alloys. These materials have a limited temperature beyond which they can not serve.

For example, maximum temperature for Aluminum is 650 degree centigrade, 1500 degree centigrade for Iron and 900 degree centigrade for Bronze.

Extremely high temperature-up to 2000 degree centigrade of heat can be released during combustion. Fortunately, this happens only for a fraction of a second in the entire operating cycle of the engine. The duration is so short that before components around the combustion chamber are affected, the heat will dissipate into the fresh air drawn in during the intake process. This means the cylinder walls, piston crown, valve seats, fuel injection tips, etc. will only experience an average temperature. Efficient scavenging air system, besides boosting engine power, also facilitates combustion chamber cooling.

The turbo-charged four-stroke, trunk type diesel engines have generally lower cylinder wall temperatures than the two-stroke cross head diesel engines due to increased scavenging efficiency of turbo-charger. In the combustion chamber, components temperature range from 500 deg. centigrade around exhaust valve seat to about 300 deg. centigrade at the piston rings and cylinder liner wall. The high temperature developed at the combustion chamber looses its intensity as it travels further from the centre. However, such temperatures are still inconvenient for smooth operation. Piston crown and exhaust valves may burn, lubricating oil film between piston ring and cylinder liner wall may lose its quality. Therefore, cooling the operating engine components to minimize excessive temperature is a necessity.

Excessive engine temperature may lead to:

a) component deformation and seizure;

b) gasket leakage;

c) stress on components which also may arise from two interconnected components having different coefficients of expansion;

d) oxidation of materials;

e) lubricating oil film destruction which will lead to abrasive wear.

5.2 **Water cooling system.**

Most diesel engines are cooled by water except some small engines which are cooled by air.

Water cooling system can be sea water or fresh water cooling system but sea water cooling system these days is not popular due to its contents of concentrated corrosive substance.

Water in general may be classified into five.

a) Pure water

b) Fresh water

c) Sea water and

d) Soft water.

a) **Pure water** - as defined by Alan Osborn in Marine Engineers Manual pg. 7.43, is a chemical compound which is colorless, tasteless and odorless liquid.

But water in its natural state is never found absolutely pure. It has a solvent action of wider range than any other liquid, and this action is affected by its temperature. For example, sodium chloride (common salt) dissolves in water with increased rate if the temperature of the water rises. The same is true for magnesium sulfate, but solubility of sodium sulfate increases up to 90 degree F. and then decreases as the temperature rises beyond 90 degree F.

b) **Fresh water** – is not the same as pure water because it contains sodium chloride in solution and other impurities such as calcium carbonate, calcium sulfate and other scale forming matters.

c) **Sea water**. This differs from fresh water because it contains large amounts of sodium chloride, calcium carbonate, calcium sulfate, magnesium chloride and traces of other impurities and scale forming substances.

d) **Soft water**. It contains non-appreciable amounts of calcium and magnesium ions. For example, natural rain water and distilled water. Soft water and pure water slightly differ because there is a possibility of soft water having some minor quantities of impurities.

Considering all types of coolants, fresh water has the following advantages.

- it is easily available;
- it is convenient to apply;
- not very expensive,
- treatment, comparatively is simple.

But this does not mean fresh water is completely trouble free because there are some scale forming substances contained in fresh water. It contains salt deposit, obstruct flow and causes corrosion. Its contact with lubricating oil could cause contamination leading to loss of lubrication. Control of leakage of coolants has to be given sufficient attention.

5.3 Fresh water cooling system.

Fresh water cooling system may comprise:

- cylinder jacket cooling system;
- cylinder cover and turbo-charger cooing;
- exhaust and fuel valve cooling;
- lubricating and charged air cooling system.

The cooling system is determined by the size of the engine and the amount of water to be circulated.

Two water cooling systems are used, the open cooling system and closed cooling system.
In an open cooling system, the water leaving the engine jackets is either not re-circulated at all or discharged overboard. Some marine engines use sea water for cooling agent which after cooling is to be discharged overboard.

In the modern highly efficient diesel engines sea water is not suitable for cooling, because of its highly corrosive nature. Instead fresh water is cooled in heat exchanger by sea water and re-circulated through the engine block, cylinder head, turbo-charger and back to the heat exchanger. The latest and more efficient diesel engine fresh water cooling system comprises lubricating oil cooler and air cooler (which usually were cooled by sea water) in addition to liner and cylinder cover cooling. For marine diesel engine with very high compression pressure, such system controls the thermal stresses very efficiently. The cooling system is divided into two sections, the low and the high temperature side. In the low temperature side, fresh water is circulated through the lubricating oil cooler and air cooler, in the process its temperature rises before it gets into the high temperature area of the engine. The other advantage of such system is, sea water involvement in the system is reduced. In this system, sea water only comes on board to cool fresh water.

Heat exchanger - The marine type heat exchangers are usually of tubular form stacked in a cylindrical casing. The end covers of the cylindrical casings are connected to pipes through which sea water is made to inter the stack tubes and leave at the other end. The fresh water which is to be cooled, enters the cylindrical casings and flow over the stack of tubes and in the mean time transferring its

heat collected from the engine.
The end covers are usually easy to remove for cleaning purposes. The tube stacks through which sea water flow has to be cleaned very often because sea water is a carrier of debris and corrosive substances. Fouling and corrosion are the main problems of heat exchangers. The radial diameter and thickness of the tube have very significant influence on the rate of heat transfer. Efficient cooling of heat exchanger depend upon the total area of the surfaces of the heat exchanger. Therefore, any amount of scale or fouling will considerably reduce the efficient cooling capacity of the heat exchanger.

The inside of the tube stacks are usually cleaned by mechanical means but the outer side, through which the fresh water flow is a problem. The cleaning method involves some acid solution containing corrosion inhibitor. The effective use of the acid solution needs some extra precaution and it is usually done by a specialist or manufacturer. The best method of avoiding deposits and fouling are to operate fresh water and sea water pumps properly so that constant pressure and temperature will be maintained in the system. Because variation of flow rate, temperature and pressure enhances the scale formation both in the inside and outside of the tube stack.

5.4 Corrosion

corrosion is electro-chemical in nature. The process of corrosion differ from metal to metal and the same metal can also be under the influence of different corrosion processes. Areas of metal surfaces which dissolves away have a negative electric potential and are called anodes. Those areas with positive potential are called cathodes. The oxygen in the water enhances the process of corrosion.

Metals corrosion takes several forms and it may be initiated in one form and then progress by an other.

General forms of corrosion on metals:
a) **Graphitization** - a form of general wastage in which the iron is being removed, for example from cast iron, leaving behind the carbon in a shape of the original casting.

b) **Dezincification** - is the process in which brasses are subject to wastage dissolving zinc and leaving the copper behind.

c) **Pitting** - is a form of corrosion that take place where the anode areas are small. Concentrated attack of pitting may quickly penetrate a metal wall.

d) **Galvanic corrosion** - is when two metals immersed in water are in contact, a potential difference will exist between them. The more noble metal having a higher electrical potential than the more base metal.
The base metal will become anodic and tend to corrode while the noble metals become cathodic and thereby protected. This is called galvanic corrosion or bimetallic.

e) **High velocity impingment** - is the result of high velocity water flow particularly if the cooling water contains abrasive particles such as sand.
Those parts already started corrosion are eroded away exposing the metal to further corrosion which is thus encouraged to proceed rapidly.

f) **cavitation** - vapor bubbles are formed at times due to vibration, which collapse with severe effect leading to cavitation corrosion. This type of corrosion is seen mostly at the back of cylinder liners and water pump impeller.

As the process of corrosion are dependent upon oxygen presence in the water much can be done to prevent it by excluding air from the system as much as possible. Vent cocks are often provided at the pump and adjustment has to be done for the restriction of excessive air entrance. High points in the cooling system have to be connected to a permanently open vents. The expansion tanks which is usually installed high above the engine serves as a permanent vent in addition to controlling the volume of fresh water in the system.

5.5 Cooling Water additives.

Cooling water additives are either anti-corrosive oils or inorganic inhibitors. Additives are applied according to the operating conditions of the components to be cooled.

Adding chemical inhibitors to cooling water in the closed system to prevent corrosion and scale formation is quite common in marine engine operation.

Most inhibitors chock or stifle the electro-chemical actions providing conditions by which the corrosion products form a protective film on the metals. The action of an inhibitor depends a great deal on the environment in which it is used. If a piston is water cooled, anti-corrosive oil is more effective as it lubricates parts which have sliding contact. The oil forms an emulsion and part of the oil builds up a thin unbroken film on metal surfaces, this prevents corrosion but is not thick enough to interfere with heat transferring.

Inorganic inhibitors form protective layers on metal surfaces guarding them against corrosion.

Corrosion prevention in one set of conditions may increase in an other.

The choice_of inhibitor is influenced by the type of the system, the composition of the water, its temperature and rate of flow, metal surface composition and the presence of dissimilar metals. Inhibitors purchased in the market have different constituents. For using it in the engine cooling system, mixing will give better result than on its own.

Positive protection of the variety of metals such as cast iron, steel copper and brass of which most engine system are composed can be achieved. Non -metallic materials used for joints, seals and rubbers are safe with a carefully selected inhibitors. The water to be treated in the closed cooling system has to be of low hardness and the exact capacity of the cooling system has to be known to effectively utilize the inhibitor.

CHAPTER SIX

CONCLUSION AND RECOMMENDATION

6.1 conclusion

The main purpose of any machine is to enhance the betterment of human living conditions.
This can be in the form of food or material production, transportation, power generation and many others.

The diesel engine is the most widely applied machine in the fulfillment of human needs.
This is more emphasized in the marine field than any other areas. Almost all marine vessels use the diesel engine as a propulsion unit or as an electric power generator.

Modern technological development has improved the diesel engine performance capacity that maximum designed operating level could be achieved.
However, the high level performance of an engine could be achieved if only supported by:

a. standardized operational procedures;
b. monitoring and control of parameters like temperature, pressure, rpm, vibration measurement and various electrical load indicators;
c. application of quality lubricating oil, fuel oil and coolants;
d. suitable maintenance policy;
e. effective usage of spare parts;
f. competent operators and maintenance crew;
g. effective planning and organizing of operation.

Lubrication, cooling and fuel oils are very important in marine diesel engine operation.
Lubrication to an engine is as important as blood is to a human body, because human being functioning without blood is unthinkable, so does a running engine. Sufficient lubrication with proper quality of oil is a necessity. This requires thorough understanding of lubricating oil

characteristics under different engine operating conditions.

Controlled diesel engine cooling system is also very important as over cooling or deprivation of cooling could be very harmful to the engine.
Cooling water temperature and flow pressure control may save the engine from accidents such as cylinder cover and liner cracking. Variation of flow of cooling water pressure can also lead to scale formation of coolers and jacket cooling systems.

In regard to engine performance, fuel oil has a major influence on the diesel engine. Poor quality fuel reduces the engine output, enhance deterioration of fuel pumps, injectors and nozzles.
Unfortunately, fuel types available for marine use at present are very low quality fuels. The heavy fuel oil used mostly by the two-stroke cycle cross head marine diesel engine is the lowest quality of all petroleum products. The lighter marine diesel fuel used in the medium speed diesel engines has also significant amount of disagreeable qualities. Therefore, efficient filtration and centrifuging all types of fuel oils before use are important.

Thanks to modern technology that used lubricating oil samples can be accurately analyzed in a laboratory and operating conditions of internal moving parts of an engine can easily be diagnosed. Very important informations can be obtained on which operators may base his decision as what to expect, when and what type of spare parts are required. Lubricating oil and fuel oil samples have to be taken at certain intervals of running hours and sent to oil companies for analysis.

The key to any operational success is determined by the type and efficiency of the organization. Well organized and comprehensive organizational policy will ensure maintenance, spare parts management, training of personnel and in general facilitates efficiency, productivity and safety.

RECOMMENDATION

Establishing a marine technical supervision section.

6.2 The need for supervision

There is no doubt about the ports importance to an economical development of a country. No country in the world is self sufficient. So, materials, food items, factory products have to be imported or the excess have to be exported. The cheapest means of transporting export and import goods is by the sea and for the sea transport, ports are required. Tugs, pilot boats and mooring boats are one of the most important equipment in port operation. To accomplish these important tasks, these vessels need to be operated in an internationally accepted standard. At all time, readiness to respond to emergencies with dependable power delivering capacity have to be their optimum goal. To accomplish this extra ordinary task, high level operation and maintenance of machineries have to be exercised. These calls for a constant supervision of operational conditions of the vessels in general and its machinery in particular.

Responsibilities of a technical supervisor.

The harbour marine crafts technical supervisor's responsibilities need to be:

1. plan and organize operation in coordination with the harbour master;
2. collect data on machinery operating conditions and plan maintenance schedules;
3. control the proper usage of spare parts and ensure availability;
4. ensure the application of proper quality of lubricating and fuel oils;

5. establish communication with oil supplying companies to have access to lube oil and fuel samples testing facilities;
6. initiate training programs for operators and maintenance crew to improve operating skills and increase production;
7. record consumption of lubricants, fuel oil, spare parts operational costs to be used as a reference for justifying future budgets;
8. establish smooth flow of information between vessels and shore establishments such as general stores, purchasing section, etc.
9. provide advise on the types of equipment to be purchased based on operating conditions and environment;
10. In general, promote the importance of planned maintenance of machines as to enhance efficiency, safety and dependability which is an effective way of increasing the much needed revenue.

Structural organization of a marine technical supervision section.

A technical supervision section can be attached to the existing port's engineering division. The shore equipment repair and maintenance shop, which is also under the port engineering division has enough facilities like offices, stores for spare parts, workbenches, etc. The other facilities such as welding shop and machine shop could be used by both, that is by the land based machine operators as well as for marine equipment operators.

Without any additional building, by just appointing a supervisor who has a marine technical knowledge and with minimum support, an effective marine supervision section could be established.

The minimum support may be assigning some mechanics who are currently working in places such as heavy truck and tractor repair sections. Since such people have the knowledge and even experience on the smaller high speed diesel engines, with minimum training based on refreshment courses and demonstration, competent marine engineers could be trained.

The benefit of having a marine technical supervisor.

The establishment of marine technical supervision will benefit the Assab Port Administration in general and the harbour marine crafts section in particular.

The main and immediate benefit could be pointed as follows.

1. Relief the shore work shop leader from the wide and diversified job responsibilities which in fact is the main reason for his disability of having closer control over the activities of harbour marine crafts.
2. Improve operational efficiency and maintain safety standards.
3. Raise economical and environmental awareness of crew members.
4. Facilitate training of personnel to improve operational skills.

These could be an immediate benefit but in the long run the section could be a starting point for the promotion of marine technology. As technology is changing all the time, this could also serve as refreshment centre to keep in touch with the fast changing technological development.

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